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Impact of climate change on the dairy industry in temperate zones: Predictions on the overall negative impact and on the positive role of dairy goats in adaptation to earth warming



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ABSTRACT

The environment within which domesticated livestock production, agricultural crops and related management practices developed over the past 10,000 years is rapidly changing due to human-induced climate change (CC). Nowadays, even countries located within the temperate zone are affected by changes in global warming. These changes are associated with unprecedented events of extreme high ambient temperature (above 40 °C) and seasonal changes. The number of days with temperature humidity index (THI) above a specific comfort threshold (>68) has noticeably increased in recent years in European countries located within the temperate zone. The rate of global warming, including in the temperate zone, is expected to continue to vulnerable in coming years. Agricultural production from crops and livestock, and thus global food security, is already affected by CC and will continue to be influenced by global warming. Thus, these changes will continue to affect the dairy industry directly and indirectly. The most significant indirect effect is expected to result from cruel reduction in worldwide grains (concentrate feedstuffs) production. This change will impose need to tradeoff between the diminished food sources: using higher proportions of grains production for human nutrition, instead of feeding it to livestock. Similar conflict is expected to be relevant in using high-quality forages that can be used as edible food for humans. Heat stress imposed by high ambient temperature in temperate zones, such as in Germany, northern Italy and the US was identified in recent years as a major factor that affect negatively milk production, reproduction, and the health of dairy cows. Heat stress also has shown to increase appreciably cow's mortality in those areas. On the other hand, there is no evidence that dairy goat production in temperate zones is affected so far; though, evidence for such an effect was notice in desert and Mediterranean (e.g., Turkey) countries. The major aim of this critical review is to analyze the literature in order to predict how the current trend in harshening of the impact of climatic changes affect dairy industry and to forecast how CC will affect the dairy cows and goat industry in countries located within the temperate zone? Particularly, the direct effects of heat stress on milk production are emphasized. Among domestic ruminants, goats are the most adapted species to imposed heat stress in terms of production, reproduction and resistance to diseases. The main conclusion that can be made is that uttermost scenarios of climatic change will negatively affect the dairy industry and that the importance of goats to the dairy industry will increase in proportion to the severances of changes in environmental temperature.

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1. Introduction

Weather patterns on a global basis have changed noticeably over the past several decades (IPCC, 2007). These climatic changes are not restricted to tropical, arid or Mediterranean zones. Weather patterns in central and northern European (EEA-JRC73 WHO, 2008) and US (Adams et al., 1990) regions have changed noticeably over the past several decades, and are characterized by more extreme events and seasonal changes such as, warmer summers and wetter and longer rainy season. It is widely predicted that warming will continue for centuries and will be associated in central-northern Europe and North America with more frequent heat waves during summers and heavy rainfall during winters. This trajectory is a foreseeable future, even under the most modest warming scenarios and thus most likely will have a significant impact on livestock farming.

The effect climatic change (CC) on dairy production are both direct through effects on the animals themselves, and indirectly through effects on production of crops and increased exposure to pests and pathogens (Gauly et al., 2013). These negative impacts occur in face of increasing demands for food, which is related to increase in population on earth (Godfray and Garnett, 2014). The demand for animal products relate to rapid increase in income in some countries (Haq and Ishaq, 2011), particularly in China (Qian et al., 2011), and the perception of dairy products as high quality and gourmet food (Silanikove et al., 2010). On the other hand, there is an increased awareness to the contribution of livestock to the greenhouse effect (EPA, 2011; Steinfeld et al., 2006), and hence to global warming. Thus, development of adaptation strategies aimed at taking advantage of new opportunities and/or minimizing the negative impacts of CC are needed in order to maintain food supply security (e.g., Knapp et al., 2014). Some climatologists consider that deliberated reduction of meat and dairy production would be an important adaptive strategy for European countries (Westhoek et al., 2014).

In this review, the potential implications of earth warming on dairy cows and dairy goat production in temperate climatic zones, such as, central-northern Europe are considered. An afford will be made to evaluate the direct and indirect effects of CC on productivity and to predict how CC will affect dairy animal's production system and how dairy goat farming would fit in those changes. Finally, some suggestions for future research priorities, which will allow predicting the effect of CC and to adjusting to CC, are made. The main conclusions that reached is that farthest scenarios of CC will negatively affect the dairy industry and that the importance of goats to the dairy industry will increase in proportion to the severances of changes in environmental temperature.

2. A short overview on the relative sizes of the global dairy cows and goat industries

While most countries produce their own milk products, the structure of the dairy industry varies in different parts of the world. The share of total dietary energy intake coming from dairy products is around 14% in developed and only 4% in developing countries (Gerosa and Skoet,

2012). Developing country growth in demand for milk and consumption of milk has been matched by population size and is quite constant. In developing countries, the production growth has significantly outpaced that of developed countries, particularly in countries with increase of income.

Cow milk dominates global milk production, but milk from other animals is important in specific regions, countries and local contexts, particularly for family type production systems in developing regions. Globally, cow milk represents 85% of world production and at least 80% of total production in all regions except South Asia, where its share is less than half (44%). Geographically, around 34% of the total milk production from cows is located in countries with temperate environment and/or in countries having the ability to invest on technologies for mitigating heat stress: USA, 10%, Europe, 14% and Russia and former USSR countries, 10%. In addition to cow milk, only buffalo milk makes a substantial contribution at the global level accounting for 11% of global production and 23% of developing countries production. The contribution of milk from goats (3.4%), sheep (1.4%) and camels (0.2%) is much lower (Gerosa and Skoet, 2012).

However, the low proportion of the contribution of the dairy goat sector to total milk production is misleading. About 80% of the goats around the world are located in tropical areas of Asia and Africa. As the proportion of cows in those areas is the lowest and as most human population lives in these areas, it is most probable that more people in the world drink milk or consume dairy products from goats than from any other animal (Silanikove et al., 2010). Moreover, productions of milk by goats have risen during the last 20 years. The increase occurred not only in countries with low income (75%), but also in those with high (20%) or intermediate (25%) income (Gerosa and Skoet, 2012). It was recently concluded that goat will continue to have an important role in harsh conditions, tropical, sub-tropical, desert and Mediterranean environments (Kولمان and Silanikove, 2014). In the rest of this review we will try to analyze the reasons for this trend and predict how CC will affect future dairy cows and goat production in temperate zones.

3. The main factors that are expected to affect dairy production under global warming

Climate change impacts on crop (Adams et al., 1990; Hatfield et al., 2011; Lobell et al., 2011) and livestock (Kولمان and Silanikove, 2014) production are already being witnessed all over the world. According to the Fourth Assessment Report of the Intergovernmental Panel on CC (IPCC, 2007), the forecasted CC and extreme events are expected to have a dramatic impact on natural ecosystems and economy in many parts of the world, including in those considered so far as temperate zones (IPCC, 2007). Climatologists forecast that temperatures across Europe will rise over the coming decades and that the frequency of periods of extremely high temperatures will double, whereas the winter will be rainier and will be associated with floods (Solymosi et al., 2010; Tobias et al., 2013).

Box 1: Major effects of changing of climatic conditions on animal agriculture:

1. Feed-grain production, availability, and price.
2. Pastures and forage crop production and quality.
3. Animal production, health, and reproduction.
4. Disease and pest distribution.
5. Water scarcity and quality.
6. By-products using and soil infertility.
7. Biodiversity, loss of genetic and cultural diversity.

The main factors that need to be taken into account in considering the effect of climatic change on livestock production are summarized in Box 1.

We have to expect that the livestock systems based on grazing and the mixed farming systems will be more affected by global warming than the industrialized system. This will be due to the negative effect of lower rainfall and more droughts on crops and pasture growth and of the direct effects high temperature and solar radiation on animals (Nardone et al., 2010). Pasture and forages in temperate zones are expected to be affected by CC, but relatively less in comparison to other climatic zones (e.g., Sautier et al., 2013). The effect would be depend of the actual geographical conditions (e.g., mountainous and forest area) and the balance between increase in growing season length and damage caused by floods in winter draught in summer (e.g., Sautier et al., 2013).

Global grain production, particularly in hot spots (Teixeira et al., 2013), grain production in the US, the larger world exporter of food/feed grains is expected to be substantially negatively affected by CC (e.g., Burke and Emerick, 2012; Thomson et al., 2005a). Local production of grains in temperate European countries, is expected to decline and being vulnerable to erratic CC (Teixeira et al., 2013). For instance, in 2010, when more than 20%

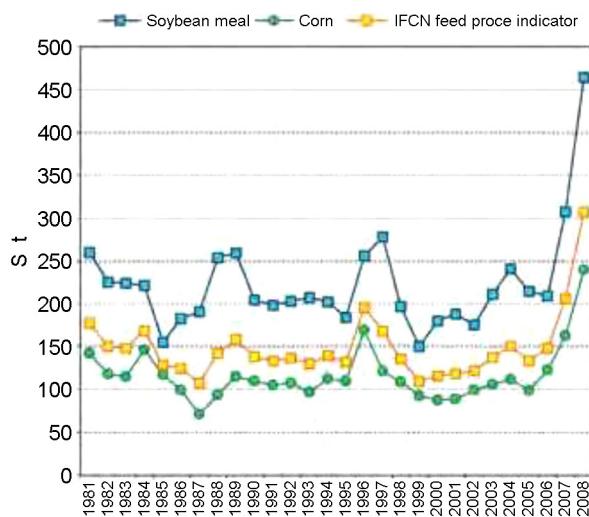
of Russian agricultural producing areas were affected by unprecedented extreme high temperatures, wheat prices increased by up to 50% in the international market (FAO, 2010; NOAA, 2011). The prices of food for dairy animal production and the prices of dairy products has been sharply increased since 2007 (Fig. 1): the price of milk was: very low – 1981–1987: US\$8–13/100 kg; volatile 182 – 1988–2006: US\$12–26/100 kg; new levels since 2007: more than US\$46/100 kg (FAO, 2012). So far, the dairy industry managed to maintains the above-described trend in milk price despite the economic strain imposed by CC. However, what will happen if food prices will start to rise and the direct impact of CC on animal production will intensify? It is possible that under extreme scenarios, a trade off between growing plants suitable for food for humans with grain for animal feeding and forages may be needed and that these changes will be associated with restructuring of the dairy animal sector, particularly with increase in the proportion of dairy goats.

Considering the limited nature of available agriculture area, the efficiency of animal production needs to be improved. This can be achieved by (i) increasing biological efficiency, (ii) technological efficiency and (iii) economic efficiency (Babinszky et al., 2011). Direct effects of CC on livestock production are summarized in Box 2 and the specific interrelationships between animal and its ambient environment are described in Fig. 2.

4. What we know about the effect of increase of heat stress associated with climatic change on the dairy industry?

Dairy cows and goats are raised in different climatic zones, including in areas where they are routinely subjected to heat stress. Consequently, quite a lot is known about the response of cows to heat stress (HS) (Kadzere

World market prices for feed



World market prices for dairy products

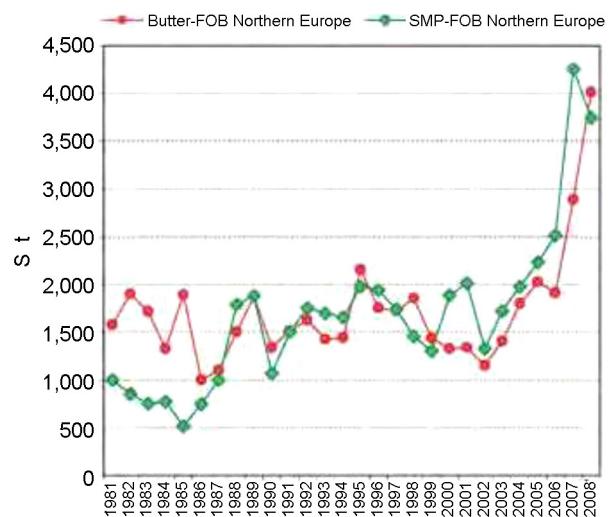


Fig. 1. Worldwide trends of market price of food used by the dairy industry (left panel). Source: FAO (2012).

Box 2: How hotter temperatures may reduce productivity of livestock and dairy animals

- Animals lose appetite, growth is slower and take longer to get to market.
- Production level and quality decreases, including milk and meat from dairy cattle and meat and eggs from poultry.
- Reproduction decreases resulting in smaller herds.
- Frequency, intensity, or distribution of animal diseases and pests rise up.
- Livestock's resistance to infections and diseases slump down.
- Pests, diseases and weeds may expand northward into newly climate-stressed areas.
- Pest will survive warming winters better.
- Control of pest will require increased use of pesticides and herbicides.

et al., 2002; Silanikove, 2000a; West, 2003). In general, it is known that HS negatively affects milk production of cows, and half of this reduction relates to reduced feed intake (Baumgard and Rhoads, 2012, 2013; Silanikove, 2000a,b). The other half of milk yield losses could be explained by metabolic adaptations to HS that are evoked by milk-born negative feed-back system that down regulate milk secretion, milk synthesize, blood flow to the mammary gland and glucose uptake by the mammary gland. Cows under HS had greater levels of insulin with improved insulin sensitivity (Baumgard and Rhoads, 2012, 2013; Silanikove, 2000a,b; Silanikove et al., 2009; Rhoads et al., 2013). This response explains the shift in glucose utilization in non-mammary gland tissue (Rhoads et al., 2013).

However, the reduction in dairy farm profit that is associated with HS when the temperature-humidity index (THI) is extremely high is not only a result of decreased milk yield. Reviews that highlight different aspects of HS on dairy cows production includes the effect of HS on impaired milk quality (Bernabucci et al., 2013), reproduction problems (De Rensis and Scaramuzzi, 2003; Sheldon and Dobson, 2003), increased health problems and health care costs (Silanikove, 2000b; Tao and Dahl, 2013), increase

culling rate (Sheldon and Dobson, 2003) and even animal death (Vitali et al., 2009).

Studies on heat stress effects on dairy animals in temperate zones are few and virtually all of them were done on dairy cows (see below). The most prevalent index to evaluate the effect of heat stress is the temperature-humidity index (THI), which combine the effect of heat and humidity. A major drawback of this index is the lack of considering the effect of radiation (Silanikove, 2000b). Thus, this index is less suitable for grazing animals and in housing conditions where the effect of radiation is not effectively insulated. Recent studies that were carried out in Germany (Bruegemann et al., 2012; Gaully et al., 2013; Lambertz et al., 2014) and Italy (Bernabucci et al., 2014; Bertocchi et al., 2014; Crescio et al., 2010; Renna et al., 2010) have shown that dairy cows were exposed to heat stress conditions under temperate climate during summer months. The imposed heat stress resulted in decreasing milk yield, fat, and protein percentages, and increasing somatic cell score. In both countries, although the fat correct milk yield, fat, and protein yields tended to decrease from $60 \leq \text{THI} < 65$, a $\text{THI} \geq 65$ was found as threshold which marks a significant steep decline in those parameters and increase in somatic cell score. Heat stress also affected the reproductive efficiency in the Apennine mountains of Italy (Boni et al., 2014). Furthermore, studies in Italy have shown that above THI of 70, the number of deaths in dairy farms starts to increase and above THI of 80 the number of death accelerate and at THI of 87 it become maximal (Vitali et al., 2009). Similarly, waves of heat stress during the summer of 2003 and 2006 caused substantial increase of dairy cows mortality in France (Morignat et al., 2014). Collectively, these studies provided evidence for the need for emergency interventions and mitigation measures, which may ensure survival of dairy cows and reduce replacement costs associated with heat stress-related mortality. Thus, there is relatively few, but convincing evidence that heat stress become a significant factor that affect the dairy cow industry in temperate zones.

5. Goat physiology in respect to heat stress and climatic changes

Goat's breeds living in tropical and desert environments are considered as the most efficient ruminants that adjust to such areas (Silanikove, 2000a). An adaptive capacity of a species is defined by its ability to cope with climate change by expressing adaptive strategies (Silanikove, 2000a,b).

The process of adaptation can be grouped into six categories: (1) anatomical, (2) morphological, (3) physiological, (4) feeding behavior, (5) metabolism, and (6) performance (Silanikove, 2000b; Devendra, 1987).

Goats are also more resilience than other ruminants (Silanikove, 2000a). Resilience is defined as 'the ability of a species to survive and recover from a perturbation' (Williams et al., 2008). Both adaptive capacity and resilience are influenced by species ecology, physiology and genetic diversity. Goats has low body mass, and low metabolic requirements, which is an important asset to them for it minimize their maintenance and water requirements, in areas where water sources are widely

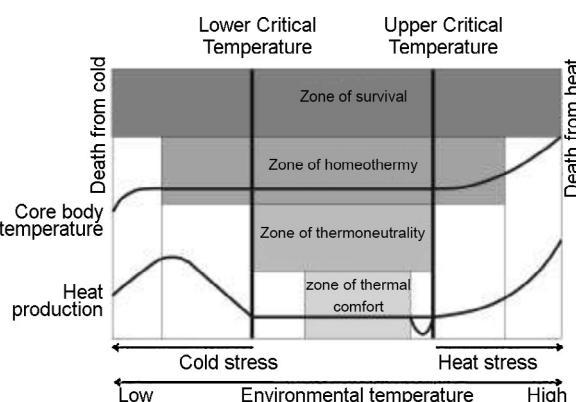


Fig. 2. Schematic representation of the relationships between temperature zones and thermal stress in mammals.
Adapted from Silanikove (2000a,b).

distributed and food sources are limited by their quantity and quality. An ability to reduce metabolism allows goats to survive even after prolonged periods of severe limited food availability. A skillful grazing behavior and efficient digestive system enable goats to attain maximal food intake and maximal food utilization in a given feeding situation. An effective urea recycling to the rumen allows goats to effectively digest low-protein feeds. The specious rumen volume of goats plays an important role in the evolved adaptations by serving as a huge fermentation vat and water reservoir. The water stored in the rumen is utilized during dehydration, and the rumen serves as a container, which accommodates the ingested water upon rehydration. Goats, when possible, eat diets composed of browse (tree-leaves and shrubs), which ensure a reliable and steady supply of food all year around, albeit, a low to medium quality food. One of the most remarkable features of goats is characterized by seasonal changes in the volume and anatomy of the digestive tract, which provide rapid acclimatization to changes in forage quality. The corresponding morphophysiological adaptations are: (i) larger salivary glands, (ii) higher surface area of absorptive mucosa than in grass and roughage eaters, and (iii) a capacity to increase substantially the volume of the foregut when fed high-fibrous food. The above-described grazing strategy in combination with the anatomical and physiological adaptations described above makes goats the most efficient desert-dwelling species among domestic ruminants.

Desert goats are very resilience to the effect of heat stress (Silanikove, 2000a). Goats are superior in reproductive traits in comparison to cows as reflected by their higher fertility and short generation interval (Devendra, 1987). However, as mentioned above, regarding the question raised in this review: how CC will affect goat industry in temperate zones: no direct information is available. To analyze this question, it is considered best to relate to effect of HS in breeds that are relatively adapted to HS under relevant climatic situations. Limited information in this line exists, particularly for goats breeds commonly raised under Mediterranean and subtropical conditions are available.

When lactating Saanen goats exposed to moderate or severe HS for 4 d (THI = 81 or 89), their milk yield lost was 3% or 13%, respectively (Sano et al., 1985). Similarly, relatively low level (6%) of reduction in milk yield was found in Alpine goats in Brazil (Brasil et al., 2000). Under equivalent conditions, the reduction in milk yield in Holstein dairy cows would be much greater (Silanikove, 2000b; West, 2003). Thus, temperate dairy goats appear to be less sensitive than temperate dairy cows to the effect of HS.

Exposure of Alpine and Nubian dairy (a breed adapted to HS) goats to moderate HS conditions for 5 wk (34 °C and 25% humidity; THI = 79) depressed milk yield in the Alpine but not in Nubian goats (Brown et al., 1988). Similar advantages of Anglo-Nubian over Alpine goats were reported by Lallo et al. (2012) in Trinidad. This breed differences suggest that milk yield in breeds adapted to hot environment are less affected by HS (see also, Lucena et al., 2013). Di Rosa et al. (2013) reported that milk production by local breed of goats herding natural pasture in Calabria (Southern Italy, within the Mediterranean zone) was not affected by summer

Table 1

Comparison of weather heat stress risk classes between dairy goats and dairy cows.

Heat stress class	Dairy cows	Dairy goats
Normal: no effect on milk yield	THI < 74	THI < 80
Alert: modest effect on milk yield	74 ≤ THI < 79	80 ≤ THI < 85
Danger: sever effect on milk yield	79 ≤ THI < 84	85 ≤ THI < 90
Extreme: can result in death	THI ≥ 84	THI ≥ 90

temperatures. One of the major strengths of the Spanish goat industry is the generalized presence of indigenous breeds that show an acceptable productivity of high-quality milk (Castel et al., 2010). This generalization is illustrated by the results of Hamzaoui et al. (2013): Murciano-Granadina dairy goats in late lactation that were exposed to different ambient conditions were able to maintain milk yield by losing body mass. However, as in dairy cows, milk protein content and protein yield were depressed. The responses to HS were evidently adaptive as dramatic physiological changes were seen during the first week of treatment and partially recovered thereafter. Payoya goats, another local Spanish breed of goats, produce less milk than Murciano-Granadina goats. However, the reduction in milk yield and reduction in milk content of protein and fat under heat stress is relatively small (Delgado-Pertíñez et al., 2013).

Goats as cows response positively to cooling measures as indicated by improvement of milk yield in treated goats in comparison to non-cooled goats (Darcan et al., 2008, p. 84). Applying cooling measures improved respiration rates (a decrease from 70 to 22 res./min), and rectal temperature (by 0.2–1.7 °C) (Darcan, 2000, p. 58; Darcan and Guney, 2008; Darcan et al., 2004) of high producing exotic breeds under the harsh conditions prevailing at the east-Mediterranean part of Turkey. The improvement in thermoregulatory indices were associated with a rise in milk yield (Darcan et al., 2004) and increase in feed efficiency and profit (Darcan and Guney, 2008).

Based, on the basic interrelationship between an animal and its environment (Fig. 2) and based on the above-mentioned information on cows and goat response to HS, we summarized the HS risk classes according to Livestock Weather Safety Index of Normal (no effect), Alert (modest effect), Danger (severe effect) and Emergency (collapse of the system, animal may die) for goats and cows (Table 1). As can see in Table 1, goats are much more adapted and resilient than cows to the effect of HS, meaning that they will much less affect than cows to climatic changes. Although, less information is available, it can be safely assume that goat will be able to maintain higher reproduction and resist better diseases under HS (Silanikove, 2000a, 2000b, 344; Escareno et al., 2013).

6. Prediction: how climatic changes will affect the dairy cows and goat industry

The Earth's climate is rapidly changing at the hands of human activities. According to the opinion of the vast climatologists, there is little doubt about it. Heat stress already negatively impacts the animal performance in tropical countries and in temperate countries during

summer, which results in very important economic losses in livestock industries (Kولمان and Silanikove, 2014; Renaudeau et al., 2012). It is predicted that the severity of heat-stress issue will become an increasing problem in the future as global warming progresses (Kولمان and Silanikove, 2014; Renaudeau et al., 2012, 354; Segnalini et al., 2013). There is doubt, however, about how and to which extend Earth's inhabitants and livestock industry will respond to CC. The problem of accurate prediction relate to the complexity of the factors affecting agricultural system sustainability in general and the dairy industry in particular.

Sustainability of the dairy industry is affected by three major cluster of effects: environmental, social and economic, each of them composed of many sub-factors such as, labor cost, land use (social effects), geographical (environmental effects) and globalization, price of food and milk (economic effects) (Hellstrand, 2013; Nardone et al., 2010; von Keyserlingk et al., 2013). One way to look on this problem is to examine the farthest scenario and see if it can provide commonsensical predictions. If warming of 10 °C (THI > 84; TW max > 35 °C) were really to occur in next three decades, as predicted by some of the severe forecasting, the effect on human society will be devastating (Sherwood and Huber, 2010). Under those conditions dissipation of metabolic heat becomes impossible without intensive cooling measures (Silanikove, 2000b). Thus, crossing this threshold will not only severely affect the dairy industry (Table 1), but also humans, where overwhelming impacts on society seem assured even with adaptation efforts (Sherwood and Huber, 2010). The damages caused by 10 °C of warming were reckoned at 10–30% of world GDP, equivalent to a recession to economic conditions of three decades earlier in time (Hope, 2006). The ability to maintain the dairy industry in the current level under this scenario is highly dubious because of the enormous increase of cost for mitigating the environmental impact (applying cooling procedures) and increase in cost of feed for farmers and milk to consumers.

Even lower increase in earth temperature at 6 °C is widely agreed to induce disastrous consequences for humankind, but it is very hard to pin down rigorously what the consequences would be (Weitzman, 2009). However, it would be reasonable to believe that the effect of CC on dairy industry will take place before the occurrence of significant effect on human economy as a result from pressure from governmental policy makers to use more effectively national food resources (e.g., Westhoek et al., 2014, 384) and from environmentalist to reduce the impact on livestock on greenhouse effect (e.g., Steinfeld et al., 2006). Thus, we predict that the severity of the effect of CC on dairy production will be reflected by two breaking points: the first that mark a noticeable reduction in dairy production on national or global scale and the second that reflect a point from which dairy production will start to reduce in accelerated rate. Another factor that will play a major role in adaptation to CC changes in coming years is the problem of water availability and quality (Nardone et al., 2010; Thomson et al., 2005b). Dairy farming consumes a lot of water. The phenomenon of water salination is spreading in many areas of the world. In addition, increased water

pollution increases the content of chemical contaminants, either organic or inorganic, such as high concentrations of heavy metals and biological contaminants, which increase risk of poisoning (Nardone et al., 2010). Thus, worsening of water availability and water quality is additional factor, which likely will increase the pressure from policy makers to decrease dairy cow's industry.

The physiological features of goats may be used to increase the proportion of milk production from goats and thus to lessen the overall impact of CC on dairy production. Analyzing of trends of dairy goat production in desert and Mediterranean areas may be interpret as subtle (i.e., without being interpreted as underlying principle) adjustments to CC is already apparent. The number of dairy camels was 2 fold greater in 2009 than in 1961, compared with 2.13 fold for buffaloes (Mainly in 404 India), 2.52 fold for goats, but only 1.43 fold for cattle with the growth in sheep population the lowest (1.08 fold) (FAO, 2012). Camels, buffalos and goats are much better adapted to desert, tropical and sub-tropical environments. The increase in dairy goat production is not restricted to developing countries in harsh environment, but also occur during the last decade in the Mediterranean zone of developed countries, such as France (3.4% increase) and above all Spain, the number of goats has increased by 8.8% (Castel et al., 2010). Goat milk is evaluated because of its exceptional nutritional value and taste; in some countries (most notably in France) goat products (cheeses) are considered as gourmet food and received the highest price in the market (Silanikove et al., 2010). Goat production in the Mediterranean areas of Spain, France and Italy is heavily based on exploiting grazing resources. Historically, agriculture has responded to increases in the demand for food by bringing more farmland into production, but Bouwman et al. (2005) showed that this is less of an option today, given projected trends in population growth and an increase need of land for crop production. Moreover, reclamation of land for agricultural purposes comes at the expense of biodiversity and deforestation or other land-use change, and these changes may exacerbate the contribution of greenhouse gas emissions from agriculture (Godfray et al., 2011). Hence, increase of the usage of unexploited rangelands resources is the most practical options to increase livestock production (Bouwman et al., 2005). From this perspective, it may be envisaged that the economical advantages associated with increase of raising goats in Mediterranean areas reflects their successful adaptation to HS and their ability to exploit effectively unexploited natural resources and by that to cut on price of milk production.

With the advance of severity of CC more and more areas will become dryer and subjected to increase HS during longer summers (EEA-JRC-WHO, 2008). Thus, it is likely that the situation which now favorite the flourishing of goat industry in Mediterranean zone will be extend to areas currently defined as temperate zones, such as central Europe. Of course, under some of the harsh CC scenarios, even goats will not be able to prevent the entire negative impact of CC on dairy goat production: first, because they are also influenced by HS (Table 1) and partially depended on feed price. Goat's typical production nowadays when maintained on Mediterranean rangelands varied between 600 and 2000

litter per year (Castel et al., 2010) for semi-intensive and intensive production systems, whereas typical production of cows range 6000–10000 litter per year (Gaully et al., 2013). Thus a second major limitation is imposed by the lower body size and milk production per unit in goats in comparison to cows and consequential limitations on practical size of herd, particularly from the substantial increase in farm workload (particularly milking).

In some countries, namely, Greece, Albania and some of the central and eastern European countries (Bulgaria, Bosnia and Herzegovina, Croatia and Slovenia) the contribution of goats and sheep to dairy production is sizable, around 40%, and in some of them (e.g., Greece) exceeds that of cows (FAO, 1998; Haenlein, 2001). The main reason relates to the ability of goats to uniquely and effectively exploit vast scrub- and wood-land that characterize those countries (Silanikove, 2000a). Thus, the level of about 40% of total dairy production may represent the upper limit of contribution of dairy goats to total dairy production.

The best situation would be one that will proof that the vast majority climatologists are wrong regarding their catastrophic prediction on the effect of CC, or that the severity of changes will be according to the mild scenario (increase of 0.7 °C), which will allow adaptation to the change (e.g. Gaully et al., 2013). However, if the devastating impact of CC on Human wellbeing and livestock production is unavoidable, the best strategy would be to prepare to those changes and to do the best to lessen the impact. Because, economic adjustments may be slow, more accurate models for prediction of the impact of CC on dairy cows and goat production, which will allow deriving accurate predictions of the optimal replacement value between goat and cows under variable scenarios, will likely be found helpful in making the necessary adaptive transitions more effective and less painful. Thus, continuation of monitoring the effect of CC on dairy cows and goat production and improving our ability to model them will be important part of science in coming years.

Conflict of interest

None declared.

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