BIOMETEOROLOGICAL CONDITIONS IN MOUNTAINOUS COMMUNITIES AND ADJACENT URBAN CENTER IN GREECE BY THE USE OF INDICES: THE CASE STUDY OF MOUNTAINOUS NAFPAKTIA DISTRICT

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ABSTRACT This study was carried out to determine the biometeorological conditions in the mountainous communities of Nafpaktia (MNC) in West Greece (Municipulity of Apodotia, Prefecture of Aitoloakarnania), a rural and unexploited region in comparison with the nearby urban center, Lamia, the capital of the Periphery of Central Greece. Air temperature and humidity data were recorded by the meteorological station of Lamia and from sensors with loggers at selected sites of the mountainous Nafpaktia district. Data were used for the calculation of the thermohygrometric (THI) and the humidex (H) indices, based on which biometeorological conditions were evaluated. It was concluded that the THI index provides more detailed information for the asssesment of biometeorological conditions of MNC than the H index. In July this district is characterized by more advantageous biometeorological conditions than the ones in Lamia. MNC can be seen as an ideal tourism and recreation destination for summer vacation.

KEYWORDS: *Mountainous communities, Nafpaktia district, thermohygrometric index, Humidex, tourism*

INTRODUCTION

It is widely recognized that, during the summer period, cities and urban centers in general do not provide satisfying environmental conditions in contrast to agricultural and mountainous areas.

Tourism is a major source of economic and social activity and is influenced both by weather and climate. Bioclimatic conditions are of high interest for decision makers in the recreation tourism policy field (Matzarakis et al., 2004). The attractive rural landscapes with small villages and picturesque communities, the rich flora and fauna, the river springs and the

network of rivers in the mountain districts offer recreation and relaxation to the residents of urban centers who visit in the vacation period.

Nafpaktia is an amenity-rich mountainous region in the central part of mainland Greece with evergreen forests. It is a potentially ideal destination for people from the urban centers. The aim of this research is the assessment of the biometeorological conditions in the mountainous communities of Nafpaktia and the nearby urban center of Lamia in Central Greece. We use two simple indices, the thermohygrometric and the humidex index, which require only temperature and humidity data as input.

MATERIALS AND METHODS

Study areas and measurement sites

This study was carried out in two regions. The first one, Lamia, a medium size city in Central Greece is the capital of the Prefecture of Phtiotis and of the Periphery of Central Greece. According to the 2001 census, the population of Lamia was 58,601. The measurement site s1 (38^0 53′ N, 22^0 23′ E) in Lamia was located at 144 m above sea level. The second study site comprised a large part of the mountainous communities of Nafpaktia district (Municipality of Apodotia, Prefecture of Aitoloakarnania) in the central part of mainland Greece. This region is rural and unexploited and is characterized by few agricultural, industrial or tourism businesses or other activities. Its natural beauty, fir (*Abies* sp.) forests, diverse topography and the river Evinos, indicate good tourism potential. There were eight study sites in the mountainous Nafpaktia communities (MNC) which covered the whole study region (676 - 1455 m altitude). In this study, the two most representative sites of the MNC (with regards to the biometeorological conditions that were determined in preliminary work) are presented. The first site, s2 ($38^0$43′ N, $21^0$57′ E), was located at 676 m altitude, near the river Evinos, in an area with various riverside plant species. The second site, s3 ($38^0$43′N, $22^0$01′E), was located at 986 m altitude in a forest area with chestnut trees (*Castanea* sp.) and firs.

Instrumentation and meteorological data

In order to investigate the biometeorological conditions of MNC, we monitored air temperature and humidity, measured 1.5 m above ground surface, every 15 minutes using sensors with data loggers (Hobo type Pro, H08-032-08, accuracy ±0.2 ^{0}C at 25 ^{0}C and ±3 % RH over the range of 0 to 50 ^{0}C). One logger was used on each site for the period from 1st to 31st of July 2006. The data loggers were enclosed in appropriate shelters, protected from rainfall and direct solar radiation. The shelters allowed for air ventilation. For Lamia, air

temperature and humidity data for the same period were provided by the Hellenic National Meteorological Service.

Biometeorological Indices

Means on an hourly basis were calculated for the air temperature and humidity data for each study site. The means were used for the calculation of two widely used biometeorological indices (Conti et al., 2005, Toy et al., 2007), the thermohygrometric (THI) and the humidex (H) indices, according to the following equations:

$$THI = t - [(0.55 - 0.0055 \cdot f) \cdot (t - 14.5)] \quad (1)$$

$$H = t + 5/9 \cdot (e - 10) \text{ as modified by} \quad (2)$$

where t = air temperature (^{0}C), f = relative humidity (%) and e = vapor pressure (hPa) which was calculated by the following function combining t and f (2).

$$e = 6.112 \cdot 10^{[(7.5t)/(237.7+t)]} \cdot f / 100 \quad (3)$$

Average values for THI and H were used in the evaluation of the human thermal comfort according to Table 1 (adapted from Conti et al., 2005, Toy et al., 2007). The relative frequencies of different classes of the above indices were calculated on an hourly basis for the examined period.

RESULTS

Biometeorological conditions as expressed through the relative frequencies of different classes of THI and H values per hour for the examined period for the two sites of Nafpaktia district (s2, s3) and the urban region of Lamia (s1) are presented in Figure 1. Five THI classes (very hot, hot, comfortable, cool and cold) and four H classes (dangerous, great discomfort, some discomfort and comfortable) were determined. Results are discussed for average values. From the 11th to the 20th hour, 19 % of all THI values lie in the "very hot" class and 2.8 % of H values were classed as "dangerous". The majority of the THI values (77.4 %) was classed as "hot" and 78.6 % of all H values were in the "great discomfort" class at the study site in Lamia (Fig. 1a, b).

Table 1: Relation of human thermal comfort with thermohygrometric (THI) and Humidex (H) indices

| *Human thermal comfort class according to THI*	*THI value (^0C)*	*Human thermal comfort class according to H*	*H value (^0C)*
Hyperglacial	< -40		
Glacial	-39.9 to -20		
Extremely cold	-19.9 to -10		
Very cold	-9.9 to -1.8		
Cold	-1.7 to +12.9		
Cool	+13 to +14.9	Comfortable	H < 27
Comfortable	+15 to +19.9	Some discomfort	$27 \leq H < 30$
Hot	+20 to +26.4	Great discomfort	$30 \leq H < 40$
Very hot	+26.5 to +29.9	Dangerous	$40 \leq H < 55$
Torrid	> +30	Very dangerous	$H \geq 55$ (heat stroke imminent)

In the area of the river Evinos (s2) the THI values were in the "hot" class in 87.6 % (Fig. 1c) while H values were in the "great discomfort" and "some discomfort" classes in 33.7 % and 31.7 %, respectively, from the 11th to the 20th hour (Fig. 1d). In the fir and chestnut forest area (s3) it was found that THI values were classed as "hot" (Fig. 1e) in 49.3 % while H values were classed as "great discomfort" and "some discomfort" in 5.4 % and 16.0 % , respectively (Fig. 1f). The remaining percentages for THI and H values (with the exception of a small percentage of THI values in "Cool" and "Cold" classes in the fir and chestnut forest area) were classed as "comfortable"(Fig. 1c, d, f).

At night and in the morning hours (from 21st to 10th hour) a considerable percentage of THI (49.3%) and H (65.1 %) values lies in the "Comfortable" class in Lamia (Fig. 1a, b). In the region of the river Evinos the majority of THI (58.3 %) and H (97.1 %) values lies in the "comfortable" class during the above period (Fig. 1c, d). It was also noticed that the THI values were classed as "cool" and "cold" in 26.7 % and 7.0 %. In the case of the fir and chestnut forest area (Fig. 1e, f) a greater percentage of THI (77.9 %) and H (almost 100 %) values lied in the "comfortable" class in comparison with river Evinos area. Additionally, it was found that THI values lied in the "cool" and "cold" classes in 14.9 % and 2.0 %, respectively, in the fir and chestnut forest area. It was noted that there was an absence of the "very hot" class for THI values and of the "dangerous" class for the H values in the areas of MNC in the examined period (Fig. 1c, d, e, f).
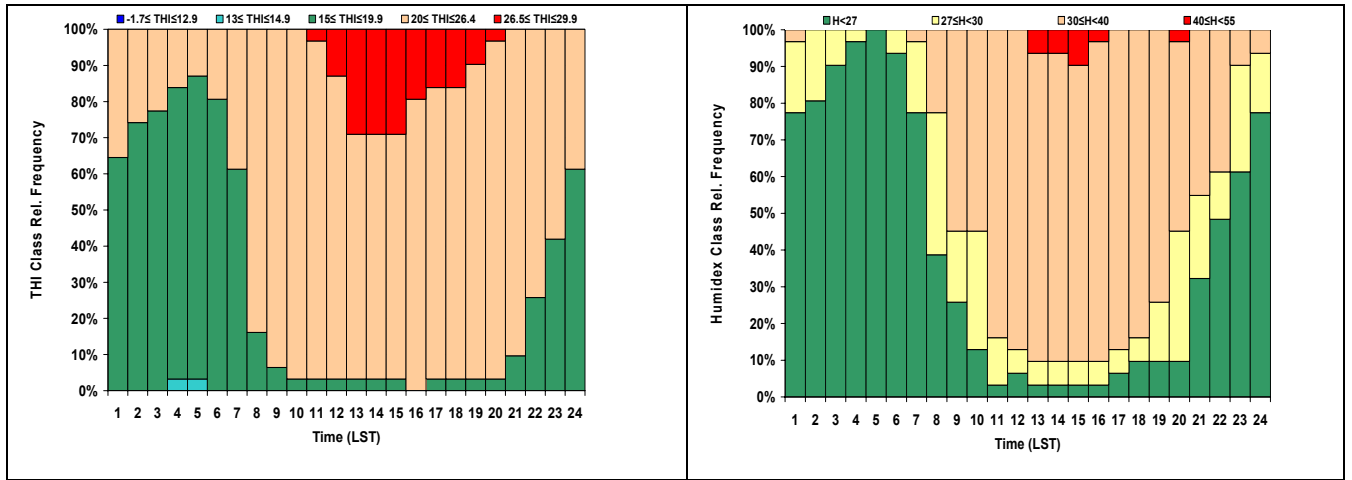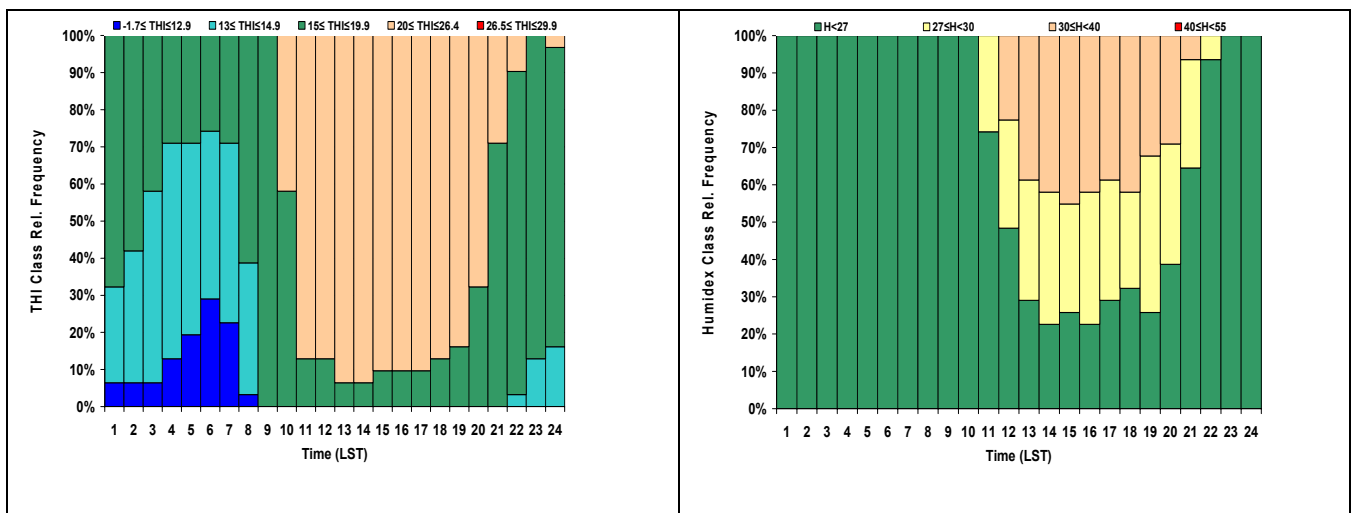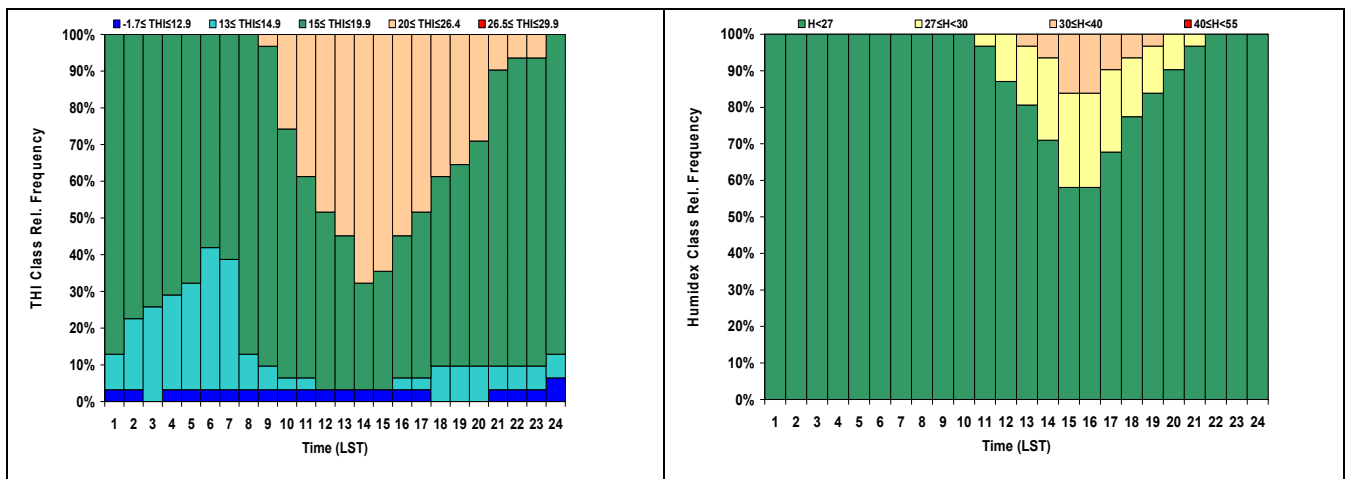
(a) (b) (c) (d) (e) (f)

Figure 1: Relative frequencies of classes of Thermohygrometric (THI) and Humidex (H) indices values on hourly basis in urban center of Lamia (a, b), in the Evinos river area (c, d) and in the fir and chestnut forest area (e, f) in Nafpaktia district during July 2006 (LST: Local time = GMT+2hr)

DISCUSSION

Unfavourable biometeorological conditions in Lamia were clearly detected, attributed to the occurrence of a large percentage of THI and H values in the "very hot" and "great discomfort" classes from 11 h to 20 h. On the contrary, good biometeorological conditions prevailed in the MNC, when compared to Lamia. This may be explained by the more frequent occurrence of the "comfortable" class in MNC compared to Lamia during the study period. The fir and chestnut forest area had a more comfortable climate, which can be seen in the more frequent occurrence of "comfortable" weather, compared to the river Evinos area. Close to the ground solar radiation and temperature (at least on sunny days) are lower in the forest compared to open sites (Morecroft et al., 1998).

The "cold" THI values, especially at the river Evinos area, can be attributed to the movement of cold air, formed by nocturnal radiative cooling under calm clear sky conditions from elevated areas towards the lower altitudes in July (Barry, 2001). The detected "Cool" and "Cold" classes of THI lead us to the conclusion that the previous index provides a more detailed approach to biometeorological conditions in MNC compared to H. Nevertheless, Nafpaktia district can be seen as a reliable tourism and recreation destination for vacation in summer, resulting in the improvement of local development through the construction of eco- and rural- tourism infrastructures.

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