GenTORE

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Report on drivers of efficiency and resilience in dairy and beef systems

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- X **PU:** Public (must be available on the website)
- ☐ **CO:** Confidential, only for members of the consortium (including the Commission Services)
- ☐ **CI:** Classified, as referred to in Commission Decision 2001/844/EC

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Summary

This report will detail the outcomes of stakeholder discussion and original research on drivers of resilience and efficiency in beef and dairy systems. The report will also sign-post planned research that will address some remaining knowledge-gaps.

Firstly, an overview of key messages from a stakeholder discussion regarding the *Future Cow* is presented in section 1. Here, themes relate to the detrimental impact of environmental disturbances on efficiency, and how changes at the animal level and the sector level may improve system resilience.

Secondly, section 2 will give an overview of the development and application of an original individual-based model that was used to investigate the direct impacts of an environmental disturbance (climate change) on a specialist dairy herd. Here, a herd representative of production circumstances in southwest Scotland was used as a case study.

1. Stakeholder discussion

The discussion involved 60 partners and stakeholders of the GenTORE project, and was structured around expectations for the future cow and implications of/for future production circumstances. In groups, participants deliberated over drivers of resilience and efficiency in terms of genetic changes to cattle and possible interactions with the environment.

For beef cattle, participants expected genetic traits related to disease resistance and calving would be beneficial to resilience in all cases. However, for some traits, participants expected trade-offs, for example between longevity and feed efficiency; and between voluntary feed intake and methane emissions. More generally, it was noted that beef cattle are likely to be more exposed to increasing frequency and duration of extreme weather conditions, therefore, resilience to the direct effects of weather are especially important. Participants also agreed that, in many cases, the desirability of genetic traits or management interventions was associated with the specific production system in question, meaning differences in production circumstances within and between countries would present different challenges/trade-offs. An example of this was provided as the different focus of suckler and finishing enterprises, where suckler systems would be most interested in genetic traits related to the cow (reproduction, calving ease, etc.), but fattening enterprises would be most interested in traits related to the calf (growth, feed efficiency, etc.). More generally, this indicates that components of resilience will be valued differently according to characteristics of the production system.

Finally, it was noted that some systemic change may be relevant to address drivers of resilience and efficiency at the system level, not just at the level of the animal or herd. In this case, participants suggest increasing production of dairy-born beef animals or utilising dual-purpose breeds. These options, together with increasing use of sexed semen, may reduce culling of male dairy calves, which would not only increase the technical efficiency of the system, but also the resilience of the system to changing societal values.

A more detailed report of the stakeholder discussion can be found in D7.4 (*Report of recommendations of stakeholders*).

2. Case study

For dairy cattle, participants of the discussion noted the beneficial impact of traits related to health, longevity, fertility, and feed intake. Maintaining productivity in the face of changing production circumstances was also suggested as important. Against this background, an original model was developed that could simulate the performance of a herd of individuals over time and in scenarios of future climate, in which genetic change for important traits related to resilience were explicitly represented.

With this, daily time-step, dynamic model we mimic the daily biological performance and management of a herd of individuals. As in real life, individuals differ in their genetic ability, and, over time, the genetics of the herd improves, driven by breeding dams to genetically improved sires and subsequent selection of genetically superior replacements. This, together with stochastic functions in the model, generates variability in the performance of individuals, resulting in realistic variation in the technical performance of the herd. The performance of individuals is also influenced by key weather variables, based on scenarios of future climate change. In terms of model outputs, individual performance data were collected daily and used to calculate financial consequences and greenhouse gas (GHG) emissions at the herd level.

2.1 Approach

The model was parameterised as representative of a specialist dairy herd in southwest Scotland. Therefore, the simulated herd consisted of approximately 200 lactating cows; they were housed for 6 months per year (October – March, inclusive), and housed part of the day for the remainder, as is common in the United Kingdom (March et al., 2014). The herd was simulated for 20-years into the future (2021-2040).

The daily performance of herd-members was affected by 7-traits of economic importance, these were: milk yield, fat yield and protein yield (production), dry matter intake (maintenance), probability of mastitis infection (health), number of inseminations to conception (fertility), and days of life (longevity). The daily phenotypic performance of each individual across these traits was a function of their genetic ability and environmental factors (including daily weather). According to these phenotypic functions, each day individuals would yield a given quantity and quality of milk, would consume a given quantity of dry matter, may succumb to mastitis infection, may conceive, and/or may be culled, respectively. Main interactions of productivity, reproduction and health occurring during the productive lifetime were integrated. However, the simulation was not an optimisation model, therefore, herd management rules remained static between climate scenarios and across time. In addition to this, we assume no adoption of climate mitigation technologies or practices by the farmer.

The explicit weather-dependence of daily phenotypes enables prediction of the degree and extent of weather effects on herd performance. In the simulation, weather affects daily yields, feed intake, and rates of mastitis, conception and mortality. This allowed us to capture the cumulative impact of seasonal and long-term weather variations on herd performance. Weather variables came from UK Climate Projections 2018 (UKCP18); downscaled for the target area. Variables including temperature (minimum, maximum and mean) and relative humidity were used to calculate metrics such as temperature-humidity index (THI) and heat-wave periods. These downscaled daily variables are only available under representative concentration pathway 8.5 (RCP8.5), which the UKCP18 overview report describes as “a world in which global greenhouse gas emissions continue to rise… where the nations of the world choose not to switch to a low-carbon future and so can reasonably be considered to represent a worst-case scenario” (Lowe et al., 2019). As well as simulation runs that accounted for climate change in this way, the simulation was also run with static weather variables that did not reflect climate change, which acted as a baseline where animals were resilient and therefore unperturbed by variable weather.

The technical output and production characteristics of the herd were used to calculate financial and environmental performance. Gross margin was calculated as income (e.g. from milk sales) minus variable costs (e.g. pregnancy testing). For the environmental performance, we calculated enteric and manure methane, and direct, volatilised and leached nitrous oxide from manure; these emissions were calculated according to the IPCC 2019 refinement to the IPCC 2006 national GHG inventory (Gavrilova et al., 2019). We did not directly calculate emissions from spreading manure on managed soils, as we assumed these emissions are captured by feed component emissions factors (EFs). Dietary assumption and associated EFs were provided by consultants at SRUC as representative for the modelled system. Emissions intensity is reported as total emissions of the lactating herd per unit of energy-corrected milk (kg CO2-eq / kg ECM). Total emissions of the herd were calculated as kg CO2-eq, using the IPCC AR5 GWP100 conversion (Myhre et al., 2013). ECM accounts for yield, fat and protein content of milk (Sjaunja et al., 1990). We did not model emissions from energy resources (fuel and electricity), aside from those captured by the feed component EFs, since we assumed no changes in farm management or infrastructure between the scenarios.

2.2 Results

Results show that estimates of technical, financial and environmental performance are significantly different between simulation runs that (i) account for climate change with daily weather variables, or (ii) do not account for climate change with static daily weather variables. Accounting for climate change effects on the technical performance of individuals led to unfavourable changes in several key herd parameters: for example, an overall decrease in productive lifespan, increased mastitis cases, and increased age at first calving (see Figure 1a & 1b). Accordingly, relative to a scenario with static weather variables, gains in gross margin were reduced by 3.5% and relative gains in GHG emissions intensity were reduced by 2.1%. In terms of total emission, this translates to a difference of approximately 50,000 kg CO_2-eq for a herd of 200 lactating cows, when climate change (RCP8.5) is accounted for in the simulation. Therefore, the direct effects of a changing climate on important genetic traits that were identified in earlier stakeholder engagement discussions are likely to be a significant driver of reduced efficiency at the herd level, even in the temperate dairy producing region of southwest Scotland over the next two decades.

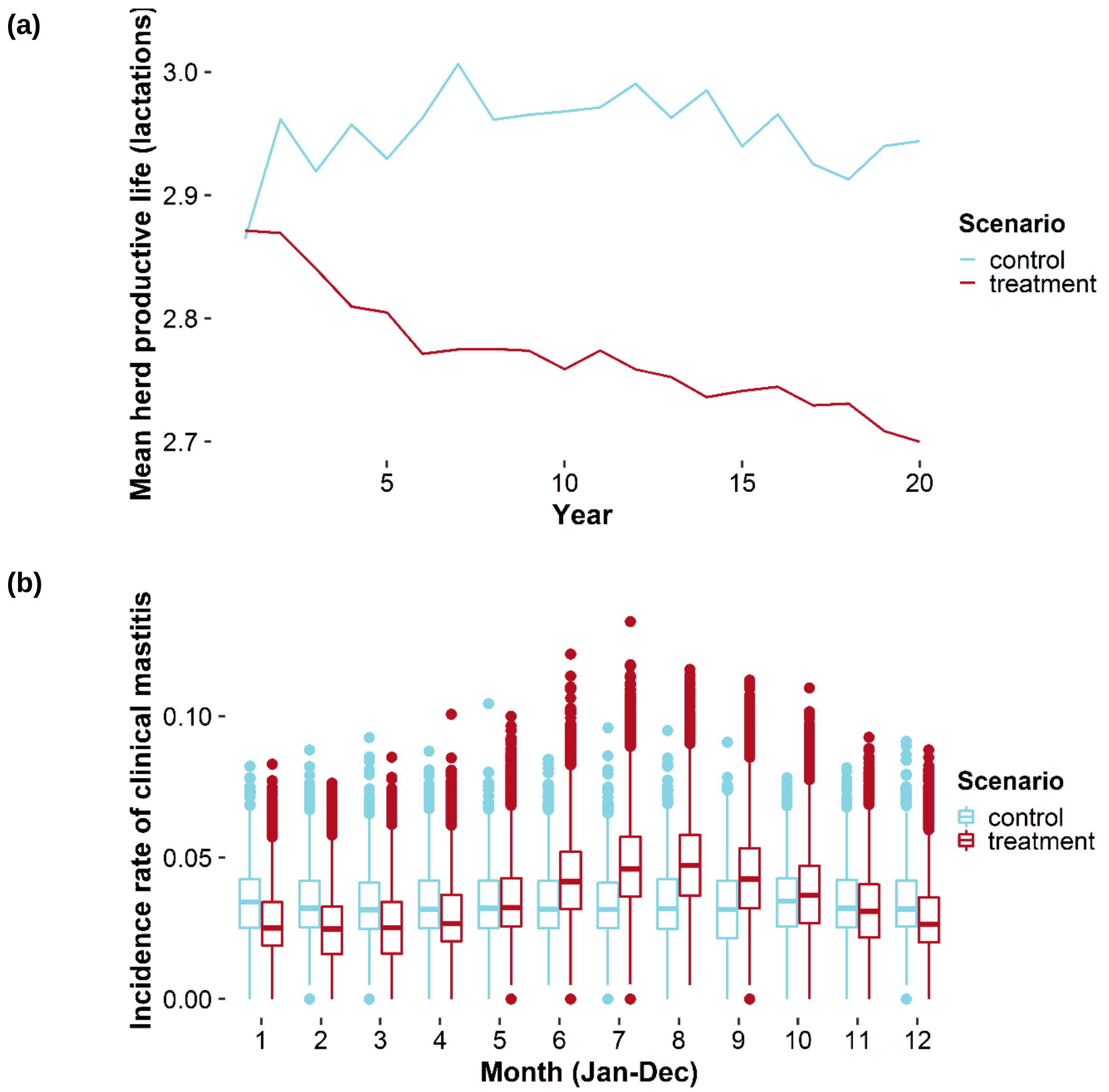

Figure 1 Plots to demonstrate the impacts of key weather variables on **(a)** productive lifespan across years, and **(b)** incidence rate of clinical mastitis within years. Treatment scenario refers to simulation runs that account for climate change, and control scenario refers to simulations run with static weather variables.

3. Further research

Future applications of the model will seek to disentangle the relative value of the 7 modelled traits towards resilient production. For example, changing herd age structure had some beneficial effect on traits such as mastitis resistance since younger animals are less likely to succumb to infection; therefore, partial *resilience values* will help identify marginal trait values. The model could also be parameterised for several production systems for comparison of partial resilience values since the differential valuation of resilience-related traits remains under-researched.

Future research by SRUC within WP6 will also quantify the impacts of projected climate change on beef production systems. Ongoing research will facilitate this climate impact analysis by identifying the direct effects of weather on economically important beef traits.

4. Conclusions

Climate change is likely to impact future production circumstances of cattle systems across Europe. A discussion with stakeholders of the GenTORE project revealed several traits, for which improvement may foster resilience to some impacts at the animal/herd level. An original model was developed to explore this issue, using a temperate dairy system in southwest Scotland as a case study. Even in the temperate climate of southwest Scotland, we found negative impacts of future climate projections on technical, financial and environmental performance of the simulated herd. Resilience to these direct effects, introduced through appropriate management or accounting for genetic-by-environment interactions in breeding decisions that may mitigate these impacts, would enable herds to maintain efficiency under future production circumstances.

Partners involved in the work

SRUC, SLU.

Annex – References

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