

ECOCLIMATIC CHARACTERISTICS OF BANJA LUKA (BOSNIA AND HERZEGOVINA) FOR THE PERIOD 1961-2009

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Abstract

Today, the conditions of the weather affect lives and health of people increasingly, hence, over the last few decades the ecoclimatic research all over the world has come into focus. However, in our region the lack of research in the field of ecoclimatology is evident. Ecoclimatology studies various relations between organisms and the perennial condition of the atmosphere, as well as the permanent connection and multiple interaction in which dominates the influence of the physical environment as opposed to a human's provoked reaction. This is why the introduction of the complex climatic connections seems practical, in order to determine the ecoclimatic influence and establish existing ecotypes. In accordance with this, the ecoclimatic research of this paper is based on equivalent temperature (air temperature and vapor pressure), physiological humidity and physiological humidity deficit (vapor pressure and maximum vapor pressure) and sultriness (temperature and relative air humidity), which have been explored on Banja Luka (Entity of Republic of Srpska, Bosnia and Herzegovina) city territory from 1961 to 2009. So far, the ecoclimatic research in this region have been scarce, also the necessity of a serious approach and the need for such research as well as the methodological structure has made this effort more complex. The research brings forth an indicator which gives a certain ecoclimatic picture of the region, which is undisputable, and also presents problems which should encourage others to do such research.

Key words: *ecoclimatology, equivalent temperature, Banja Luka*

Introduction

Climate is a set of weather phenomena and processes in the atmosphere, which are characterized by moderate physical state of the atmosphere (Duki , 1998). Moderate physical state of the atmosphere is obtained from data collected by many years of observation of meteorological elements and meteorological phenomena that should be gathered together and statistically processed. In this way is obtained a series of median years of meteorological elements, and also variations, medium, as well as extreme, of certain elements of the obtained average values (Radi evi , 1998). Creation of climate at some place or area happens under the joint influence of solar radiation, atmospheric circulation and surface conditions. Because the climate is a result of long-term climate effects of the aforementioned factors, it has the character of certain stability. Based on the climatic characteristics the regionalization of life on the Earth's surface is created (ukanovi , 1972). Ecoclimatology is the relationship between the climate and environmental effects, in particular the impact of climate on humans, and represents a separate branch of climatology. Ecoclimatology research in recent times has been extremely actualized, thanks to the technological development that performs a negative impact on the climate. Human adaptation to climate conditions of the environment in which he lives, may be faster or slower, and it depends on several circumstances: the natural adaptation of the organism, physical and mental and health status, age, activity, genetic adaptation et al. Therefore, the criteria for defining the most favorable ecoclimatic conditions

and climate comfort are different. The biggest practical application of ecoclimatic research is in health care and tourism (Trbić, 2010).

The research addressed several ecoclimatic elements for geospace of the city of Banja Luka, on the basis of which can be provided quantitative and qualitative rating of ecoclimatic characteristics. Ecoclimatic research was based on the analysis of physiological humidity and physiological deficit of humidity (water vapor pressure and the maximum pressure of water vapor), the equivalent temperature (air temperature and water vapor pressure) and stuffiness (temperature and relative air humidity) for the period 1961-2009.

Materials and methods

The data used in this study were obtained from the Hydrometeorological Service of the Republic of Srpska (RS). Data for air temperature, average annual and monthly temperature, absolute maximum and absolute minimum temperature, humidity, relative humidity, vapor pressure, precipitation, average monthly and annual precipitation and maximum daily precipitation amounts were taken from the hydro-meteorological station of Banja Luka city.

The methods by which we obtained the results are related to the formula. Equivalent temperatures are determined by the formula of Becold which is acceptable for our requirements:

$$Et = T + 2e$$

t - average monthly temperature

E - actual vapor pressure

Analysis of equivalent temperatures is done based on Krüger's classification of physiological feelings of heat and weather types tab. 1.

Tabela 1: Krüger's classification of physiological feelings of heat and weather types

Et (°C)	<5	5-18	18-22	22-30	30-40	40-50	50-58	58-70	>70
Philological feeling of heat	very cold	cold	very chilly	fresh	pleasant	warm	little sultry	sultry	very sultry
Weather types	cold			pleasant		overheated			

According to the statement of Ramzin calculation for physiological humidity (ef) and physiological moisture deficit has been done:

e

$$Ef = \frac{E - E_{36,5}}{E_{36,5}} \times 100\% = Df$$

E_{36,5}

EF physiological humidity

E actual vapor pressure

E_{36,5} - maximum pressure of water vapor at high body temperature the body (mmHg)

DF- physiological moisture deficit

Based on Charles' method, which is based on temperature and relative humidity, it was found whether in Banja Luka, in the average for the period from the year 1961 to 2009, appears stuffiness, and in which months the occurrence of stuffiness is possible.

Results and discussion

Banja Luka is located in the northwestern part of the RS. It is located at 44° 57' north latitude and 17° 11' east longitude, at an altitude of 163 m. Maximum distance from end, north and south points of the territory of the city is 55 km, and the western and eastern points is 40 km (Marjanac, 1994).

The city is located in the valley of the Vrbas River in the tectonic bay in the direction northeast-southwest. More specifically, as the territory of Banja Luka has a rectangular shape in the direction north-south, the eastern part of the city belongs to the catchment area of the river Vrbas, western, smaller part of the city belongs to the basin of the river Gomjenica. Vrbas River at a distance of about 50 km north of Banja Luka flows into the river of Sava (Trbić, 2005).

Banja Luka is located halfway between the equator and the North Pole in the strip of moderately warm climate. The spacious basin is 202 km far from the Adriatic Sea, from the Atlantic 1 650 km, and therefore its climate is exposed to more continental climate impacts of the Northern and Eastern Europe. This is corroborated by the characteristics of the relief, i.e. openness to the plains in the north and east. Climate of Banja Luka is temperate continental with the influences of the Pannonian belt (LEAP, 2009).

Equivalent temperatures

Using the connection between air temperature and actual water vapor pressure we have selected weather types and physiological feelings of heat (equivalent temperature) for geospace of Banja Luka.

Table 2. Ecoclimatic characteristics of Banja Luka, 1961-2009

Ecoclimatic element	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	sr.god.
x	-0.2	1.9	6.4	10.9	15.9	19.4	21.0	20.5	16.1	11.1	6.1	1.2	10.9
U	84	79	73	70	71	72	71	73	79	82	83	85	77
e	3.9	4.4	5.3	6.9	9.6	12.1	12.9	12.8	10.7	8.1	6.1	4.5	8.1
Et	7.6	10.7	17	24.7	35.1	43.6	46.8	46.1	37.5	27.3	18.3	10.2	27.1

Legend: Tx- median air temperature (oC)

U - relative humidity (%)

e - actual voltage e of water vapor (mm Hg)

Er - equivalent air temperature (oC)

Cold weather type ($5^{\circ}\text{C} < \text{Et} < 22^{\circ}\text{C}$) present in the period November-March. Physiological feeling of warmth cold ($\text{Et} = 5\text{-}18^{\circ}\text{C}$) dominates in four months (December, January, February and March). Class very cool ($\text{Et} = 18\text{-}22^{\circ}\text{C}$) is present in November. During the winter period, the average class very cold is not present, but it still occurs in periods of extremely low temperatures.

Pleasant weather type ($22^{\circ}\text{C} < \text{Et} < 50$) characterizes summer and much of the spring and fall, the period from April to November. It is a period of predominantly anticyclonic activity and extremely favorable bioclimatic characteristics. Class of fresh ($\text{Et} = 22\text{-}30^{\circ}\text{C}$) is present in April and October. Class pleasant ($\text{Et} = 30\text{-}40^{\circ}\text{C}$) is present in May and September, while the class warm ($\text{Et} = 40\text{-}50^{\circ}\text{C}$) is present during the summer, i.e. from June to August.

From the standpoint of equivalent temperatures Banja Luka during the summer period, on average does not have overheated weather type, i.e. there is no unbearable heat, so-called sultriness. However, the possibility of occurrence of stuffiness, i.e. sultriness is still present during the summer months, and a more complex evaluation will be given after ecoclimatic analysis according to Charles' method.

Physiological humidity and physiological humidity deficit

Table 3. Average physiological humidity (ef) and physiological humidity deficit (Df) of Banja Luka, 1961-2009

Parameter	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	P.A.
e_f	8,6	9,7	11,6	15,2	21,1	26,6	28,4	28,1	23,5	17,8	13,4	9,9	17,8
D_f	41,6	41,1	40,2	38,6	35,9	33,4	32,6	32,7	34,8	37,4	39,4	41,0	37,4

Based on Table 3. it is evident that the physiological humidity and physiological humidity deficit have an opposite and symmetrical annual disposition. Physiological humidity increases during the transitive period from colder to warmer months in the year, and decreases during the period from warmer to colder months, whereas the annual trend is similar to air temperature. Physiological humidity deficit has an opposite annual mode, and the trend is similar to a relative air humidity. The biggest loss of humidity from a human organism is, on average, in July, while the least humidity is lost in January. Based on the obtained data, it is evident that, on average, the loss of humidity is less in spring 38,2 mm Hg, as opposed to autumn 37,2 mm Hg, while during the vegetation period the loss of humidity is on average 34,7 mmHg.

Stuffiness

Based on Šarl's method, which rests on temperature and relative air humidity, it is determined if in Banja Luka, on the average scale for the period of 1961-2009, appears stuffiness and during which months is possible for stuffiness to appear.

Table 4. Standard values of air temperature (°C) and relative air humidity (%) for determination of stuffiness according to Scharlou

t°C	16.50	18.60	20.06	22.23	24.79	27.88	31.76
U %	100.00	90.00	80.00	70.00	60.00	50.00	40.00

The data for the stuffiness limit, which separates the comfort zone from the stuffiness zone, is gained based upon the standard valued, and the data for temperature and relative air humidity for Banjaluka, is gained through data processing. There is an average level of air humidity in the comfort zone, i.e. it does not intersects or overlaps with the stuffiness limit. However, such an estimate can be given only for the perennial average 1961-2009. If a more detailed analysis was conducted for particular years, months or even days it could be determined that the stuffiness days, nevertheless, appear during the summer months, such as July and August. As an example, the July 2005 can be stated, when the average monthly temperature was 22°C, and the average monthly relative humidity was 74%. Based on these data, it is concluded that

July of 2005 was sultry. Furthermore, according to equivalent temperature, July of 2005 was, on average, „a bit sultry“.

Conclusion

Today, the conditions of the weather affect lives and health of people increasingly, hence, over the last few decades the ecoclimatic research all over the world has come into focus. However, in our region the lack of research in the field of ecoclimatology is evident.

Based on the previous analysis, it has been determined that Banja Luka has, on average, favorable ecoclimatic characteristics. The cold weather type ($5^{\circ}\text{C} < \text{Et} < 22^{\circ}\text{C}$) is present from November to March. Physiological feeling of warmth cold ($\text{Et} = 5-18^{\circ}\text{C}$) dominates over four months (December, January, February and March). The class very chilly ($\text{Et} = 18-22^{\circ}\text{C}$) is present in November. During the winter period, on average, the class of very cold is not present, however, it still appears with periods of extremely low temperature. Pleasant weather type ($22^{\circ}\text{C} < \text{Et} < 50^{\circ}$) is characteristic for summer and most part of spring and autumn, i.e. the period from April to November. That is the period of mostly anticyclonic activity, but also extremely favourable bioclimatic characteristics. The class fresh ($\text{Et} = 22-30^{\circ}\text{C}$) is present in April and October. The class pleasant ($\text{Et} = 30-40^{\circ}\text{C}$) is present in May and September, whereas the class warm ($\text{Et} = 40-50^{\circ}\text{C}$) is present during the summer, i.e. from Jun to August. From the standpoint of equivalent temperatures Banja Luka during the summer period, on average does not have overheated period, i.e. there is no unbearable heat, so called sultriness. However, the possibility of occurrence of stuffiness, i.e. sultriness is still present during the summer months. Physiological humidity and physiological humidity deficit have an opposite and symmetrical annual disposition. Physiological humidity increases during the transitive period from colder to warmer months in the year, and decreases during the period from warmer to colder months, whereas the annual trend is similar to air temperature. Physiological humidity deficit has an opposite annual mode, and the trend is similar to a relative air humidity. The biggest loss of humidity from a human organism is, on average, in July, while the least humidity is lost in January. Based on the obtained data, it is evident that, on average, the loss of humidity is less in spring 38,2 mm Hg, as opposed to autumn 37,2 mm Hg, while during the vegetation period the loss of humidity is on average 34,7 mmHg.

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The ongoing presence of the problem imposes the need for additional research which would complete the picture of ecoclimatic determinants of Republika Srpska's biggest city.

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