Research Paper Engineering

A User Friendly and Low Cost Method of Recording and Analyzing Climatic Parametersat Taxiarchis Forest for Bioclimatic Building Design

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ABSTRACT

Abstract
Buildings consume almost 40% of final energy demand in Europe and consequently are responsible for large emissions of greenhouse gases. The bioclimatic building design is now included as a compulsory measure to reduce energy consumption and, at the same time, to increase the shares of renewable energy systems for power generation in new and existing buildings.
The bioclimatic building design rely on climatic data collection and their effective processing in such a way to point out the energy needs.The selected research site is situated in Taxiarchis-Vrastama forest which belongs to protectedforest. The building establishment consists of traditional timber lodges and a masonry building which form a small forest village.
This paper presents a methodology of recording and processing the basic climatic parameters (air temperature, relevant humidity, solar radiation, wind speed and direction),indoors and outdoors of selected buildings,using a low cost set of instruments and processing software. The method offers a value for money solution for remote areas like Taxiarchisforest building establishment,providing continuous long period recording measurements.The processed data are presented in a user friendly way providing useful information for decision making, specifically on actions involving improvements of energy performance and thermal comfort of the existing buildings.
The results showed average annual values for wind velocity of1.58m/s,for total solar insolation of985.8 kWh/m2, an annual temperature range of -4.9to 29.9 °C and a range of relevant humidity from25.9to 100%.Thermal comfort of the timber lodgehas been found to bewithin satisfactory limits from end of May to late September even with no heating system. Most importantly, these outcomes could triggerconsiderable improvement measures by applying passive bioclimatic designthat could extent the thermal comfort period.

KEYWORDS climatic parameters, thermal comfort, bioclimatic design, forest environment

INTRODUCTION

According to the European Commission (2015) buildings account for almost 40% of the energy consumption in Europe. The efforts of the international scientific community against climatic change resulted inthe adoption of directives and standards concerning energy consumption of buildings such as the Energy Performance Buildings Directiveof the European Parliament(2010), the US Department of Energy ASHRAE 90.1.2013 [3]and the International Code Council (2012) InternationalEnergyConservationCode for buildings. European Union moving one step forward implementeda compulsory program named Horizon 2020 with specific aims towards sustainability. The tools for application of the above measures without compromising thermal comfort of building's indoor environment are the ASHRAE-55/2013(American National Standards Institute, 2013), the ISO 7730/2005(International Organization for Standardization, 2005) and EN 15251/2007(European Committee for Standardization, 2006) amongst others.

In order to define thermal comfort several mathematical models and indices have been developed over time. The main disadvantage of these models and indices are their complexity in terms of calculations,testing requirementsfor controlled experiment environment,and the required special instruments. Usually the implementation is carried out by academics and specialı zed scientists (Eipstein and Moran, 2006). In addition the whole process is a very costly one,especially for remote areas. This paper present a method of recording measurements of the basic climatic parameters and the processing of the recorded data in order to obtain the required results concerning the energy performance of buildings and their thermal comfort conditions with low cost and in a user friendly way.

MATERIALS AND METHODS

Research Area

The research area is the Taxiarchis-Vrastama public forest situated at North Greece, 65 km from the city of Thessaloniki as shown in figure 1. Itcovers an area of 5800 hectares, and it belongs to Natura network considering wildlife (birds and habitats) [9].The research area is limited to the building establishments that form a small forest village,owned and managed by the Aristotle University of Thessaloniki (2015). The latitude and longitude of the Taxiarchis forest village is respectively 40°25.90 and 23° 30.32 UTM, situated at 860m above sea level and the prevailing climatic conditions are characterized by cold winters and mild summers.

Figure 1. Location of Taxiarchis-Vrastama forest at North Greece. **Figure 2.** The research area and the positions of recording instruments

Source of figures 1 and 2: Google earth.

forest village consists of six timber lodges which are located on the north side of the masonry Forest Service building. The large concrete building at the east side is used for student's accommodation. The timber lodges are used for the accommodation of teaching staff and visitors during the summer field exercises organized by the Faculty of Forestry and natural environmentbut also for accommodation of academic research visitors throughout the year.

Methodology and Instrument recordings

The following Table 1 demonstrates the complexity of determining thermal comfort as it contains different parameters that should be measured for that purpose.

Table 1. Parameters for thermal comfort determinationby Papadopoulos (2006).

Physical Parameters	Biological Parameters	User Parameters
Air temperature (°C)	Gender	Metabolic rate (met)
Temperature of surrounding surfaces (radiant temperature) (°C)	Age	Type of clothing (clo)
Air humidity (%)	habits	
Air speed and turbulence (m/s)		
Space allocation of the above		

The most commonly accepted index is the Predicted Mean Vote - Predicted Percentage of Dissatisfied persons (PMV-PPD) developed by P.O. Fangerand adopted by ASHRAE-55, ISO 7730 and EN 15251 standards which set the requirements for indoor thermal conditions. The ASHRAE-55standard refers to an 80% of the occupant's thermal satisfaction and the outcome of the corresponding equation is limited to a range between -3 to +3, where zero represents thermal comfort.

Earlier research by Hensen(1990) showed that thermal comfort is strongly related to the thermal balance of the body,therefore temperature being the most important parameter on human perception, concerning thermal comfort.Following these findings Toftum, Jorgensen and Fanger (1998a,b) experimented in thepercentage of dissatisfied persons from fluctuations of air temperature and air humidity, setting upper limits of air humidity for thermal comfort. These findings led to the determination of a diagramshown in figure 3, consisting of air temperature against air humidity defining thermal comfort and satisfaction zones. This diagram has been adopted for its practicality on checking the indoor thermal comfort conditions.

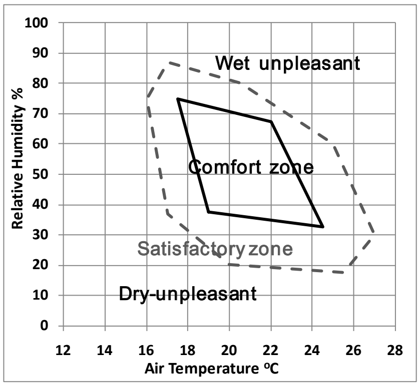


Figure 3. Defined thermal comfort by air temperature and humidity limits**.**

The instruments and software selection has been made based on the following criteria:

- Ability to record continuously specific climatic parameters for prolonged period.
- Accuracy of measurements.
- Cost.
- Convenience, user friendly processing of data.
- Capability of mathematical processing of data and production of diagrams

Table 2. Characteristics of the instruments and software used based on selected criteria

Instrument Label	Type of Measurements	Recording characteristics	Accuracy	Cost (€)
Power Predictor 2.0 	Wind Speed (m/s) Wind direction (deg) Solar energy hours (insolation) (W/m^2)	Every 10min -10 to 50°C and 0 to 100 % RH 50 m/s max air speed >3 months continuous operation Memory stick	+/- 3%	405
Hobo U-12-011 × 2 Indoor Loggers 	Air temperature °C Relevant Humidity (%)	Every 30 min -20 to 70°C 5 to 95 % memory of 43000 measurements	+/- 0.35°C (0 to 50°C) +/- 2.5% to 3.5%	120 × 2 = 240
Hobo U-23-002 Outdoor Logger 	Air temperature °C Relevant Humidity (%)	Every 30 min Memory of 21000 measurements	+/- 0.2 °C (-40 to 70°C) +/- 2% to 3.5%	157
Software label	**Compatibility**	**Processing-analyzing capabilities**		**Cost (€)**
Microsoft Office Excel 2010	Both PC and Macintosh	Mathematical, statistical analysis production of graphs		109
Hoboware 3.7.2 Interface	>>	View recorded data Graph production Launch instrument recordings		Free from official site
Powerpredictor.co m	Internet operation	View recorded data Graph production		Free from official site
Cost:		Total		911

Sources: ONSET Hobo Data Loggers (2015), better generation (2015) andMicrosoft Office (2015).

Positioning of Instruments

The recording period of Powerpredictor 2.0 covers a year, from September 2013 to August 2014. The corresponding period for Instruments 2, 3 and 4 (Hobo loggers) has been the full year 2014.The timber lodges consist of two 2cm thick solid wood panels (sheathing and internal wall cover) with intermediate 5cm thick insulation of expanded polystyrene and 3cm thick insulation at the attic floor.The Instruments have been positioned indoors and outdoors at specific locations as shown on figure 2 as follows:

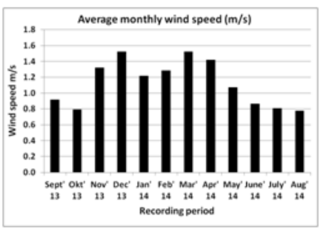
1. The power predictor 2.0labeled Instr.1 mounted on the timber lodge over the roof, 6m above ground. Deciduous Oak trees are surrounding Instrument 1 except from the south side having a mean height of 14m. The abso-

lute height of the surrounding trees are shown in figure 2. According to James H. S. (2004) windbreaks may reduce wind speed by a maximum of 50% but in this case the deciduous trees are not the as windbreak. Additionally the prevailing winddirection is south,therefore the maximum decrease in wind speed is less than 50%.

2. The hobo data logger U-12-011labeled Instr.2 placed inside the timber lodge,at the south- east wall,in order to measure indoor conditions with no heating at all.
3. The Hobo data logger U-23-002 labeled as Instr.3 was placed outside the glazing of the timber lodge's window, facing north, in order to measure the external conditions without the influence of sun.
4. The Hobo data logger U-12-011 labeled as Instr.4 was placed inside the timber lodge occupied by a forest service employee and an operating heating system in order to measurethermal comfort.

Results

The data analysis has been focused on air temperature, relevant humidity, wind speed and direction and solar insolation. The results presented consist of average values. The data have been exported from the software interfaces into Microsoft Excel from which the following figures produced.



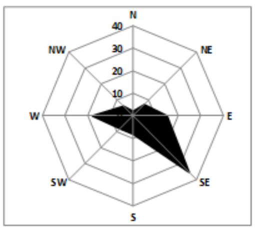


Figure 8. Monthly average wind speed **Figure 9.** Wind direction frequencies (Sep.13 - Aug.14)

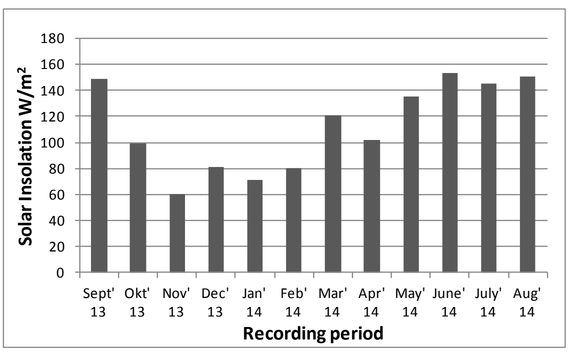


Figure 10. Average global (direct + diffused) insolationday values per month

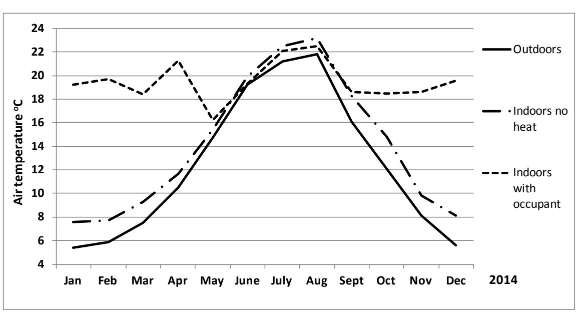


Figure 11. Average monthly air temperature over the recording period

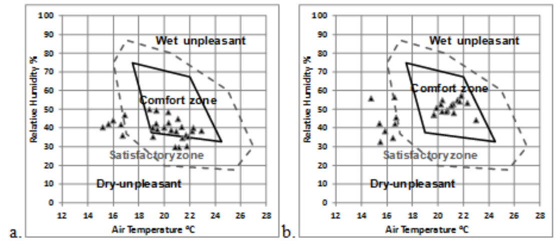


Figure12. Thermal comfort diagrams indoors of a timber lodge with one occupant of a. February 2014 and b. December 2014

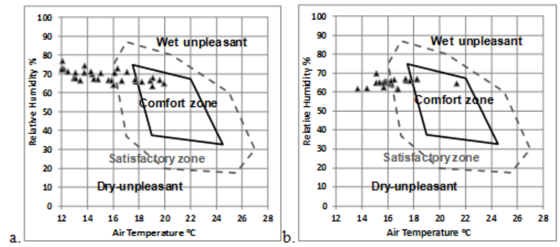


Figure 13. Thermal comfort diagrams of a timber lodge with no heating system a. May 2014 and b: October 2014.

The annual average solar insolation is usually given in kWh/m² rather than W/m². The transformation is given by:

$$\text{Averagesolar insolation day value} \times 0.024 \times 36 \quad (1)$$

The calculated annual average values for wind velocity has been equal to 1.13m/sbut due to the presence of surrounding trees the value is not representing the true wind speed. The corrected value is increased by 40 %, i.e.to 1.58m/s. The annualglobal solar insolation has been985.8 kWh/m², the air temperature range was from -5.0°C to 29.9 °C and of relevant humidity from 25.9 % to 100%.

Discussion-Conclusions

The research area over the recording period hada low annual average wind velocity of 1.69 m/s and an annual average total solar insolation of 985.8 kWh/m².The possible use of renewable energy systems should be limited on the use of solar panels considering the satisfactory levels of solar insolation but only to cover energy needs other than heating.Any investment on wind turbines is not an option due to the low annual wind speed.The annual range of air temperature and relevant humidity values have been from-5.0 to 29.9 °C and from 25.9to 100%respectively. There are considerable energy needs for heating during winder and the relevant humidity is high due to the forest environmentcharacteristics. The summer period is mild, thus no air cooling systems are required. Focusing on thermal comfort conditions it appears that the period that requires operation of heating system ranges from late October to mid of May. Some pair of values outside the thermal comfort diagram (figure 12) limits haωε been due to the absence of the occupant during weekends.Thermal comfort conditions are satisfactoryfromend of May up to late September. Passive bioclimatic design techniques like insulation enhancement may extent the thermal satisfaction periodinside the timber lodge with no heating system by one to two months.The total cost for both instruments and analysis software is limited to 911€.

Except from thermal comfort results it provides analysis information that can be used in decision making concerning an investment on renewable energy systems to produce part of the building's energy needs. In addition the results can be used in conjunction to energy consumption information in order to assist in decision making for investment in building retrofit or renovation techniques to improve the energy performance of buildings.

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