Potential summer heat-stress of sheep at Greek husbandry areas of different landscape

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Abstract: During the last years and due to its economic importance sheep farming expands at flat land areas in Greece exhibiting less favourable climatic conditions especially during summer. It is therefore justifiable to assess the potential summer heat-stress of sheep growing at areas of different landscape. Potential heat-stress of sheep during summer was studied at three Greek husbandry areas of different landscape, namely Larissa - flat land, Ioannina - semi-mountainous and Trikala Korinthias - mountainous. Indices used were the night hours during which ambient temperature was below 21 ℃, the Temperature Humidity Index (THI), the time percentage (%) within predefined heat-stress categories and the THI-hrs index. Overall, the area of Larissa exhibited the worst heat-stress conditions. Average ambient summer temperatures were above 21 ℃ during the whole 24 h period, whereas at Ioannina and Trikala Korinthias average temperatures were below 21 ℃ for almost half of the day including night. Daily average THI values were 27.2±0.2 for Larissa, 21.8±0.2 for Ioannina and 21.3±0.2 for Trikala Korinthias. During the hottest and the coolest summer days the average daily THI values at the area of Larissa were higher than those at Ioannina, which were also higher than at Trikala Korinthias. At Larissa the time percentage (%) within the extreme severe heat-stress category (IV) was significantly ($P<0.05$) higher, namely 58.3%, compared to Ioannina (34.3%) and Trikala Korinthias (9.2%). Average (2010-2014) THI-hrs under heat-stress were 11491 for Larissa, 5722 for Ioannina (49.8% of Larissa) and 1868 for Trikala Korinthias (16.3% of Larissa). Expansion of sheep husbandry at flat land areas and design criteria (e.g. breed used, feeding strategy, housing density, floor type, etc.) within sheep facilities should be implemented very cautiously.

Keywords: potential heat-stress of sheep, landscape, average ambient summer temperature, THI, THI-hrs, Greece

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1 Introduction

Thwaites (1985) documented that a combination of high ambient temperature and high relative humidity is detrimental for sheep as it imposes heat-stress. Silanikove (2000) stated that growth, milk production and reproduction of ruminants are impaired by long-term exposure to heat-stress resulting from changes in biological functions. Sevi et al. (2001) concluded that high temperatures induce adverse effects on the thermal and energy balance, the mineral metabolism, the immune function, the udder health, and the milk production of lactating ewes during summer under the Mediterranean climate. Also, Sevi et al. (2002) reported that high temperatures may induce a worsening of nutritional properties associated with the fatty acid profile of ewe milk. Finocchiaro et al. (2005) found that milk production yields of Mediterranean dairy sheep are affected by heat-stress conditions and Caroprese (2008) concluded that during the hot season, shaded areas should be provided to protect lactating ewes from immune depression, reduction of the mammary gland defence mechanisms and thermal stress. Caroprese et al. (2012) concluded that greater proportions of ewes protected under shade were observed ruminating than ewes exposed to solar radiation, displaying reduced ruminating behaviour, whereas Sevi and Caroprese (2012) clearly demonstrated that exposure of sheep to high ambient temperatures has a detrimental impact on their production performance, including nutritional and technological

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properties of milk. Sitzia et al. (2015) stated that for a continuous (i.e. including summer) milking period in the Mediterranean environment the animal heat-stress risk is maximized and concluded that confined systems may face negative effects due to heat-stress, whereas Todaro et al. (2015) concluded, among others, that although sheep are considered to be among the most heat tolerant species, exposure to high ambient temperatures has a detrimental impact on their production performance, immune function and udder health. Finally, Marino et al. (2016) describing the relationships between small ruminant farming and climate change, pointed out that a temperature raise increases the negative effect risks on animal health.

Studies (Panagakis and Deligeorgis, 2008; Panagakis, 2011) have proved that Greek summer conditions are harsh for sheep, which demonstrate (Panagakis and Chronopoulou, 2010) signs of short term heat-stress (i.e. increased respiration rate, altered shade seeking behaviour) in an attempt to cope with the heat loads imposed upon them. Papanastasiou et al. (2015), using daily (summers of 2007 to 2012) maximum hourly Temperature Humidity Index (THI) values concluded that sheep at the Velestino area (Lat: 39^{o} 24′ N, Long: 22^{o} 45′ E, Alt: 120 m) Greece experienced heat-stress in 99% of the examined days, while extremely severe heat-stress conditions were established during the vast majority (82%) of the examined days. The increase in temperature that is expected to occur due to climate change will probably have a direct effect on animals' heat-stress (Kuczynski et al., 2011). Segnalini et al. (2011) used monthly mean values of temperature and relative humidity to study the dynamics of the THI over the Mediterranean basin for the period 1951-2007. Their seasonal analysis pointed out an increase of summer THI values.

Sheep farming in Greece is the largest livestock sector and mostly oriented towards milk (705,000 tonnes) and cheese (125,000 tonnes) production (FAOSTAT, 2013). Eighty five percent of sheep farming in Greece takes place at semi-mountainous and mountainous areas, resulting in low overall efficiency (Greek Ministry of Agriculture and Food, 2011). It is for this reason that during the last years, sheep farming expands at flat land areas with less favourable climatic conditions especially during summer. The economic importance of the sheep sector justifies the assessment of the potential summer heat-stress of sheep growing at areas of different landscape.

2 Materials and methods

2.1 Sheep heat-stress assessment

According to Silanikove (2000), if the ambient night temperature drops below 21℃ for three to six hours, sheep have sufficient opportunity to lose at night all the heat gained from the previous day. He further stated that in the Northern Hemisphere, severe heat-stress is expected during the months of July and August because in many instances the above condition is not met.

Marai et al. (2007) suggested that an appropriate index to estimate the severity of sheep heat-stress is the THI given in Equation (1):

$$\mathrm{THI} = \mathrm{T} - [(0.31 - 0.31 \times \mathrm{RH})(\mathrm{T} - 14.4)]$$

Where T is the dry-bulb temperature,°C, and RH is the relative humidity, RH%/100.

They defined four possible heat-stress categories, namely: no heat-stress (THI<22.2 - I); moderate heat-stress (22.2 ⩽ THI<23.3 – II); severe heat-stress (23.3⩽THI<25.6 – III) and extreme severe heat-stress (THI ⩾ 25.6 – IV). Its validity has been tested (Panagakis and Chronopoulou, 2010) under summer conditions in Greece, when Chios and Karagouniko sheep exhibited normal respiration rates above, which were significantly related to the THI. The same index was used by McManus et al. (2015) to classify whether the environment was moderately stressful for sheep or subjected the animals to extremely severe stress.

Papanastasiou et al. (2014) proposed the use of seasonal THI-hrs index (Equation 2) to study the potential heat-stress (THI⩾22.2) of dairy ewes under summer

conditions in the east coast of central Greece and provide a measure of the intensity and duration of heat load.

$$\text{Seasonal THI} - \text{hrs} = \sum \text{Daily THI} - \text{hrs} \quad (2)$$

2.2 Climatic data

Ten minutes of temperature and relative humidity data (2010-2014) were averaged per hour and used to estimate the heat-stress indices. Data were from automatic meteorological stations located (Figure 1) in three sheep husbandry areas, namely Larissa, Ioannina and Trikala Korinthias (Table 1). Climatic data referred to summer (June 1st to August 31st).

Figure 1 Sheep husbandry areas under assessment

Table 1 Meteorological stations details

Location	Latitude	Longitude	Altitude, m	Landscape
Larissa	39 °63' N	22 °39' E	82	Flat land
Ioannina	39 °59' N	20 °86' E	475	Semi-mountainous
Trikala Korinthias	38°00′ N	22°47′ E	1077	Mountainous

3 Statistical analysis

Basic descriptive statistics were used to estimate THI average, standard error, maximum and minimum values at the sheep husbandry areas and an ANOVA test (StatSoft, 2001) was used for comparing the effect of landscape. Time percentage (%) within each heat-stress category was analyzed using both the angular transformation (Steel and Torrie, 1980) and the logit transform (Warton and Hui, 2011). Duncan's test was used for post-hoc comparison of means.

4 Results and discussion

Figure 2 shows the average (2010-2014) summer 24-h ambient temperatures at the three areas. Their values were 27.9 ℃±0.8 ℃, 23.1 ℃±0.9 ℃, 21.9 ℃±0.4 ℃, at Larissa, Ioannina and Trikala Korinthias, respectively. Larissa significantly differed from the two other areas ($P<0.05$), which did not differ between them ($P<0.05$).

At the area of Larissa sheep had no chance to cool-off during the night as average temperatures were above 21 ℃ during the whole 24-h period. On the contrary, at the area of Ioannina average temperatures were below 21 ℃ for 11 h (from 20:00 h in the afternoon to 07:00 h in the morning), allowing night cooling off and at the area of Trikala Korinthias they were also less than 21 ℃ for half of the day (from 18:00 h in the afternoon to 06:00 h in the morning).

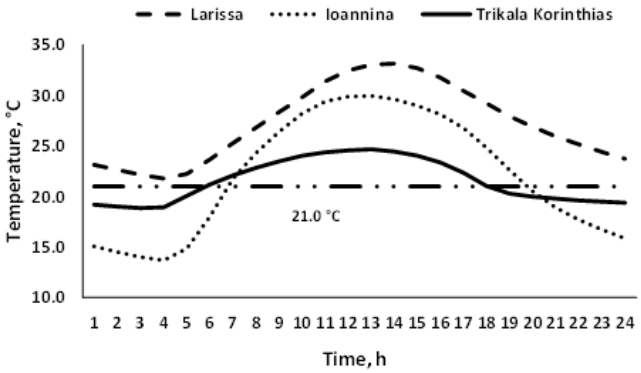


Figure 2 Average (2010-2014) ambient summer temperatures at the three areas

Average summer THI values were 27.2 ±0.2 at Larissa, 21.8 ±0.2 at Ioannina and 21.3 ±0.2 at Trikala Korinthias. Post-hoc comparisons among average values revealed that the Larissa area differed significantly ($P<0.001$) from Ioannina and Trikala Korinthias, which were similar ($P>0.05$). Descriptive statistics are given in Table 2.

Table 2 Average summer THI values at the sheep husbandry areas

	Larissa	Ioannina	Trikala Korinthias
Average	27.2	21.8	21.3
Standard error	0.2	0.2	0.2
Maximum	29.5	24.8	26.1
Minimum	21.2	15.0	13.8

Average daily THI values during the hottest and the coolest summer days are depicted in Figure 3. It is clear that at the Larissa area the average daily THI values were higher than those of Ioannina, which were also higher than Trikala Korinthias. During the hottest summer day the THI values at Larissa were above the severe heat-stress limit (THI≥25.6) for 16 h (from 08:00 h in the morning to 24:00 h at night), whereas at Ioannina and Trikala Korinthias they exceeded this limit for 11 h (from 08:00 h in the morning to 19:00 h in the afternoon) and 12 h (from 06:00 h in the morning to 18:00 h in the afternoon), respectively. Throughout the coolest summer day the THI values at Larissa exceeded the moderate heat-stress limit (THI≥22.2) for 9 h (from 08:00 h in the morning to 17:00 h in the afternoon), but the THI values were below this limit during all day at Ioannina (only reached it at 12:00 h in noontime) and Trikala Korinthias. Average daily maximum THI values are shown in Figure 4. At the area of Larissa they all exceeded the extreme severe heat-stress limit (THI ≥ 25.6) indicating very serious potential heat-stress problems for sheep.

Time percentage (%) within each heat-stress category is tabulated in Table 3. Notably, extreme severe heat-stress (category IV) was potentially imposed upon sheep at all three areas. The area of Larissa was the most stressful (time percentage 58.3%), compared to Ioannina (time percentage 34.3%) and Trikala Korinthias (time percentage 9.2%). Angular transformation and logit transform of the percentages showed that Larissa significantly differed from Ioannina ($P<0.05$), which significantly differed from Trikala Korinthias ($P<0.05$).

Average (2010-2014) summer THI-hrs under heat-stress (THI≥22.2) were 11491 for Larissa, 5722 for Ioannina (49.8% of Larissa) and 1868 for Trikala Korinthias (16.3% of Larissa). The distribution among the three heat-stress categories is shown in Figure 5. It is interesting to note that at the area of Larissa the THI-hrs within the extreme severe heat-stress (category IV) were 1.98 and 11.3 times more than at Ioannina and Trikala Korinthias, indicating that at the flat land area extreme severe heat-stress is a major problem potentially burdening sheep welfare.

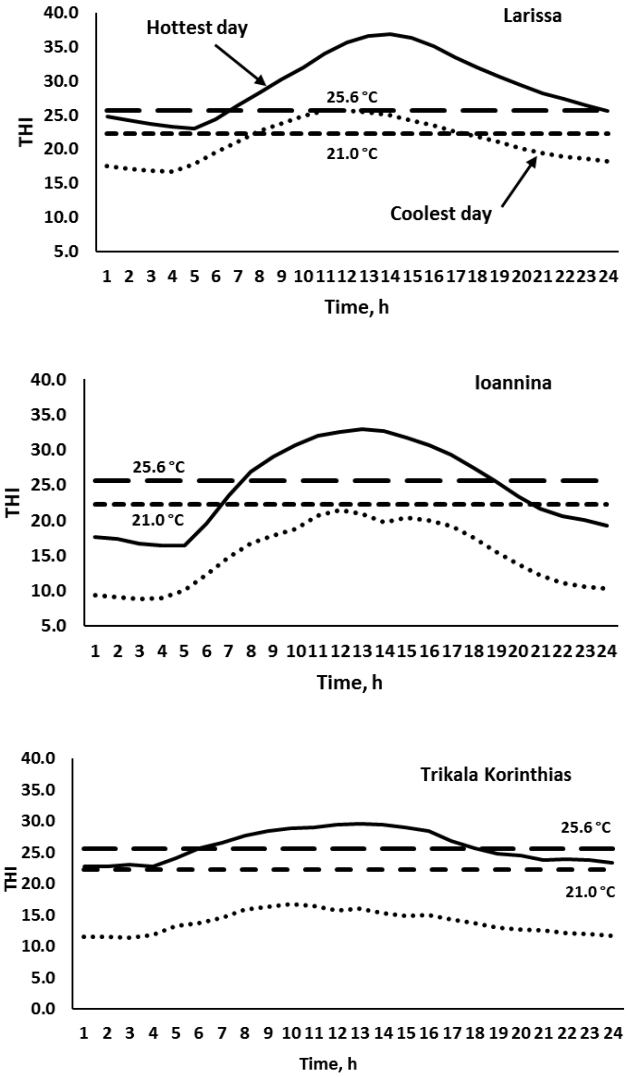
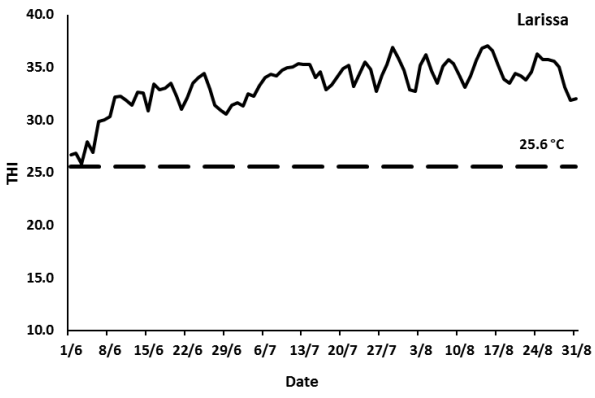


Figure 3 Average (2010-2014) THI values during the hottest and the coolest summer day

(— — —:25.6 ℃; : 21.0°C)



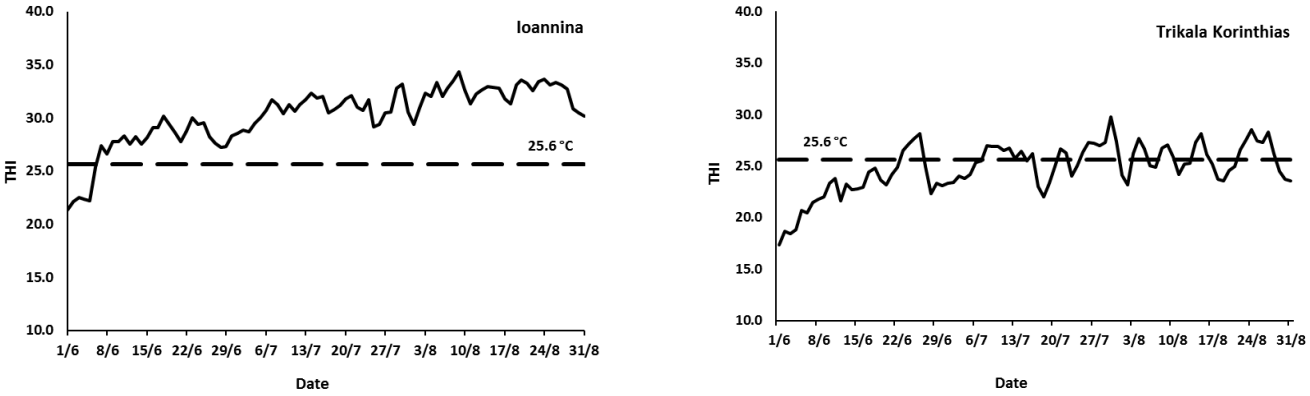


Figure 4 Average (2010-2014) daily maximum THI values during summer
(— — — — : 25.6 ℃)

Table 3 Potential summer heat-stress at the sheep husbandry areas

Larissa				Ioannina				Trikala Korinthias			
Time percentage (%) of THI within heat-stress category				Time percentage (%) of THI within heat-stress category				Time percentage (%) of THI within heat-stress category			
I	II	III	IV	I	II	III	IV	I	II	III	IV
11.6	9.7	20.4	58.3	52.9	3.8	9.0	34.3	63.0	11.9	15.9	9.2

(I) THI < 22.2 - no heat-stress
(II) 22.2 ≤THI < 23.3 - moderate heat-stress
(III) 23.3 ≤THI< 25.6 - severe heat-stress
(IV) THI ≥ 25.6 - extreme severe heat-stress

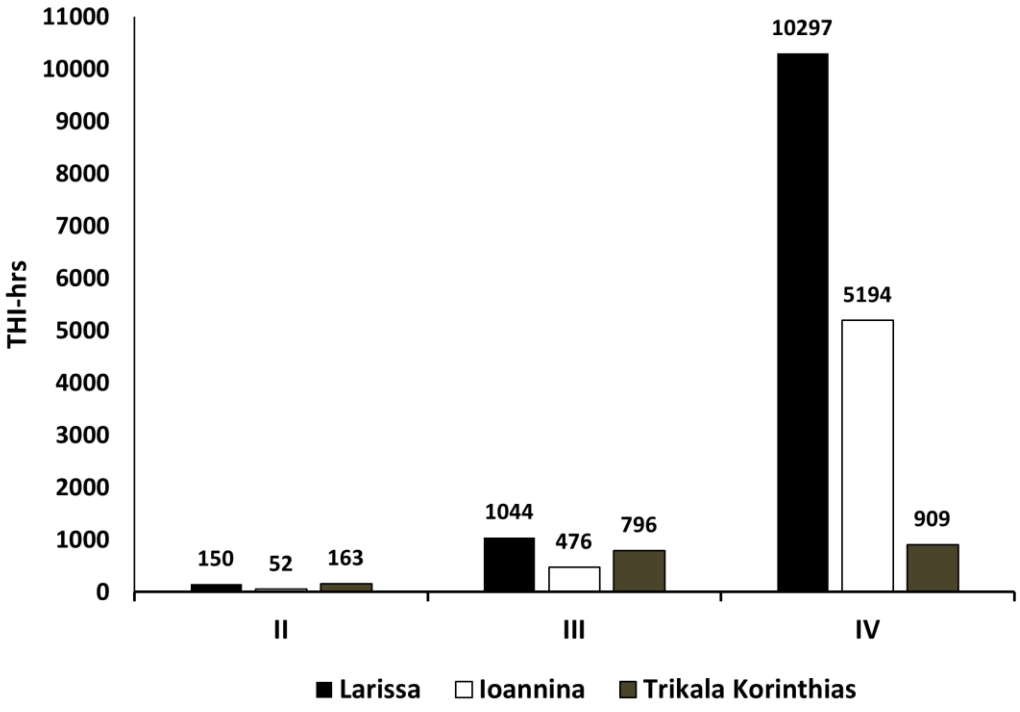


Figure 5 Average (2010-2014) summer THI-hrs under moderate, severe and extreme severe heat-stress

All the above are in agreement with the statement of Papanastasiou et al. (2014) that under Greek summer climatic conditions severe heat-stress is imposed upon sheep and supported further by the conclusion reached by Papanastasiou et al. (2015) for the Velestino area. Both studies strongly indicate that sheep grown at flat land areas potentially experience worse heat-stress conditions than those grown in semi-mountainous or mountainous areas and raise a serious question concerning the decision to expand sheep husbandry in such areas.

5 Conclusions

Potential summer heat-stress of sheep growing at three Greek areas (Larissa - flat land, Ioannina – semi-mountainous and Trikala Korinthias - mountainous) was studied using indices such as the night hours during which ambient temperature was below 21℃, the Temperature Humidity Index (THI), the time percentage (%) within predefined heat-stress categories and the seasonal THI-hrs index.

The flat land area of Larissa exhibited the most strenuous heat-stress conditions potentially hampering the welfare of sheep. Average ambient temperatures were above 21℃ during the whole 24-h period, whereas at Ioannina and Trikala Korinthias they were below 21℃ for almost half of the day including night. Daily average THI values were 27.2±0.2 for Larissa, 21.8±0.2 for Ioannina and 21.3±0.2 for Trikala Korinthias. More specifically during the hottest and the coolest summer days these values were higher at the area of Larissa than those at Ioannina, which were also higher than those at Trikala Korinthias. At Larissa the time percentage (%) within the extreme severe heat-stress category (IV) was significantly higher, namely 58.3%, compared to Ioannina (34.3%) and Trikala Korinthias (9.2%). Average THI-hrs under heat-stress were 11491 for Larissa, 5722 for Ioannina and 1868 for Trikala Korinthias.

Future long-term experiments studying sheep physiological responses vs. local climatic conditions can verify whether the expansion of sheep husbandry to flat land areas is justifiable and what design criteria (e.g. breed used, feeding strategy, housing density, floor type, etc.) should be used within sheep facilities.

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