GenTORE

Genomic management Tools to Optimise Resilience and Efficiency

Grant agreement n°: 727213

H2020 - Research and Innovation Action

D3.4
Demonstration software for combining proxies for farm management

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Workpackage concerned: WP3

Concerned workpackage leader: Claudia Kamphuis

Lead Beneficiary: RAFT Solutions Ltd

Dissemination level:

- 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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1. Summary

This task 3.4 built a demonstrator software, based on end-user input and partner exchange, to showcase the kind of vehicle that could ultimately contain a sensor-based herd decision-support tool. Combining individual level data from multiple technologies (T3.1, T3.3) in a form that is useable in real world situations in real time requires an additional integration step to deal with synchrony of indications at animal level. In combining them, consideration needs to be given to which is the most relevant or reliable for use in an on-farm index but also which data are practically available. Statistical methods to deal with these issues and combine proxies into a practical tool have been proposed in T3.1 (Adriaens et al 2020).These methods could be adapted to the resilience and efficiency (R & E) proxies and extended to include the herd-level information. The herd context provided by Big data (3.2, 3.3) for local adjustment of the sensor information is one element of the herd-level information; another is synchrony of individual indications at herd-level. Data could be adjusted for herd level monitoring using across animal statistics built into software to provide integrated output. Noldus reviewed a range of sensor fusion middleware to assess which could be suitable software for this task and RAFT (involved in national data integration projects with commercial software partners) contributed technical expertise alongside UNIPD and DLO. A small sample set consisting of real data from DLO in T3.1 was used in building a demonstration software which illustrates the potential arising from GenTORE WP3. The outcomes of this task 3.4 could contribute to the applicability of WP5 'on-farm management tools'. Moreover, they will also be demonstrated in conjunction with WP7 'communication and dissemination.

2. Introduction

2.1 Contents of Deliverable

The deliverable consists of three main outputs:

- Report
  - Dashboard Concept Development
  - Software Development Journey
  - User experience and working demonstration dashboard
- Demo software – live link to demonstration version of the dashboard https://www.noldus.com/projects/gentore. (see section 3.3)
- Training video – to support the use of the dashboard https://youtu.be/H9UDryIWFVc

2.2 Aims & Objectives

Task 3.4 aims to integrate elements of the work in Tasks 3.1, 3.2 and 3.3 to demonstrate the potential of combined usage of animal and herd-level data to support advisor input (e.g., veterinary herd health) on a whole herd basis over time, providing practical and high impact decision support tools for farms.

The objective is to develop and provide a demonstration software tool to allow farm advisors, such as veterinarians and technicians, to deliver herd-level prioritization of target herd health and management areas for intervention. For example, combining sensor information on milk yield perturbations with equivalent accelerometer information may provide the user with estimates of the prevalence of broad disease classes eg: mastitis, lameness or infertility. The vision is to develop a demonstration decision support software 'dashboard' design from which projects after GenTORE can be forthcoming to explore the further potential of the software and possible commercialization of the product.

3. Results

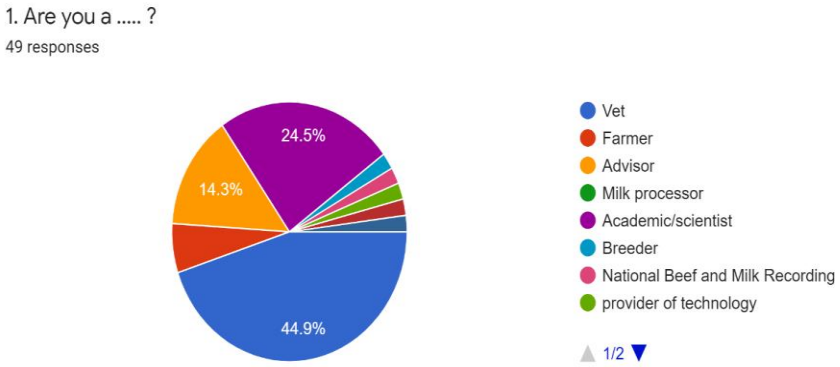
3.1 Dashboard Concept Development

3.1.1 User Requirement Survey

Because the intent was to create a demonstration software tool that was highly user-oriented and of practical interest, an online User Requirements Survey was undertaken before starting the development of the dashboard at the beginning of T3.4. The survey was circulated among the partners of GenTORE and their respective stakeholder networks with the aim to understand the potential user needs more comprehensively in order to inform the construction of both the dashboard concept design and software functionality. Involving end-users into the early stages of software development is a well-recognised approach; it allows early detection of flaws in both the concept and the design of the software, minimises unnecessary development costs and ensures relevance for the end-user.
The on-line survey was therefore circulated in 2020 by RAFT, UNIPD, DLO to the respective British, Italian & Dutch stakeholders.

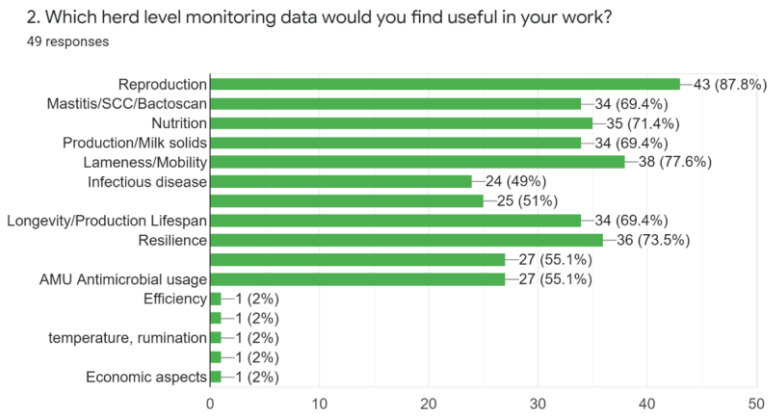
Results summarised below describe the potential composition of users; technical topics for monitoring (ie reproduction, nutrition, mastitis etc); preferred frequency of use for specific topics (ie daily to weekly to annually); preferred format of use (ie smartphone, tablet or laptop); preferred payment frequency, systems integration requirements and access permissions.

Composition of Users



The majority of users surveyed were veterinarians at 44.9%, although nearly 25% were academics.

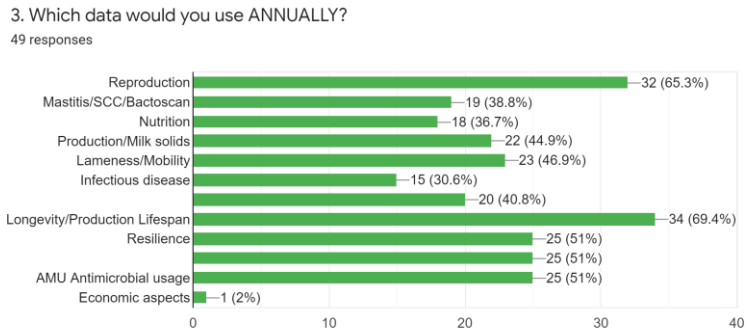
Herd Level Monitoring Data



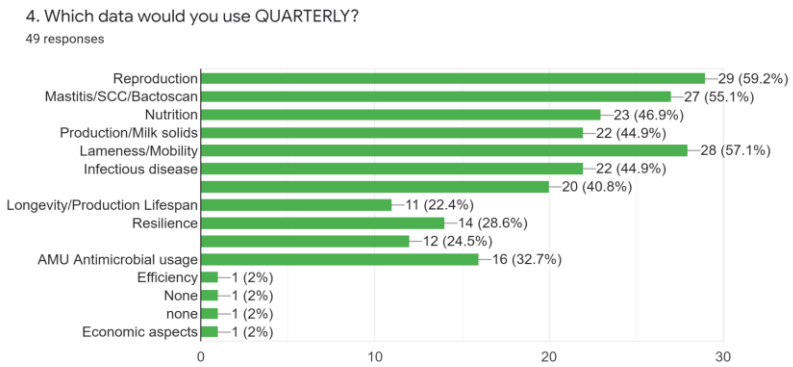
Reproduction was identified as the most useful data but health challenges such as mastitis and lameness as well as nutrition and production were also scored highly.

Frequency of Use

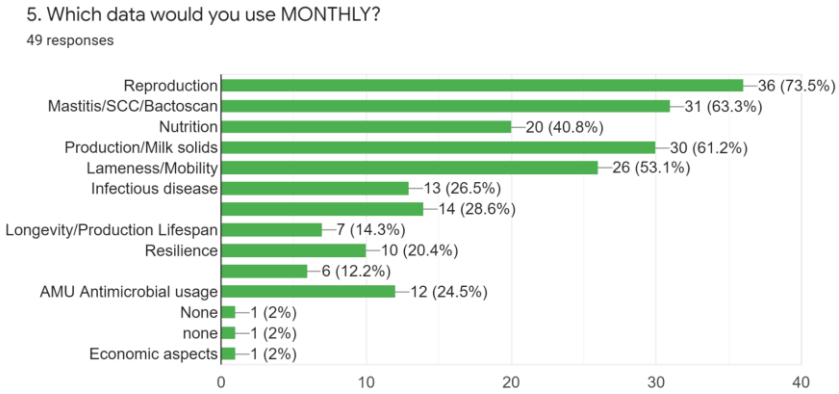
- **Annual Use of Data**



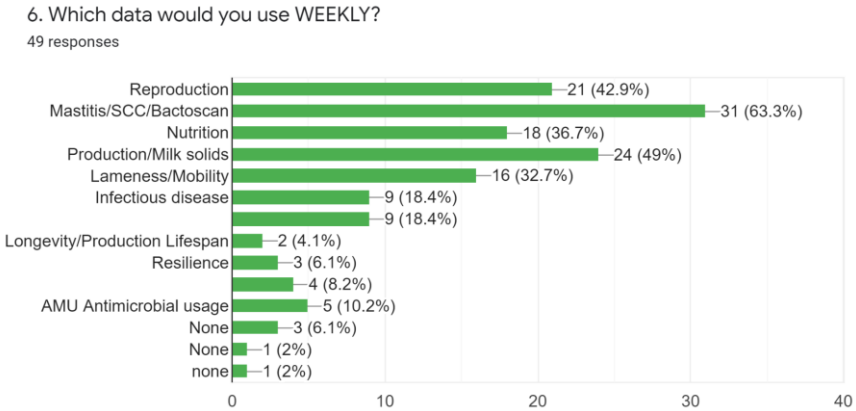
- **Quarterly Use of Data**



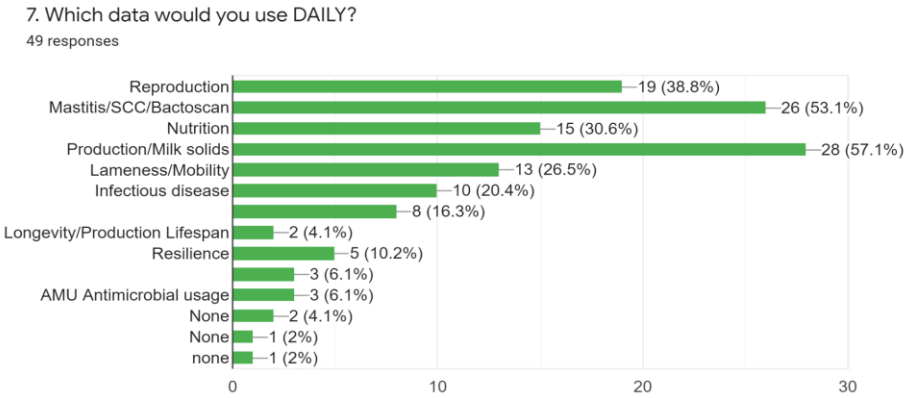
- **Monthly Use of Data**



- **Weekly Use of Data**

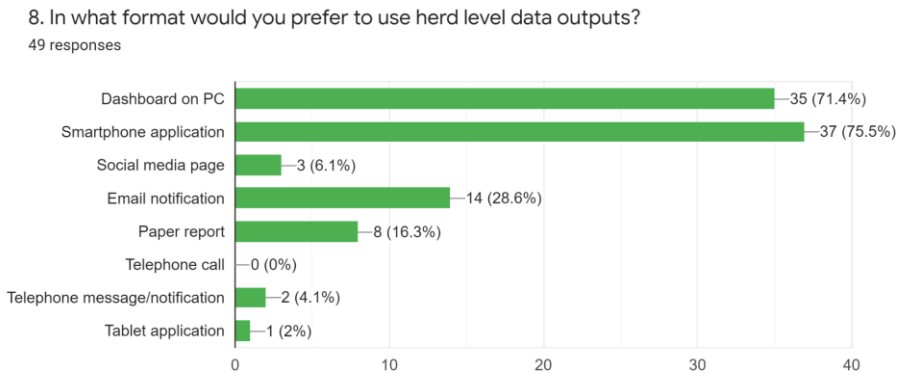


- **Daily Use of Data**



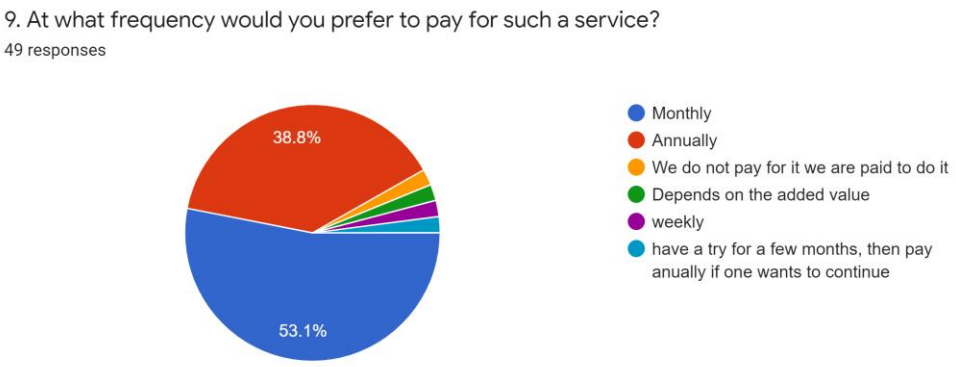
Although longevity/productive lifespan were identified for use at an annual frequency, it became less important as frequency increased. Reproduction remained important but mastitis and production became most frequently of interest for weekly and daily use.

Preferred Format of Data



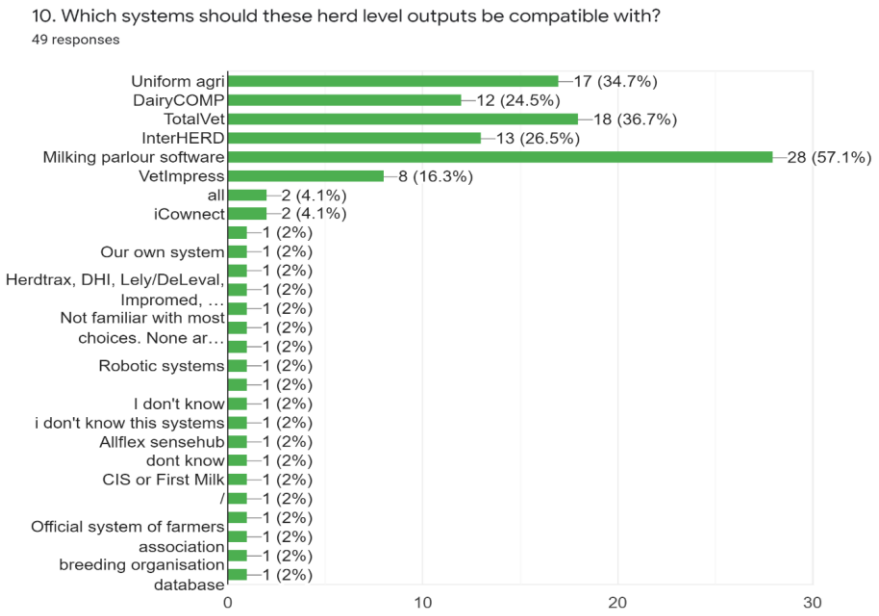
Both PC and smartphone formats were preferred for use, with paper and tablet formats much less popular.

Frequency of Payment



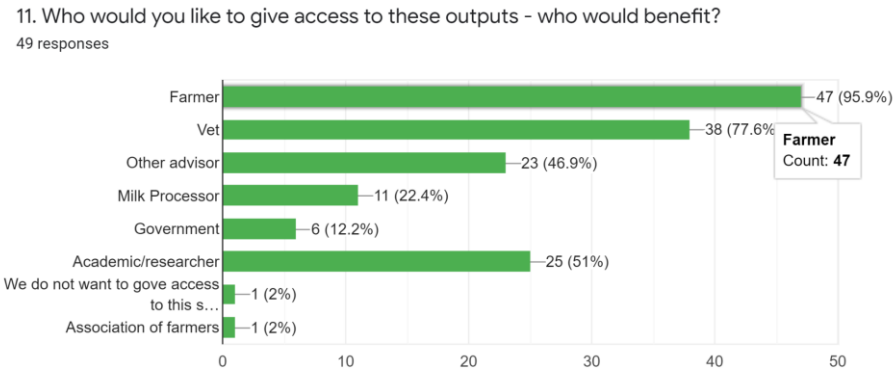
Monthly payments were most popular at 53.1% and annual payments followed at 38.8%, with very few responses describing other preferences.

System Compatibility



Compatibility with milking parlour software was regarded as most important, but other key systems were identified including Uniform agri, TotalVet, InterHERD & DairyCOMP.

Access Requirements



Farmer and veterinarian access permissions were most frequently identified.

Additional Survey Comments

- *I practice mostly beef cow-calf and feedlot medicine hence I have little interest in the dairy parameters.*
- *I answered based on my approach as a reproductive veterinarian.*
- *Hope that the sustainability/GHG recognises that growing plants can/should be carbon sinks and that carbon sinking is taken into account versus emissions. Will the project move onto covering cross-bred cows as the majority of the herds I deal with are not purebred.*
- *Information about herd should be confidential. Unauthorized persons have to ask for permission.*
- *My job consists in managing local cow breeds, very small populations. Then these resilience data would mostly be used annually to describe the characteristics of these breeds.*
- *Crown funding or co-funds by AI studs or milking precision industries.*
- *The device should be practical and simple to be managed by unexpert end-users.*

The results of the survey, for example 'System Compatibility', offered useful insights regarding both the current work programme as well as the further development of the demonstration software beyond the end of GenTORE. The largest group of respondents were veterinary surgeons, and it was apparent that reproduction, health & production factors were all highly desirable for monitoring, with some changes in prioritisation as reporting frequency changed. Integration with popular dairy software such as '*Uniform Agri'* or '*DairyComp'* were stated, alongside milking parlour software and veterinarians and farmers were both identified as priority users for permissions. Monthly payments for software access were the most frequently preferred.

3.1.2 Demonstration Dashboard Concept

Following the stakeholder survey and discussions among the GenTORE task 3.4 partners, it was proposed that a dashboard concept for functionality should be developed. This would describe the ultimate wish list of requirements this dashboard should contain to be functional for advisors and farmers.

The following questions were therefore additionally posed by the internal GenTORE Task 3.4 partners to further focus the workplan. These discussions were held at annual meetings in 2020 and 2021 but also in regular WP3 meetings, held online monthly and facilitated by RAFT:

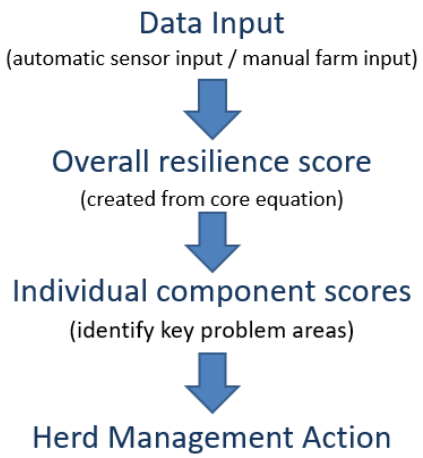
- What can make this demonstration software unique compared to what is already on the market?
- How can we link this demonstration software best to GenTORE WP2, WP3.1, WP3.2, WP3.3?
- What data can flow into this demonstration software?

It was agreed that the demonstration dashboard proxies for R&E developed by T3.4 should be:

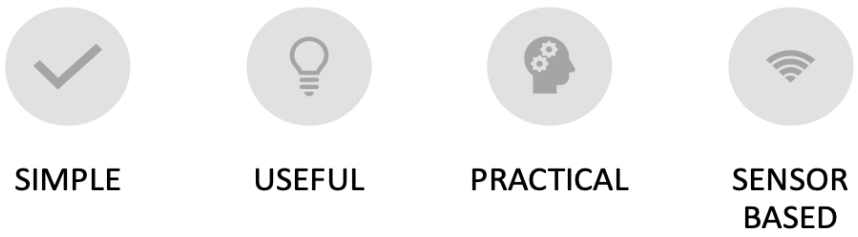
- Pitched at the herd level
- Based on WP3 outputs
- Sensor based with regard to input data

The current section is consequently the result of many discussions on how a dashboard could be set up, which information could be most relevant for users, including drilling down from an overall impression at herd level, to focus on specific areas of attention, where perhaps it could also reveal cow specific data. It might be even more helpful if areas of attention could be accessed through portal tiles, and these portal tiles change in size depending on which portal-area has the biggest effect in a signalled change in R&E.

The flow of data was clearly defined at the start of the development journey and developed from the Core equation for Resilience of GenTORE WP3.1:



and kept the following key ideas in mind;



The key concept is therefore to be able to visualize the herd's actual **R&E** scores using a simple, useful, and practical application that can be used by both farmer and advisor.

Taking into account the results from the user requirements survey, the demonstration software should provide R&E features of the herd through the analysis of different macro-areas that group several herd-level indicators.

0. **General Herd Information** – Herd location; Herd size; Replacement stock;
1. **General herd performance areas** – Milk production; Number of cows culled; Average age at culling / number of lactations at culling;
2. **Health** – Herd health infectious disease status; Milk fat to protein ratio; Rumination time; Cow body condition score (**BCS**) as percentage of cows over or below critical threshold;
3. **Udder health** – Milk somatic cell count (**SCC**); Proportion of clinical mastitis events; Proportion of sub-clinical mastitis events; Number of chronic cows;
4. **Fertility** – Age at first calving; Average herd days in milk; Days open / Calving interval; Number of inseminations per pregnancy; Conception rate;
5. **Behaviour** – Eating time; Rumination time; Pattern of rumination;

Comparisons of herd R&E performance could be visualized against a benchmark score that, for example, could be the average herd-population score. The reference herd population could be made up of herds sited in the same region for example or rearing the same breed, or having the same production system (eg. organic; conventional).
This functionality, however, is not incorporated in this initial demonstration software, but allows future development and benchmarking is shown on a small dataset. Trends over time can also be displayed by using historical herd data and this is shown in the demonstration software on a small dataset.

The initial concept of the dashboard was then developed into four portals and an overall herd R&E indicator, as reported below. These four integrated portals were proposed to include the initial six macro-areas (listed above) but more clearly represented the work of T3.1 as described below and were less visually cluttered on the home-screen of the dashboard.

3.1.3 Demonstration Dashboard R&E Equations

The dashboard is the first screen an end-user would see and visualizes the herd's R&E scores on two dials. The indicators of the R&E scores comparatively show the actual herd value and its benchmark position relative to the herd population R&E score tertiles.

Resilience Score
The agreement was to use the Core Resilience Equation from WP3.1 (most essential and common data available) because it is the most adaptable to different farm situations and according to data availability. The resilience score, and how to compute this, has been published in scientific papers (Ouweltjes et al, 2021;, Adriaens et al, 2020; Poppe et al, 2020; Friggens et al (2022) and it is a scoring system that assigns bonus or malus points to a specific cow based on a number of criteria. In this current work, we used the following points for the different criteria:

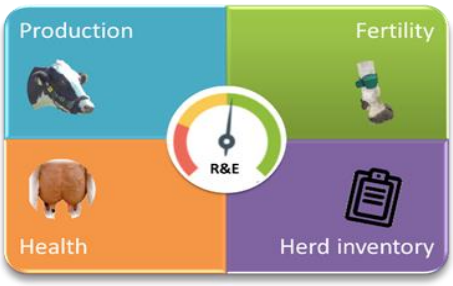
- 500 plus points for each calving
- Age at first calving compared to herd mean - 1 plus / minus point for each day difference (1st calving only)

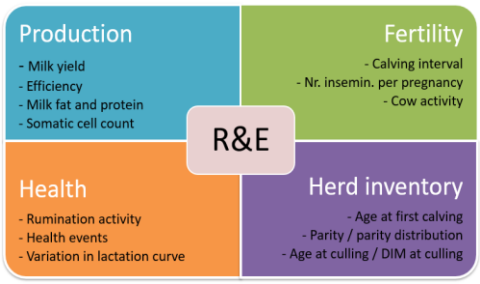
- Calving interval compared to herd mean - 1 plus / minus point for each day difference (>1 calving)
- Milk yield: Daily Milk Yield / 305-day milk yield
- Number of inseminations - 25 minus points for inseminated culled cows (last lactation only)
- Number of events - 1 minus point for each curative treatment day / 1 minus point for each day culled before 100DIM

Then, four main components of the Resilience Score (RS) were highlighted in the dashboard 'portal segments:

Resilience	=	ability to **RECALVE**	>	Number of calvings	→	***"Herd inventory"***
	+	good **FERTILITY**	>	Calving interval; Age at first calving; Number of inseminations	→	***"Fertility"***
	+	good **HEALTH**	>	Health events; Culling before days in milk (**DIM**) 100	→	***"Health"***
	+	good **PRODUCTION**	>	305-day milk yield	→	***"Production"***

These four main components of the RS were then presented visually as a design concept for the dashboard. As shown below, the four components were proposed to act functionally as 'portals' to receive the data listed in the lower dashboard graphic:



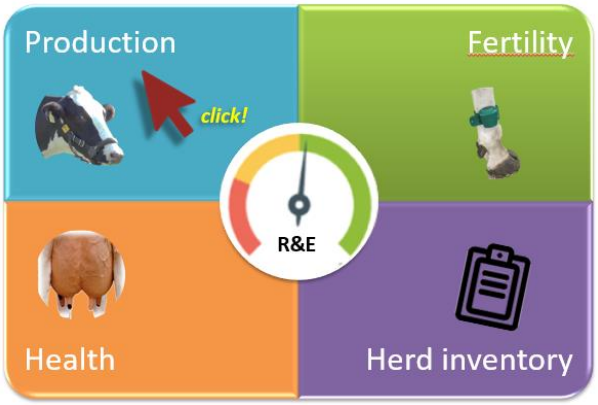


EFFICIENCY SCORE

For Efficiency, the following definition was agreed upon in WP3.1: *'feed efficiency is the sum of feed intake(kg) divided by the total sum of milk produced (kg) per day'*. This definition requires the actual recording of cow individual feed intake (via e.g., roughage intake control bins), or approximation of feed intake with in-depth sensor information. Both of these are not widely or readily available on commercial farms. Therefore, feed efficiency was not studied in the same detail as resilience by all partners, and only at the parity level rather than over the whole lifetime of the cows.

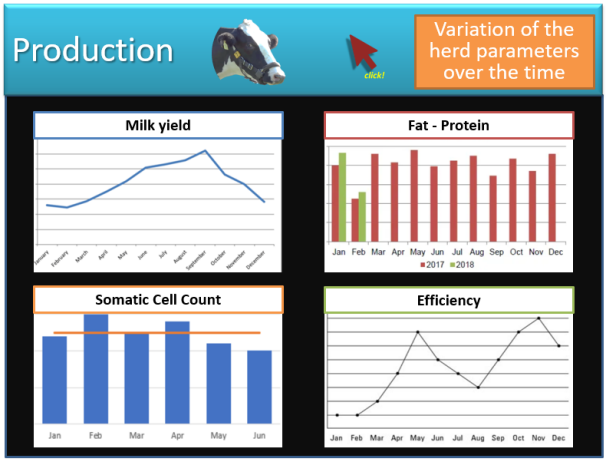
3.1.4 Herd Level Indicators of Resilience & Efficiency-Portal Details

By clicking on one of the four portal subsections of the dashboard home screen (Production, Fertility, Health, and Herd inventory), it was intended that the user could enter into that specific portal where further and specific indicators are displayed. Each portal demonstrates at least one indicator included in the R&E score formula, and / or one indicator based on sensor technology, and other indicators linked with resilience and efficiency.



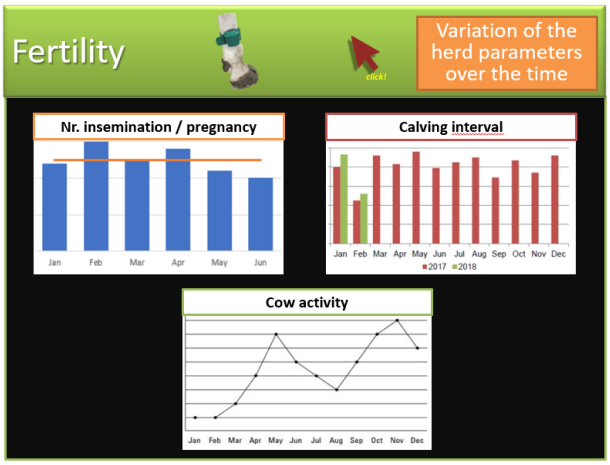
A list of the *potential* indicators that can be included in each portal is reported below. Data origin (i.e., from sensors or not) and main field of influence (Resilience or Efficiency) are reported in brackets. Indicators included in the demonstration software are printed in **Bold.**

a) **"Production" portal:**
- **Milk yield** (sensor data; efficiency): daily variation in average milk yield production per cow and the total amount of milk produced – comparison with the herd population quartiles
- Efficiency : the sum of feed intake (kg) divided by the total sum of milk produced (kg) per day; where available
- Milk Fat and Protein content (sensor or non-sensor data; efficiency): daily variation or variation at each new test day – comparison with the herd population quartiles
- Somatic Cell Count (sensor or non-sensor data; resilience): daily variation or variation at each new test day – comparison with the herd population quartiles



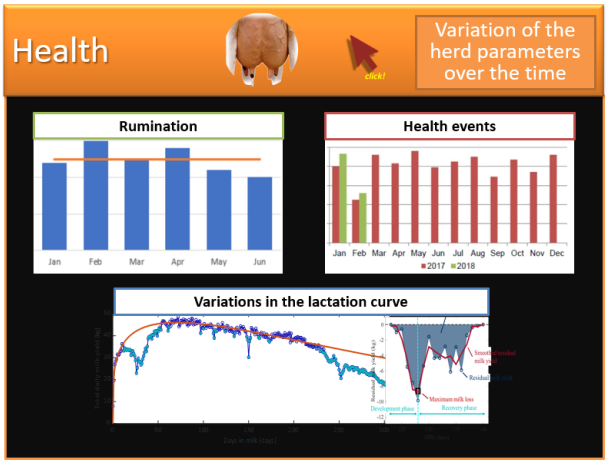
b) **“Fertility” portal:**

- **Calving interval** (non-sensor data; efficiency): variation at each new calving – comparison with the herd population quartiles
- **Number of inseminations** per pregnancy (non-sensor data; efficiency): variation at each new pregnancy diagnosis – comparison with the herd population quartiles
- **Cow activity** (sensor data; resilience): as described in the ‘adapted equation’ of WP3.1: the addition of further available sensor-based data (Adriaens et al 2020).



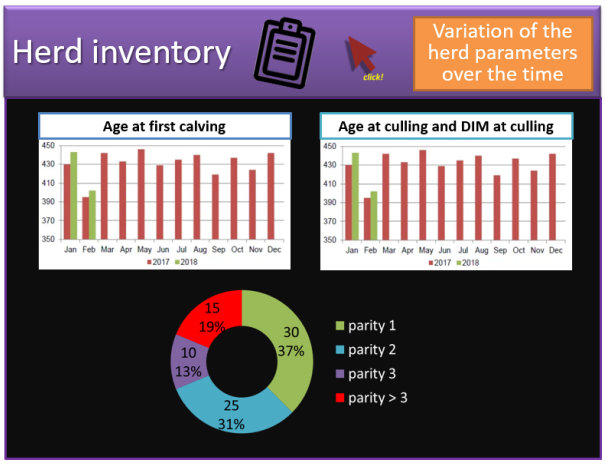
c) **“Health” portal:**

- **Rumination** minutes per day (sensor data; resilience): daily variation - comparison with the herd population quartiles
- **Health events** (non-sensor data; resilience): variation at each new event, per month – comparison with the herd population quartiles
- Variations in lactation curve (sensor data; resilience): as described in the ‘core’ and ‘adapted equation’ of WP3.1: the addition of further available sensor-based data (Adriaens et al 2020).



d) **“Herd inventory” portal**

- **Age at first calving** (non-sensor data; efficiency): variation at each new calving – comparison with the herd population quartiles
- **Parity** (non-sensor data; resilience and efficiency): average number of lactations of the herd, variation at each new calving – comparison with the herd population quartiles
- Parity distribution (non-sensor data; resilience and efficiency): proportion of cows in the first lactation among the cows – comparison with the herd population quartiles / parity distribution of the herd
- Age at culling (non-sensor data; resilience): average age at culling, variation at each new culling event – comparison with the herd population quartiles
- Days in milk (DIM) at culling (sensor or non-sensor data; resilience): average DIM at culling (or proportion of cows culled within a certain DIM, as used in the Core Resilience Formula), variation at each new culling event – comparison with the herd population quartiles

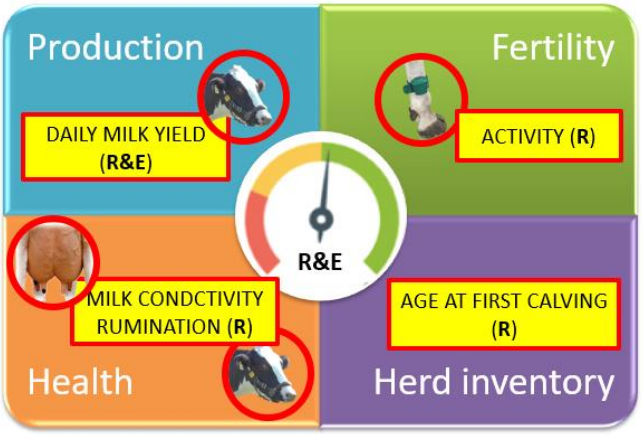


Changes in R&E scores are due to changes in one or more components contributing to the overall calculation. When the user sees a change in the R&E score it is expected that a motivation exists to identify which components are responsible for it, in order to prioritize herd interventions. Therefore, different methods can be adopted to guide the user as to which portal subsection/s should be investigated first.

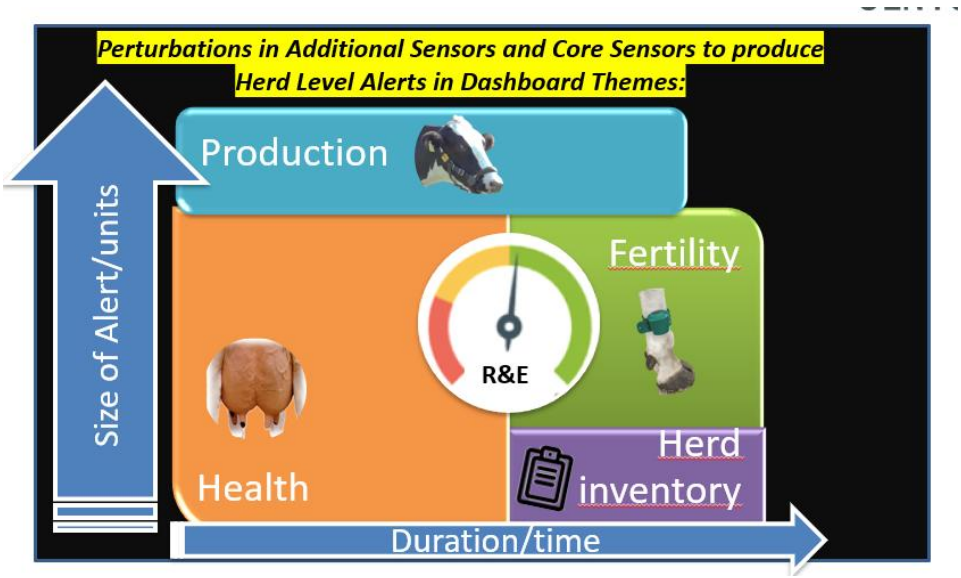
Perturbations in Core Sensors and Additional Sensors to produce Herd Level Alerts in Dashboard Themes; examples of Alerts:

Specific sensor measures are principally responsible for changes in R&E scores that could be displayed in the main dashboard via changes to the dial, as shown in the figure below:

Variation in herd-level sensor data



The four portals could potentially change in size based on the extent to which each main area (fertility, health etc) contributed to the change in R & E scores:



However, this approach was not taken forward. The changes in the dials for resilience and efficiency, as displayed in the home screen, were deployed as the primary signal of changing Resilience or Efficiency.

3.2 Software Development Journey – Noldus

3.2.1 Development Process & Decisions

In this section we demonstrate what has been implemented (to the time of writing) from the above conceptual proposals into the demonstration software. This is not yet a comprehensive generic infrastructure, but we picked essential pieces from the conceptual proposals to demonstrate. The reasons for the limitations in aspects included were technical difficulties of linking to Precision Livestock Farming sensor sources, heterogeneity of available data types on farms and as-yet unrealized pooling of data across sufficient farms to allow real benchmarking. Consequently, we could only develop a showcase demonstration rather than a (real) prototype software. Nevertheless, we hope a prototype software will be developed by stakeholders seeing the demonstration version of the dashboard.

The next steps following the development of the dashboard concept were for Noldus to scope functional software in more detail given existing results in WP3 and available coding resources to produce a specification of the demonstration dashboard.

3.2.2 Main Concepts

Herd Resilience and Efficiency performance monitoring:

- To have the ability to visualise herd Resilience and Efficiency performance through a scoring system
- To be a simple, useful, and practical view for farmer or advisor such as a vet

Comparison of actual performance:

- To have the ability to view the herd Resilience and Efficiency score against a benchmark, such as average herd score from the region or from farms rearing the same breed.
- To have the ability to view trends in Resilience and Efficiency scores using historical data

In-depth insights:

- Visualization of main component scores (Health, Fertility, Production and Herd Inventory)
- Detailed view of underlying data for Farm Advisor or Researcher (e.g. sensor based from Tasks 3.3)

Noldus were tasked to write the code with the following stipulations:

- Key indicators relating to each individual parameter that then gives an overall resilience number score, can change weekly / monthly depending on how the farm is performing
- Must have daily input / update options
- Ability to calculate weekly / monthly / seasonality averages
- Ability to drill down into individual parameter data to identify trends and problem areas

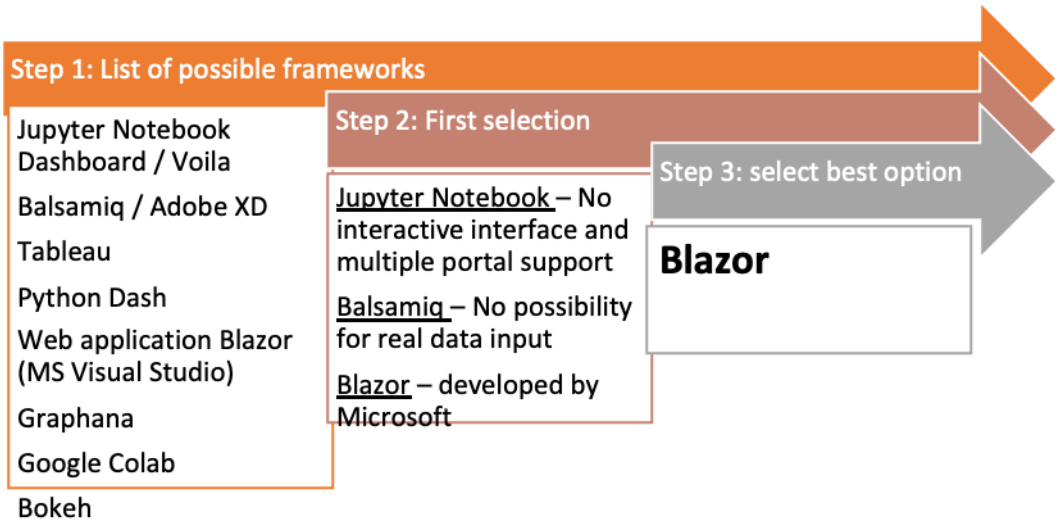
3.2.3 Software Requirements

The requirements of the software were therefore as follows:

- develop into a professional looking application
- fast to design/implement GUI showing dashboard
- easy import of data from (predefined) csv file
- easy adjustment of algorithms - common languages like Java / Python (script) is preferred
- preferably works on PC and mobile devices (smartphone, tablet)
- preferably open source (easy access for researchers)
- scalable architecture
- fits lean and agile development

3.2.4 Decision Framework

With the above considerations in mind, a series of potential software frameworks were explored:



The reasons for the final choice of Blazor are described below, with the only drawback being a knowledge of web application is required.

Benefits of Blazor Framework

- Free and open source web framework
- Web apps using C# and HTML
- Quick design, rapid development User Interface
- Early customer evaluation
- Runs directly in browser
- Can run on a server (thin client)
- Supports mobile devices
- There is a rich charting UI library

3.2.5 Data Set

The decision was then made regarding which data set should be used for the dashboard development. A data set was provided by DLO for both resilience and efficiency assessment. This was a small database with historical data (2009-2016) from 10 cows.

It contained time series tables with information on calving, disease events, activity, rumination, bodyweight etc and also time series tables for feed intake and milk yield. This therefore offered the opportunity for monitoring efficiency as well as resilience.

Lifetime Resilience Score was calculated based on the Core formula using bonus/penalty points depending on the number of calvings, inseminations, health events etc. as described in Deliverable 3.1

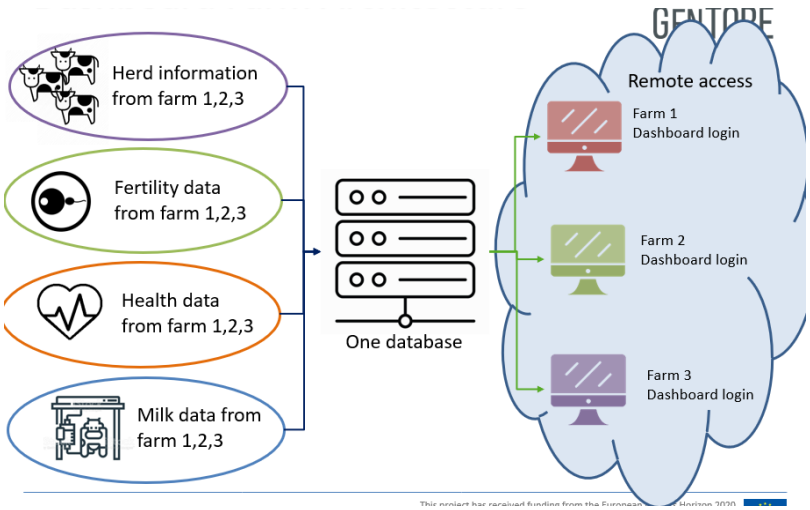
The DLO data set was used to demonstrate the main concepts; it was used to compute the lifetime resilience score with the daily average over the available herd data as a benchmark.

3.3 User experience and working demonstration dashboard

Throughout the development journey there have been regular software updates by Noldus – with a total of 7 versions to February 2022
Below is the final demonstration version of the dashboard. It can be accessed via the following link: https://www.noldus.com/projects/gentore.

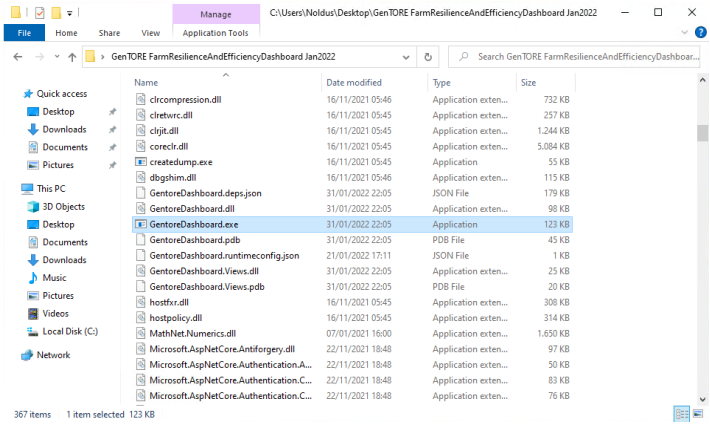
The overall flow of data and processes envisaged in a mature product is shown below.

Individual data from identified farms will feed into one central database with their unique farm identity remaining. Each farm will be able to access their data remotely via a unique farm-specific log-in to the dashboard:

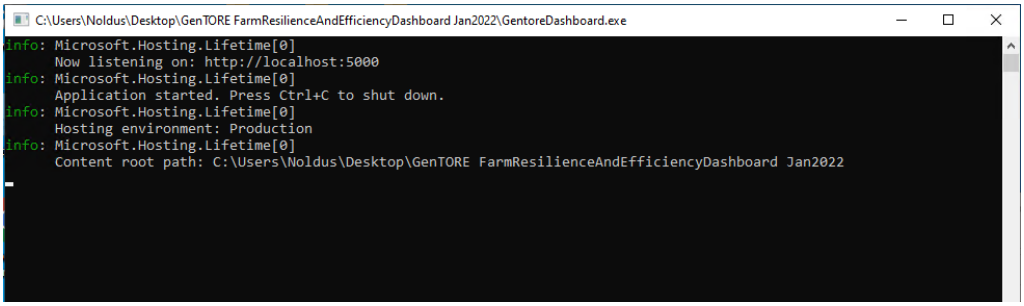


Throughout the development process the initial access route to the demonstrator dashboard for the Task3.4 group was carried out as follows:

1. Download zip file using the Dropbox link
2. Open Windows File Explorer
3. Select zip file and Unzip files into a local folder (like GenTORE)
4. Open the subfolder GenTORE FarmResilienceAndEfficiencyDashboard Jan2022
5. Launch GentoreDashboard.exe by double clicking on the icon



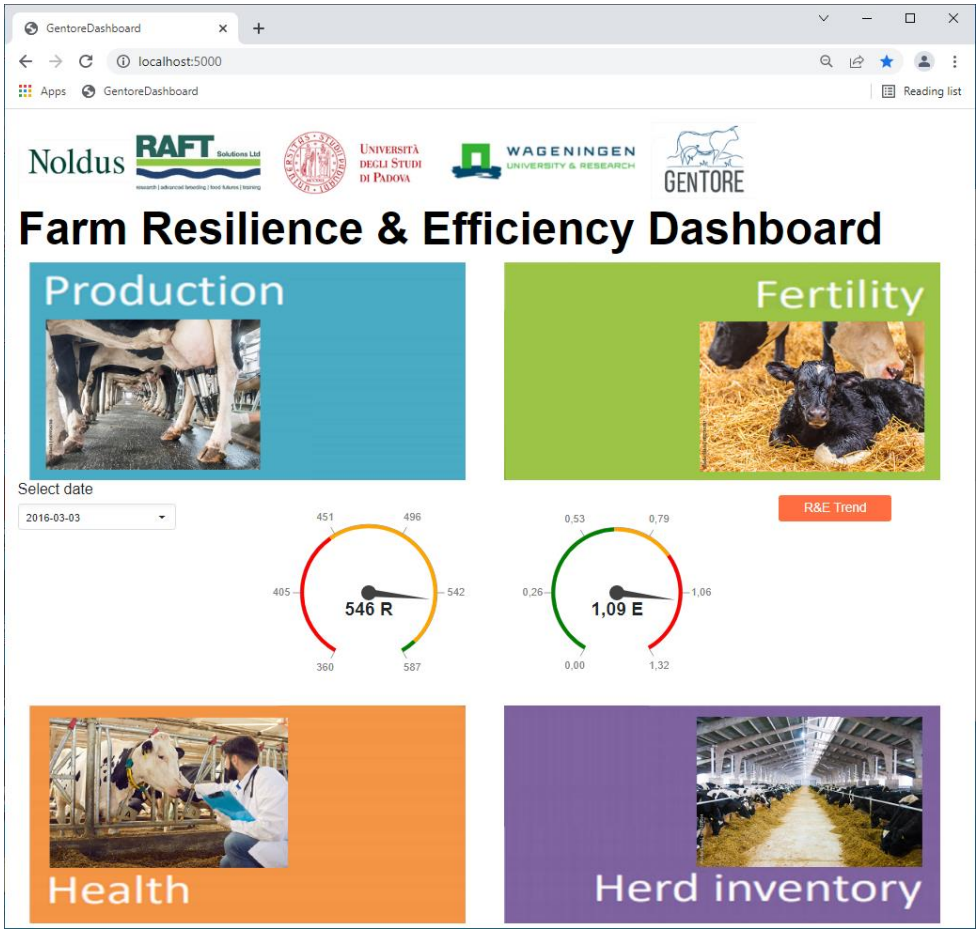
6. A new window appears showing next black screen.
7. Leave this screen open in the background



8. Start your favourite web browser (like Google Chrome)
9. Enter http://localhost:5000 in the browser
10. The GenTORE dashboard web application can be used from this point onwards

The following section shows screenshots taken from the live demonstration software.

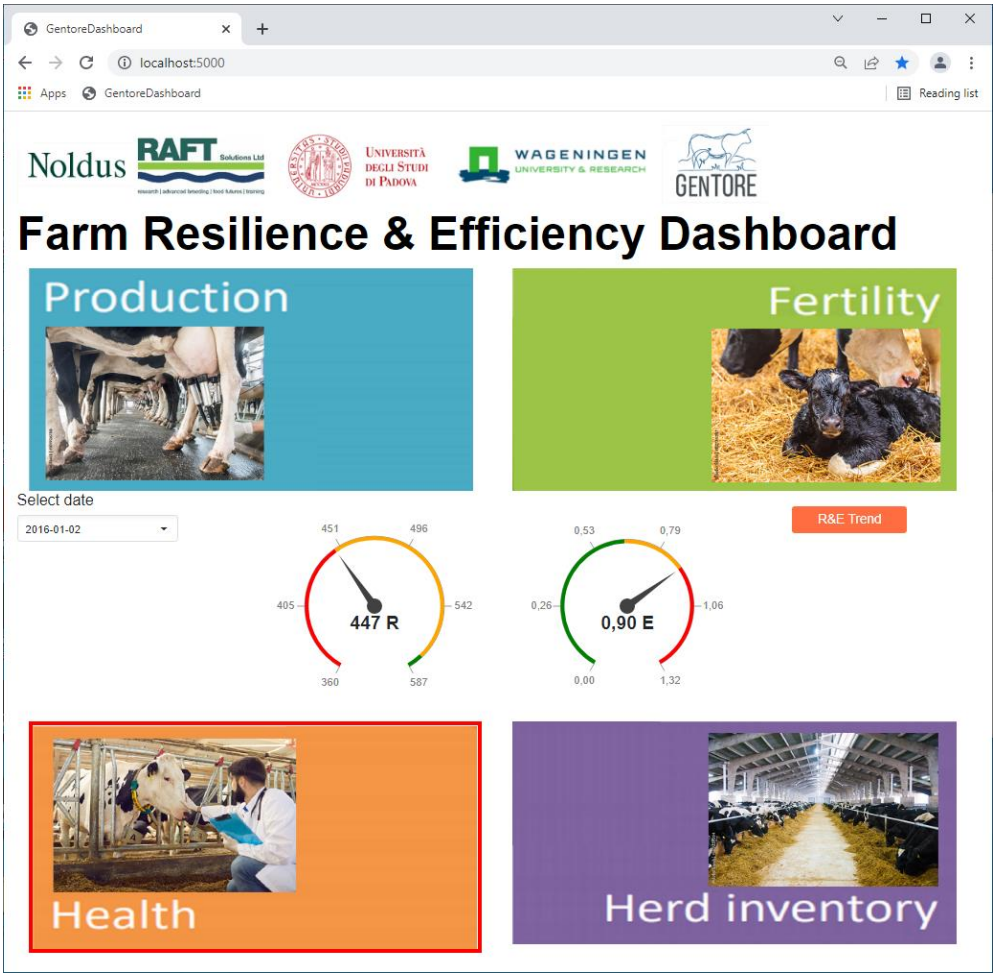
Farm Resilience & Efficiency Dashboard – Main home screen page



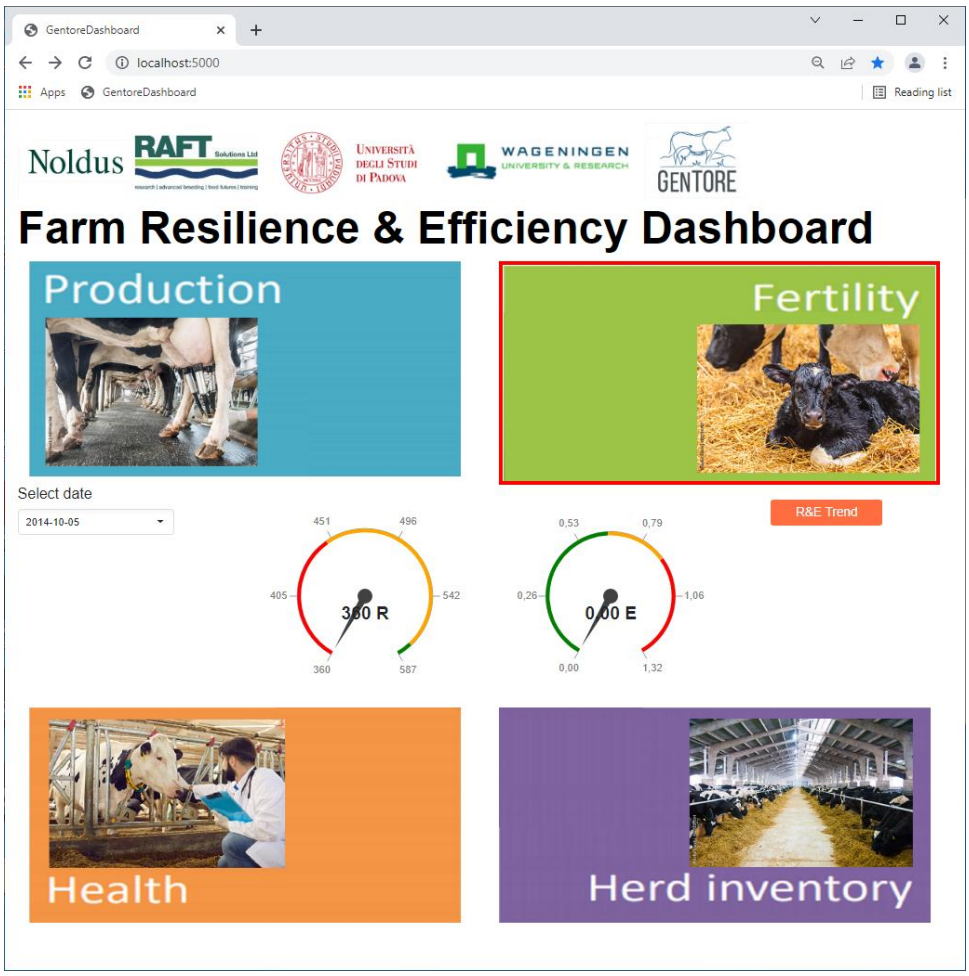
The Farm Resilience & Efficiency Dashboard main page shows two dials and four portals. The two dials provide a dynamic output each for Resilience and Efficiency; scores are derived as described above in section 3.1.3. The four portals each offer an opportunity to drill down into four categories of herd management factors that can be highlighted as responsible for a change in the herd Resilience or Efficiency dials shown on the main screen. These four portals are: Production, Fertility, Health & Herd Inventory. They are described in more detail below.

Main home-screen page – portal component indicator

The red border shown around the health portal indicates a need to inspect the Health related parameters. This is applicable when the date 2016-01-02 is selected. On other selected dates the red border is not shown**.**



Similar applies for when the date 2014-10-05 is selected. The Fertility portal gets a red border to indicate a need to inspect the Fertility related parameters:



The gauges on the main page are indicating zero when there is *'no data available'* for the selected data, this is not correct but due to the limited and incomplete data set.

Resilience & Efficiency – Trends over time

The resilience and efficiency chart gives an overview of the calculated resilience (the lifetime resilience score) and efficiency scores for the sample dataset during the selected period of time. This demonstration dataset of 10 cows was used in this way so that each cow represented a 'herd' in order to demonstrate the potential bigger picture. Selection of one particular 'herd' or all 'herds' is possible to enable the user to analyse trends over time and in relation to a benchmark. Currently the implemented benchmark is the calculated average of all 'herd' data.

Significant deviation in herd resilience score can be apparent from this overall herd chart over time. However, stakeholder survey discussions suggested that the advisor then seeks to identify which area of herd management such a deviation originates from. As described above, the demonstration software will highlight one of the four portals in red if the change in the overall resilience score can be attributed to one portal area in particular. Drilling down to this next level is then possible to investigate through further data charts potential areas for more specific veterinary/advisor management attention.

This dashboard is clearly a demonstration version; decisions had to be made as to what to develop further given the time restraints of the project.
The reasons for the limitations in aspects included were technical difficulties of linking to Precision Livestock Farming sensor sources, heterogeneity of available data types on farms and the challenges of pooling of data across sufficient farms to allow real benchmarking.
Consequently, we could only produce a showcase demo rather than a (real) prototype software.
The group decided to select the following for further development showing actual data behind the Health & Fertility portals.

The following section illustrates the information available in the demonstration software if this process is followed for 'Health' and 'Fertility' portals. A similar functionality could be built for the other two portals 'Production' and 'Herd Inventory'.

Health Portal

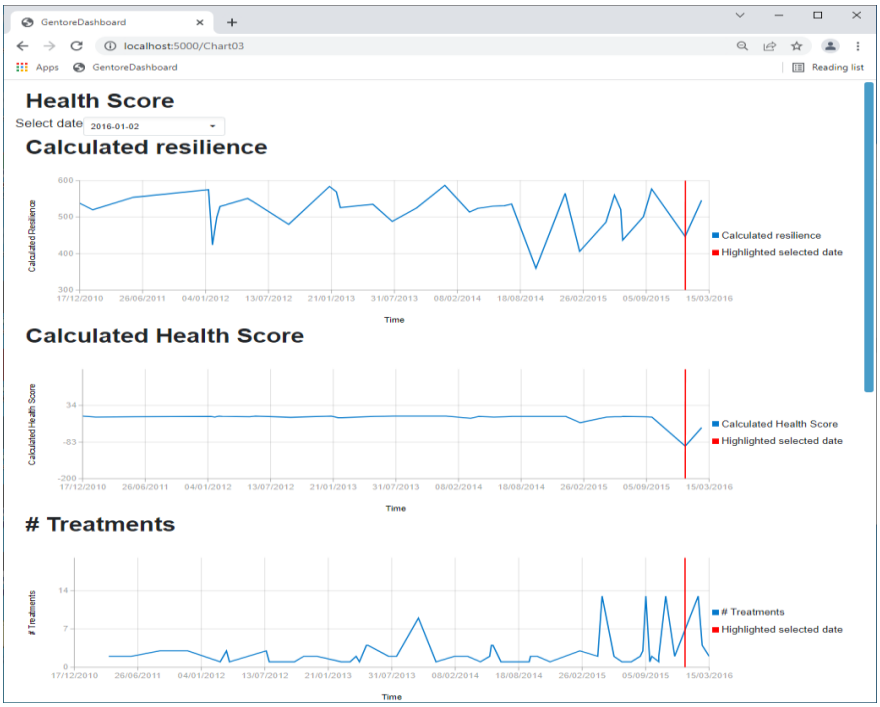
Three charts showing available health related parameters for the whole herd data were implemented. The red vertical line represents the selected date.

1) Calculated resilience demonstrates the resilience score of a herd over time.

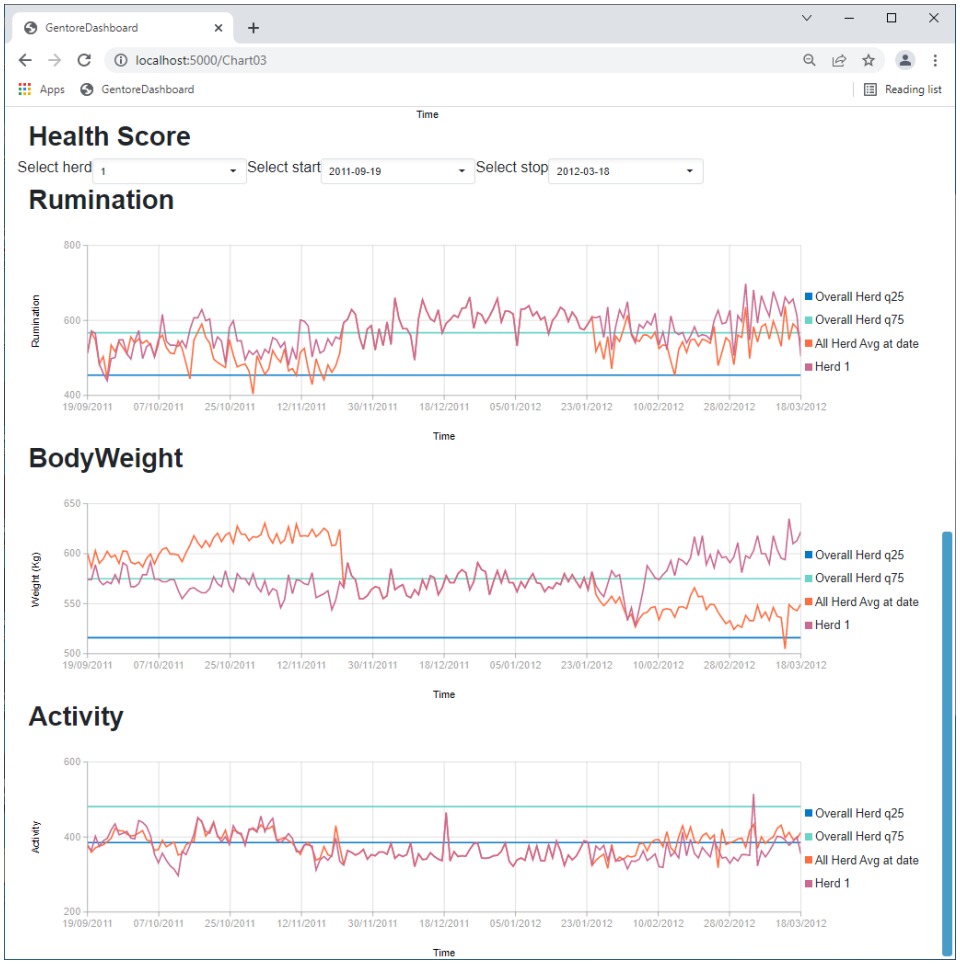
2) Calculated Health Score chart shows the complete timeline for calculated values for the health parameter as included in the core resilience definition developed in WP3.1. The score reflects the total number of health events with both the number of recorded events during the lactation and early culling taken into account.

3) The Treatments chart shows the number of treatments in time.

The three 'HEALTH' charts could potentially enable the user to gain insight into the impact of the health related parameters on the overall resilience score, by highlighting priority management areas for further veterinary/advisor investigation at a clinical or herd data level.



Below the health-related parameters, an example of automated sensor-based parameters is shown. The Rumination, Bodyweight and Activity parameters for the selected herd are shown graphically for the entered period:



In this way, we introduce the opportunity for automated sensor-based outputs to also signal and inform the prioritised resilience alerts described in the 'HEALTH' charts above.

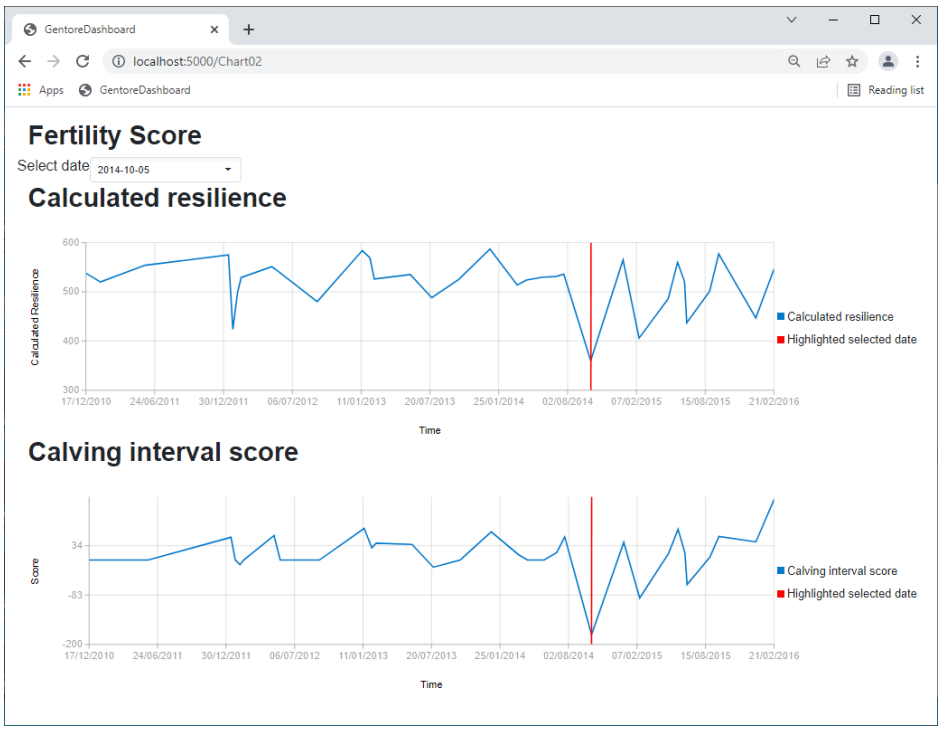
Fertility Portal

In a similar fashion to the 'Health' section above, two further charts are available in the demonstration software, showing available 'Fertility' related parameters for the whole herd data:

1) Calculated Resilience chart shows the complete timeline for all calculated resilience data available. Red line shows the selected date.

2) Calculated Calving Interval Score chart shows the complete timeline for calculated values for parameter p5 (as defined in D3.1). Difference of calving interval ("p5") is calculated as $CI-CI_{avg}$, where CI is the lactation figure and CI_{avg} is the associated herd mean. For the adapted

score we used the overall herd average; all herd average values are in table T_CI. Red line shows the selected date.



Similarly to 'Health', the 'Fertility' portal could offer the opportunity to drill down from a change in overall herd resilience score that is signposted to 'Fertility'. Potentially linking automated sensor outputs (as with 'Health') could present the same value to a herd veterinary surgeon/advisor in prioritising herd management areas for further investigation and intervention.

'Herd Inventory'' is an important measure of herd age profile reflecting resource management for a farm in terms of youngstock rearing costs, feed and space requirements. This is increasingly important in understanding greenhouse gas emissions intensity metrics in livestock farming. Displaying changes in Age At First Calving (AFC) and parity distribution on the dashboard tile may offer an opportunity for strategic management intervention. 'Production' could similarly highlight performance through changes in milk yield.

3.4 Potential Benefits of the Dashboard

Although this demonstration software is limited in functionality, it is intended to highlight the commercial applied potential arising from WP3 and this herd dashboard approach. These potential benefits could include:

Quick and easy access

- Gives access to herd data, anytime, anyplace, and on any device. The end-users benefit from the inclusion of information coming from different sources (milking equipment, test days) and sensors into a single device.

- No need to install an application, just login via a web browser to start analyzing herd information.

Future proof

- The Dashboard can handle multiple scenarios and selections.
- It can grow within regions and countries.

Live tracking of resilience and efficiency score

- Daily updates of resilience and efficiency score.
- Follow trend developments of scores.
- Compare your scores with other herd data

Understand herd information through synchronized data

- Obtain all herd information in a synchronized way.
- Align and visualize all results easily and intuitively.
- This allows an understanding of the cause and effect of higher or lower herd resilience.

A healthy working system

- With many different sources of information and devices connected, it is important to know when a data stream is not sending information.
- The Dashboard provides insights and can send warnings when a herd score is below a certain threshold.

Timely investigation of problem areas

There is the ability to 'drill down' into the main components (Health, Fertility, Production and Herd Inventory) to give a view of underlying data for Farm Advisor or Researcher (e.g. sensor based from Tasks 3.1-3.3). This will identify trends and locate problem areas.

4. Conclusions

In this Task we integrated lessons learned from Tasks 3.1, 3.2, and 3.3 into a demonstration software tool. This tool can be found at https://www.noldus.com/projects/gentore., accompanied with an instruction video findable at https://youtu.be/H9UDryIWFVc
The demonstration software tool shows the basis of a dashboard that combines information from different data sources, allows for monitoring resilience and efficiency and benchmarking, and where users can dive into more detailed information in four major areas of interest (portals). With this, there is a solid basis for future and further development of a dashboard following on from the GenTORE project. Besides the possibility of including further indicators within each of the four main dashboard portals (Health, Fertility, Production, and Herd Inventory), there is a wide possibility for benchmarking with different outputs/interpretations. Herd data can be compared with several reference limits, for example:

- vs. gold-standards → evaluation of the herd performances, prioritization of the areas for improvement, planning for specific interventions, monitoring of improvements over time;
- vs. national data → herd's R&E vs. national situation → **herd ranking**

- vs. herds within a region or with similar management (eg: organic vs. conventional…) → herd's R&E vs. regional/specific situation → analysis of specific regional challenges to R&E (e.g. heat stress, …)

The software is not commercially robust and consequently remains error prone, although we hope still shows concepts of how a dashboard could appear for the inspiration of stakeholders.

Both the Demonstration software tool and the instruction video will be accessible after GenTORE at the aforementioned websites for 5 years.

5. Partners involved in the work

The project partners involved in the development of the demonstration software were RAFT Solutions (UK), University of Padova (Italy), DLO (NL) and Noldus (NL).

6. References

Adriaens, I., Friggens, N.C., Ouweltjes, W., Scott, H., Aernouts, B., and Statham, J. (2020). Productive life span and resilience rank can be predicted from on-farm first-parity sensor time series but not using a common equation across farms. Journal of Dairy Science, 103: 7155-7171. DOI: 10.3168/jds.2019-17826.

Friggens N.C.; Adriaens I.; Boré, R.; Cozzi, G.; Jurquet, J.; Kamphuis, C.; Leiber, F.; Lora, I.; Sakowski, T.; Statham, J.; De Haas, Y. (2021) Resilience: reference measures based on longer-term consequences are needed to unlock the potential of precision livestock farming technologies for quantifying this trait. ANIMAL https://zenodo.org/record/5215798.

Ouweltjes W, de Haas Y and Kamphuis C (2019). At-market sensor technologies to develop proxies for resilience and efficiency in dairy cows. In 9th European Conference on Precision Livestock Farming, Cork, Ireland, 246-252.

Poppe M, Veerkamp RF, van Pelt ML and Mulder HA (2020). Exploration of variance, autocorrelation, and skewness of deviations from lactation curves as resilience indicators for breeding. Journal of Dairy Science 103, 1667-1684.