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IBIOM
Istituto di Biomembrane, Bioenergetica
e Biotecnologie Molecolari



UNIVERSITÀ
DEGLI STUDI DELLA
TUSCIA

Identification of the most impacting environmental variables on dairy cow's milk yield using Machine Learning methods

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Introduction

- Several reports show that **the effects of climate change are tangible for different aspects of life on earth** (e.g., World Health Organization, National Oceanic and Atmospheric Administration, Intergovernmental Panel on Climate Change)
- Such effects are particularly true for **the food production sector, in terms of economic losses and decreases in food quality** (Unanaonwi, 2014; Maulu et al., 2021; Singh et al., 2021; Chandio et al., 2022)
- Plus, **the effects of climate change are well-documented for milk production** (Sheik et al., 2017; Cheng et al., 2022)



The effects of climate change on milk production


Literature shows that environmental changes can lead to:

- **Reductions in milk yield**
- **Reduction in milk quality:** fat and protein content
- **Poorer cows' health:** higher somatic cell counts during heat-stress conditions: somatic cell counts are used as a proxy of animal health

(e.g., Nasr & El-Tarabany, 2017; Sheik et al., 2017; Cheng et al., 2022; Toghdory et al., 2022)



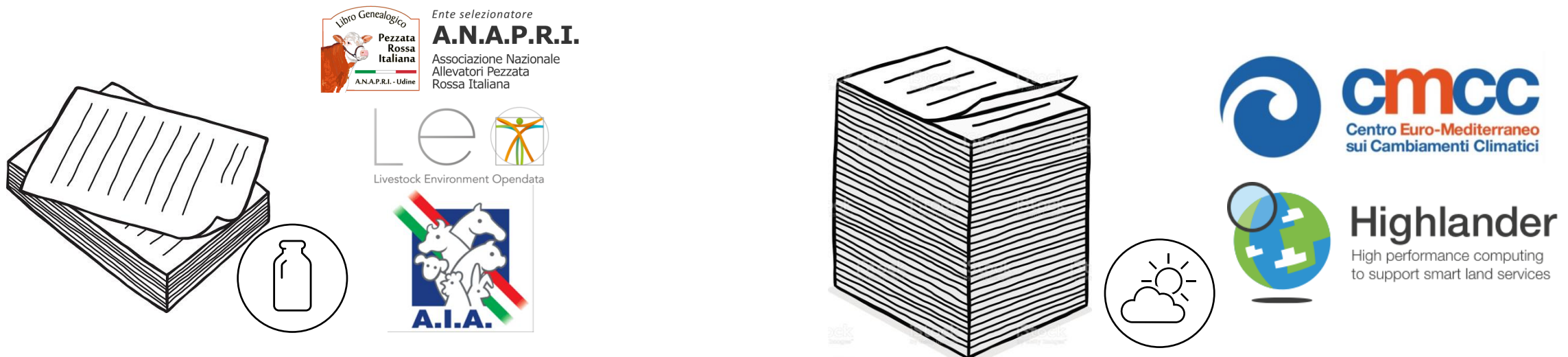
Our research question

- 
- The short term effects of the climate on milk yield and production has been reported in literature (Biswal et al., 2019)
 - It is not well-known **the individual impact of the climatic variables and how quickly these climatic conditions can affect milk production and quality.**
 - We developed a Machine Learning pipeline to identify the most important climatic variables that may influence milk yield and quality and their long-term effect

Methods

Data collection

- The “**production**” dataset: dairy cows’ records from 1990 to 2020 (AIA, ANAPRI, LEO Project)
- The “**climatic**” dataset: daily meteorological information from 1990 to 2020 (downloaded from HL and CMCC's DDS)



Methods

Data collection

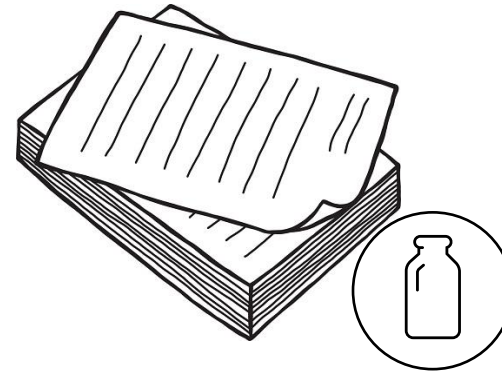
- **“Production”** dataset variables:

- milk yield
- fat
- protein
- SCC (Somatic Cells Count)
- **date of functional control (FC)**
- **latitude and longitude of the farm**
- **EBV**
- **Parity numbers**
- **Farm ID / Animal ID**
- **Days in Milk**

- Data were quality checked and filtered



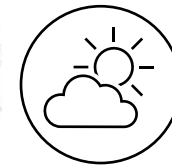
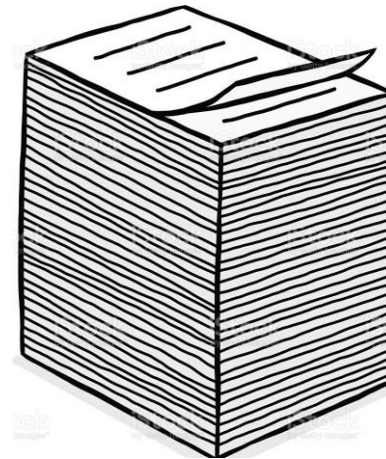
- For each variable (milk yield, fat, protein, SCC) a Linear Model was used to mitigate the effects of genetic factors or farm management



Methods

Data collection

- “**Climatic**” dataset variables:
 - **date of the measurement**
 - **latitude and longitude**
 - Temperature (min, max, mean)
 - Relative humidity (min, max, mean)
 - Wind
 - Precipitation (total)
 - Cloud cover (total)
 - Discomfort Index (min, max, cumulated)

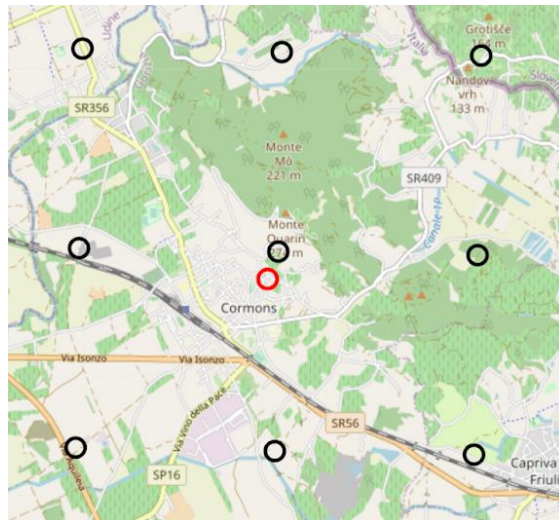


Highlander
High performance computing
to support smart land services

Methods

Data and plan of analysis

- The production and climatic data were paired
- The production of each animal **was paired with the climatic variables assessed for up to 30 days before the functional control date**



JUNE 2020

SUN	MON	TUE	WED	THU	FRI	SAT
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

Methods

Data and plan of analysis

Pilot dataset: farms located in **Friuli-Venezia-Giulia**

- The number of FC analyzed in the Machine Learning approach to detect the best prediction model were:
 - **2,332,083** FC (1375 farms * 105,285 animals)
- The total number of climatic variables analyzed is:
 - **198**
- Given the high amount of data and dimensions, we applied a **Machine Learning (ML) approach to identify the best climatic variables affecting milk production.**

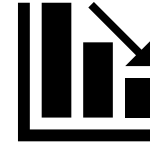


Methods

Our pipeline



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1

2

3

4

5

Remove collinear climatic variables to maintain the most informative ones before data analysis

Identify the best algorithm family to use climatic variables as milk production predictors

Optimize the parameters of the best algorithm to increase its accuracy

Evaluate the importance of all variables to subset the most important

Explain how each variable can affect milk production and quality

Climate variables

Features

Milk yield / quality / SCC

Targets

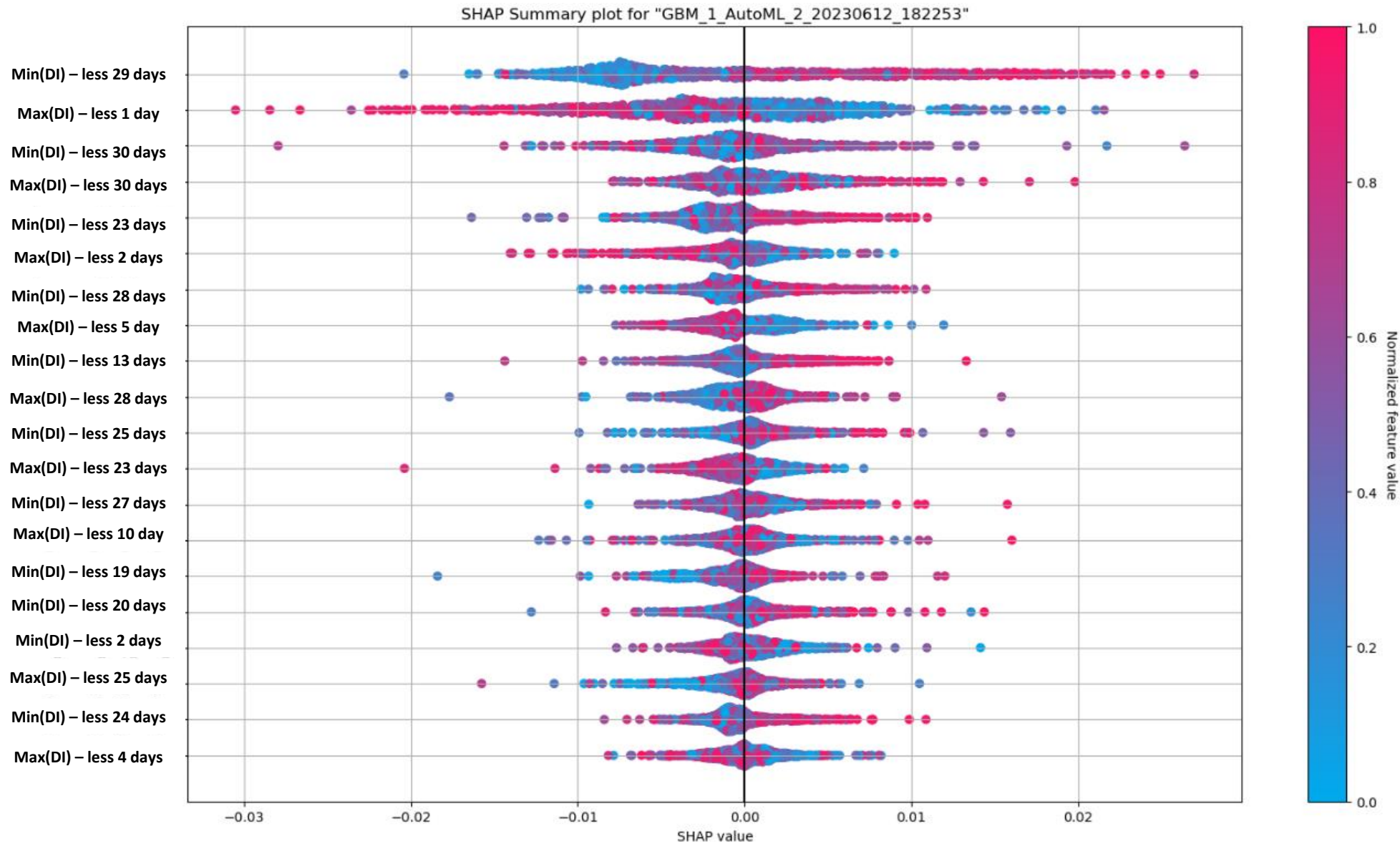
Results

Feature	Algorithm	Proxy	Root Mean Square Error	Mean Absolute Error	R-squared	Range
Milk yield	Random Forest	Production	3.90	2.91	0.06	[-32.93, +32.55]
SCC	XGBoost	Health	0.45	0.34	0.20	[-2.33, +2.70]
Protein	Gradient Boosting Machine	Milk quality	0.20	0.15	0.22	[-1.89, +2.77]
Fat	Gradient Boosting Machine	Milk quality	0.20	0.14	0.20	[-3.79, +3.32]

- Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) are used to predict the model accuracy
- They provides an estimate of the typical magnitude of prediction errors. Lower values indicate better model performance

Results

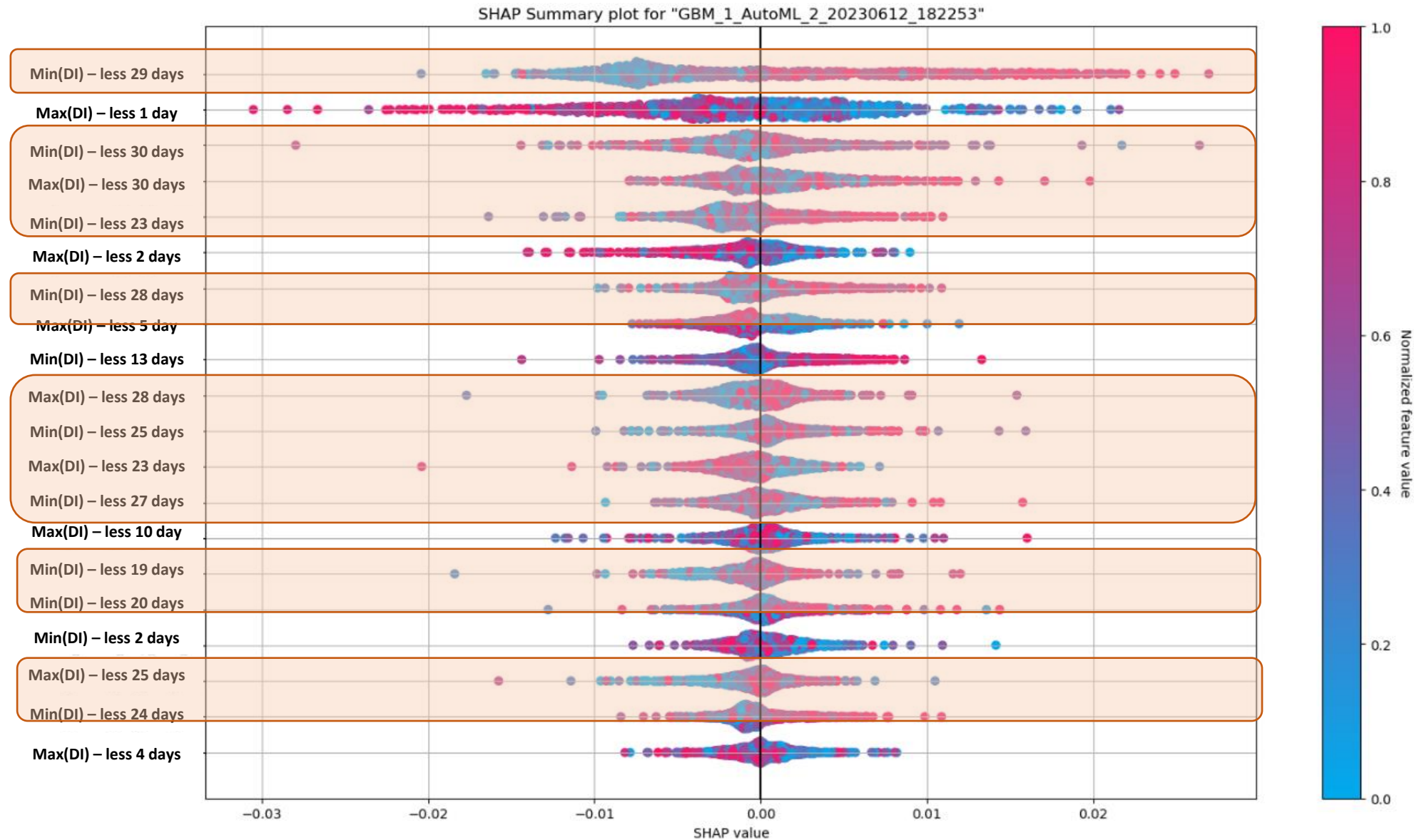
Protein %



- For each of the four phenotypic traits, the most important variables in determining the predictive model were identified using the SHAP (SHapley Additive exPlanations) algorithm

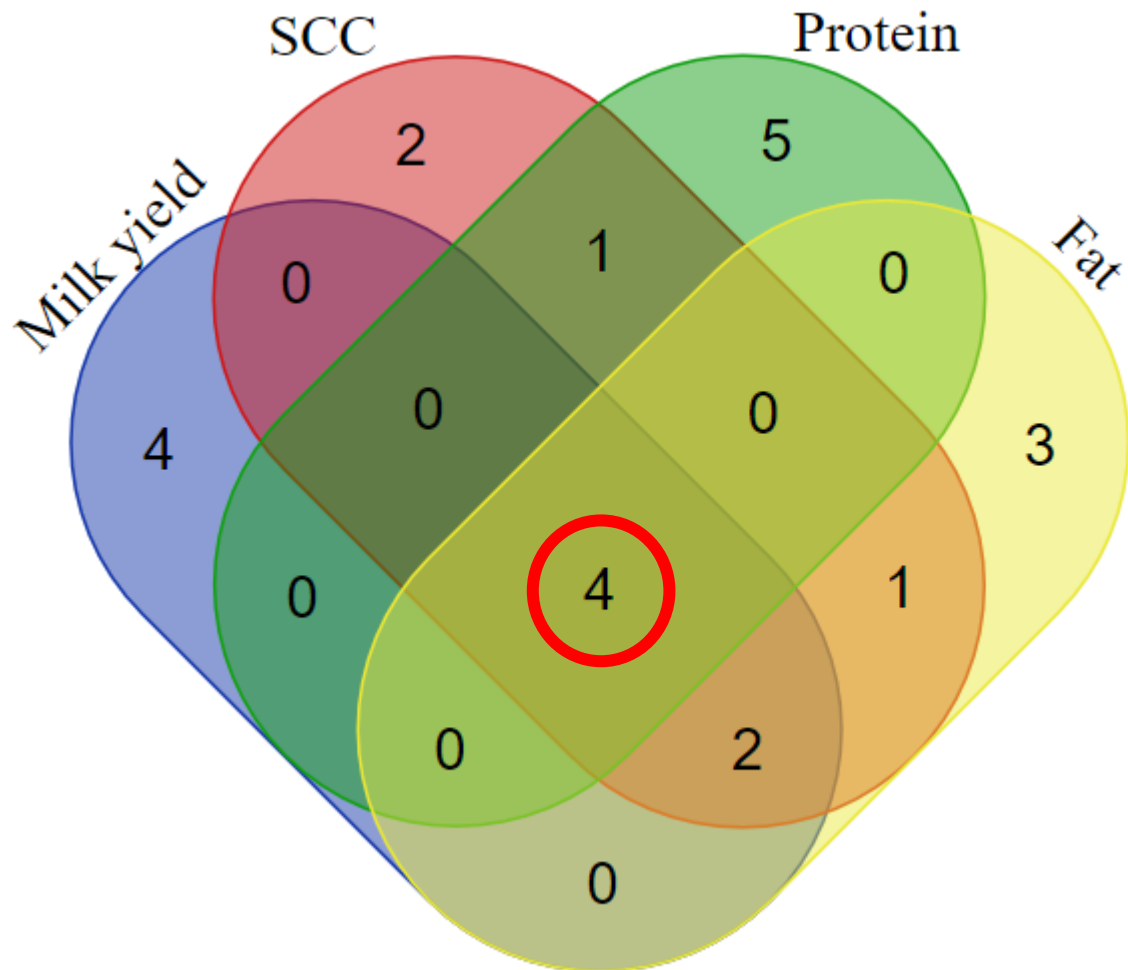
Results

Protein %



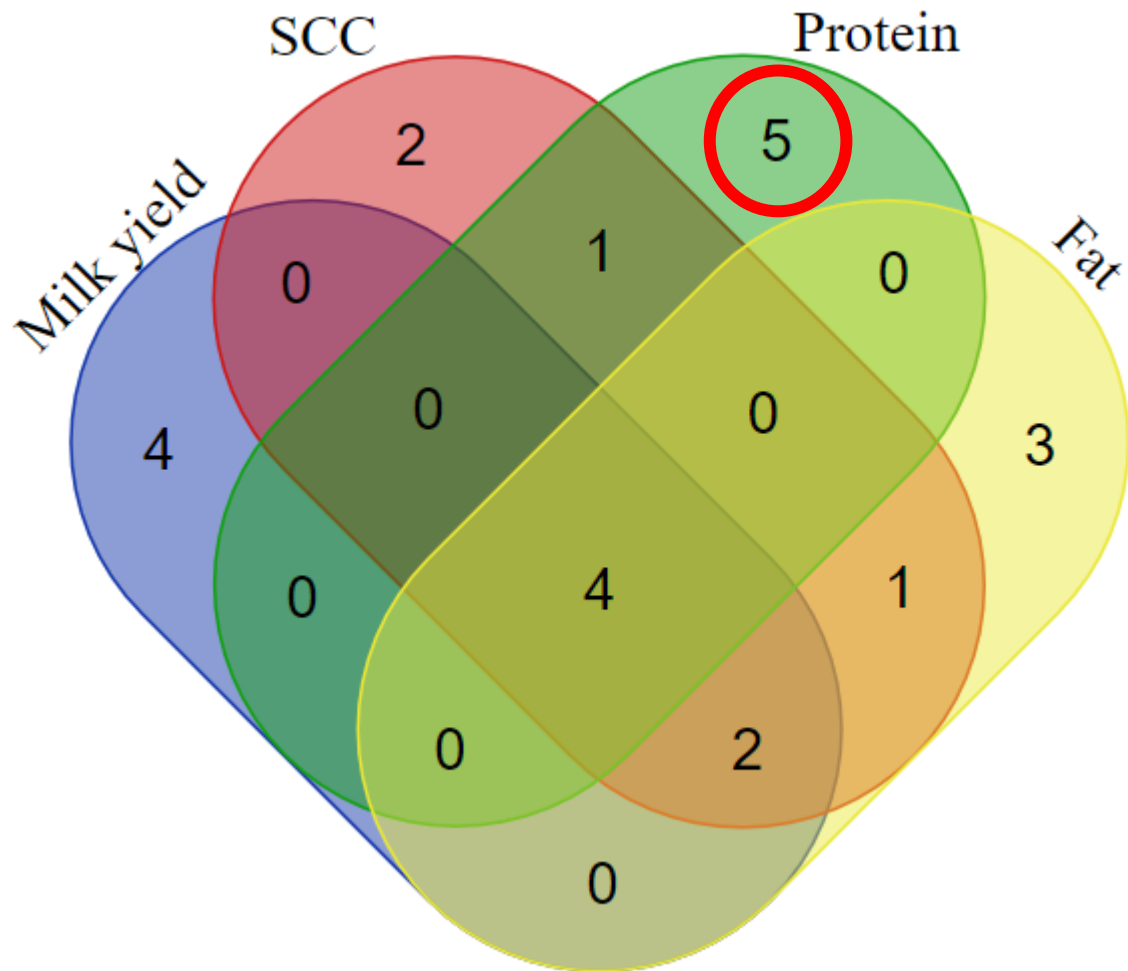
- Among the most important variables in explaining the prediction, data from days well before the functional check are found. **This suggests a potential long-term effect on milk production and quality**

Results



- Several days emerged as important for each feature: **1**, **2**, **25** and **29** days before the Functional Control
- Some dates were specific for each variable, such as, for example, day 10, 16, 18, 25 and 26 for Proteins

Results



- Several days emerged as important for each feature: 1, 2, 25 and 29 days before the Functional Control
- Some dates were specific for each variable, such as, for example, day **10**, **16**, **18**, **25** and **26** for Proteins



Conclusion

- We have developed a machine learning model that allows us to predict milk production data, quality indicators (protein and fat), and somatic cell count based on environmental data
- The model highlights the long-term effects that climatic variables can have on these parameters, while also emphasizing the short-term effects as previously reported (Biswal et al., 2019)
- Furthermore, the model enables the identification not only of the important variables but also of the specific days of interest
- These data can be used to construct more complex models and build risk maps for specific areas or seasons

Take-home message



Extending the model to different dairy cattle breeds to test species-level resilience with varying capacities to adapt to climate change



Optimizing the predictive model on specific areas (e.g. Italian regions) and developing risk maps for the upcoming years



Generating risk maps that can be useful for prediction and provide farmers with the ability to make proactive decisions

Thank you!



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Spoke 5: Sustainable productivity and mitigation of environmental impact in livestock systems

Thank you!



Ente selezionatore

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sui Cambiamenti Climatici



Livestock Environment Opendata



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Livestock Environment OpenData Project
<https://opendata.leo-italy.eu/portale/home>

<https://highlanderproject.eu/>

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