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SusCatt Synthesis Report: Productivity, resource efficiency and product quality of forage and grazing based cattle production systems

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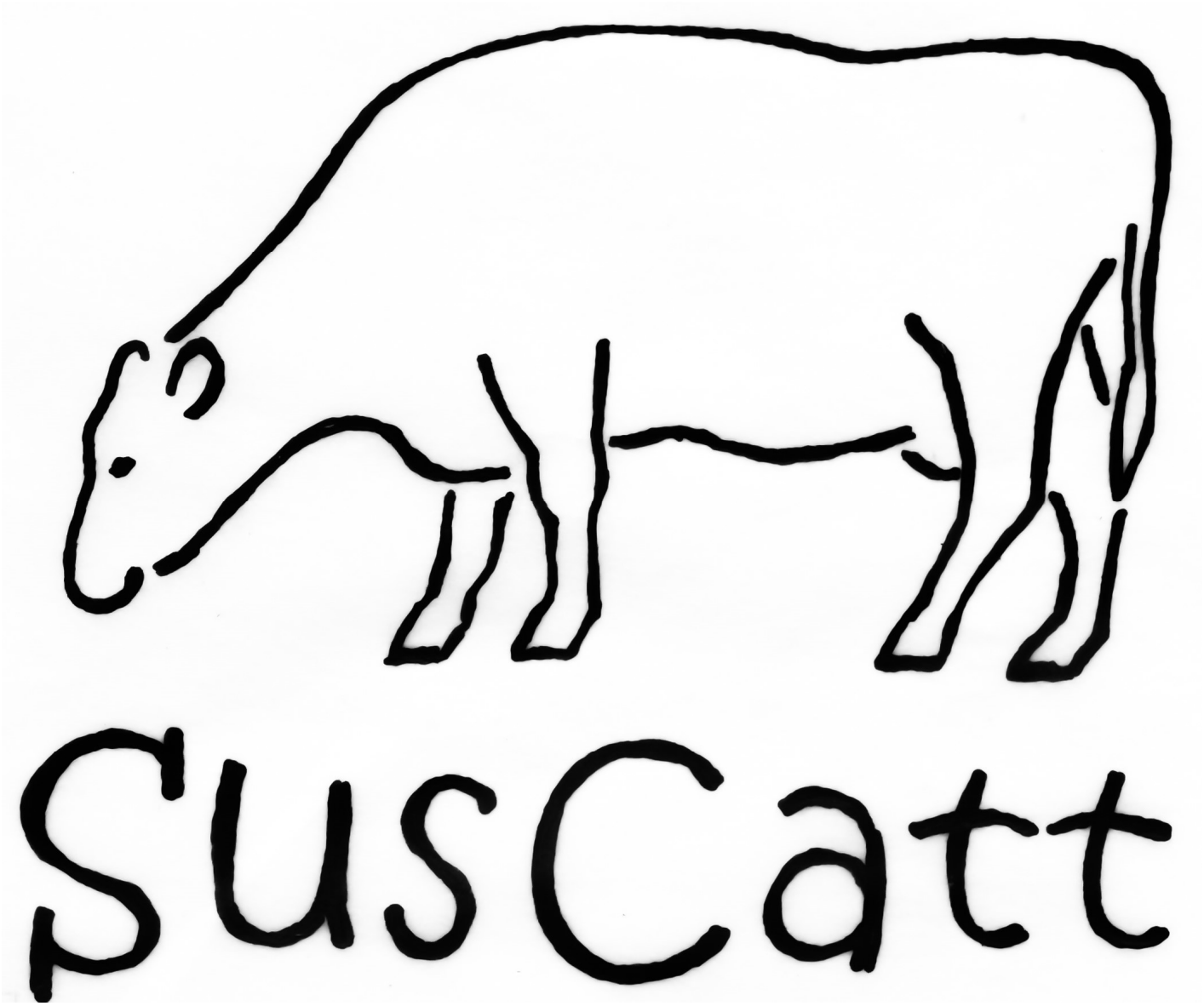

Gillian Butler[1], Bjørn Egil Flø[2], Flaviana Gottardo[3], Anna Hessle[4], Matthias Koesling[2], Elisabet Nadeau[4], Carsten Malisch[5], Giorgia Riuzzi[3], Tomasz Sakowski[6], Anna Woodhouse[7], Finn Walland[2], Håvard Steinshamn[2]

[1]Newcastle University, [2]Norwegian Institute of Bioeconomy Research, [3]University of Padova,[4]Swedish University of Agricultural sciences, [5]Kiel University, [6]Institute of Genetics and Animal Breeding of the Polish Academy of Sciences, [7]Research Institutes of Sweden

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FORFATTER(E)/AUTHOR(S)

Gillian Butler, Bjørn Egil Flø, Flaviana Gottardo, Matthias Koesling, Elisabet Nadeau, Carsten Malisch, Giorgia Riuzzi, Tomasz Sakowski, Anna Woodhouse, Finn Walland, Håvard Steinshamn

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Preface

The main objectives of the research project “Increasing productivity, resource efficiency and product quality to increase the economic competitiveness of forage and grazing based cattle production systems”, with the acronym SusCatt, were to evaluate the productivity, resource-use efficiency and consumers’ acceptability of a transition to high forage and pasture diets for European cattle.

The project focused on dairy, integrated dairy/beef and specialized beef production systems, addressing:

- Productivity, product, animal health and welfare, and economic performance,
- Resource use efficiency and environmental impacts, both assessed experimentally, by modelling and life cycle analysis,
- Consumers’ appreciation.

The project involved modelling, experimental and participatory R&D activities and covered contribution from SMEs (farmers, advisory service) and pooled expertise from seven academic centres of excellence in six European countries. The project was organised in 4 work packages; two focusing on beef and milk production, feeding into one on overall assessment of economic, resource-use efficiency and societal acceptance and the fourth was dedicated to disseminating our findings.

This report synthesis the findings from work on technical analysis of cattle beef and dairy production and from economic, environmental and societal assessment.

The research was made possible by funding from SusAn, an ERA-Net co-funded under European Union’s Horizon 2020 research and innovation program (www.era-susan.eu), Grant Agreement n°696231, with funds from national funding bodies; Research Council of Norway (RCN, Norway), the Swedish Region Västra Götaland and Swedish Research Council (FORMAS, Sweden), Department for Environment, Food & Rural Affairs (DEFRA, UK), Ministry of Agricultural, Food and Forestry Policies (MiPAFF, Italy), National Centre for Research and Development (NCBR, Poland), and the Federal Ministry of Food and Agriculture (BMEL, Germany).

Tingvoll, Norway, 20th February 2021

Håvard Steinshamn

Project leader

Innhold

Summary

SusCatt considered a wide range of innovations or system comparisons in the 6 countries, all aimed to improve sustainability within European cattle farming. On the whole, these involved reducing production intensity, making greater use of home-grown grass and other forage crops on farms – generally with promising results for beef and dairy production when we considered their potential impact across the 3 pillars of sustainability.

As expected, in most cases milk yield and growth rates of beef cattle were comparable to or lower than the 'standard' systems in our comparisons. However, any differences in output were more than offset by substantially lower input costs and/or better product quality attracting higher, resulting in better economic returns to the farms, especially if also triggering qualification for Agri-environmental payments.

From an environmental perspective we conducted life cycle analysis, land use assessment and biodiversity prediction for selected systems' innovations. As with the economic budgets, no innovations tested had a larger carbon footprint or acidification potential (per kg standardised milk or kg liveweight) than comparable benchmarked systems. However, for some, eutrophication was suggested to be higher, as was nitrogen leakage potential – surprising for some farms with zero incoming nitrogen fertiliser or feed. The novel prediction on biodiversity dynamics was also interesting since the method used assumed all active management of land reduces diversity. Despite this limitation, our innovations appeared to achieve the best we could hope for, being 'less bad' than benchmarked systems.

Social sustainability focused on animal health and welfare, attitude to pasture fed cattle systems and food quality with respect to consumer health. Animal health and welfare proved to be comparable or better under less intensive dairy production, reporting lower somatic cell counts (higher milk prices) and some farms showing the possibility of eliminating antibiotic use altogether. Awareness of pasture only feeding was very varied, with interested consumers favouring this very extensive systems rather than what might happen as other farms potentially become more intensive in the future. Without exception, all milk and meat from innovative systems had a fatty acid profile more appropriate for consumer health than standard production systems, being higher in beneficial fatty acids, especially long chain omega-3.

Overall, the innovations considered in SusCatt reducing intensity of cattle production ticked many boxes across all pillars of sustainability offering economic, environmental and social benefits. Details are covered in a number of academic papers and technical notes, targeting farmers, policy makers and consumers, accessible from the project website.

1 Introduction

Increased demand for livestock products, exacerbated by the expectation of 'cheap food', has led to intensification of milk and beef production, reducing reliance on forage crops - fueling the food vs. feed debate, ethics and environmental issues relating to soy imports and land-use change. In terms of edible energy and protein, it is inefficient to feed cereals, pulses and oilseed products to livestock. Including legumes in mixed swards as an alternative to fertiliser nitrogen offers numerous advantages to animal health, farm economics, milk quality and environmental impact. It is widely accepted that nutritional quality of milk and meat is heavily influenced by livestock management and feeding. Pasture milk and meat, especially from legume swards are valuable sources of beneficial fatty acids and could help society fulfil EFSA and WHO recommendations to increase consumption of long-chain omega-3 fatty acids. Contrasting strategies have been proposed to improve sustainability, like 1) intensification, 2) reduced demand for animal product and 3) reduction in the use of food-competing feed components in the livestock diet. High forage and pasture diets associated with option 3 also improve societal credibility, product quality, animal health and welfare and reduce negative environmental impacts. In addition, much of European land is unsuitable for arable cropping, so ruminant livestock are the only option for food supply and grazing animals are integral to manage and preserve biodiversity on semi-natural pastures. Furthermore, many consumers are willing to pay for traceable milk and meat, produced with home-grown or local feed.

In the SusCatt project, sustainable intensification over a wide range of production systems has been investigated. We considered the scope to improve resource use efficiency and product quality from cattle, simultaneously enhancing eco-system services and decreasing net GHG emissions - meeting consumers' expectations of milk and beef production. Farms with more sustainable production, will have greater reliance on forage and by-product feeds to replace cereals and soya. At the other end of the spectrum, production efficiency has been assessed in forage only systems, identifying individual animals capable of maintaining health with minimal external inputs and creating high-quality dairy and beef products. Dairy-bred beef is biologically more efficient than dedicated beef herds with GHG emission covering both milk and meat, however, dairy calves are not always reared, with many killed at birth. Selective use of beef semen on dairy herds can avert this practice and, if combined with sexed semen, could improve biological efficiency, targeting cows to produce either replacement dairy heifers or crossbred bulls for beef. These strategies offer a competitive economic advantage for producers, in addition to positive effects on environment, animal health and welfare, producers' satisfaction and give consumers ethically produced milk and beef, which enhances rather than challenges health.

There are differences for cattle production across Europe, but we believe SusCatt findings are relevant beyond participating countries. We investigated beef in three contrasting countries and dairying in five, spanning much of European diversity from Mediterranean to Scandinavian, UK, German to Polish production systems. This report, built upon the common three pillar of sustainability - economic, environmental and social, summarises and synthesises our findings, to identify common conclusions, critical aspects and general recommendations for beef and dairy production.

2 Economic sustainability

Profitability or economic sustainability on cattle farms depends on a combination of a) the level of production (milk yield from dairy cows and calving- or growth-rates for beef cattle), b) the selling price of milk or meat (or calves) and c) costs incurred in the production sytems. Encouragingly, many studies within SusCatt found our innovative, forage based practices reduced feed costs, increased the level of production and/or enhanced the potential or actual value of the milk and meat produced.

Another aspect that can help financial returns to farm is accessing agri-environmental funding, highlighted by the study with dariy bred calves in **Sweden**. In contrast to indoor feeds, herbage from semi-natural pastures can be associated with a negative cost when the agri-environmental payments are included in production budgets. Also, since payments are often allocated per hectare, disadvantaged land might not only attractive greater payment per ha but, often needs for more hectares to produce necessary forage. Herbage production from these semi-natural pastures dictated the level of agri-environmental payment, can differ by as much as sixfold.

2.1 Profitability

Some of the innovative production systems studied in SusCatt were monitored for economic performance and benchmarked against more typical, comparable systems, considering returns from selling products and income from other sources, balanced with costs involved.

Contributing margins were calculated as:

- Contributing margin 1 = revenues (sales of livestock products including direct livestock subsidies and Agri-environment grants) minus total variable costs (purchased feed, ferilisers, veterinary sevices, straw…) minus production dependent fixed costs (machines, ….)
- Contributing margin 2 = Contributing margin 1 minus production independent fixed costs (buildings..)

In **Sweden** we assessed grazing dairy born calves as profitable climate-friendly opportunity to maintain biodiversity, comparing economics of pure-bred dairy and beef-cross **steers** under two pasture-based systems (21 vs 28 month slaughter), in three Swedish regions with a range of conditions - giving 12 different scenarios. Calculations assumed 70% semi-natural pastureland qualified for basic agri-environmental payment (100 Euro/ha) and 30% was high biological values, eligible for a higher payment (280 Euro/ha).

A similar study was conducted with **intact dairy bull calves**, again comparing performance of pure bred and beef cross calves, under two fully housed forage systems (15 vs 18 month slaughter), in three Swedish regions - another 12 systems. In this case, an enterprise budgeting technique used performance from the original all-in-all-out trials to assess profitability of continuous rearing, assuming calves were born throughout the year.

Bulls achieved higher carcasses income but lower support payments than steers. For bulls, breed choice influenced incomes more than the production system and slaughtering older heavier bulls gave higher revenue compared to a faster finish. In contrast, for steers, the production system was more important for income and contributing margins than the breed choice. Older, heavier steers, grazing over two seasons, gave higher revenue and margins than younger, lighter steers only grazing one season. Interestingly, in LFA regions, agri-environment support for steers was almost as high as carcasses returns, especially for older cattle.

Costs were relatively similar in the options tested, with differences mostly arising from i) calf purchase, as the beef crosses were more expensive than pure dairy bred, ii) higher feed costs for the more intensive finishing (for both steers and bulls) , counteracted with iii) higher labour and building

costs associated with delaying slaughter by 3 or 7 months (for bulls and steers respectively) for the less extensive systems. Costs were similar between the regions except for silage making, due to estimated differences in assumed forage yield, harvest machinery chains, and home grown or purchased grain.

If cows are not needed to breed replacement dairy heifers, using beef rather dairy semen is a good choice for profit on farms with facilities for housed, forage-based finishing of bulls. On the other hand, on farms with access to semi-natural grazing for steers, using beef semen does not have a big influence on profitability whereas access to agri-environmental payments does, especially for extensive finishing over two grazing seasons. Details are presented in technical notes 2.1.3 and 2.2.3 and SusCatt economy report

The economics of beef was also compared in **UK**. Records from 2 certified Pasture Fed Livestock Production Association (PFLA) beef suckler farms selling directly, through a farm shop, internet sales and/or farmers' markets were compared with Agriculture and Horticulture Development and Advisory Board (AHDB) benchmarking figures for 67 recorded herds in UK. On the whole returns for meat sales on PFLA farms (per breeding cow) were lower than the AHDB recorded herds, 22% less than top 25% of farms (ranking farms on net margins) and 3% less than average performance. This was more than offset by much higher 'other' payments coming into the farms, mostly for Agri-Environment payments and Feed-in-Tarif for PFLA farms, giving higher returns per cow compared with the benchmarked farms – total returns onto PFLA farms were 25% higher than the average for the AHDB reorded herds. The most striking aspect of the economic performance was the discrepancy in production cost, with incremental increase going from PFLA (£369 per cow), the top 25% farms (£674 per cow) and the AHDB average (£971 per cow), largely driven by feed purchase (negligible on PFLA farms) and labour. The bottom line is that the *bottom line* on the PFLA farm exceeded that of even the top 25% AHDB recorded farms with the margin between costs and returns more than doubled.

For **Norway,** data from 200 dairy farms in the certral region, was categorised into 3 equal sized groups; 'Low', 'Medium' and 'High', according to the level of concentrate feed in the cows' diet. Overall, on average 'Low' farms performed financially better, with higher gross margin and contributing margins than 'Medium' and 'High' farms, although, it is important to note 'own labour' was not recorded or accounted for in the analysis. Although cows on these farms produced less milk, they had a higher milk price (likely to be due to lower somatic cell counts) and governmental payment (per kg milk). Details are presented in SusCatt technical notes 3.3.1 SusCatt economy report (Steinshamn et al 2021).

Data from 14 dairy farms in the Po Vally in the Veneto region of **Italy** was grouped into two systems, one, described as 'conventional', was typical for intensive dairy farms feeding maize silage. The other, 'alternative' group, was more heterogenous, but where hay from permanent meadow and rotational grassland, and/or cereal silage (other than maize) were used in the diet. The 'alternative' farms achieved on average higher milk price and their margins was 1.6 cent higher per kg ECM delivered than the average for the 'conventional' group. Milk produced in the Veneto region is mainly used for cheese production with milk pricing partly based on coagulation properties and milk from the alternative farms was better suited for cheese making. Details are presented in the SusCatt economy report (Steinshamn et al 2021)

This typifies many of the SusCatt forage based production systems found to enhancing milk and meat quality – with superiour nutritional properties, often evidence of low levels of disease and high animal welfare. The study in Italy, identified marker components to authenticate on farm production systems and trace supply chains. Together these attributes offer the potential for niche marketing and premium pricing, which could contribute to greater profitability. Details are reported in SusCatt Technical note 3.4.2 and paper by Riuzzi et al. (2021)

Many of the SusCatt studies identified how performance in dairy and beef cattle on our extensive or more forage based production systems can be comparable to 'standard practices' or possibly had tradeoffs with other characteristics essential for sustainability.

2.1.1 Dairy production - Milk yield

Differences between the 8 most popular breeds and crosses on low-input and organic dairy herds in the **UK** study were relatively small - the monitored farms appeared to select genotypes to suit their particular system and most breeds had some superior attributes. With respect to performance, average milk yield was 20 litres per cow per day, with pure bred Holstein/Friesian (HF) and Holstein/Friesian x Scandinavian Red (HFSR) cows recording 9% higher than the average, although the advantage of the pure Holstein/Friesian cows reduced slightly when considering output of milk solids. The higher yields from HF and HFSR might be explained by the higher than average levels of concentrate and silage supplementation (together +23% above average), although this also applied to the Shorthorn cows who had the lowest milk yields, 11% less than average despite supplementation being 40% higher.

Interestingly results from the follow up 'within herd' study in UK revealed variation between cows under the same management was greater than the performances of these different breeds, when averaged over multiple farms. Within each herd, the range in milk yield between the highest and lowest yielding cow ranged from 49% to 68% of the herd averages, however, selecting for milk yield may not necessarily be positive for economic sustainability. Intakes were assessed with Rumiwatch halters and in 2 of the 3 herds, the higest yielding cows were not the most efficient (as hinted at in the breed comparison study) it is more sensible to select cows on production efficiency i.e. litre of milk produced per unit of dry matter intake.

In **Italy**, UNIPD found no major differences in performance between farm adopting contrasting feeding regimes based on maize silage vs. other silages vs. permanent meadow hay, suggesting it is possible to shift to a more animal and environmentally friendly feeding regime while maintaining production and reproductive standards.

Holstein Friesian and Simmental cows in **Poland** responded to better nutrition following meadow renovation, producing 1.8% more milk compared with comparable cows fed with forage from unimproved pasture. Milk urea concentrations suggested higher protein intakes from improved pastures, especially for Holstein Friesian cows on summer grazing and both breeds during the 2nd winter on silage from improved pasture.

Retrospective records from the 200 cows in the **Norwegian** study calculated average milk production for 'Low', 'Medium' and 'High' farms was 7868, 8421 and 8906 kg energy correct milk (ECM), with concentrate use equivalent to 0.29, 0.33 and 0.36 kg DM per kg ECM. Whereas average farm size was similar across groups (45 ha), 'Low' farms had lower stocking rate than 'High' and more grazed forage in the diet than either 'Medium' or 'High' farms. Milk production on dairy farms in Norway is restricted by quota, and farms in all three groups achieved similar quota fill at 93%. Thus, it appears feeding strategy and therefore milk production on most farms was linked to the quota held although, as mentioned, farms with moderate yields from 'Low' concentrate feeding performed financially better.

To identify the effect of sward diversity on milk yield, CAU in **Germany** established two pasture systems with different sward complexity: the simple mixture was a binary mixture of white clover and perennial ryegrass, and the complex mixture consisted of 8 species including three legumes and four herb species. These were grazed with 90 spring-calving jersey cows, full-grazing during most of the experiment, with 2 kg concentrate per cow per day given at milking. Cows rotated between paddocks twice daily, introduced at maximal pre-grazing heights of 10 cm, grazing each paddock 10-11 times each year. Milk production was extremely high for Jersey cows with ECM yields of 29.4 and 30.3 kg

cow^{-1} day^{-1} at peak lactation and 22.1 and 23.5 kg cow^{-1} day^{-1} in late lactation for binary and diverse swards, respectively - comparable or possibly only slightly less than housed dairy systems.

2.1.2 Beef production: Animal growth rate, carcass weight and classification

In **Sweden** trials compared performance of male dairy calves sired by both dairy or beef bulls, rearing bulls semi-intensively (slaughtered at 15 vs 18 months) or as steers in an extensive grazing system for 21 or 28 months. Swedish Red and Swedish Holstein dairy cows were bred either with dairy semen or using Angus (bulls) or Charolais (steers) sires. Over both these studies, results show crossbreeding dairy calves improves their potential growth rate, both for entire bulls under intensive or semi-intensive feeding or for steers under more extensive forage dominated feeding systems.

Angus-cross bulls had higher live weight gain, carcass weight, dressing percentage, conformation, fatness and marbling score than the pure dairy bulls. Growth rates were lower on the less intensive diets (56% grass-clover silage) but postponing slaughter gave heavier carcass and better marbling score compared to bulls finished on 36% silage diets.

The extensive system for the steers was dominated by forages and grazing semi-natural pastures. Lifetime growth rates were similar for pure or cross-bed steers (0.85 kg per day) but superior killing out gave crossbreds cattle heavier carcasses (+32 kg at 21 months, and +50kg at 28 months of age) and better conformation, especially for cattle slaughtered at higher liveweights/age. The dairy steers deposited more fat, reflecting a tendency to a higher degree of visually assessed intramuscular marbling, in the sirloin steak. Despite the younger slaughter age, the longer housing period leading up to slaughter for the 21-month-steers (163 vs 100 days) lead to a higher fat class.

Productivity performance (average-min-max days of fattening, age at arrival and at slaughtering, mortality, early slaughtering) were compared for 11 **Italian** beef farms, some with and some without maize silage in the finishing diets. Cattle breed was also considered, comparing French imported vs home sourced Italian cattle. As with the dairy study, analysis showed no differences in performance between feeding groups or breeds: no parameters differed between farms using maize silage and those that did not. This is a positive result for SusCatt's aims, showing it is possible to both rear (Italian) crossbreeds cattle and shift to more sustainable diets without sacrificing beef performances.

3 Environmental Sustainability

3.1 Carbon footprint and lifecycle assessment

Data from the **Norwegian, Italian** and **German dairy** farms were used to calculate a cradle to farm-gate life cycle assessment (LCA) to judge the environmental performance, comparing CO_2ep per kg energy corrected milk (ECM) produced i.e. the carbon footprint. In both Italy and Germany the LCA results were lower for farms using more roughage feed, but no differences were found for the farm goups in Norway. The lower predictions were significant for the German dairy systems although differences were smaller for the Italian farms, due similarities in the systems compared; none of the farms were able to graze and concentrate feeding was higher than in Germany.

Acidification potential for all the interventions monitored in the project were lower than comparable benchmarked systems and the resource use was more than 50% less for these systems, as was the eutrophication potential for the German herds compared to the benchmarked performance. In Italy the eutorphication pontential for alternative innovation farms was similar or higher to the 'standard system'. In Norway, the groups of dairy farm did not differ in either fossil energy nor fertiliser nitrogen use per kg protein sold from the farms.

Although the **Italian** dairy study found no major differences in performance between farms feeding different forages, those feeding maize silage had a higher proportion of heifers in the herds, which could suggest poorer longevity, higher replacement rates and hence increase the 'overhead' carbon cost of the rearing phase over fewer lactations.

In **Germany**, CAU assessed sward diversity on methane emissions using two subgroups of 11 dairy cows in a crossover design, in two measurement periods of two weeks each, covering grass/clover and diverse sward types. Measured methane emissions from well managed pastured cows were comparable or lower to those produced in barn systems. Due to the generally very high production from the Jersey cows in this study. Emissions per kg of ECM produced were very low, with slightly higher values from the complex sward at 11.2 g compared with 10.4 g CH_4 kg $milk^{-1}$ from grass/clover swards in spring and 12.6g vs 11.2g CH_4 kg $milk^{-1}$ in autumn – all considerably lower than previous published value of 17g / kg ECM for Jersey cows.

Higher emissions from the diverse sward is likely to be explained by the relatively low proportion of bioactive herbs maintained with high intensity use. A second experiment harvested all species from the pastures and tested pure concentration and binary mixtures with perennial ryegrass *in vitro*, using increasing herb shares. This identified particularly big trefoil (*Lotus pedunculatus*) and salad burnet (*Sanguisorba minor*) to possess antimethanogenic potential. We identified big trefoil to be very rich in condensed tannins, while salad burnet was particularly rich in hydrolysable tannins. However, while big trefoil possessed stronger antimethanogenic potential, salad burnet was better at also maintaining digestibility.

For the beef production in **Sweden** bulls and steers of pure bred dairy and dairy-beef breed crosses were assessed for environmental performance. Beef breeds had a lower or similar environmental footprint compared to pure dairy breeds. Regarding the carbon footprint, the beef breed steers had a 14% lower carbon footprint compared to the pure bred dairy steers and for the bulls the carbon footprint was 7% lower. For the other environmental impact categories such as acidification, eutrophication potential and resource use, the differences were small approximately 3-9% lower or higher than the dairy breeds. The results show the potential of beef breeds. As the slaughter weight is higher for beef breeds, the amount of meat on which to allocate the environmental burden increases. The differences in this trial were small however, so more research is needed to find parameters that potentially reduces the environmental footprint further.

In the **UK** Pasture-fed beef production, performance on two 'test' farms were evaluated with LCA for environmental sustainability and compared to the UK average and top 25% of recorded beef producers (AHDB figures, ranked on economic performance). The carbon footprint (per breeding cow) for the 2 'test' farms was 13% lower than the UK average beef farm and 6% lower than those in the top 25% of recorded beef systems. The acidification potential was also lower for the 'test farms' compared to the UK Average and comparable to the top 25% farms. Potential phosphorus leakge was also less for the test farms with freshwater eutrophication 33% lower than than the UK average and again, at a similar level to top 25%. Calculated nitrogen leakage was however higher for the test farms, with a marine eutrophication potential 10% more than for the UK average and on a similar level as for UK top 25%. With minimal inputs from off-farm, this needs to be investigated further for an explanation, since resource use was much lower for test farms due to the absence of concentrate feed, pesticides and mineral fertilisers.

3.2 Land use

For land use the **Italian dairy** experimental case used less m^2 than the conventional case due to feed production demanding less land than in the conventional case. For the **German dairy** case the land use was similar for all systems studied. The conventional case used concentrate feed that demands land use for production and the experiemtnal case uses land for roughare production and grazing and in this case both systems used similar amount of land per kg of milk (ECM).

The dairy farms in the group with 'Low' concentrate use in the data from **Norway** were less dependent on land outside the farm to produce purchased concentrate. On average, 0.39, 0.43 and 0.46 ha of land outside the farm was used to produce ingredients in purchased concentrate, for every ha of total land used in 'Low', 'Medium' and 'High', respectively. The agricultural area outside the dairy farm produce grain, oilseed, and pulsed used in the purchased concentrate mixtures. In other words, 'Low' farms based milk and meat production more on local land resources than the two other groups. However, the total land occupation per kg energy corrected milk and meat delivered were greater on 'Low' farms than the two other groups, 3.24 m^2 in 'Low', 2.88 m^2 in 'Medium' and 2.84 m^2 in 'High'.

In the **Swedish** beef trials with steer and bulls, steer used more land per kg of meat due to the grazing and longer life time compared to bulls. However if comparing the different breeds within the two categories, pure bred dairy and cross bread beef, then cross breds used slightly less land than the pure breds. The cross bred steers used approximately 13% less land per kg of meat compared to the pure bred dairy steers, mainly due to less rapseed meal in the feed ration. For the bulls, the tendency for less land use for the cross breeds could be seen for bulls aged 15 months at slaughter but for the group that was 18 months old at slaughter, the cross breeds had a 6% higher land use than pure bred bulls. The cross breeds had twice as high intake of silage which explains the results.

The **UK** organic beef LCA study showed that land use was 10% lower for the pasture feeding farms compared to the UK average. The UK average used a similar amount of land for grazing per kg of meat as the two pasture farms but the UK average also used more land for the silage, barley and soy production. The farms in the UK top 25% (based on net margns) had similar land use as the pasture farms despite the use of soy and barley in their feed rations.

The **UK** within herd study with dairy cows did not directly assess land use but monitored cow feed intakes relative to milk yields. The range between the most and least efficient cows was between 45-65% of the herd averages, implying milk output per ha could potentially vary by a similar magnitude.

3.3 Biodiversity

Currently, there are no widely accepted ways to estimate the impact of land management on biodiversity - it is complex and difficult to predict dynamics of multiple species in different environments. One potential method, developed in Switzerland (Chaudhary and Brooks, 2018), is

recommended by the UNEP-SETAC Life Cycle Initiative. However, whilst it is practical and easy to use, it is not without flaws. It can only predict negative impacts, yet high biodiversity in many semi-natural landscapes is a direct result of farming activity over the millennia. Due to lack of a viable alternative, the Chaudhary and Brooks (2018) based assessment was used in SusCatt.

Contrary to previous reports, management on the extensive **dairy production** in **Germany** and **Italy** were predicted to have a less negative impact on biodiversity when benchmarked against more *conventional* production. Since pasture was defined as "light" land use with lower negative impact on biodiversity compared with "intensive" annual crop production, the greater pasture use and lower concentrate feed levels meant overall land use and negative impact was less than for the extensive systems. Also, conventional dairying in both Germany and Italy fed more soy, allocated a high negative impact on biodiversity. Using this method, farm location is also important as some regions have greater diversity or more rare species. This applies to the Padova region which holds rare species, resulting in a tenfold higher negative impact compared to the German dairies in this study. The Chaudhary and Brooks method predicted extensive systems to have a less negative impact on biodiversity and if the milk were to be produced in one location only, northern Germany is less sensitive to change than the area around Padova.

Extensive **beef** production on semi-natural pastures show high biodiversity as these landscapes are important for so many species, with fauna at different states of succession, depending on grazing management. Numerous studies report moderate grazing activity enhances heterogeneity in species richness, composition and state of succession, compared with abandonment or other forms of management (such as mowing or burning). Limitations of the Chaudhaury and Brooks (2018) methodology became apparent when considering the extensive beef systems in Sweden (for dairy bred bulls and steers) and the UK suckler beef since, on assessed farms in both countries, grazing is known to enhance diversity of semi-natural pastures. Despite this, for the dairy beef in Sweden, calculations show housed, semi-intensively reared bulls lead to less loss in biodiversity than grazing steers, largely as a result of their earlier slaughter age and lower lifetime land use. The beef-cross calves were also deemed to have less impact (per kg meat) than purebred dairy calves, in this case due to heavier carcass weights, distributing diversity loss over a higher yield of meat. As stated it has been shown that biodiversity on natural pastures are positively affected by light to medium grazing, hence the results for the Swedish beef study must be interpreted with caution.

In the project in **Sweden** grazing beef-cross and pure-bred dairy steers on forage and semi-natural pastures, no direct biodiversity data was obtained but biodiversity preservation per animal could be estimated indirectly. The proportion of animal's lifetime weight gain obtained from grazing semi-natural pasture was 13% for semi-intensively reared steers and 30% for extensively steers. These may seem low from a biodiversity preservation point of view also for nemoral and boreal climate zones but are less important on a farm scale than the proportion of income from pastures and carcasses. Use of pastures categorized as "keeping general biological values" and the stocking rate of 0.44 ha animal^{-1} used for the moderately high-intensity steers meant that the system qualified for an environmental payment corresponding to 4% of the economic value of the carcasses, besides the single-farm payment for which all systems qualified. Lowering the indoor feed intensity to the level of the low-intensity steers and allowing them to graze another summer increased the agri-environmental payment per steer, which was based on 1.32 ha animal^{-1}. Thus, using semi-natural pastures for the low-intensity steers yielded an agri-environmental payment corresponding to 10% of carcass value, with the possibility to reach 28% with even greater diversity in sward composition.

The Chaudhaury and Brooks (2018) prediction was applied to the **UK suckler- calf system**, comparing recorded farms with figures for the national average and top 25% of AHDB recorded herds, classifying pasture on all farms as 'managed' (rather than natural). Based purely on performance records, both 'test' farms had a similar predicted diversity loss to the top 25% farms, which were lower

than predicted for the UK average. As with the dairy study, figures were largely driven by the negative impact on diversity from higher concentrate feed use, predicting more intensively farmed land use.

Sward diversity was considered in **Poland** in the 1st two years after regenerating meadow swards. Although the proportion of *weeds* declined (28% vs. 7%) initially, this increased to 12-19% in year 2. Valuable grasses increased (60% vs 69%) and in year 1 the share of legumes rose from 3% to 25%, mostly with white and red clover although fell to 11-16% of total species in year 2.

Species composition of the meadow sward without undersowing, in the third year of use, was subjected to various shifts. The majority of grasses showed a decrease in share by 1% or 2%, with meadow fescue showing the highest 3% decrease. Grasses with lower *Luv* (sward usage value), such as the couch grass with a 2% growth in share, ultimately did not increase the share of this plant group, ending in an overall decrease of grasses by 4-8%. The share of legumes was in this case no more than 2-5% while weeds and herbs constituted about 30% of the species composition of the pasture and meadow sward. This led to a slight decrease in usage value. The rather dynamic changes in the species composition of the meadow and pasture sward after undersowing showed a significant increase in usage value in 2019 and undersowing need in autumn2020. Based on species composition and usage values (Luv), the effects of undersowing were found in both the pasture and the meadow sward, with the most visible effects seen in the second year of after renovation. The clear decrease in usage value of the pasture and meadow sward in the third year of use resulted from the decrease in the share of both sown grasses and legume species.

4 Social sustainability

4.1 Consumer attitude

Farmers', as well as consumers' interest in grass-fed meat and milk seem comparable. Based on a **Norwegian** consumer panel combined with qualitative in-depth study with "grass-fed farmers", we found the main reason for producing or buying grass-fed are similar. Both groups perceive this to be better than other systems for the environment, animal welfare as well as the climate. Indeed, many farmers also report grass-fed husbandry to be both more challenging and interesting than more common conventional systems. In addition, we believe (we say believe here because our material is too small to conclude strongly) some consumer groups tend to look at grass-fed products as symbols of identities rather than solely a conscious act for promoting a specific production.

Factors expected to drive the choice of grass fed, such as health and food quality/taste, seemed to be weaker in a Norwegian context than suggested from other Europe, Oceania or North America studies, on a par with studies of organic farming in the 90ies. It might be explained if consumers and farmers see conventional Norwegian agriculture to be less industrialized than in other countries. Farmers view their choice to produce grass-fed meat and dairy products as a resistance, not necessarily against current Norwegian practice, but more towards future agriculture. They talk about a agriculture moving towards industrialisation and becoming less sustainable. Parallel to this, consumers' preferences are also motivated by a desire to be "pro-active", rather than a strong critique of farming today.

A look elsewhere in Europe suggests Norwegian grass-fed production and consumption could represent an alternative to cutting meat and milk from the menu, for groups that perceive Norwegian agriculture is becoming more "industrial."

4.2 Animal health and welfare.

Many of the SusCatt studies found better animal health and welfare in our innovative forage-based production systems compared to those we compared them with.

Udder health in the **UK dairy breed comparison** was judged by a combination of milk somatic cell counts (SCC) and treatment rates with antibiotics. The mean SCC across the study population was extremely variable with a few cows, across all breeds except the Scandinavian Red cross, pushing the average mean values over 200 000 per ml, although median values for all breeds were similar between 60 000– 90 000. Antibiotic treatment was more variable and higher than average for Ayrshire crosses, Holstein/Frisesian (HF), and HF Jersey crosses (with 30-40% of cows treated) compared to only 8-10% of Jersey crosses, New Zealand Firesian crosses and Scandinavian red Holstein crosses cows treated – well below the average in the study. Identifying superior cows within the other UK study was challenging since 2 of the 3 dairy herds had zero antibiotic use over several years.

UNIPD evaluated the impact of feeding regimes on animal health and welfare of **Italian** dairy cows, comparing farms feeding maize silage, other silages or permanent meadow hay. Cows receiving hay and silages other than maize seemed to be less affected by diarrhoea or lameness and were generally cleaner (likely to impact on hygienic milk quality). Although no other differences proved significant (e.g. body condition scores and rumination), overall, the animals' health status was found to be better on farms feeding forages other than maize silage, which are usually considered more appropriate for rumen health and more sustainable under an environmental and economical point of view. In addition, occasionally, farms feeding hay had more cows with higher somatic cell count (SCC, >200 000 units) and lower milk fat content (<2.5%) comparing to farms with maize feeding.

The **Polish** study investigating the impact of pasture renovation on dairy production found higher milk yields compared to cows on unimproved pasture, but somatic cell counts were higher when cows were grazing in summer months.

Health status of the **Norwegian dairy** cows was similar across the 3 concentrate feeding groups of farms. There were no differences in indicators of fertility and health, such as non-return rate, average days from parturition to first insemination, age at first calving, calving interval or proportion of cows treated for mastitis, ketosis or milk fever. 'Low' farms had lower somatic cell count, with an average of 111 000 vs 122 000 and 129 000 per ml milk on 'Medium' and 'High' farms.

As with the dairy study in **Italy** cattle health and rumination varied according to amounts of maize silage in finishing diets on **beef** farms, rearing either French meat breeds or dual-purpose Italian crossbreeds. Breed had the strongest effect: specialised beef animals had more lameness, nasal and ocular discharge, hampered respiration, diarrhoea than crossbred cattle. Diet also proved relevant mainly for these specialised beef cattle: hampered respiration and diarrhoea were more prevalent in cattle without maize silage whereas bloated rumens were more common on farms feeding maize silage; crossbreed cattle were more affected by diarrhoea and bloated rumen if fed maize silage. As regards body condition (BCS), against the expectations of many farmers, the diet did not influence the presence thin animals of either breed type. Furthermore, locally sourced dual-purpose crossbreed cattle proved to be a viable alternative to specialised imported breeds, showing greater resistance and adaptability to different housing, feeding and management conditions. Regardless the feeding system applied, rearing Italian crossbreed cattle would avoid welfare issues, associated with long-distance transportation of animals from France.

4.3 Food quality in respect to consumer health and traceability through the supply chain

Several studies considered the impact of management, especially animal feeding, on milk or meat quality, mostly considering fat composition, which has a potential influence over consumer health. Since differences were expected, partners in Italy also considered wider milk composition, using technology for easily identifiable markers to differentiate feeding systems and allow authentication of claims and supply chains.

The **UK studies** confirmed the superior nutritional composition of milk from low-input or pasture reared cows. On the whole, milk fat composition from monitored cows confirmed the wealth of published evidence reporting beneficial fatty acids in milk are higher from pasture and forage diets. Even although dairy feeding is known to have a stronger influence over milk fat composition than genetics, differences were identified between the various breeds and crosses of cows in the **UK breed comparison study**. However, since this study followed commercial practice on 17 real farms rather than a controlled trial with all cows on the same diet, it is unlikely the 'healthier' milk was a direct result of genetical control over milk quality. Some breeds maybe better suited to production systems and feeding practices that produces more beneficial fatty acids. Ayrshire cross cows produced milk with a number of positive health attributes – compared with average composition, it had more conjugated linoleic acid (CLA), total and long chain omega-3, less of the damaging saturated fatty acids and just below average concentrations of omega-6 fatty acid (FA), giving a 1:1 ratio of omega-6:omega-3 FA. At the other end of the scale, milk from cows described as Holstein/Friesian crossed with Jersey or Scandinavian Red was lower than average in total and long chain omega-3 and Shorthorn cows produced milk more n-6 FA resulting in a higher than average ratio with n-3 FA.

Even with a high proportion of grazing and forage in dairy diets (which we know leads to good fat composition), the **UK *within herd*** study found wide differences in milk fatty acid profiles between cows under the same management and feeding. Across the 3 farms monitored, the widest difference between cows with the highest and lowest ratio of milk n-6:n-3 was equivalent to 75% of herd average.

Even on a farm with 100% forage feeding (no concentrate supplementation) the lowest ratio was 34% less than the highest and the concentration of long-chain n-3 in milk varied by 36% of the herd average.

For the records collected from the **Norwegian** study, no differences were found between farm groups in major milk constituents (milk fat, protein and lactose), despite the differences in concentrate feeding and the proportion of forages in dairy diets.

UNIPD were able to discriminate metabolic and fatty acid profiles of **milk** produced from the different feeding strategies (maize silage, other silages and permanent pasture hay) using Direct Analysis in Real Time and High-Resolution Mass Spectrometry (DART-HRMS) and Gas Chromatography (GC for the FA profile). In particular, the DART-HRMS analysis selected the following most relevant metabolites to discriminate the forage sources: lactate, glutamate and hydroxycinnamic acid for maize; creatinine, methyl 2-furoate, FA C18:2-, C20:2- and C22:2- and trace of norgramine for other cereal silages; palmitate, flavonoids and lipophilic compounds for the sole use of hays. This study also developed a traceability model considering proximate composition and micro-element profile, to indicate the likely nutritional value of milk from the different production systems. The model had medium ability to discriminate the dairy systems, considering both the breed (Italian Friesian vs. Italian Brown) and the roughage source. It also identified 4 predictive variables: total protein, casein (for Italian Brown animals receiving maize silage) and lactose (for Italian Friesians receiving maize silage) content and bromine (Br; for Italian Friesians receiving hays); plus 2 less relevant variables: SCC and potassium (K) content. Once again, it demonstrated tools are available to discriminate milk coming from farms adopting different systems.

As regards fatty acid, the major differences were between a high use of maize silage and hays/fresh-cut green grass: the latter having less saturated FA and, consequently, the highest values of monounsaturated FA and polyunsaturated FA (due to an increased proportion of herbage in the diet). Furthermore, there seems to be specific FA that can be considered as biomarkers of the different feeding regimes: c9 t11 C18:2 (CLA 9) and C18:3 (n3) (ALA) for hays and fresh-cut green grass; C18:2 (n6) (LA) and C20:4 (n6) for maize and other crop silages.

Meat from the bulls in the **Swedish** study showed a lighter redness and a more yellow colour of the fat of the sirloin from the dairy x Angus cross compared to the pure dairy breed. The greater lightness is most likely due to the higher degree of fat marbling. Also, the thawing losses and the cutting-up fat losses were greater for the beef cross than for the dairy breed. The high intensity diet resulted in more thawing losses than the low inetsity diet. The fatty acid composition was not affected by breed nor by feed intensity. The bulls have all been genotyped for several of genes that are normally accociated with meat tenderness. The first statistical analyses only showed weak and not significant differences between breed and genes that are expected to be connected with meat tenderness. These markers belong to the Calpastatingene.

Meat from younger (21-month-old), semi-intensively reared steers in the **Swedish** study, regardless of breed, was more tender than meat from older, extensively reared animals slaughtered at 28 months. Further, meat from Charolais crosses had poorer eating quality than purebred dairy steers, due to coarser fibre structure, less tenderness and juiciness. However, the fatty acid profile was preferable from the crossbreds with a higher proportion of polyunsaturated fatty acids. Preliminary results showed no significant differences between breed and genes that are expected to be connected with meat tenderness.

The **meat** samples (42 in total) collected by **UNIPD** over the project timeline were analysed for dry matter, crude protein, crude fat, crude ash content and pH. Because of the small quantity, only 33 samples were analysed also for tenderness, colour, weight loss after cooking, main FA composition. The 11 beef farms involved in the project were considered as 2 groups depending on feeding system with or without maize silage in their diet. Analysis showed chemical composition, pH, tenderness,

weight loss after cooking and meat colour were not influenced by the diet used on farm. However, FA analysis showed meat from farms feeding hay-based diets was consistently lower in mono-unsaturated FA and higher in polyunsaturated FA and omega-3 FA, although this trend needs to be confirmed with analysis of more meat samples.

The studies with certified pasture-fed cattle in **UK** showed considerable differences in the fat composition for the resulting **meat**, relative to comparable organic and non-organic steak purchased in supermarkets. Steak from pasture reared cattle had significantly higher concentrations of beneficial fatty acids (total and long-chain omega-3 fatty acids and CLA) compared to shop bought meat. In societies with low consumption of oily fish, such meat from cattle fed solely on pasture could be useful to contribute to our deficient intake of long chain omega-3 fatty acids; we identified they exceed the legal threshold of 30 mg/100g to be recognised as 'sources of long chain omega-3 fatty acids'

5 Conclusions

When drafted in 2016, the SusCatt proposal hypothesised that moving away from intensive cattle production, feeding less human edible food to our ruminants and using more forage and/or grazing in dairy and beef diets, would enhance sustainability. Four years later we are now able to present evidence confirming many of these assumptions.

5.1 Economic

If well managed, increasing forage in dairy and beef diets can reduce external inputs leading to comparable, if not greater, profitability than more intensive production systems. Since extensification often leads to environmental and social benefits, rewarded financially by price premia and/or agri-environement payment, it looks positive from an economic perpective.

5.2 Environmental

Almost without exception, the less intensive innovation trialed and monitored in SusCatt, had a lower carbon footprint, impact on acidification and less resorucse use than the *standard* systems we used to benchmark performance. The opposite was however the case for leakage of nitrogen to water, expressed as eutrophication. In several cases the SusCatt cases had a higher eutrophication potential than the standard systems, despite lower inputs.

The situation regarding land use, was not clear - some SusCatt innovations used less land, other more than comparable benchmarked systems.

5.3 Social

SusCatt results also confirm the nutritional quality of milk and meat are enhanced by forage based feeding, especially if cattle are able to graze and animal health and welfare are comparable or better than on more intensive systems. There were also indication of better animal health and welfare under the less intensive systems monitored here.

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