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The Mediterranean basin is warming faster than the rest of the planet. Average annual temperatures are now 1.4 °C higher than during the period 1880-1899, well above current global warming trends, especially during the summer. Depending on the climate scenario and on the season, a rise in temperatures from 2 to 6 °C by 2100 is expected. High temperature events and heat waves are likely to become more frequent and/or more extreme. A reduction in summer precipitation has already been observed and model simulations indicate that such tendency should persist. For each degree of global warming, mean rainfall will likely decrease by about 4% in most of the region, particularly in the south. Heavy rainfall events are likely to intensify in all seasons except in summer.

Climate change in the Mediterranean basin has both direct and indirect effects on small ruminant systems. At the animal level, the increased temperature and radiation cause heat stress, which triggers behavioural and metabolic changes affecting animal health and welfare. Reproduction performance could be impaired by a reduced semen production and changes in the sexual activity of males, but also by a lower conception rate of females and lighter birth wight of lambs. Heat stress is usually associated with a low feed intake, and thus a reduced performance. Milk production could be reduced by 20-30%, with lower protein and fat concentrations and a reduction of coagulation properties in milk. Meat could develop an abnormal flavour, associated with a greater water holding capacity and a shorter shelf-life. In terms of feed supply, heat and water stress might modify the timing and length of plants' growing season. The productivity of forage and cereals in rainfed conditions is expected to decrease. Warming and the higher CO_2 concentration might decrease the nitrogen content of forage, but also favour nitrogen-fixing species (legumes), which could compensate for it. Thus, understanding and predicting the changing climatic patterns is increasingly important for Mediterranean farming sytems.

The simulation model SIMS-SR was designed, in the framework of the iSAGE project, to predict the performance of different small ruminant systems in a context of climate change. Inputs include : management strategy, animal genetics (breed), soil characteristics and climatic parameters. Outputs are: farm environmental performance (especially in terms of N and C losses), basic economic indicators and other attributes of sustainability. An example of simulation, for a sheep farm in Zaragoza, is presented. Under the current hypothesis of climate change, by 2100 the feed purchased is expected to increase by over 50% for forage (alfalfa) and over 25% for concentrate. As

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1. This summary was elaborated by Magali Jouven on the basis of the presentation delivered by Agustin del Pardo in the 1st Joint Meeting of the FAO-CIHEAM Networks on Sheep and Goats and on Mediterranean Pastures, "Efficiency and resilience of forage resources and small ruminant production to cope with global challenges in Mediterranean areas" (Meknes, Morocco, 23 to 25 October 2019).

a consequence, the economic return is expected to drop sharply, putting into question the economic sustainability or calling for a substantial increase in public subsidies. The question of adaptation of small ruminant systems to climate change deserves further research.

What about the contribution of Mediterranean small ruminant systems to climate change mitigation? Methane (CH_4) emissions are by far the main contribution of the livestock sector to global warming. A second noteworthy emission identified for Mediterranean small ruminant systems with the widely used IPCC (2006) is nitrous oxide (N_2O) at pasture, which discriminates against pasture-based systems. Fortunately, the emission factors at pasture have been recently re-considered, and with the new IPCC (2019) this component has become minor compared for example to CH_4 emissions of stored manure. Further credit would be given to pasture-based systems if, instead of normalising the warming effect of different greenhouse gases (GHG), the metrics would take into account the type and duration of natural recycling. In fact, the CH_4 produced by ruminants comes from the degradation of plant material and takes only 10 years to be converted into CO_2, which is taken up by plants, with an equilibrium between production and consumption at a global scale. Conversely, fossil fuel takes millions of years to be produced, and only a short time to be converted into CO_2, with limited recycling. Taking this into account could change the image of Mediterranean small ruminant systems, making them either marginal contributors (goat systems) or even net sinks of carbon (sheep systems, considering the uptake of CO_2 by natural pastures).

Different mitigation options for livestock and manure management have been provided by a recent report by FAO. They include: flexible grazing, alternative feeds (by-products, crop residues, alternative forages), alternative feeding practices (increasing number of meals, targeted supplementation…), landscape and stall developements (to provide shelter, water, shade…), choice of adapted animal and plant genetics, increased biodiversity in animal and plant components, novel reproduction techniques, manure treatments (anaerobic digestion, separation…). Such options need to be studied in the framework of an integrated approach taking into account the various components of the system, and a wide range of products and ecosystem services.

Sheep and goats production systems in the Mediterranean area are threatened by the severity of climate change. If they are to be part of action plans to become CO_2-neutral, then research and developement projects should: (i) incorporate the latest methodologies in GHG inventories, (ii) analyse pathways of changes with metrics that take into account the real warming effect of CH_4; (iii) consider together, in a synergic perspective, strategies of GHG mitigation and of adaptation to climate change.