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Method paper

Method: open-source economic tool for dairy farmers planning extended cow-calf contact

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ABSTRACT

Extended cow-calf contact (CCC) is gaining popularity among European dairy farmers. Any change in farm management strategy should be preceded by economic considerations and an accurate assessment of the costs and benefits of the new management strategy. In this study, we have developed an economic tool for farmers planning extended cow-calf contact. The tool allows producers to calculate the costs and benefits of the new practice (CCC lasting from 1 to 3 months) and compare it with the current operation (conventional system with a maximum of 1 day of cow-calf contact). The tool has been developed using the free and open source R package Shiny and is accessible from the following link: <https://cowcalfeconomictool.github.io/>. The CowCalfEconomicTool consists of two tabs: calculator and user guide. The calculator tab has 7 distinct frames: language selection, housing, herd size, operational costs and revenues, milk production, calf parameters in the current system and expected CCC effect. Additionally, the calculator tab has one output frame which is dedicated to presenting an interactive cost-benefit table, a Gauge cost-benefit chart, net present value and a cost-benefit ratio. Finally, the user can download all input and output data. To test the economic model behaviour and determine which parameter has the biggest impact on the economic result, sensitivity analyses were conducted. Tool verification was performed with a group of experts. The source code for the tool as well as baseline variables and results of sensitivity analysis are available from the GitHub repository: <https://github.com/CowCalfEconomicTool/CowCalfApp>.

Sensitivity analyses indicated that building costs together with additional milk price premium for improved welfare were the most critical factors affecting the net present value of CCC operations. The user is encouraged to use the tool as a simulator by adjusting production variables accordingly. CowCalfEconomicTool is still in early stages of the development. As CCC research progresses, the default values should be adjusted and new fields could be added in the calculations. The tool assists farmers to make informed decisions on whether and how to adopt CCC, but the results of the analyses have to be used with caution. The final decision should be made after careful consideration and consultation with relevant experts (e.g. farm advisors, barn planning companies, veterinarians).

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Implications

The CowCalfEconomicTool is a simple, open-source economic tool. It is mainly intended for farmers who want to assess the economic viability of a new dairy production model with higher welfare standards for calves suckling their own mother for at least 1 month. The CowCalfEconomicTool can also be used by farm advisors and the research community to facilitate discussion on the economic consequences of a possible herd management transition. Providing free and easy-to-use economic tools could further

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motivate farmers to implement new business models and meet growing consumer demand for high cow and calf welfare.

Specifications table

Subject	Livestock Farming Systems
Type of data	R code, baseline variables used in economic model and results of sensitivity analyses
How data were acquired	R code has been written by authors, baseline variables of the economic model were obtained from literature and by consulting relevant experts, and input/output values for sensitivity analyses have been obtained by authors
Data format	The tool files are stored in GitHub (https://github.com/CowCalfEconomicTool/CowCalfApp): (1) app.R contains code to run the tool (2) www folder contains pictures stored as.png which are used in the tool (logo of all institutions involved in the project and flags for language selection) (3) Scenario_number.json files containing input/output variables obtained from the sensitivity analysis (4) Scenario_metadata.xlsx file with metadata of all variables used in each scenario
Parameters for data collection	Software building was done using standard laptop 64bit Windows 10 computer equipped with Intel® Core™ i7-1255U processor 1.7GHZ and 32 GB RAM. R software system, version 4.4.1 (R Core Team, 2024), and R studio, version 2024.04.2 (Posit team, 2024), and the following R packages were used for tool building: shiny, version 1.9.1 (Chang et al., 2024), flexdashboard, version 0.6.2 (Aden-Buie et al., 2023), shinyjs, version 2.1.0 (Attali, 2021). Package Shinylive, version 0.2.0 (Schloerke et al., 2024) was used to export the app from local files to github directory.
Description of data collection	The source code for the app was developed by the authors. The structure of the tool was designed during several meetings. Firstly, the initial structure was developed by all co-authors; secondly, the tool structure was presented to the members of the steering committee of CowCalfSolution project which included representatives of funders, farm advisory company, dairy company, and barn designing company. During the steering committee meeting, the functionality of the tool was validated by experts. AS performed sensitivity analyses and stored results.

Data source location	Institution: Natural Resources Institute Finland (Luke) City/Town/Region: Helsinki/Uusimaa Country: Finland Latitude and longitude (and GPS coordinates, if possible) for collected samples/data: Not applicable
Data accessibility	Repository name: GitHub Data identification number: Not available Accessed from: https://github.com/CowCalfEconomicTool/CowCalfApp and https://cowcalfeconomictool.github.io/ Data usage specify under GNU General Public License 3.0
Related research article	No

Introduction

In his popular science book, Harari (2015) portrays dairy calves which are separated from their mothers after birth as victims of the agricultural revolution. Harari is not isolated in his views. Currently, the practice of early separation of calves faces criticism not only from animal welfare advocates and animal behaviour scientists (e.g. Brombin et al., 2019; Cook and Von Keyserlingk, 2024) but also from the general public (Sirovica et al., 2022). Also, the dairy sector, as demonstrated by studies from New Zealand (Neave et al., 2022), Canada (Wilson et al., 2024), and Denmark (Bertelsen and Vaarst, 2023), is increasingly interested in switching their calf management practices to more welfare friendly. However, to enhance the sustainability of the dairy sector, it is essential to analyse the rearing systems from multiple disciplines, integrating both animal welfare and economic aspects (Knierim et al., 2020).

Wider implementation of prolonged cow-calf contact (CCC) remains a challenge due to, among other things, the need to adapt barn infrastructure, herd management issues and economic concerns (Alvåsen et al., 2023; Vaarst and Christiansen, 2023; Eriksson et al., 2022). So far, Alvåsen et al. (2023), as well as Asheim et al. (2016), have studied the economic effects of extended CCC strategy for dairy calves. Asheim et al. (2016) concluded that a longer suckling period had a positive influence on the farm economics, whereas Alvåsen et al. (2023) stated that costs associated with CCC systems were high and resulted in a decrease in revenues for most analysed scenarios. These contradictory results could be explained by different methods used for economic analyses (linear programming vs stochastic partial budget models, respectively), differences in various production costs in Norway and Sweden as well as differences in studied management practices for dual purpose dairy-beef farms (3, 7 days and 13 weeks of suckling vs 30 min per day, 21 days or mix with foster cows, respectively). Indeed, management procedures in the currently operating CCC systems are diverse, and standardised practices are lacking (Bertelsen and Vaarst, 2023), which hinders the economical evaluation of CCC systems. However, the common feature in the two studies mentioned above was that they provided only general recommendations. A recent survey of Finnish dairy farmers interested in switching to CCC revealed that practitioners lack information and experience on how to successfully implement CCC, with the financial aspects being the most critical for farmers (Hautala, 2024). Even though there are dairy herd simulation models which

give the farmer a possibility to estimate the economic impact of alternative management strategies (e.g. SimHerd (Østergaard et al., 2005)), those, to the best of our knowledge, lack specific features that would allow taking into account costs and benefits of a CCC system in the long term. Furthermore, open-source tools providing individual decision support for farmers wishing to implement a CCC system are still missing.

The aim of this study was to develop a flexible and open-source economic tool for dairy farmers planning extended CCC.

Material and methods

Programming language and tool publishing

The tool was built using R and the Shiny package (Chang et al., 2024). The package enables developing a website using R including the use of custom JavaScript code and styles with CSS. Shinylive (Schloerke et al., 2024) package was used to compile the application to WebAssembly and run it in the web browser making it accessible to users without relying on server-side components. This approach ensures that the tool will be available to users even after funding for web hosting has been exhausted. With Shinylive, the R interpreter runs directly on the user's device, so the tool downloads approximately 90 MB of data the first time it is used, and the page load time on mobile devices can take several seconds. Modern web browsers cache the resources, so the subsequent runs of the app are faster.

Cost-benefit analyses

In order to determine the profitability of a CCC system over an extended period of time, the tool was constructed using a cost-benefit approach, as defined in Dijkhuizen et al. (1995). The net present value (NPV) of CCC was defined as the difference between the discounted present value of benefits PV(B) and costs PV(C) over time (t):

$$NPV = PV(B) - PV(C)$$

The PV(B) and PV(C) earned at time t were defined as

$$PV(B) = \sum_{t=1}^T B * e^{-rt}$$

and

$$PV(C) = \sum_{t=1}^T C * e^{-rt}$$

Table 1

Seven cost-benefit items considered in the economic tool for dairy farmers planning extended cow-calf contact (CCC).

Item	Calculations
Housing	Minor changes to the existing facility Renovating the existing facility Building a new facility
Feeding	Feeding costs in CCC system ¹ - Feeding costs in conventional system ²
Animal welfare price premium for milk	Additional milk price for CCC * milk sold from a herd per year
Labour	Labour for feeding and animal care in CCC - Labour for feeding and animal care in conventional system ³
Health	Mortality costs and veterinary expenses in CCC system - mortality costs and veterinary expenses in conventional system ⁴
Sold animals premium	Number of sold animals * extra revenue from heavier calf due to cow-calf contact
First lactation yield effect	Total milk production for cows in first lactation (l/lactation) * number of heifers * expected impact on milk yield for cows in their 1st lactation (% change)

¹ calculated as number of feeding days * average loss in saleable milk * number of calves * price of milk.

² calculated as number of feeding days * amount of feed use in feeding system * price of feeding (replacer or whole milk) * number of calves.

³ calculated based on expected effect on expected impact on labour for feeding (minutes/calf) and expected impact on other labour for animal care (minutes/calf).

⁴ calculated based on expected effect on calf mortality rate (%) and expected effect on veterinary expenses (EUR/calf).

where r is the interest rate (Kristensen et al., 2010) and B and C are benefits and cost associated with CCC. The time of investment (T) is defined by the user. Seven different cost-benefit items were considered in the tool: housing, feeding costs, animal welfare price premium for milk, labour, health, sold animal premium, and first lactation yield effect. Details of how each category was calculated can be found in Table 1 and in the source code (<https://github.com/CowCalfEconomicTool/CowCalfApp>). The cost-benefit item could have a positive or negative effect on the NPV. If the effect was positive, it was a benefit; if negative, it was a cost.

The cost-benefit ratio (CBR) was calculated as:

$$CBR = PV(B)/PV(C)$$

Results of the analyses are presented to the user in seven different categories (Fig. 1): housing, feeding costs, animal welfare price premium for milk, labour concerning feeding and animal care, health, sold animals premium, and first lactation yield effect. Finally, the sum of PV(B) and PV(C), NPV and CBR are displayed. All input variables have default values (based on literature or average values from Finnish national statistics), that the user can change. Initial biological and price-related variables are summarised in Table 2.

Housing costs were calculated depending on the user-selected options of (1) making minor changes to the existing facility, (2) renovating the existing facility, (3) building a new facility as well as the number of cows in the planned facility (existing or new). For simplicity, additional building costs, such as building permits, taxes, insurances, maintenance as well as loan costs, were omitted. The feeding costs were calculated as the difference between CCC and a conventional calf feeding system. The cost of the conventional feeding system was set based on the current farm feeding strategy, with two options available: milk replacer and whole milk (from own farm). The feeding costs in the CCC system were calculated based on the average loss in saleable milk. The feeding costs were multiplied by the number of cows, feeding days and price of whole milk or milk replacer. The default cost of CCC feeding was simulated assuming the average mean and standard deviation for the average loss in saleable milk as determined by Churakov et al. (2023). The remaining five items (animal welfare price premium for milk, labour, animal health, sold animals price premium, and first lactation yield effect) represent areas where CCC has been observed to create various effects (e.g. Johanssen et al., 2023; Webb et al., 2022; Wenker et al., 2022), and the farmer can simulate the impact of these changes. However, to date, these effects have been found in a few studies including a handful of (research) farms and animals, or the results are not yet conclusive. For example, most studies report no effect of CCC on calf health scores or treatment levels (Bieber et al., 2022; Beaver et al.,



Fig. 1. Results of cost-benefit analyses for dairy farmers planning extended cow-calf contact in four different scenarios: (A) The farmer is planning to make small changes to facility costing in total 25 000 EUR, other variables as default in CowCalfEconomicTool, (B) as A but the farmer additionally assumes 0.01 EUR/l in milk price due to animal welfare price premium for milk, (C) as B, but farmer is additionally expecting 1% decrease in calf mortality rate, 5 EUR decrease in veterinary expenses per calf, 2-min decrease in time spend for feeding per calf and 2-min decrease for other labour for animal care per calf, (D) as C but additionally, the farmer is expecting a 5% increase in milk produced by cows in their 1st lactation.

2019), but farmers themselves perceive that CCC has improved the health of their calves (Hautala, 2024; Eriksson et al., 2022). The effect of large milk allowance in early development on milk yield of the heifer calf in her first lactation derives largely from studies in conventional production as opposed to CCC systems specifically (Shamay et al., 2005), or from producer estimates in varying management systems (Asheim et al., 2016). In a survey, Norwegian dairy farmers estimated that female calves that are allowed to suckle their dam for 7 weeks will produce approximately 200l more milk in their first lactation compared with artificially reared calves (Asheim et al., 2016); however, the survey was conducted on organic farms where the main breed was Norwegian red, a dual-purpose breed, and the results cannot be directly applied in conventional farms with other breeds. In addition, the impact of CCC on these factors is highly dependent on the status quo on

the farm before implementing CCC. A farm that feeds whole milk *ad libitum* or in large quantities to the calves cannot expect an increase in first lactation yield due to the implementation of CCC, as the milk intake of calves will not change significantly. Thus, the default values in all these variables in the tool are deliberately set to neutral, allowing farmers testing various positive and negative scenarios. By adding a price premium to milk and/or sold calf, as well as by increasing or decreasing the expected production effect, a user can simulate net present value and determine which variables are critical in determining the profitability of CCC operations. It should be noted that most Finnish dairy farms have a practice of selling dairy bull calves at the age of between 2 and 4 weeks for beef production, resulting in about 80 per cent of the Finnish beef market coming from these surplus calves (Vanhanen, 2020). Currently, the large operators do not pay a premium for calves

Table 2
Economic variables used as default in cost-benefit analyses for dairy farmers planning extended cow-calf contact (CCC).

Item	Value	Source
Economic variables¹		
Housing renovation costs (EUR/m ²)	150	Personal communication with a barn planning company
Building costs (EUR/m ²)	500	Personal communication with a barn planning company
Building salvage value (%)	15	Feuz and Larsen (2020)
Milk price (EUR/l)	0.55	Latvala et al. (2023)
Labour price input (EUR/h) ³	7.5	Latvala et al. (2023)
Revenue from sold calf (EUR/calf)	190	Hautala (2024) and personal communication with a slaughterhouse representative
Veterinary costs (EUR/calf)	25	Personal communication with farm advisors
Liquid feed cost for calves (EUR/l)	0.43	Based on supplier information ⁴
Average interest rate (%)	3	Internet source ⁵
Biological variables		
Baseline values in conventional system		
Mortality rate (%)	7.1	Sørensen et al. (2018)
Total milk production for cows in their first lactation (l/lactation)	8 800	Sørensen et al. (2018)
Average milk yield (l/cow/day)	35	ProAgria (2023)
Baseline values for cow-calf contact system ²		
Average loss of saleable milk (l/cow/day) for cow-calf contact cows	7.3	Churakov et al. (2023) ⁶
Variation in the loss of saleable milk (l/day) for cow-calf contact cows	6.6	Churakov et al. (2023) ⁶

¹ Additional milk price for cow-calf contact (EUR/l) and extra revenue from heavier calf due to cow-calf contact (EUR/calf) were set to 0.

² Production effect variables for cow-calf system: The expected effect on calf mortality (%), veterinary expenses (EUR/calf), labour for feeding (minutes/calf), other labour for animal care (minutes/calf) and the impact on milk yield of cows in their 1st lactation (% change) was set to zero, as the research on these effects is scarce.

³ assuming farmer's own labour.

⁴ <https://www.hankkija.fi/rehut/nautojen-ruokintaohjeet/ia-vasikan-juotto-ohjeet-2029613/>.

⁵ <https://www.suomenpankki.fi/fi/Tilastot/korot/>.

⁶ the default value was set based on the study of (Churakov et al., 2023); however, in the tool, the user is informed about the large variability in this parameter. Based on Zipp and Knierim (2024), loss in saleable milk can range between 10 and even 25 kg per day.

from CCC farms, but agreements with smaller operators or private finishing farms may be possible.

CBR is presented to the user as a value and in the Gauge chart. Values on the Gauge chart were classified as follows: green if $CBR > 1$, meaning the benefits included in the tool exceed the costs and CCC is financially justified; yellow if $0.90 < CBR \leq 1$, equal to a break-even or near break-even scenario; red if $CBR < 0.90$, meaning the costs exceed the benefits and CCC may not be financially justified based on the included parameters.

Model verification and sensitivity analyses

The functionality of the tool was presented and discussed during two meetings with the steering committee of the CowCalfSolution project which included representatives from the project funders, a farm advisory company, a dairy company, a barn design company and dairy farmers.

Additionally, in order to determine which variable had the biggest impact on the economic result and to test whether the model behaves as expected, the variables associated with the expected impact of CCC were systematically varied by $\pm 10\%$ (depending on the variable) while the other variables were kept constant. Sensitivity analyses were performed assuming 21 different scenarios for data input, including different housing options (minor changes to the existing facility, renovating the existing facility and building a new facility). Variable inputs for each scenario have been saved in the project GitHub account (<https://github.com/CowCalfEconomicTool/CowCalfApp>) as json files.

Results

Tool functionality

The tool has two tabs: the calculator and the user guide. The calculator tab has seven distinct frames: language selection, housing, herd size, operational costs and revenues, milk production, calf

parameters in the current system and expected CCC effect. Additionally, the calculator tab has one output frame which is dedicated for presenting an interactive cost-benefit table, a Gauge cost-benefit chart, net present value and cost-benefit ratio. The first action to be taken by the user is to adjust the language of the tool in the language selection frame. The tool can be used in three languages: Finnish, Swedish and English. In the second step, the user is required to input fixed building costs ("Housing" input table) and desired production conditions ("Herd size" input table) (Fig. 2).

For housing, the user has the possibility to enter different costs related to the adaptation of the barn (minor changes to the existing facility, renovating the existing facility and building a new facility) according to their needs. The cost of minor alterations to an existing building can be estimated by the producer, but in the case of a renovation or a new building, it may be useful to contact a professional designer for more precise cost estimates. The tool allows the producer to define the desired production conditions: average cow number in a production year, the number of calves to be reared in the CCC system each year with split according to the length of contact between mother and calf in months (1, 2 or 3), and the number of CCC calves kept for replacement. The following example is set as a default: the farm has 50 cows, the farmer expects that 30 cows will have prolonged contact with their calves for 2 months, and ten of the calves reared with their mothers will remain on the farm to become the replacement heifers. In the next step, the user should specify operation cost and revenues as well as milk production conditions (Fig. 3). All input variables, relating to both price and income, such as the price of milk and the income from the sold calf, have default values, but these should be updated according to farm specifications. The tool also includes the possibility to consider current or future price premium for higher animal welfare standards, such as a possible additional price for milk or meat from a farm where animal welfare has been improved through extended cow-calf contact. Default price premium is however set at zero EUR. In the "Milk production" tab, the user can enter the average daily yield of the cows. The default value of average loss in saleable

Housing

How are you adjusting the building?

I will be renovating the existing building

I will be building a new facility

I will be making small changes to the existing facilities and I know/can approximate the total cost

Enter the renovation cost (€/m²):

Total space for mother with calf (m²):

Predicted time-span of investment

Herd Size

Number of cows

Number of cows with 1 month cow-calf contact

Number of cows with 2 month cow-calf contact

Number of cows with 3 month cow-calf contact

Number of cow-calf contact calves kept for replacement (heifers)

Operational costs and revenues

Milk price (EUR/l)	Additional milk price for cow-calf contact (EUR/l)
<input type="text" value="0.55"/>	<input type="text" value="0"/>
Revenue from sold calf (EUR/calf)	Extra revenue from heavier calf due to cow-calf contact (EUR/calf)
<input type="text" value="190"/>	<input type="text" value="0"/>
Labour price input (EUR/hour)	
<input type="text" value="7.5"/>	
Average interest rate (%)	
<input type="text" value="3"/>	
Veterinary costs (EUR/calf)	
<input type="text" value="25"/>	
Liquid feed cost for calves (EUR/l)	
<input type="text" value="0.43"/>	

Milk production

Average milk yield (day/l/cow)

Total milk yield - cows in first lactation (l/lactation)

Average loss of saleable milk (l/day/cow) for cow-calf contact cows

Variation in the loss of saleable milk (l/day) for cow-calf contact cows

Fig. 2. Housing and herd size input tables with default settings from the CowCalfEconomicTool for dairy farmers planning extended cow-calf contact.

milk is based on literature (Churakov et al., 2023), but the user can also modify this variable. For example, the user needs to keep in mind that the amount of extra milk consumed by the calf is defined as the difference between the current calf feeding system and the chosen CCC system, and is thus highly dependent on the amount of milk that the calves are fed in the current system. The differences are due to cow factors such as parity and calf sex (Mutua and Haskell, 2022), the management of contact and milking (Barth, 2020), or variation in milk ejection success and allosuckling (i.e. suckling cows other than the dam) (Churakov et al., 2023). For example, Zipp and Knierim (2024) reported an average loss of saleable milk of about 10 kg per day, and noted that the existing literature reports even higher values (absolute loss of saleable milk ranging from 12 to 26 kg per day). There could also be a large variation between CCC systems and individual animals in the milk yield and loss of saleable milk. The range of daily machine milk yield among dams during full CCC has been reported to be 1–50 kg (Sorby et al., 2024).

In the “Calf parameters in current system” frame, the user can specify the current mortality rate of calves on the farm (deaths occurring between days 1 and 180) and the current calf feeding strategy (liquid feed or whole milk from own farm) (Fig. 4).

In the “Expected CCC effect” frame by default, the effects of CCC on production variables such as calf mortality, veterinary costs and labour for feeding and animal care are set to zero (Fig. 5).

Fig. 3. Operational costs and revenues, and milk production tables with the default settings from the CowCalfEconomicTool for dairy farmers planning extended cow-calf contact.

The user is encouraged to use the tool as a simulator, by accordingly adjusting production variables (e.g. 1 l increase in average milk loss, % change in calves’ mortality, minutes change on labour, % impact on milk yield for cows in their first lactation or additional 0.01 EUR/l for milk price). Examples of results based on different parameter values are presented in Fig. 1. The tool uses dynamic adjustment, meaning that the effects of changes to any variable are immediately visible in the results section. The user guide tab has been added to improve the user experience. The guide is available in three languages and is displayed according to the user’s language preferences set in the Calculator tab. The guide provides instructions on how the tool should be used. All input tables have short explanations to ensure that it is clear what information needs to be provided. If the user encounters problems while using the tool, such as slow performance or crashes, the actions to consider are reloading the tool or restarting the device. In case of problems with tool loading, we also recommend checking the internet connection status. For persistent bugs or unexpected behaviour of the tool, users are encouraged to contact the team behind the tool using the email addresses provided in the user guide.

Fig. 4. Calf parameters in current system with default settings from the CowCalfEconomicTool for dairy farmers planning extended cow-calf contact.



Fig. 5. Expected cow-calf contact (CCC) effect with default settings from the CowCalfEconomicTool for dairy farmers planning extended CCC.

CowCalfEconomicTool verification and sensitivity analyses

In order to verify that all functions of the tool work as intended, the tool was tested with a group of experts (e.g. farm advisory company, dairy company, barn designing company, farmer representative). The user interface elements worked as expected. Inputs were systematically varied, and outputs were generated without discrepancies.

Results of sensitivity analyses are presented in [Table 3](#). The CBR results were dependent on selected housing adjustment options and were the most sensitive for changes in additional milk price for cow-calf contact (additional price premium) and for changes

in expected impact on milk yield for cows in their 1st lactation. For instance, a 10% increase in the milk price would result in CCC being financially justified for scenarios with renovation and small changes in the facility. Regarding changes in milk yield of cows in their 1st lactation, when other variables are on default, a 10% increase would result in CBR ranging from 0.09 to 0.50, which means CCC may not be financially justified in this scenario. Changes in other parameters (extra revenue from heavier calf due to cow-calf contact, expected effect on calf mortality rate, expected effect on veterinary expenses as well as expected impact on labour for feeding and animal care) resulted in only marginal increase in CBR, ranging from 0.01 to 0.07.

Author's point of views

The aim of this study was to develop a simple and open economic tool for dairy farmers planning extended CCC. The user, by accordingly adjusting production variables, can simulate how the introduction of the new system would affect the operation profitability over an extended period of time.

So far, to the best of our knowledge, a couple of studies has been conducted, to provide the economic evaluation of the CCC system ([Alvåsen et al. \(2023\)](#) and [Asheim et al. \(2016\)](#)). Our study adds to the existing literature by providing a decision support tool that is freely available for farmers, farm advisors and veterinarians and producers allowing them to simulate the costs and benefits of the new practice (CCC lasting from 1 to 3 months).

Best practices and limitations

There are a number of considerations that the user needs to take into account when using the CowCalfEconomicTool. Firstly, some farms may need to adjust the existing buildings irrespective of CCC, and the costs should therefore not be allocated only to CCC. For example, a new barn may need to be built to comply with new legislation, the building structure may simply have reached its life expectancy, or the farmer wants to expand the production in general. Since new barns may be designed for improved workflow and efficiency in general, allowing various tasks (e.g. milking, feeding, cleaning) to be performed faster, the user needs to acknowledge that these aspects are not included in the tool calculations.

Secondly, to produce valid results, the farmer needs to have correct values that describe their current production model (e.g. level of milk production, mortality rate). These production variables can be mostly obtained from farm management systems. When using the tool, the farmer should consult the user manual as well as other available materials providing information on the impact of CCC. Practical guides for designing and implementing CCC systems have been published in several countries in recent years, for example, in Finland ([Mughal et al., 2024](#)), Switzerland ([Spengler Neff et al., 2023](#)) and Germany ([Barth et al., 2022](#)). The guides include information on herd management methods and issues to be considered for successful implementation of CCC, as well as a discussion about animal welfare benefits and challenges.

Thirdly, all costs have been assumed for farms where dams are taking care of their own calves. The tool is not directly applicable for foster cow systems. Fosters systems are a relatively common CCC option ([Eriksson et al., 2022](#)), but the management is profoundly different from dam-rearing and thus also the variables needed in the economic modelling would be very different, potentially making the tool too complex for users. For example, the loss of saleable milk in foster systems can be assumed to be smaller, as the foster is providing milk to several calves, and is rarely milked during the CCC period. The economic implications of diverse CCC systems were assessed by [Alvåsen et al. \(2023\)](#), who also examined

Table 3

Results of sensitivity analyses for model verification assuming various housing adjusting scenarios for dairy farmers planning extended cow-calf contact (CCC). Model parameters associated with the expected impact of CCC were systematically varied by $\pm 10\%$. For each scenario, all input variables and results were downloaded from the CowCalfEconomicTool and stored in the GitHub repository (<https://github.com/CowCalfEconomicTool/CowCalfApp>).

Variable name	Value ¹	Cost-benefit ratio for different housing adjustment options (values in brackets indicate scenario number) with 30-year investment horizon ²		
		Minor changes to the existing facility ³	Renovating the existing facility ⁴	Building a new facility ⁴
Additional milk price for cow-calf contact (EUR/l)	+10% (0.06 EUR) ⁵	4.1 (1)	2.0 (2)	0.7 (3)
Extra revenue from heavier calf due to cow-calf contact (EUR/calf)	+10% (20 EUR) ⁶	0.1 (4)	0.0 (5)	0.0 (6)
Expected effect on calf mortality rate (%)	-10% (-1%) ⁷	0.0 (7)	0.0 (8)	0.0 (9)
Expected effect on veterinary expenses (EUR/calf)	-10% (-3 EUR)	0.0 (10)	0.0 (11)	0.0 (12)
Expected impact on labour for feeding (minutes/calf/day)	-10% (-1 min)	0.0 (13)	0.0 (14)	0.0 (15)
Expected impact on other labour for animal care (minutes/calf/day)	-10% (-1 min)	0.0 (16)	0.0 (17)	0.0 (18)
Expected impact on milk yield for cows in their first lactation (5)	+10% (+10%)	0.5 (19)	0.3 (20)	0.1 (21)

¹ Value shown as percentage change and in parentheses, variable change inserted into tool.

² Files were downloaded and saved in GitHub repository as Scenario_Number.json, e.g. Scenario_1.json represents the scenario with minor changes to the existing facility and additional milk price for cow-calf contact (EUR/l).

³ assuming small changes to existing facilities costing 25 000 EUR.

⁴ as in tool default settings.

⁵ calculated as percentage increase in default milk price.

⁶ calculated as percentage increase in default revenue from the sold calf.

⁷ calf mortality decreasing from 7.1% to 6.3%.

a combined dam-foster system, but they did not provide an interactive tool where users could use data and estimated from their own farms.

And finally, the tool is only an aid to the farmer to take into account different aspects of extended CCC in the decision process. The user should test different options and consider the best- and worst-case scenarios in terms of the production and financial impact of the CCC system. It is advisable that the farmer uses the tool or discusses the results together with a farm advisor or veterinarian before taking a final decision.

Further development of the tool

We hope that the tool can be further developed and used by the research community interested in the profitability of CCC farms. The tool could also be used as training material or additional support when conducting interviews or focus group discussions with farmers. By publishing the source codes, we hope that in the future, new functionalities could be added according to user needs (e.g. new language versions, easy printing and sending of calculation results to farm advisors or bank, insurance experts). The source code could also be used as a framework for tools dedicated to other management adjustments, such as allowing calves access to pasture. As CCC research progresses, the default values can be adjusted or even new fields could be added in the calculations. The functionality of the tool should be also further tested with farmers intending to switch to CCC. In addition, the proposed economic model is based on cost-benefit analysis, which is recommended when a farmer needs to decide whether a project is worth undertaking. With further knowledge and data on the effects of extended cow-calf contact on animal health and productivity, other economic methods should also be considered to determine how best to allocate limited resources. For example, methods such as dynamic programming could be used in the future to simultaneously optimise calf and heifer rearing, weaning and replacement strategies. An example of the application of dynamic programming in the calf rearing process can be found in the papers of Stygar et al. (2014) and Mourits et al. (1999). However, as the authors noted, although the model based on dynamic programming can simulate a realistic level of variability, some of the model functionalities and

recommendations may be too complex, which may hinder the practical implementation by farmers.

Finally, it should be noted that the tool was verified but not validated. Future projects should focus on long-term observational studies following the CCC transformation on farms to investigate how the economic efficiency of farms changes after the introduction of the new system and how accurate the NPV and CBR estimates provided by the tool are.

Peer Review Summary

Peer Review Summary for this article (<https://doi.org/10.1016/j.anopes.2025.100109>) can be found at the foot of the online page, in Appendix A.

Ethics approval

Not applicable.

Declaration of generative AI and AI-assisted technologies in the writing process

We acknowledge the use of DeepL Write to check English spelling and DeepL Translate for labels translations. We reviewed feedback generated by DeepL critically.

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Author contributions

AS, MP, MM, LF developed the study concept. All authors contributed to designing of the tool. **AS** programmed the app and drafted the text of the paper. All authors contributed to the article and approved the submitted version.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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