Economic Comparison between Pasture-Based Beef Production and Afforestation of Abandoned Land in Swedish Forest Districts

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Abstract: Large areas of agricultural land have been abandoned or are at risk of being abandoned such as small scattered fields and pastures in forest-dominated landscapes are unsuitable for modern mechanized agriculture and cost-efficient grazing. These areas have therefore become unprofitable to cultivate and graze. Spruce planting has been seen as the obvious alternative on these lands but is today questioned from landscape points of view. Now most abandoned land is left for natural afforestation. This study aims to compare the profitability in use of abandoned or marginal agricultural land in Swedish forest districts for spruce planting, natural birch afforestation, or organic beef cattle grazing large pasture-forest mosaics. The pastures consist of remaining semi-natural pastures, abandoned and marginal agricultural land, and adjacent forest land. Calculations of contribution to land, management, and risk suggest that, given present supports and environmental payments, organic beef production with herds of more than 20 suckler cows in large pasture-forest mosaics could be more profitable than forestry, except for in the most fertile areas of southern Sweden, where spruce planting has the highest contribution. Future tree breeding progress and possible decrease of livestock-related support and environmental payments would however increase the competitiveness of resumed afforestation relative to beef production.

Keywords: agricultural land; pasture; abandonment; beef; suckler cow; afforestation; forestry; spruce; landscape; climate; profitability

1. Introduction

Sweden's land area consists of 69% forest, 8% agricultural land, 3% built up areas, and 20% mires, heath, and bare rocks etc., mainly located in the mountain areas in the northern part of the country [1]. South of the mountain areas, Sweden is thus dominated by forest in which there is scattered agricultural land at the most fertile spots. The forest dominance has increased since the 1920s due to the fact that 40% of the agricultural land of that time is no longer used for agriculture [2] and mainly been afforested, i.e., converted from other land use into forest, while the previously extensive forest grazing has largely disappeared [3,4]. Since 1960, only 10% of the land that is no longer used for agriculture has been used for buildings and roads [2,5].

The abandonment of agricultural land has occurred mainly in already forest-dominated districts [2]. The reason is that small arable fields and pastures, scattered in forest-dominated landscapes [6], are unsuitable for modern mechanized agriculture and traditional ways of cost-efficient grazing. They have therefore become unprofitable to cultivate and graze when wages have increased relative to the prices of agricultural products [7–9]. Of the remaining Swedish agricultural land there is 1.1 million hectares (Mha) in the forest districts (0.9 Mha arable land and 0.2 Mha semi-natural pasture) and

1.9 Mha (1.7 Mha arable land and 0.2 Mha semi-natural pasture) in the plain districts with mostly economically sustainable agriculture in the latter [10].

During the 1960s and further back in time, large areas of the abandoned agricultural land was afforested by spruce (*Picea abies* (L.) H. Karst) plantation and this was expected to continue at that time [7,11]. More recently, an increasing number of ex-dairy farmers, who finished dairying and started to work outside the farm, chose beef production as a side line rather than planting forest on the agricultural land [12,13]. However, this often small-scale beef production was generally not economically sustainable. The total number of holdings with cattle in Sweden has decreased from 191,000 in 1961, most of which were dairy farms, to 16,000 in 2018, of which only 3500 are dairy farms. During the same period the total number of cattle in Sweden has decreased from 2.3 million to 1.5 million [2].

During the 1970s, the forest plantation of agricultural land drastically decreased and the subsidies for planting also ceased in 1981 [14]. Instead, society increasingly wished to preserve open agricultural land for landscape and biodiversity conservation considerations [11,15]. In recent decades, conservation and preferably expansion of the semi-natural pasture area has become an increasingly important societal goal due to the high biodiversity and amenity values of these pastures [4]. Interviews with citizens have also shown high willingness to pay for preserving open agricultural land, especially by livestock grazing, if the option is spruce planting [16]. Aversion to planting spruce on agricultural land still persists among both landowners and the public [17]. Deciduous trees are more accepted [17]. Of the agricultural land that has been abandoned during the period 1996–2016, only 11% has been actively afforested by plantations [18], whereas no active measure of usage has been taken on the major part of the abandoned land.

Agricultural abandonment is comprehensive not only in Swedish forests districts but also in many European regions [19]. As in Sweden, widespread abandonment in these regions began in the mid-20th century and is forecast to continue in the future decades [20]. A literature review from studies carried out in Europe suggests that letting revegetation of abandoned farmland continue has, compared to retrieving the land for grazing, both environmental advantages (e.g., increased carbon sequestration) and disadvantages (e.g., decreased biodiversity in mid- and long-term) [21].

In 2002–2006 there was 0.3 Mha unused abandoned agricultural land in Sweden [22] and since 2005 a further 0.2 Mha of agricultural land has been abandoned [2]. Model calculations suggest that up to 1 Mha of the still used agricultural land may be unprofitable to cultivate in the long term and therefore is at risk of being abandoned. This marginal land, which is mainly found in forest districts or in forest-dominated areas of regions designated as plains in the official statistics, is supposed to in the long term become forest by planting or natural regeneration [6].

The technical and economic development thus means that the abandonment of agricultural land is likely to continue in forest districts. However, at the same time as small, hard-to-use arable fields and semi-natural pastures have been abandoned, significant areas of other arable land and forest land have been transformed to semi-natural pastures [4]. Such transformation resulting in large coherent pasture-forest mosaics has considerably increased the profitability on a number of Swedish farming enterprises with organic suckler cow-based beef production. This is mainly thanks to improved land consolidation, economies of scale, and agri-environmental payments and supports for the extended pasture area [23].

By creating large cohesive pasture-forest mosaics of remaining semi-natural pastures, abandoned and marginal agricultural land and adjacent forest land, which may have been agricultural land or grazed forest in the past, the costs of fencing, water supply, and supervision time per grazing cattle could be considerably lower than in present livestock production based on small scattered pastures common in forest districts. Large coherent grazing areas would also enable larger herds and thus economies of scale by increasing the pasture supply. By converting present forest land in the mosaics into pasture after final felling instead of reforestation, i.e., re-establishment of forest after final felling, additional cost and scale benefits can be achieved in the beef production.

Increased beef production can be particularly important because the present domestic beef production in Sweden only covers half of the domestic beef consumption [2]. Due to the decreasing number of dairy cows [2], increased beef production in Sweden must be based on calves born by suckler cows. Organic production, with its premium price of beef and governmental support, should have particularly good economic conditions on semi-natural pasture since, as a result of environmental payment rules, fertilizers and pesticides are not used neither in organic nor conventional production. In grazing-based beef production on abandoned land with low or no opportunity cost in forest districts with high environmental supports per hectare (ha), the somewhat lower yields of organic production should not be a disadvantage. Low yield per ha creates a high level of environmental payment obtained per animal. It would therefore rather be an economic advantage, at least if the pastures and total area are so large that, despite the low yields, fence and water costs per kg dry matter (DM) pasture herbage can be low and economies of scale achieved in the animal husbandry.

We hypothesize that beef production on large pasture-forest mosaics would be more profitable than afforestation of abandoned agricultural land and reforestation of forest land in the mosaics and by that profitable enough to expand on abandoned and marginal agricultural land and forest land. A transformation to this kind of beef production would also meet the goal of preserving open rural landscape in forest districts and grazing dependent biodiversity as well as governmental goals to increase the domestic food production [24] and the proportion of organic products [25]. The purpose of this study is to test the hypothesis that organic suckler cow-based beef production grazing on large pasture-forest mosaics can be more economically profitable than afforestation and reforestation, together defined as forestry, and profitable enough to expand on abandoned and marginal agricultural land and forest land.

2. Material and Methods

2.1. General

The organic beef production assumed in this study includes suckler cows and their calves that are raised as heifers and steers and slaughtered at about two years of age. It also includes pasture and winter feed cultivation for these animals. The forestry alternatives include spruce planting, historically the main option on abandoned agricultural land, and natural afforestation, which has become the most common alternative over the last decades. It was assumed that natural regeneration will be dominated by birch (*Betula pendula*), which is by far Sweden's most common deciduous tree.

The calculations were undertaken for forest districts in southern (Götaland), central (Svealand), and northern (Norrland) Sweden. They were based on 2017 prices in SEK (1 SEK ≈ 0.1 Euro) since the results for 2017 best correspond to the average profitability during the period of 2014–2018 for both beef production [26] and forestry [27].

To compare the profitability of the various alternatives and to obtain a basis for assessing whether beef production can become profitable enough to expand on abandoned and marginal agricultural land, the alternative contributions to land, management, and risk (CLM&R) were calculated. The CLM&R was calculated as the revenues minus all calculated costs except land and business management. Business management includes planning, labor management, administration and accounting. Risk includes biological and physical risks (e.g., feed-crop failure, abnormally high calf mortality and fire, windthrow, insect and decay-damage in forestry), economical risks (e.g., reduced beef price and increased interest-rate), and political risks (e.g., reduced or abolished farm support).

In the forestry calculations it was assumed that current real net conversion values remain unchanged during the forest rotation. In the beef calculations it was assumed that the current technology and real prices as well as present agricultural supports and environmental payments were unchanged during the depreciation period for new buildings for wintering the cattle. In sensitivity analyses effects of conceivable changes in beef prices and EU´s Common Agricultural Policy (CAP) with its agricultural supports and environmental payments were investigated.

2.2. Comparing Profitability in Beef and Forest Production

In beef production there are revenues (slaughter animals, environmental payments, and supports) and costs (pasture management, winter feed production, labor, and depreciation of building etc.) every year. The forestry options, on the other hand, have only costs in the short-term (soil scarification, planting, pre-commercial thinning, etc.), while the revenues (net conversion values from thinning and final felling) are obtained in the distant future. In order to compare the profitability of forestry with the beef production´s annual CLM&R, the profitability of a forest rotation was first calculated using the net present value method [28] as the present value of net conversion values from logging operations minus the present value of afforestation or reforestation and other silvicultural costs according to Equation (1).

$$NPV = \sum_{t=0}^{t=T} (NCV_t - C_t) * (1 + i)^{-t} \qquad (1)$$

NPV = Net Present Value of a rotation
t = Year t
T = Year to final felling (rotation time)
NCV_t = Net Conversion Value from thinning and final felling
C_t = Afforestation, reforestation, and other silvicultural costs
i = Real interest rate (nominal interest rate − inflation)
$(1 + i)^{-t}$ = Discounting factor which transforms future conversion values and afforestation, reforestation, and other silvicultural costs to present value year 0

In order to make the NPV comparable to the annual CLM&R of beef production, the annuity of NPV (ANPV) was calculated according to Equation (2) [28]

$$ANPV = \frac{NPV * i}{1 - (1 + i)^{-T}} = CLM\&R \qquad (2)$$

In Swedish agricultural calculations, real interest rates used are normally 3%–5% [29–31]. In Swedish forestry calculations, lower interest rates are generally used: ≤ 3% [17,32,33], 2%–4% [34], and 2%–5% [35]. The reason for using lower interest-rates in forestry are tax benefits and the forest industry's expressed interest in directing the wood-production towards high proportions of saw timber. This requires long rotations manifested in regulations for minimum final felling ages in the Forestry Act [35]. The tax benefits make it appropriate to reduce the interest rate in our business economic forestry calculations. However, there is hardly any reason for a farmer, when choosing between beef production and forestry, to take into account the forest industry's requests and the felling age regulations of the Forestry Act. It is permissible under the Forestry Act to transfer forest land to agricultural land even if felling takes place prematurely. Hence, we used the 4% interest, common in agriculture calculus, in the beef calculations. In calculation for afforestation of abandoned or marginal agricultural land and reforestation after final felling, as the alternative to pasture for beef production, we used 3% in the basic calculation due to tax benefits, and 2% and 4% in sensitivity analyses.

2.3. Spruce Plantation

The ANPV for spruce plantation at different site quality classes (SQCs) and interest rates were calculated from T, NCV_t, and C_t values computed by the forest economic consult Rosvall Forest Consulting AB Sävar (Tables S1 and S2 based on [36]) using a calculation model based on spacing experiments and ordinary forest economic models for calculating T, costs and revenues at given SQC, and interest rate [32]. The SQC-figures for spruce and pine were defined as dominant height in meters at 100 years of total age and for birch defined as dominant height at 50 years of age after breast height. The calculations assume that the initial spacing is relatively sparse (2000–2200 stems per ha at first thinning) and that only two thinnings are done which never occurs after 20 m height as

this reduces the risk of windthrow. It was supposed that currently available genetically improved spruce-seedlings growing 15% faster than unimproved seedlings are used. In a sensitivity analysis, it is assumed that continued breeding progress will result in improved seedlings growing 25% faster than natural seedlings.

The NCV of thinning and final felling was calculated as revenue for timber and pulpwood minus the cost for logging with a harvester and transport to landing at lorry road with forwarder. The average distance between cutting area and road was assumed to be 300 m. Wood prices in southern Sweden 2017 were used for the calculations for southern Sweden. In central and northern Sweden, the wood prices are usually 10% and 15%, respectively, lower than in southern Sweden [37] which was taken into account when calculating ANPV for central and northern Sweden.

The ANPV calculations include SQCs from the most fertile spruce land in southern Sweden (G36) with a mean annual increment per ha during a 50 years rotation of 16 m3sk (total volume over bark from stump to tip) to normal spruce land in northern Sweden (G24) with a mean annual increment per ha of 6 m3sk during an 84 year rotation (Tables S1 and S2). ANPV was also calculated for pine (*Pinus sylvestris* L.) planting that may possibly be relevant on small areas of dry abandoned agricultural land.

When comparing profitability in spruce plantation with naturally regenerated birch and organic beef production, only areas with the most likely SQCs at abandoned and marginal agricultural land was included. Hence, in southern and central Sweden, the highest and third highest spruce SQCs were included in the comparison. This corresponds to the 2% and 30%–40%, respectively, highest producing spruce sites in each region and is supposed to represent the most fertile and normal abandoned agricultural land respectively in each region. In northern Sweden only the highest spruce SQC occurring in the region was included.

2.4. Natural Regeneration of Birch

Plantation of birch, as well as most other deciduous trees, must be protected by high fences to safeguard the seedlings from game browsing. Such fences are unprofitably expensive per ha on small abandoned agricultural fields [17]. We, therefore, assume natural regeneration of birch, which is common on abandoned agricultural land [6], and can, if it succeeds, give so many seedlings that it generates good stands even if many seedlings are browsed. However, natural regeneration of abandoned agricultural land, without soil scarification, can take up to 25 years or more until there are stands with sufficient number of trees to make full use of the site's production capacity due to the stands being incomplete and uneven [38]. We therefore assume soil scarification in the form of deep plowing that hasten and improve the natural regeneration on abandoned agricultural land [39,40]. Natural regenerations of agricultural land generally result not only in birch but also in other tree species of which spruce is the most economically important [38].

Our ANPV calculations for natural regeneration of birch were based on NPV calculations on forest land after final felling, cleansing, and soil scarification, assuming that it, without delay, gives stands with sufficient number of birches to make full use of the site´s production capacity of birch wood (Tables S1 and S2 based on [41]). How the economic result may differ on abandoned agricultural land is analyzed by literature studies.

An investigation based on side by side birch and spruce stands suggests that birch-SQC is B24 on sites with spruce-SQC G28 and B26 on sites with spruce-SQC G36 [42]. However, this overestimates the birch´s increment especially on high-fertility sites (G36) according to data from existing older stands collected by the Swedish National Forest Inventory [43].

2.5. Beef Production

It was assumed that the examined beef production is suckler cow based and organically run with feed production without pesticides and synthetic fertilizers. The animals are raised on high proportions of roughage and grazing in the feed rations [44]. The entire rearing of the animals is performed in the

same enterprise which also produces the silage and manages the pasture, whilst the bedding straw and organically grown concentrate is purchased from elsewhere.

The production per cow and year is 0.42 steers killing out at 390 kg at 30 months old, 0.22 heifers killing out at 310 kg at 21 months old, and 0.2 culled cows killing out at 375 kg (Table S3). The culled cows are replaced by 0.2 heifers reared on the farm. The total annual feed consumption per cow, including the young stock reared for slaughter and replacement (cow+), was calculated from [45] for southern Sweden (Table S3). In central and especially in northern Sweden the grazing part of the annual feed consumption is lower and the silage part higher due to shorter vegetation period [46] which result in a shorter grazing period and a longer indoor period. Shorter vegetation period in the north than in the south also results in lower silage and pasture yields [47], and thus a higher cost for feed production the further north in the country the production is located. The silage yields per ha are in the interval 5300–6700 kg DM and the pasture yields on semi-natural pasture in the interval 1200–1500 kg DM (Table S3). The yields of semi-natural pastures also vary greatly within the same region depending on soil conditions and year [48]. Due to this, lower pasture yields were investigated in sensitivity analyses.

The forest grazing in the mosaics was expected to yield 50 kg DM per ha throughout the country and not to damage the timber production (Table S3). The stocking rate was assumed to be lower than in the past, when forest grazing was common, and the livestock had access only to forest grazing [49–53]. At that time the amount of grazing utilized was higher and the forest damage was extensive [49–53].

A total of 80% of the feed consumption on pasture is supposed to take place in semi-natural pasture in large pasture-forest mosaics, 5% on forest land in the mosaics, and 15% in arable land to ensure satisfactory animal weight gain throughout the grazing season. The mosaics are supposed to be 32 ha large rectangles (800 x 400 m) and their surface is assumed to consist of 40% small scattered semi-natural pastures and 60% adjacent forest that ties together the scattered pastures, or have other sizes, shapes, and proportion of pastures giving the same cost per ha of pasture. The cost of fencing and water supply is much lower per ha in these large mosaics than in pastures comprising only a few ha´s, which is now common in forest districts (Figure S1).

The silage production was assumed to be on typical arable land in forest districts, meaning small and unevenly shaped fields in many cases and situated far from the winter housing unit [6,7]. Contractors are hired in the silage production, which means that the machine and labor cost per kg feed will be the same in all herd sizes but higher in northern than in central and southern Sweden due to lower yields in the north (Table S3 based on [29,47,54,55]).

The labor requirement in the beef production (excluding silage and pasture production) was calculated using a model based on experience of labor required in various large beef herds. The estimated labor requirement per cow+ is higher in small herds than in large ones because the fixed labor requirements are distributed to fewer animals in small herds than in larger ones. The labor requirement is also higher the further north the production is located due to a longer indoor period when the daily labor requirement is higher than during the grazing period (Figure S2 based on [29,56–58]).

It was assumed that the cattle winter in a cubicle barn bedded with sawdust with the exception of the calving pens which are bedded with straw. Barns with deep litter bedding and scraped floors are cheaper to build but require much bedding straw which is expensive in forest districts far from areas with considerable grain cultivation and good conditions for straw harvesting. Cubicle barns also produce maximum amounts of liquid manure which has a greater nitrogen effect than deep litter manure. This is important in organic arable systems where conventional fertilizers are not used. Total annual net building costs per cow vary with herd size (Figure S3 based on [29,44,59–61]).

Calculations for interest on animal and working capital and various costs such as minerals, breeding bull, veterinary and medicine, and the organic certification fee is shown in Table S4 based on [29,45,62].

The revenues consist partly of beef and partly of environmental payments for semi-natural pastures and organic production and supports (animal premium, support for less favored areas and

single farm payment, and enterprise support) from the EU and the Swedish state. The beef revenue was determined by the annual number of slaughtered cattle of different categories per cow+ and the average slaughtering weight and price per kg in each category (Table S5 based on [29,45]). The payments and supports were determined by the area of semi-natural pasture and arable land, the number of cattle of different categories in different age groups, and the production´s geographical location (Table S6 based on [63,64]). It is likely that EU payments and support will be reduced from 2021 [65] without being fully compensated by the Swedish state. Nor it cannot be ruled out that the Swedish beef prices may fall due to forecasted falling of the international beef prices [66]. Therefore, sensitivity analyses were undertaken with 10% lower beef prices and 20% lower total supports and payments.

The CLM&R per cow+ and year was calculated as revenues for beef, supports, and payments less costs for feed, building, labor, and other costs except land (Table S7). The CLM&R per ha and year was obtained by dividing the result per cow+ by the area of semi-natural pasture and arable land needed for forage production per cow+ (Table S7). The calculation model was applied to herds of 20, 50, and 100 cows+ in southern, central, and northern Sweden (Table S7).

3. Results

3.1. Spruce Plantation

The ANPV for spruce plantation varies greatly between different SQCs and the interest rates (Figure 1). For example, on G24, which is relatively good forest land in northern Sweden, ANPV is only 100 SEK/ha at 2% interest and – 600 SEK/ha at 4%. On G36, which is the best forest land in southern Sweden, ANPV is 2500 SEK/ha at 2% and 900 SEK/ha at 4%. In the basic calculation at 3% interest rate, the results are between the results at 2% and 4%.

Abandoned and marginal agricultural land, and forest land relevant for transfer to semi-natural pasture, most likely has a high fertility equivalent to the best 50% of the present spruce forest. It is therefore only relevant to consider the highest 0%–50% of the accumulated share of spruce land in each part of the country. The ANPV for spruce plantation in this interval, at the basic calculation interest rate of 3%, is 1600–500 SEK/ha in southern Sweden, 500–100 SEK/ha in central Sweden, and ≤ 100 SEK/ha in northern Sweden.

The most fertile pine land in Sweden has SQC T28 [67] and gives approximately the same ANPV as spruce planting on G28, i.e., about zero in the basic calculation with 3% interest. Most (98%) of the pine land in Sweden has SQC below T28 [67] and hence gives negative ANPV in the basic calculation.

The ANPV in the analysis above (Figure 1) presupposes reforestation costs after final felling on forest land. Afforestation of abandoned agricultural land not yet overgrown with shrubs can however be ≈4000 SEK/ha cheaper ([17] indexed up to the 2017 cost level). This increases ANPV by about 100 SEK/ha.

Continued breeding progress, resulting in spruce seedlings growing 25% faster than unimproved seedlings, will result in higher ANPV than in the basic calculation with 15% growth improvement (Figure 2). This profitability improvement is highest on high SQC (i.e., 300 SEK/ha on G36 3% interest) and considerably more modest on low SQC (i.e., 100 SEK/ha on G28 at 3% interest). The profitability improvement is higher at low interests than at high interests (Figure 2).
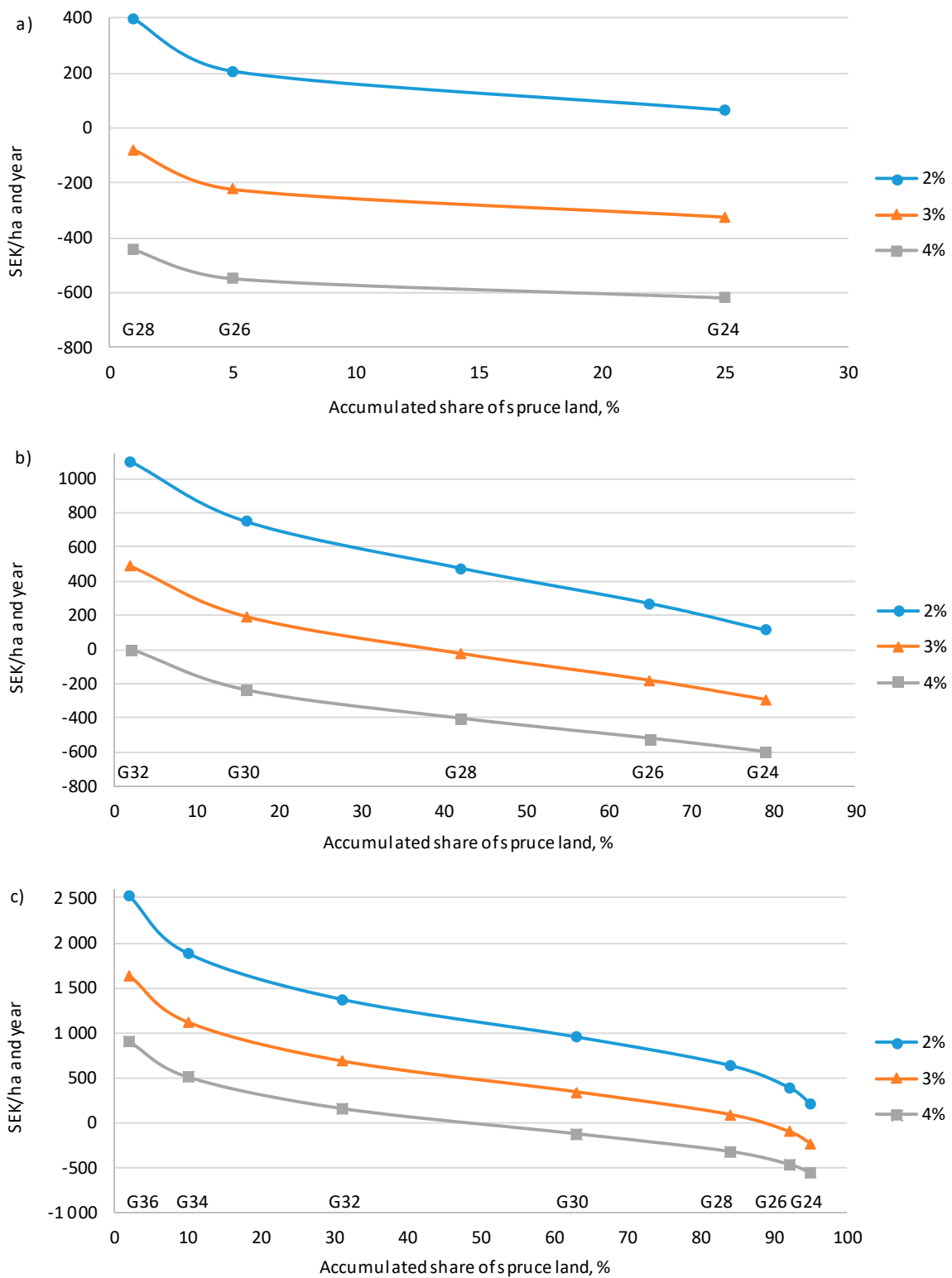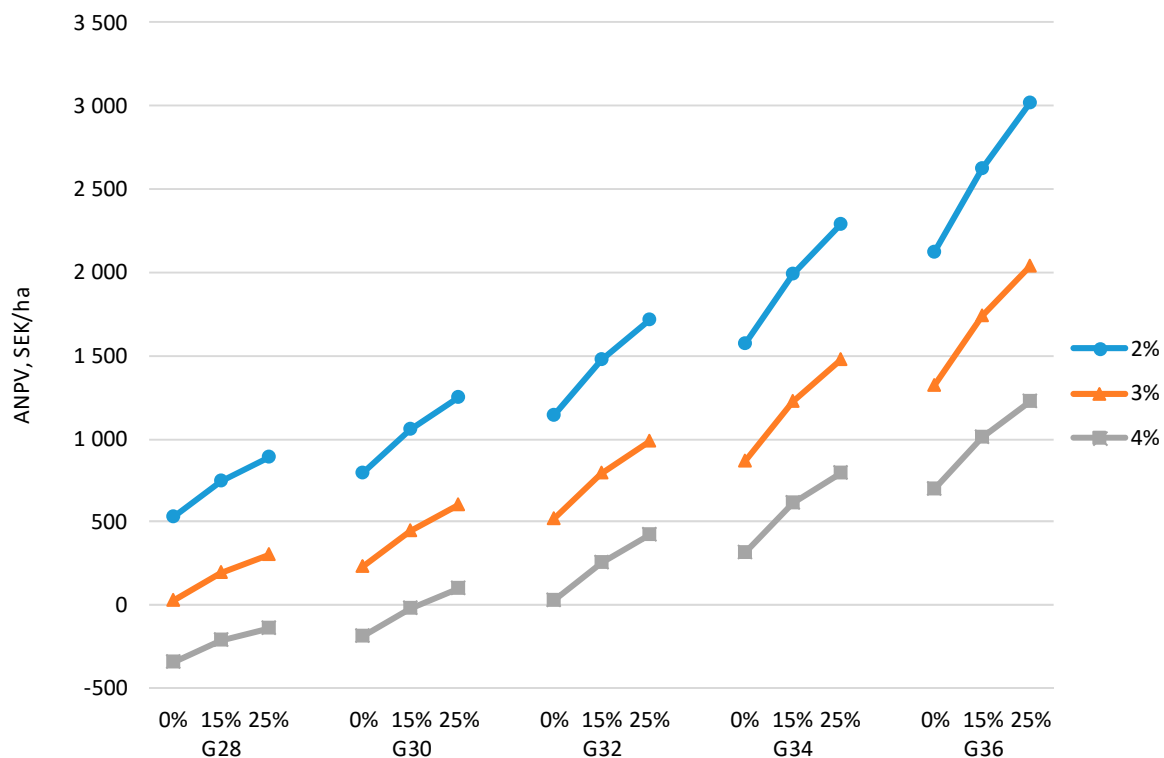
Figure 1. Annuity of net present value (ANPV) (contributions to land, management, and risk; CLM&R) of spruce plantation at site quality classes (SQC) G24–G36 using genetically improved spruce seedlings growing 15% faster than unimproved seedlings at real interest rates of 2%, 3%, and 4% in northern (**a**), central (**b**), and southern (**c**) Sweden. The x-axis indicates the accumulated share (%) of the existing spruce land in each region according to [67]. For (a) the remaining 75% of spruce land is SQC < G24.

Figure 2. Annuity of net present value (ANPV) (contributions to land, management, and risk; CLM&R) of spruce afforestation of abandoned agricultural land not yet overgrown with shrubs with unimproved seedlings (0%) and genetically improved seedlings growing 15% and 25% faster at site quality classes (SQC) G28–G36 in southern Sweden and at real interest rates of 2%, 3%, and 4%.

Warmer climate in the future may increase spruce growth by two SQCs, i.e., from G28 to G30 and from G34 to G36 [68]. This would increase ANPV by 200 and 500 SEK, respectively, at 15% breeding improvement and 3% interest.

3.2. Naturally Regenerated Birch

Natural regeneration without soil scarification and other silvicultural measures can without any costs generally generate positive, though small, net conversion values from thinning and final felling [17] and thus give ANPV ≥ 0 at any interest rate. Silvicultural measures can hasten and improve the regeneration but are also associated with costs.

Figure 3 shows ANPV of natural regeneration of birch on B24 and B26 on forest land after final felling, cleansing, and soil scarification assuming that it, without delay, produces stands with sufficient number of birches to make full use of the land´s production capacity for birch wood. At 3% interest, ANPV is 100 SEK/ha on B24 and 200 SEK/ha on B26. It is considerably higher at 2% but insignificant or negative at 4% (Figure 3).
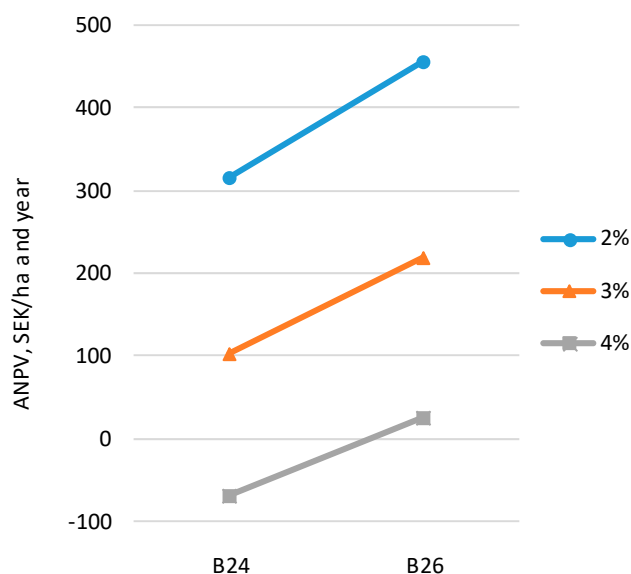
Figure 3. Annuity of net present value (ANPV) (contribution to land, management, and risk; CLM&R) of naturally regenerated birch on site quality classes (SQCs) B24 and B26 at real interest rates of 2%, 3%, and 4%.

On abandoned agricultural land, overgrown with worthless shrubs, the cost of cleansing, and soil scarification by deep plowing are equivalent to the corresponding costs after final felling on forest land. Therefore, ANPV should be about the same in the two cases. On agricultural land that is not overgrown, the cost of cleansing disappears which makes the profitability somewhat better on such agricultural land than on forest land shown in Figure 3.

In the case of natural regeneration, generally birch is not the only volunteering species, but also e.g., spruce will appear. By including spruce in the stands, as is generally done in practice, the profitability will probably be better than in pure birch stands. Compared with pure spruce stands, such mixed stands also imply economic flexibility and addresses some of the growing risks caused by anthropogenic climate change. The mixed stands also have higher biodiversity, recreational, and aesthetic values than pure spruce stands [69].

3.3. Beef Production

The basic calculation of profitability in beef production with grazing on large pasture-forest mosaics, shows that CLM&R is negligible in herds with 20 cows+ but increases sharply as the herd size increases to 50 and 100 cows+ (Figure 4, Table S7). The reason is lower labor and building costs per cow+ in larger herds (Figures S2 and S3). There is a tendency for better profitability in the northern than in the southern part of Sweden. The reason is that higher levels of support compensate more than well for the assumed higher feed and labor costs in the north (Tables S3 and S6, Figure S3).
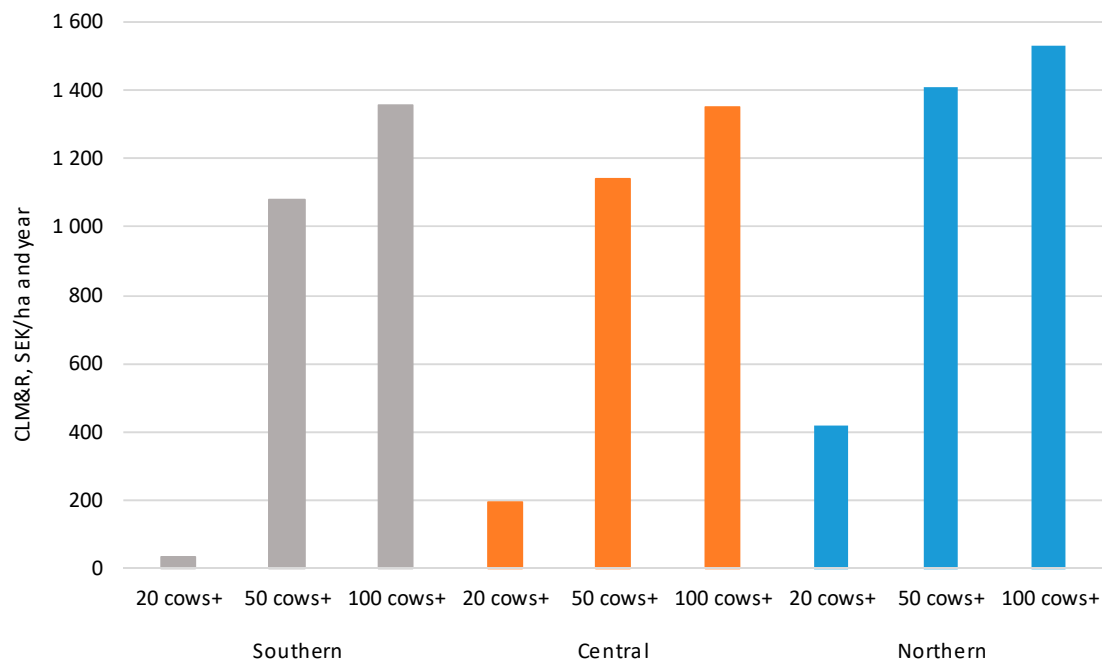
Figure 4. Basic calculation of contribution to land, management, and risk (CLM&R) in organic suckler cow-based beef production in herds with 20, 50, and 100 cows+ grazing on large pasture-forest mosaics in southern, central, and northern Sweden. Cows+ is beef suckler cows + rearing of their calves to slaughter and replacement.

The CLM&R may deviate greatly from those in the basic calculations (Figure 4) depending on political decisions, market changes, and natural conditions, according to Figure 5 which assumes 50 cows+ in all cases except in the case of 2 ha pastures where the herd size is 20 cows+. At 20% lower support and payments, but still large pasture-forest mosaics, the contribution is reduced to nearly nothing (Figure 5). A 3 SEK/kg lower beef price, corresponding to a removed premium for organic beef, reduces the contribution considerably less (Figure 5). The third sensitivity analysis highlights a paradox; the profitability is better when the pasture yield per ha is lower than in the basic calculation (Figure 5). The reason is that the revenue for beef and the direct animal-related supports does not cover the production costs. It is economically advantageous for the pasture to be low-yielding and thus require fewer animals to achieve the grazing pressure needed to qualify for environmental payment and area-related supports paid per ha (Figure 5). Grazing on only 2 ha large semi-natural enclosures with herds with only 20 cows+ results in a considerably negative CLM&R.
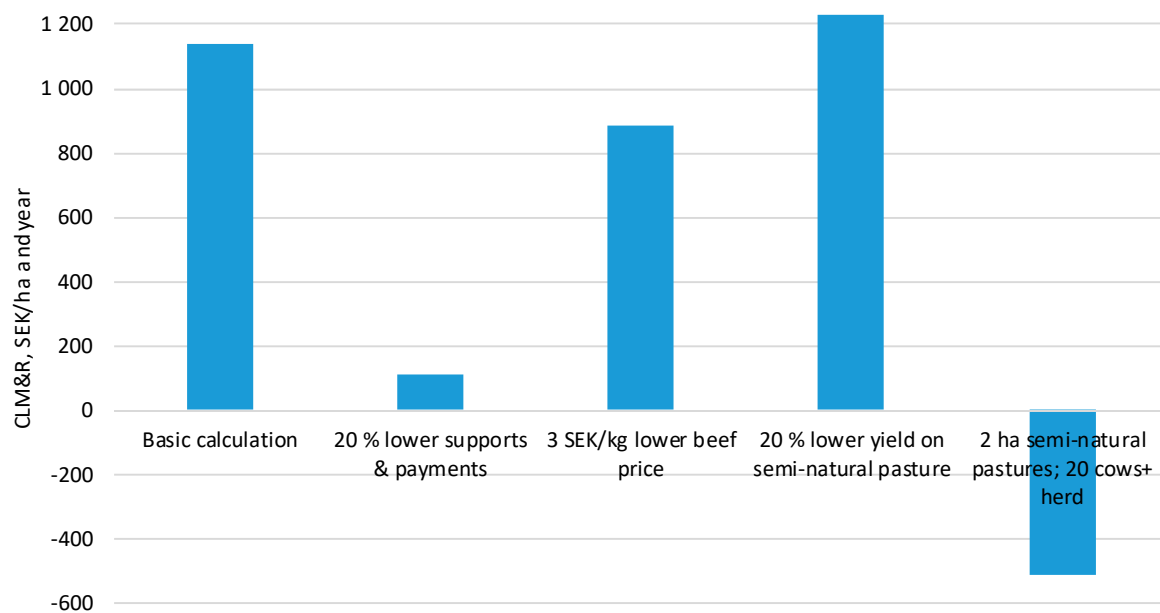
Figure 5. Contribution to land, management, and risk (CLM&R) in the basic calculation for central Sweden and four sensitivity analyses. The herd size is 50 cows+, that is beef suckler cows + rearing of all their calves to slaughter and replacement, except in the case of 2 ha pastures where the herd size is 20 cows+.

3.4. Comparisons between Spruce, Birch, and Beef Production

According to the basic calculation for northern and central Sweden, beef production in herds with ≥ 20 cows+ requiring ≥ 70 ha pasture and arable land gives higher CLM&R than spruce planting and naturally generated birch (Figure 6a,b). When comparing smaller herds and areas with forestry in these regions, spruce planting is the most profitable option only for central Sweden on very fertile land (G32). On less fertile soils, G28, spruce planting gives negative CLM&R while natural regeneration of birch, hastened and improved by cleansing and scarification, gives a small positive compensation if it grows corresponding to B24 in both northern and central Sweden (Figure 6a,b).

The basic calculation for the most fertile sites in southern Sweden (G36) shows that spruce planting always gives higher CLM&R than beef production (Figure 6c). Even on normal abandoned or marginal agricultural land in this region (G32), the spruce gives higher contribution than beef production in herds with less than about 30 cows+ requiring 100 ha semi-natural pasture and arable land for feed production (Figure 6c). On the other hand, beef production in herds larger than 30 cows+ is more profitable than spruce planting on normal abandoned or marginal agricultural land in southern Sweden (Figure 6c). Naturally regenerated birch is never the most profitable option on reasonably fertile land in southern Sweden (Figure 6c).

It is possible that birch on G28 sites has lower growth than the supposed value corresponding to B24 (Section 2.2), which, if so, reduces the birch's profitability. Natural regeneration of birch, without soil scarification and other silvicultural measures, can without any costs generate positive, although small, net conversion values from thinning and final felling. Thus, giving a CLM&R for birch greater than or similar to 0 which is greater than CLM&R for spruce planting on G28 at 3% interest rate. In reality, spruce also generally emerges in natural generations which can improve its profitability (Section 3.2). Thus, on large areas of abandoned and marginal agricultural land in central and northern Sweden, where it is not possible to create profitable grazing-based beef production, natural regeneration of mixed forest is the best business option. Natural regeneration without any measures to hasten and improve the natural regeneration is also what most commonly happens to abandoned agricultural land although it is not compatible with the Forestry Act [70].
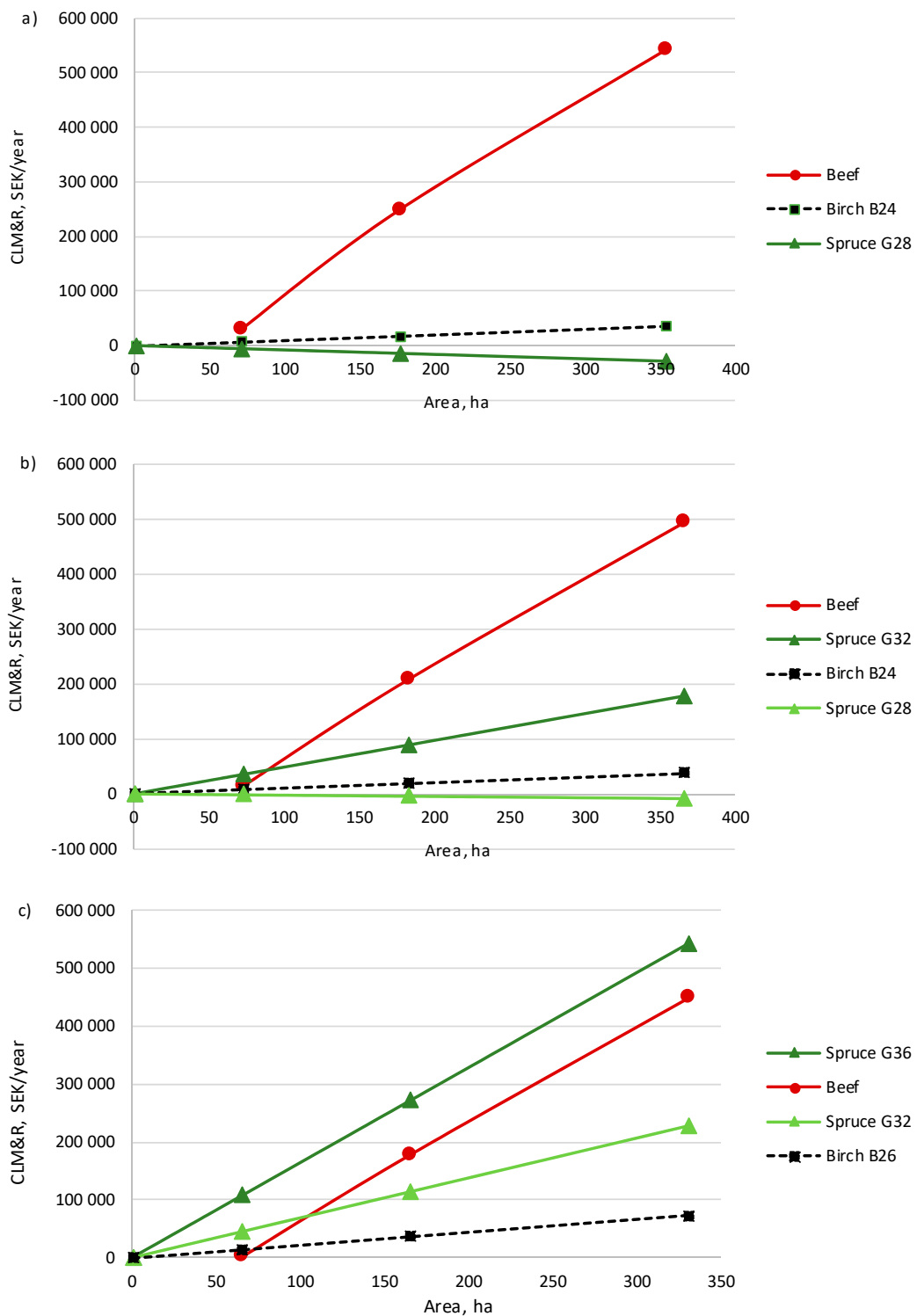
Figure 6. Contribution to land, management, and risk (CLM&R) for spruce plantation and natural regeneration of birch on different SQCs and organic suckler cow-based beef production according to basic calculations in northern (**a**), central (**b**), and southern (**c**) Sweden. The points mark the area of semi-natural pasture plus arable land required for herds with 20, 50, and 100 cows+, that is beef suckler cows + rearing of all their calves for slaughter and replacement.

4. Discussion

The typical beef production in forest districts with abandoned and marginal agricultural land is similar to the examined alternative with small (2 ha) scattered pastures and small herds (≤ 20 cows+), giving negative CLM&R (Figure 5). Therefore, these enterprises can continue only as long as there are appropriate existing buildings for wintering the cattle and farmers willing to work for a low hourly compensation. When these resources run out, beef production and other agriculture activities will cease in many forest districts and the abandonment of land will probably continue unless the production can become more cost-efficient. This abandonment process has been addressed in previous studies [6,7,11,13,15]. However, in the previous studies, the possibilities of making beef production sustainable by creating large pasture-forest mosaics have not been considered.

4.1. Beef Production in Large Pasture-Forest Mosaics or Forestry?

In the basic calculation the examined organic beef production in herds with ≥ 20 cows+ grazing in large pasture-forest mosaics gives higher CLM&R than afforestation and reforestation, i.e., forestry, except on sites of the highest SQCs in southern Sweden where spruce planting gives higher contribution. At SQCs normal for abandoned agricultural land, and with larger beef cattle herds, beef production gives significantly higher CLM&R than forestry.

Beef production in herds with 100 cows+ requiring around 350 ha gives, compared to the best forest options on normal abandoned land, about 200,000 SEK higher compensation in southern Sweden, 300,000 SEK higher compensation in central Sweden, and 500,000 SEK higher compensation in northern Sweden (Figure 6). Larger herds than 100 cows+ grazing in even larger enclosures than supposed in the basic calculation (32 ha) are even more superior compared to forestry options, due to lower labor requirement per cow+ (Figure S5) and lower costs of fence and water supply in the larger enclosures (Figure S4).

In other words, transfer of forest land in the pasture-forest mosaics to pasture after final felling may allow expansion and thus economies of scale in beef production. This, combined with the fact that there may be reasons to have higher discount rates in enterprises where beef production is the main business than in forest companies (Section 2.2), means that the economically optimal final felling age is lower in beef enterprises than in forest companies. For example, regardless of the economies of scale that can further reduce the optimum final felling age, the optimal final felling age on G30 decreases to 58 years at 4% interest from 62 years at 3% and 68 years at 2% [36].

Conventional beef production using artificial fertilizers on leys can reduce the cost of silage production by SEK 0.30/kg DM [29] which reduces the cost per cow+ by approximately SEK 1300. This is significantly less than the loss of support for organic production and additional market payment for organic beef (Tables S6 and S7). In addition, higher silage yield lowers the need for area and thus reduces the single farm payment and enterprise support per cow+ and in many cases also the support for less favored areas. The supposed organic beef production thus has a better profitability than corresponding conventional beef production. It also has higher profitability than the average Swedish beef, milk, pork, and crop production [26]. Thus, the basic calculation supports the hypothesis that organic beef production in large pasture-forest mosaics in most of Sweden´s forest districts can be more economically profitable than forestry and profitable enough to expand on abandoned and marginal agricultural land and forest land.

4.2. Obstacles to Creating Large Pasture-Forest Mosaics

Organic beef herds that are large enough to be profitable require large total areas for grazing and cultivation of winter feed (Figure 6). This can be difficult to obtain in forest districts dominated by small farms. In the examined beef production, about 70% of the land requirement is semi-natural pasture and 30% arable land. However, in Swedish forest districts the arable area is most often several

times larger than the semi-natural pasture area [2]. Thus, the availability of pasture is generally the bottleneck for developing economically sustainable grazing-based organic beef production.

One way to obtain enough pasture for economically sustainable beef production in forest districts can be to extend existing semi-natural pastures by including abandoned and marginal agricultural land and adjacent forest land, which often may have been agricultural land or grazed forest in past times as assumed in this study. However, in many places, roads and scattered houses and gardens make it difficult or impossible to create such large pasture-forest mosaics.

Another obstacle is that the land in such potential mosaics may be owned by several landowners. To obtain enough land a great many land leases or purchases are therefore often required, which can lead to resource-demanding negotiations and other management costs as well as financing problems and risks. Therefore, it is doubtful to what extent the calculated CLM&R is sufficiently high to motivate entrepreneurs to try to create potentially profitable beef operations in the forest districts dominated by small farm properties.

A third obstacle may be fear of forest damage in the mosaics. The risk of forest damage was an important reason behind the ceasing of forest grazing in Sweden during the first half of the 20th century. Livestock, including goats, at that time in many cases only had access to forest grazing [3,51]. However, the risk of damaging timber production would be insignificant when the cattle, besides forest grazing, also have access to more lush grazing [52] as in the supposed pasture-forest mosaics. The historically conditioned fear of forest damage in many forest owners, as well as an emotional resistance to non-regenerating after final felling, would probably work against the possibilities of leasing land to create large pasture-forest mosaics.

Another obstacle related to forest owners may be fear that enclosing one´s land in a large fenced pasture-forest mosaic reduces the hunting value. Unwillingness to abandon the right of disposal over one's land, especially if it is a small area that can give only insignificant rent, is also an obstacle. For many landowners, it may be more attractive to obtain production decoupled agricultural support by only small maintenance measures.

4.3. Obstacles for Active Afforestation

Both most landowners and the general public have aversions to spruce planting on agricultural land out of landscape reasons [17]. When the subsidies for forest planting ceased in the 1980s [14], and neighbors increasingly disliked spruce planting [16], the landowners' interest in active afforestation decreased. Deciduous planting is more accepted for landscape reasons [17], but such plantations must be protected by high fences to be safeguarded from game browsing [17]. Unfortunately, these fences are unprofitably expensive per ha on small abandoned and marginal fields [17]. In addition to these obstacles, most forestry calculations, as in this paper, assume that forest plantations succeed over the entire surface [3,17,36,41]. However, in practice some plantations fail on e.g., wet and frosty sites [71]. If plantation is refrained there, CLM&R becomes zero on these surfaces but if they are planted CLM&R becomes negative for the forestry activities.

Due to lack of competitive alternatives only a very small part of the agricultural land, that has been abandoned during the last decades, has been afforested actively by planting [18]. Most have been left without any measures for natural regeneration which often takes a long time in the absence of scarification [38–40].

4.4. Beef Production is Support Dependent and Forestry Is Interest Rate Dependent

The profitability of grazing-based organic beef production is highly dependent on supports and environmental payments. A 20% reduction in these would wipe out almost the entire CLM&R (Figure 5). A reduction of the beef price by 3 SEK/kg (e.g., a removed premium price on organic beef) would not reduce the profitability nearly as much (Figure 5). Indeed, the risk of reduced support and payments may be a further reason why the calculated CLM&R may be too small to stimulate investment in large-scale beef production in areas with much abandoned and marginal agricultural land.

While the beef production is support-dependent, so is the profitability of forestry highly dependent on the interest rate (Figure 1). The interest in the forestry calculations is reduced from 4% (as in the beef calculations) to 3% due to e.g., tax benefits (Section 2.2). Without this reduction, and thus 4% interest, spruce planting gives negative or negligible CLM&R everywhere except on high SQCs in southern Sweden. On the other hand, at even larger tax benefits reducing the interest rate to 2%, the spruce planting´s CLM&R increases sharply but is higher than 1300 SEK/ha (CLM&R in beef production in herds with 100 cows+ in the basic calculation) only for high SQCs in southern Sweden (Figures 1 and 4).

The fact that spruce planting on abandoned agricultural land has had very little scope in recent decades [18] suggests that landowners are depreciating revenues that arise far in the future, in a way that corresponds to high interest rates, and/or have a strong aversion to spruce on agricultural land due to landscape reasons.

Fast-growing deciduous trees such as hybrid aspen (*Populus tremula* L. x *Populus tremuloides* Michx.) and poplar (*Populus* spp.), that can be harvested as early as 20–30 years after planting, are not as dependent on low interest rates as species with considerably longer rotation. However, hybrid aspen and poplar are grown on only 300,000 ha in Sweden, despite investment support and single farm payment if harvested at least every 20 years [72]. One reason for this insignificant area may be that the fast-growing deciduous trees in game-rich forest districts must be protected by game-fences [17] and the cost for these is prohibitively high for small, abandoned, and marginal fields.

4.5. Grazing for Food and Landscape or Afforestation for the Climate?

Organic pasture-based beef production on otherwise abandoned land, contributes to fulfilling the national goals for increased domestic food production and an increased organic share of this production, as well as goals for landscape and biodiversity preservation. On the other hand, afforestation of this land would by carbon sequestration in growing trees, and production of wood substituting fossil fuels and energy-intensive materials [73], contribute to achieving the goal for Sweden to have no net greenhouse gas emissions by year 2045, and to achieve negative net emissions through carbon sequestration [74]. Spruce planting and soil scarification, hastening natural birch and spruce regeneration, provides much greater climate benefits than the slow and often patchy afforestation that arises if the abandoned land is left without any measure which is now the most common event.

One way to address the climate change problem is to increase the production of woody biomass by tree breeding progress [75]. During the 2020s, traditionally bred spruce seedlings that grow 20%–25% faster than natural spruce seedlings will become available [75]. It would also significantly improve the profitability of spruce planting especially on high SQCs (Figure 2). By using cloned spruce seedlings even greater growth-increases can be achieved [75]. It is important in future research to investigate how the economic competition between beef production and forestry may be affected by such tree breeding progress in combination with possible consideration of the climate in future agricultural supports and environmental payments.

5. Conclusions

Using abandoned or marginal agricultural land in Swedish forest districts for organic beef production, with herds of more than 20 suckler cows and their calves grazing large pasture-forest mosaics, is under present economic conditions more profitable than afforestation with planted spruce or naturally regenerated birch, except on areas of high site quality classes in southern Sweden where spruce planting gives a higher economic contribution. Future tree breeding progress and possible decrease of support and environmental payments to pasture-based livestock would however increase the competitiveness of resumed afforestation relative to the beef production.

Supplementary Materials: The following are available online at http://www.mdpi.com/2073-445X/9/2/42/s1.

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