PhD School of Agriculture, Environment and Bioenergy

(http://sites.unimi.it/dottorato_aab/)

(XXXVIII cycle, 2022-25)

Project draft

1.Field of interest

AGR/17 – Animal breeding and genetics

2.Project title: Phenomics and genomics to study biodiversity and adaptation in small ruminant populations

3.Tutor: Prof. Paola Crepaldi

4.Relevance of the topic and state of the art:

Small ruminants, *Ovies aries* and *Capra hircus*, were among the first species domesticated and since that first event of domestication they have accompanied man's migration all around the globe due to their small size and their adaptability to different environments (Clutton-Brock, 1999). As a result, goats and sheep colonized and adapted to a wide range of environments, from the subarctic climate of the Alps and the Siberian steppe to the high temperatures of the Sahara Desert, and from the high altitude of the Tibetan plateaus to the South Pacific islands. They developed adaptative traits such as skin protection strategies against solar radiation or extreme below zero temperatures, adaptation to hypoxia and the maintenance of normal circadian rhythms in situations of extreme light/dark oscillations (Chebii et al., 2021). Moreover, in response to human selection they adapted to different farming systems (pastoralism, nomadism, low and high input farming systems) and breeding purposes (milk, meat and textile productions) (Bertolini et al., 2018, Cortellari et al., 2021). Today the descendants of these animals number approximately two billion, distributed over five continents (Mazinani and Rude, 2020). It has been estimated that there are more than 2,000 different breeds of goats and sheep worldwide (https://www.fao.org/home/en). Italy is a reservoir of biodiversity for these species with more than 80 local breeds, all well-adapted to the climate condition of their native regions. The latest climate projections, according to the widely used Koppen-Geiger classification, indicate that dramatic climate change will characterize most terrestrial regions (Beck et al., 2018). In the next 70 years some areas in Italy, currently classified as 'temperate-warm', will shift to increasingly arid and warm climate classes (Beck et al., 2018). There are also shorter-term climate change predictions for global warming that forecast an average temperature rise of about 1.5 degrees by the end of this decade, longer drought periods and an increase in extreme and short-term rainfall events (Tabari, 2020). Climate change poses increasing challenges for the biodiversity management of native Italian breeds belonging to species historically bred in extensive and low input systems. Consequently, it is vital to investigate in depth the genetic impact of climate change on these species in terms of adaptation and selection, looking at the evolution of their genomic and environmental landscape.

5.Layout of the project (draft)

The project aims at investigating, in different Italian goat and sheep breeds, the evolution of biodiversity and adaptation through the comparison of animals and breeds genotyped in the past and during the PhD project.

These studies of goat and sheep, that take into account their characteristic or specific farming systems which in turn are greatly influenced by the climatic condition, could help disentangle the complex biological mechanisms of their adaptation to environmental and climatic change by identifying pertinent genomic regions, genes and haplotypes. Moreover, it could be possible to explore recent variations in terms of the evolution of genetic and allelic frequencies in different breeds that have adapted to changes in local conditions.

The project will also create maps of risk for goat and sheep breeds raised in Italy, together with genomic tools to characterize individual animals and breeds and will try to develop a system of identification of the different breeds raised in Italy using AI tools to divulgate the Italian reservoir of biodiversity for these species.

5.1. Materials & Methods:

Phenotypical and medium density SNP chip-derived genomic data will be collected during the first part of the project and integrated with Italian (Biovita -Ciani et al 2014; Italian Goat consortium - Cortellari et al, 2021) and international (Adaptmap, http://www.goatadaptmap.org/; Vargoat projects - http://www.goatgenome.org/vargoats.html) public genomic databases.
The population genetic variability will be analysed by calculating parameters related to heterozygosity and inbreeding, including runs of homozygosity-based inbreeding coefficient (F_{ROH}), which also provide information about the time that inbreeding events occurred. The genetic background of small ruminant breeds and populations will also be assessed, in order to shed light on their common history and to better allow the breed identification of individuals.
Selection signatures will be detected by using different methods, such as F_{ST} Wright's fixation index; cross-population extended haplotype homozygosity and ROH analysis (McQuillan et al., 2008).
Genomic data will also be investigated using landscape genomic approaches, together with bioclimatic and geological risk indicators obtained from numerous databases publicly available, such as Worldclims (Fick and Hijmans, 2017) and CMCC-BioclimInd (Noce et al., 2020), and maps of geological risk (earthquakes, landslides and floods).

5.2.Schedule and major steps (3 years):

Months 1-3: literature update and design of the experiments;
Months 2-18: collection of biological samples and phenotypical, genomic, climatic and environmental data;
Months 12 -24 Training for the analysis of genomic data and for the use of AI tools for breed identification (alsowith international experiences) / ongoing collection of data and samples; genotyping.
Months 12- 30: analysis of the data collected
Months 18- 36 writing of scientific papers and PhD thesis, developing of maps for biodiversity characterization.
Dissemination of results will take place during national and international meetings as soon as the first results become available (probably around month 12-18) and will last until the end of the project.

6. Available funds (source and amount)

Project PSRN_SHEEP and GOAT: about 30,000 €

7. Literature:

Clutton-Brock, J. (1999). *A natural history of domesticated mammals*. Cambridge University Press.
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Beck, H. E., Zimmermann, N. E., McVicar, T. R., Vergopolan, N., Berg, A., and Wood, E. F. (2018). Present and future köppen-geiger climate classification maps at 1-km resolution. *Sci. Data* 5, 1–12. doi:10.1038/sdata.2018.214.
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Fick, S. E., and Hijmans, R. J. (2017). WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas. *Int. J. Climatol.* 37, 4302–4315. doi:10.1002/joc.5086.
Noce, S., Caporaso, L., and Santini, M. (2020). A new global dataset of bioclimatic indicators. *Sci. Data* 7, 398. doi:10.1038/s41597-020-00726-5.