Agroforestry system for mitigation and adaptation to climate change: effects on animal welfare and productivity

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ABSTRACT. – Climate change alters the thermal environment of animals, affecting animal health, reproduction, and the feed conversion efficiency. Environmental stress and, more specifically, thermal stress directly affect productivity and health of livestock resulting in significant economic losses. Agroforestry is a land-use strategy to cope with climate change and provide environmental, economic, and social benefits. Agroforestry system may contribute to alleviate the effects of heat stress, by providing thermal comfort to the animals. Specific studies, in fact, demonstrated that the presence of trees and their arrangement in the agroforestry systems provide better microclimate conditions and animal thermal comfort in pastures. However, large part of the information about the effect of agroforestry systems on livestock production is related to tropical and subtropical environment, whereas data from temperate zone are still scarce. In 2017, a multidisciplinary research team has been established to evaluate the transition of a conventional specialized system towards agroforestry in Tuscany. Preliminary data about the effect of agroforestry systems on livestock production are presented and discussed.

INTRODUCTION. – Livestock sector needs to face environmental issues associated to animal products. At the same time, the efficiency of the system should be improved, in order to produce more food without increasing land consumption (Pulina *et al.* 2017; Tilman *et al.* 2011). According to the last estimations, livestock sector produces nearly half of the greenhouse gas emission of the whole agricultural sector

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(Cassandro *et al.* 2013). Moreover, ruminants are responsible of the major part of the methane emission of the agricultural sectors, as a consequence of the physiological production of methane during the process of fibre digestion in the rumen (Buccioni *et al.* 2015).

Increasing concentration of the greenhouse gases is associated with the greenhouse effect, which, in turn, results in global warming and global climate change. There is a general consensus about the effects of climate change on global temperature, precipitation, atmospheric carbon dioxide (CO_2) levels, and water availability. At the same time, there is increasing evidences about the effect of climate change on productivity of crop and livestock systems (Hatfield *et al.* 2008). As regard livestock systems, climate change alters the thermal environment of animals, affecting animal health, reproduction, and the feed conversion efficiency. Environmental stress and, more specifically, thermal stress directly affect productivity and health of livestock resulting in significant economic losses (Bernabucci and Mele, 2014). During the last 10 years, meteorological extreme event, such as heat waves, happened more and more frequently in the summer season also in the Mediterranean area (Bernabucci *et al.* 2014). In the next 50 years an increasing frequency of heat waves is expected, with consequences on the total length of the summer season and on the number of heat days (IPCC, 2007; Segnalini *et al.* 2013). As a consequence of this scenario, in both temperate and tropical areas there is an increasing concern about the effect of heat waves on livestock production and welfare (Nardone *et al.* 2010).

In the figure 1, the main effect of climate changes on livestock production and reproduction traits are reported.

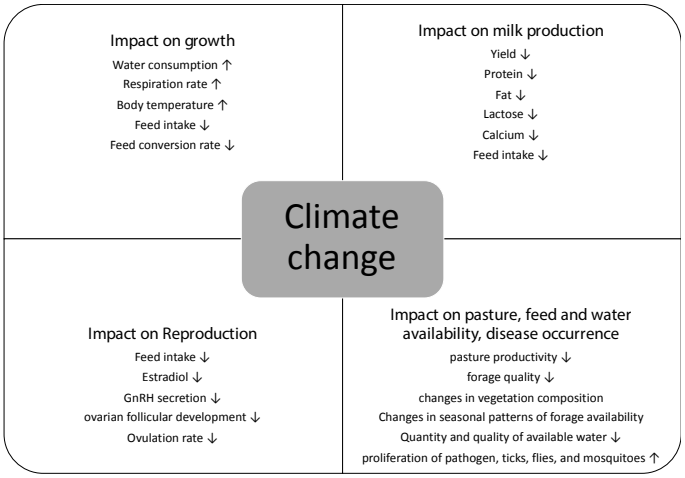

Fig. 1. Impact of climate change on livestock production and reproduction traits.

THE AGROFORESTRY SYSTEMS. – Agroforestry (AF) is a land use practice integrating woody perennials (trees or shrubs) with crops and/or animals on the same land unit (Nair 1993). More specifically, AF is the deliberate integration of woody vegetation (trees and/or shrubs) as an upper storey on land, with pasture (consumed by animals) or an agricultural crop in the lower storey (Mosquera-Losada *et al.* 2018). There is a general consensus of both international researchers and policy makers that AF is a land-use strategy to cope with climate change and provide environmental, economic, and social benefits (Lasco *et al.* 2014).

Recent studies in Italy highlighted the historic importance of traditional and innovative AF systems and their capacity to produce climate-smart food and sustainable high value timber production (Paris *et al.* 2019). During the past century, the tradition of separating between science and practice in agriculture and in forestry has left many opportunities for a functional use of trees in the agroecosystem unexploited (van Noordwijk *et al.* 2018). Latawiec *et al.* (2014) recently reported that integrated crop, livestock and forestry systems, namely AF systems, can increase agricultural productivity and sustainability of animal products. Agroforestry systems, in fact, are able to provide several benefits:

- To mitigate greenhouse gas emission from livestock sector
- To improve the adaptability of livestock to the climate change effects
- To improve the nutritional quality of animal derived food.

As regards the first point, it is well known that specialized livestock production systems are land, energy and water consuming. In tropical areas, AF systems have been proposed as a model of sustainable intensification for beef production, allowing to counteract the greenhouse gas emissions of livestock, by the carbon oxide sink derived from photosynthesis of the trees (De Oliveira *et al.* 2016). Similar results are expected also in temperate areas, although specific data still lacks.

Agroforestry system may contribute to alleviate the effects of heat stress, by providing thermal comfort to the animals. Specific studies, in fact, demonstrated that the presence of trees and their arrangement in the agroforestry systems provide better microclimate conditions and animal thermal comfort in pastures (Karvatte *et al.* 2016). Thus, agroforestry systems may improve the adaptability of livestock to the climate change effects.

Large use of pasture in the diet of ruminants leads to an improvement of nutritional quality of milk and meat (Mele 2009). In the

Mediterranean area, agroforestry systems may enlarge the grazing period by mitigating the effect of heat waves on both pasture and grazing animals. As a consequence, the availability of fresh forage in the diet of ruminants might be higher.

Finally, AF systems coupled with extensive animal rearing may contribute to the recovery of abandoned lands in Europe and to preserve high nature value farmland, by increasing labour and farm income (Lasanta *et al.* 2015). For this reason, in the framework of the Tuscany Rural Development Program, an operational group about AF has been proposed and recently funded by the Tuscany Region.

THE NEWTON OPERATIONAL GROUP (OG). – The NEWTON OG is composed by nine partners: three farms, four research institutions (Centro di Ricerche Agro-ambientali "E. Avanzi", University of Pisa; Istituto di Scienze della Vita, Scuola Superiore S. Anna di Pisa; IBIMET-CNR, CREA – Foresta e Legno) and two no-profit organizations. The NEWTON OG promotes AF with a participatory transfer of the innovative knowledges among all the stakeholders in order to: (i) recover the traditional AF systems and (ii) promote innovative AF systems.

This objective will be reached through the transfer of knowledges and the application and dissemination of the innovations. The specific objectives of NEWTON are: (1) to create a regional network of knowledges for the AF systems, (2) to develop a network of the innovations through case studies in private or public farms, (3) to disseminate knowledges and innovative strategies with a new web-platform for the AF systems in Tuscany (www.newton.eu) and (4) to valorize the AF productions.

A network of farmers and stakeholders will be created in order to disseminate and transfer the innovations through a participatory approach and with interactive systems such as the web-platform and gamification. A specific WP of the project will be dedicated to the constitution of the "Agroforestry school" in which seminars, meetings, courses and study visits will be used for training and information.

The project will favor the network with other European projects on the topic such as: H2020 project AFINET, the European Agroforestry Federation EURAF (www.agroforestry.eu) and European Innovation Partnership EIP-AGRI. At national level the communication among the stakeholders of the OG of different Italian regions will be favored

through the National Rural Network. At regional level NEWTON will organize workshops inviting the members of other OG from Tuscany. The innovative strategies proposed by NEWTON will be applied in four farms in Tuscany in case studies in which environmental and economic parameters will be evaluated at field scale to disseminate information about the effects of the adoption of AF systems.

The web-platform developed in the project will be aimed at: (i) visualizing informative maps on the presence of AF systems and on the suitability of the territory for the establishment of new systems in Tuscany, (ii) favoring the interactive communication among partners and stakeholders, (iii) disseminating the project news.

THE ARNINO LONG TERM EXPERIMENT. – Starting from 2017, a multidisciplinary team is focusing on the design and the establishment of a 40-ha Long Term Experiment (LTE), to evaluate the transition of a conventional specialized system towards AF in Tuscany. The purpose of the LTE is to assess the sustainability and the feasibility of AF compared with conventional arable, grazeland and forestry systems as well as the potential transferability to real farm conditions. The research team has the priority to investigate synergies and trade-offs among the components of the AF system, in order to evaluate whether a diversification, based on annual and perennial herbaceous and woody species consociation, may enhance the resilience of cropping and livestock systems to variability of weather conditions. Secondly, it is mandatory to evaluate the potential of AF systems to climate change mitigation and efficient resource exploitation, considering, in particular, the effects on carbon storage, soil fertility, biodiversity, animal welfare and productivity, quality and availability of forage.

The LTE, established in 2018, is located at the Centre for Agro-Environmental Research "Enrico Avanzi" of the University of Pisa, San Piero a Grado (Pisa) (43.667205 N, 10.313160 E). The field trial was established on soils derived from alluvial sediments, with loam to clay-loam textures, sub-alkaline pH and soil organic matter varying from 1.5 to 2%. Two AF systems, Silvo-Arable (SA) and Agro-Silvo-Pastoral (ASP), are compared with the respective controls, Arable (AR) and Mixed (MX) systems. The AR and SA rotation consists in durum wheat, sorghum and faba bean. In MX and ASP, the 3 annual crops are followed by a 4-year meadow of Italian ryegrass, orchard-grass, tall fescue, sulla and alfalfa. In SA and ASP, oak (*Quercus robur* L.) and poplar

(*Populus* spp.) have been planted alternate on the row every 5 m, along one side of each field, 2 m away from drainage ditches, corresponding to a density of 60 trees ha^{-1}. The space between tree rows and ditches is managed as semi-permanent buffer strips to support functional biodiversity and to limit nutrient leaching. Forestry control fields are two pure stands of poplar and oak and a polycyclic plantation based on oak, poplar, hazelnut and alder (Figure 2). In this preliminary stage, different management options for the establishment of trees in rainfed condition and to contrast the action of wild animals are under evaluation.

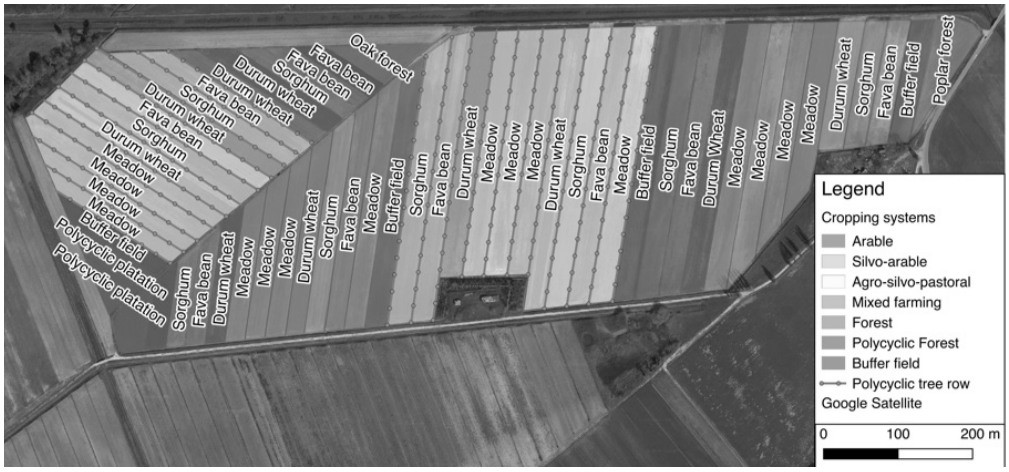

FIG. 2. Location and overview of the agroforestry Long-term Experiment in Pisa.

AGROFORESTRY SYSTEMS AND ANIMAL WELFARE PRELIMINARY AND EXPECTED RESULTS. – In the last three years, preliminary results have been obtained from mature AF systems located in the Tenuta di Paganico (TPA) farm, a partner of the Newton OG. In this farm, thanks to a specific project financed by the Tuscany Rural Development Program, measure 16.2, the first data about the adaptive response of beef cattle to the warm season in Maremma have been recorded.

Two groups of beef steers maintained on pasture with (agroforestry) or without (grazeland) the presence of native trees (mainly oak) were compared. During the hot season, in July, the temperature humidity index (THI) remained below the alert level in the AF area, whereas grazeland area without trees was characterized by higher levels of THI, above the alert threshold (Figure 3).

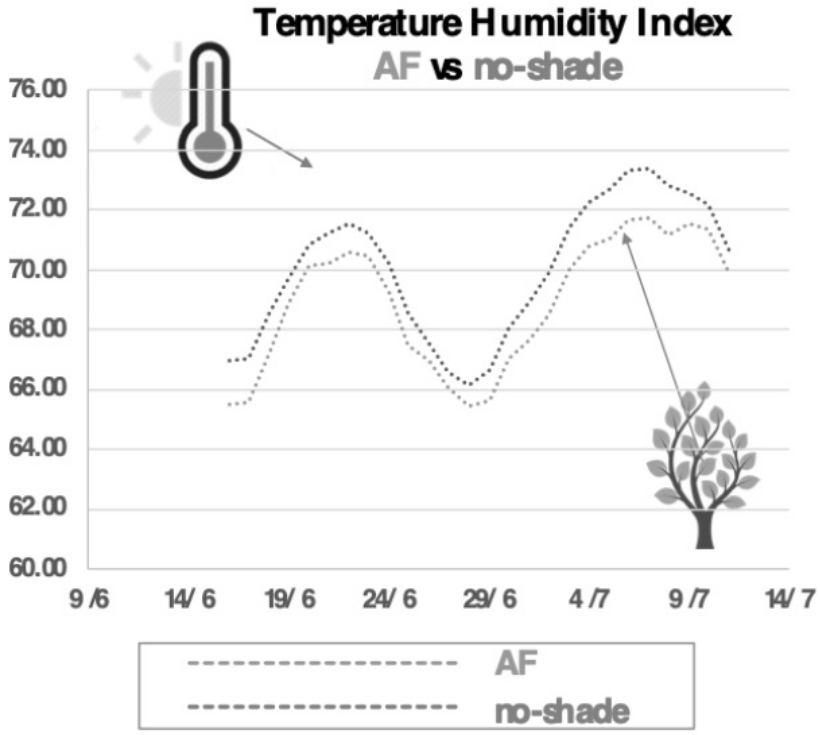

Fig. 3. Variation of THI in AF or no-shade pasture area.

This preliminary result confirmed what previously reported in tropical areas where the AF systems are successfully adopted as a strategy to mitigate the hot weaves (Karvatte *et al.* 2016). For instance, a silvopastoral systems based on native trees in the State of São Paulo, Brazil, presented lower radiant thermal load than the full-sun pasture, achieving differences up to 22% (Pezzopane *et al.* 2019). Specific studies on the effect of shade on animal welfare and productivity have already demonstrated that beef cattle with access to shade had smaller panting scores, which suggests improved welfare, and had better feed efficiency (Sullivan *et al.* 2011).

In the next future, microclimatic and physiologic data will be collected in order to better characterize the environment and the animal adaptive response. In this way, the real contribute of AF systems in the mitigation of the effects of climate change will be better defined. Data will be collected in both mature (TPA farm) and transition (Arnino LTE) AF systems.

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