THE PREDICTING OF THE AVERAGE TEMPERATURES EVOLUTION FROM ROMANIA AND THE RESULTS VISUALISATION WITH THE AID OF THE GEOGRAPHICAL INFORMATION SYSTEMS

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Abstract: *In this article we have tried to present some significant aspects regarding the evolution of average temperatures in Romania. For the study, the statistical data provided by the National Meteorological Administration were used. Finally, it was presented the way of temperatures evolution, through suggestive maps, made using GIS applications.*

Keywords: *predicting, temperatures, visualisation, maps, GIS*

1. Introduction

The purpose of this article is to study whether from the evolution of the yearly average temperatures recorded in our country can be deduced a certain cyclicity or can establish an upward / downward trend, leading to as realistic as possible prediction for a reasonable period of time.

The estimation of meteorological phenomena began in the ancient times. According with [2], for this thing the periodic astronomical and meteorological events were taken into account, in order to monitor the seasonal changes of the weather.

Around 650 B.C., the Babylonians tried to estimate the short-term weather changes determined by the appearance of the clouds.

According to [1], at the beginning of the 19th century, the greatest progress was made in weather forecasts, such as understanding how the winds rotated clockwise around a low pressure point.

Another innovation of this century is that represented by the weather charts. These allowed the visualization of the air masses movement.

With the advent of the electric telegraph, real-time meteorological data could be collected.

The leap in terms of weather forecasts is represented by the emergence of the satellite technologies. The first meteorological satellite, named "Vanguard 2", was launched on February 17, 1969, by the United States, as stated in [6].

According to [5], the images provided by the satellites are used as input data in weather forecast models. Thus, when the accuracy of the input data it is better, the variables of a model can be determined more precisely.

Also, the GPS systems on the commercial aircraft provide data retalating to the wind speed and the temperatures at the aircraft flight altitudes, helping to make more accurate weather forecasts, as shown in [4].

2. The location of the weather stations used in this study

In this article we used the data obtained from the National Meteorological Administration, from 24 weather stations, regarding to the evolution of the monthly average temperatures.

The data used within the study are significant and we consider that these are quite conclusive, because these cover half a century, from 1961 to 2013.

The location of the weather stations taken into consideration in the study concerning to the evolution of the yearly average temperatures in Romania, it is presented in figure 1.

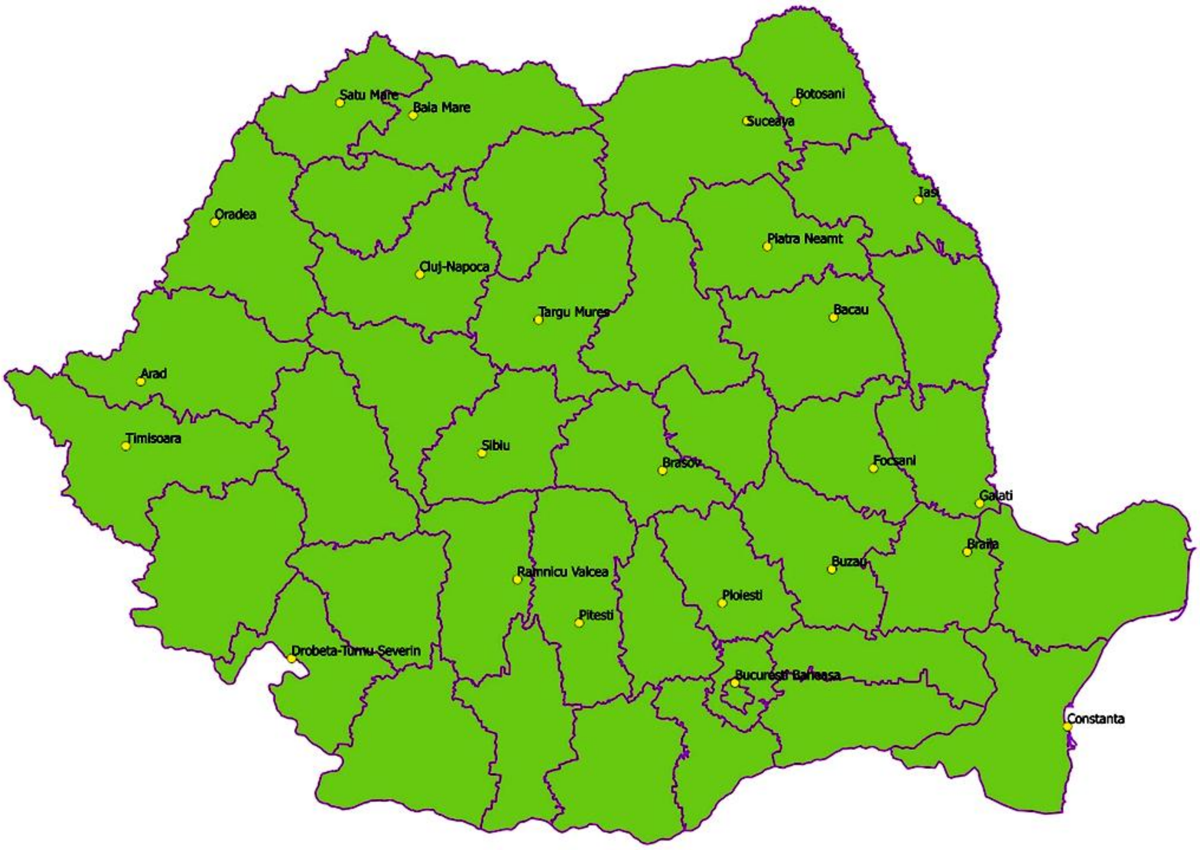

Figure 1. The location of the weather stations used in study

In figure 1, the weather stations represented with yellow there are those for which we obtained data regarding to the evolution of the monthly average temperatures from 1961 to 2013, from the National Meteorological Administration.

3. The analysis of the yearly average temperatures evolution

Starting from the monthly average temperatures, we calculated the yearly average temperatures from 1961 to 2013. The values thus obtained were transposed in the graph with their evolution, presented below.

For the ease of the evolution visualising of the yearly average temperatures, we averaged the values of the temperatures from each year, from all the weather stations used in the study and we represented the results within the graph in figure 2.

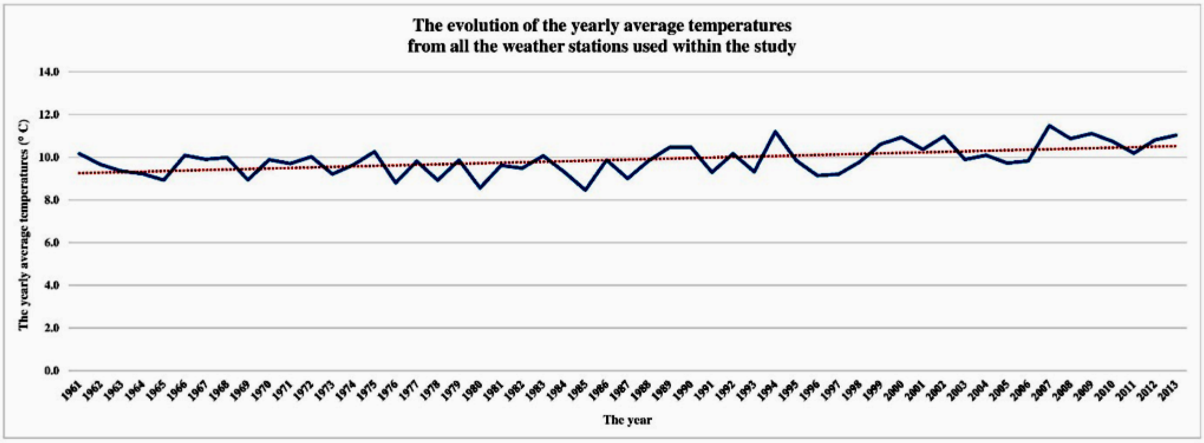

Figure 2. The evolution of the yearly average temperatures from 1961 to 2013

From the graph shown in figure 2 it can be seen the variation of the yearly average temperatures from one year to another, with increases and decreases in their evolution. At the same time, it can be seen the increasing trend of the evolution of the yearly average temperatures, represented by the dotted line, shown with red within the figure.

4. The method used for the predicting of the yearly average temperatures

To estimate the yearly average temperatures, we adapted the method presented in [3], in order to obtain the variation of the trend values. In the following we explained the forecasting method used, based on the data in figure 3.

In the “B” column, we passed the years, starting from 1961, until 2013, years for which we calculated the values of the yearly average temperatures based on the data regarding the evolution of the monthly average temperatures. Then we passed the years, starting from 2014, until 2050, for which we estimated the values of the yearly average temperatures.

We passed in the “C” column the calculated and estimated yearly average temperatures.

To calculate the values presented within the table in figure 3, we used the mathematical relationships presented below.

$$\overline{T_y}^{i}=\frac{\sum \overline{T_m}^{i}}{12} \quad (1)$$

where: $\overline{T_y}^{i}$ represents the yearly average temperature corresponding to the “i” year;

$\overline{T_m}^{i}$ represents the monthly average temperatures in the “i” year.

$$M_{i+1}=\frac{\overline{T_y}^{i}+\overline{T_y}^{i+1}}{2} \quad (2)$$

where M_{i+1} represents the successive averages of the yearly average temperatures, values shown in the “E” column of the table in figure 3.

$$I_v^{i+1}=\frac{M_{i+1}}{\overline{M_{i+1}}} \quad (3)$$

where I_v^{i+1} represents the variability index, expressed as a percentage, calculated within the column "F", as the ratio between the value of the successive average in the "i+1" year and the arithmetic mean of the values of all the successive averages in the "E" column.

$$V_u^{i+1}=\frac{\overline{T_y^{i+1}}}{I_v^{i+1}} \quad (4)$$

where V_u^{i+1} represents the underlying value, calculated as the ratio betweeen the yearly average temperature in the "i+1" year and the value of the variability index from the same year.

For the first year, the underlying value has been calculated using the following mathematical relationship:

$$V_u^{1961}=\frac{\overline{T_y^{1961}}}{I_v^{2012}} \quad (5)$$

For the next years, the underlying values have been determinated by applying the (4) relation.

$$V_e=\overline{V_u^i}-\frac{\sum(i-\bar{i})\cdot\left(V_u^i-\overline{V_u^i}\right)}{\sum(i-\bar{i})^2}\cdot\bar{i}+\frac{\sum(i-\bar{i})\cdot\left(V_u^i-\overline{V_u^i}\right)}{\sum(i-\bar{i})^2}\cdot i \quad (6)$$

where: V_e represents the estimated values of the the underlying values, calculated in the "H" column of the table;

i represents the number of the year, from 1961 to 2013, inclusive;

$\bar{i}$ represents the average value of the number of the year;

V_u^i represents the underlying value in „i" year;

$\overline{V_u^i}$ represents the average of the underlying values, previously calculated.

$$\overline{T}_e=V_e\cdot I_v^{i+1} \quad (7)$$

where: $\overline{T}_e$ represents the estimated values of the yearly average temperatures, calculated in the "I" column and passed in the "C" column of the table, from 2014 to 2050;

I_v^{i+1} represents the values of the variability index. In this case, "i" takes values from 1973 to 2009, depending on the year for which the yearly average temperature is estimated.

To exemplify the calculation method used, we took into account the yearly average temperatures recorded at the weather station from Arad.

	A	B	C	D	E	F	G	H	I
1	The average	The year	The yearly average temperature, expressed in °C ($\overline{T}_y^i$)		The successive averages from the years 1961 ÷ 2013 (M_{i+1})	The variability index calculation (I_v^{i+1})	The underlying values calculation (V_u^i)	The predicting of the underlying values (V_e)	The application of the variability to the estimted values (T_e)
2	THE ESTIMATED YEARLY AVERAGE TEMPERATURES	1961	11.0				10.4		
3		1962	10.2		10.6	101.0%	10.1		
4		1963	10.0		10.1	96.4%	10.4		
5		1964	9.5		9.8	93.3%	10.2		
6		1965	9.6		9.6	91.3%	10.5		
7		1966	10.5		10.1	96.0%	11.0		
8		1967	10.6		10.6	100.8%	10.5		
9		1968	10.7		10.7	101.7%	10.6		
10		1969	10.0		10.4	99.0%	10.1		
11		1970	10.3		10.2	96.9%	10.6		
12		1971	10.2		10.3	97.8%	10.5		
13		1972	11.0		10.6	101.1%	10.9		
14		1973	10.0		10.5	99.9%	10.0		
15		1974	10.7		10.3	98.4%	10.8		
16		1975	10.6		10.6	101.2%	10.4		
17		1976	9.5		10.0	95.5%	9.9		
18		1977	10.3		9.9	94.4%	11.0		
19		1978	9.5		9.9	94.7%	10.1		
20		1979	10.6		10.0	95.7%	11.0		
21		1980	9.4		10.0	95.2%	9.9		
22		1981	10.2		9.8	93.7%	10.9		
23		1982	10.3		10.2	97.6%	10.5		
24		1983	10.6		10.4	99.5%	10.7		
25		1984	10.1		10.4	99.0%	10.2		
26		1985	9.3		9.7	92.7%	10.0		
27		1986	10.3		9.8	93.4%	11.0		
28		1987	9.9		10.1	96.2%	10.3		
29		1988	10.5		10.2	97.1%	10.8		
30		1989	10.6		10.5	100.5%	10.5		
31		1990	10.7		10.6	101.3%	10.5		
32		1991	9.7		10.2	96.8%	10.0		
33		1992	11.0		10.3	98.4%	11.2		
34		1993	10.3		10.6	101.5%	10.2		
35		1994	11.7		11.0	104.9%	11.1		
36		1995	10.4		11.1	105.5%	9.9		
37		1996	9.8		10.1	96.4%	10.2		
38		1997	9.8		9.8	93.6%	10.5		
39		1998	10.2		10.0	95.5%	10.7		
40		1999	10.8		10.5	100.1%	10.8		
41		2000	11.8		11.3	107.6%	10.9		
42		2001	10.8		11.3	107.6%	10.0		
43		2002	12.0		11.4	108.4%	11.0		
44		2003	10.6		11.3	107.3%	9.8		
45		2004	10.5		10.5	100.4%	10.5		
46		2005	9.9		10.2	97.2%	10.2		
47		2006	10.5		10.2	97.0%	10.8		
48		2007	11.9		11.2	106.4%	11.1		
49		2008	11.6		11.7	111.9%	10.4		
50		2009	11.8		11.7	111.6%	10.6		
51		2010	11.2		11.5	109.6%	10.2		
52		2011	10.9		11.0	105.2%	10.3		
53		2012	11.3		11.1	105.8%	10.7		
54		2013	11.7		11.5	109.9%	10.7		
55		2014	10.4					10.5	10.4
56		2015	10.7					10.6	10.7
57		2016	10.1					10.6	10.1
58		2017	10.0					10.6	10.0
59		2018	10.0					10.6	10.0
60		2019	10.1					10.6	10.1
61		2020	10.1					10.6	10.1
62		2021	9.9					10.6	9.9
63		2022	10.3					10.6	10.3
64		2023	10.5					10.6	10.5
65		2024	10.5					10.6	10.5
66		2025	9.8					10.6	9.8
67		2026	9.9					10.6	9.9
68		2027	10.2					10.6	10.2
69		2028	10.3					10.6	10.3
70		2029	10.6					10.6	10.6
71		2030	10.7					10.6	10.7
72		2031	10.2					10.6	10.2
73		2032	10.4					10.6	10.4
74		2033	10.7					10.6	10.7
75		2034	11.1					10.6	11.1
76		2035	11.2					10.6	11.2
77		2036	10.2					10.6	10.2
78		2037	9.9					10.6	9.9
79		2038	10.1					10.6	10.1
80		2039	10.6					10.6	10.6
81		2040	11.4					10.6	11.4
82		2041	11.4					10.6	11.4
83		2042	11.5					10.6	11.5
84		2043	11.4					10.6	11.4
85		2044	10.7					10.6	10.7
86		2045	10.3					10.6	10.3
87		2046	10.3					10.6	10.3
88		2047	11.3					10.6	11.3
89		2048	11.9					10.6	11.9
90		2049	11.9					10.6	11.9
91		2050	11.6					10.6	11.6

Figure 3. The determination of the predicted values for the yearly average temperatures

5. The evolution mode visualisation of the yearly average temperatures from the 1961 to 2050

In order to see the evolution of the yearly average temperatures from 1961 to 2050, we made maps every 10 years, in which the yearly average temperatures were classified into 5 classes, from 6 ° C to 14 ° C, every 2 degrees.

To make the maps we used the "QGis" application, 2.14.14 version, and we interpolated the values of the yearly average temperatures by the method of the inverse distance weighting.

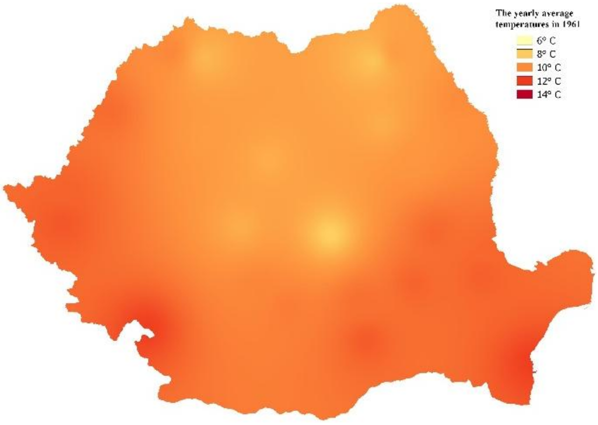

Figure 4. The yearly average temperatures in 1961

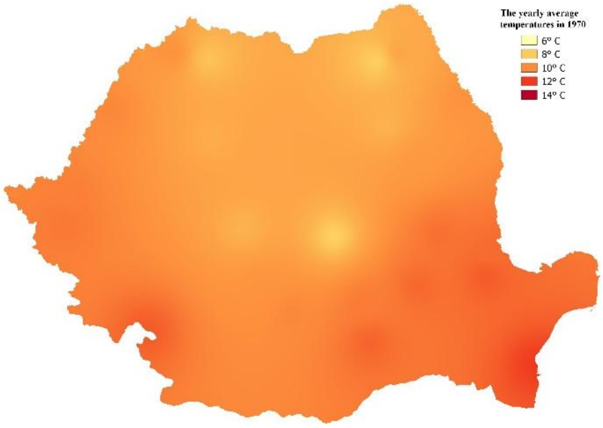

Figure 5. The yearly average temperatures in 1970

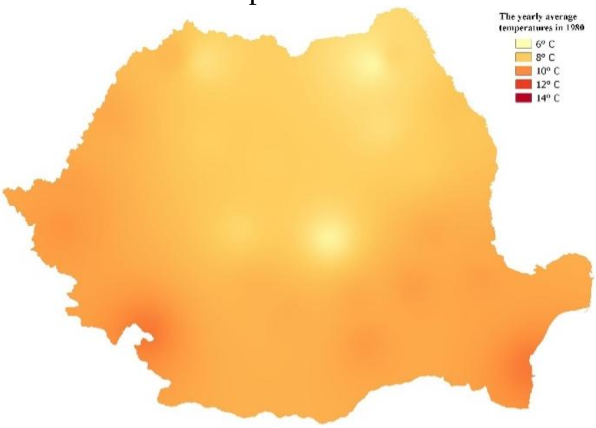

Figure 6. The yearly average temperatures in 1980

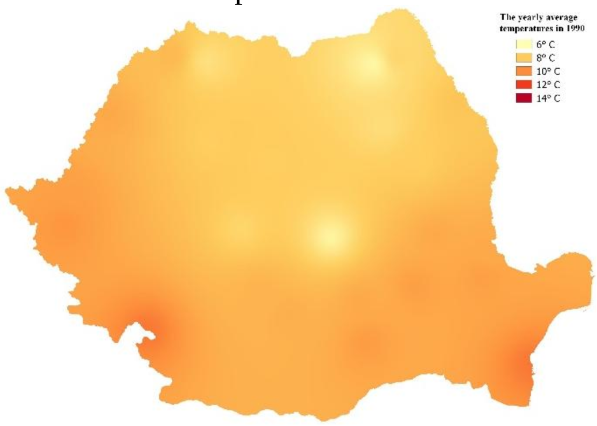

Figure 7. The yearly average temperatures in 1990

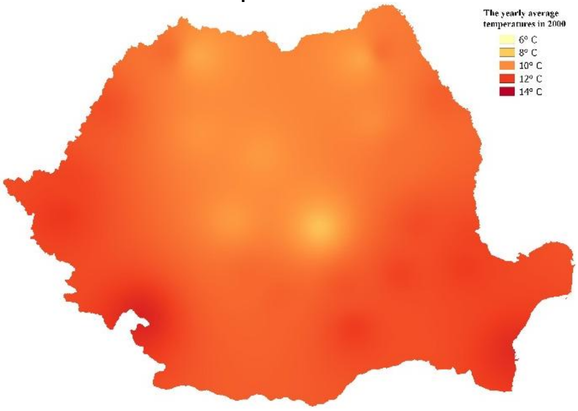

Figure 8. The yearly average

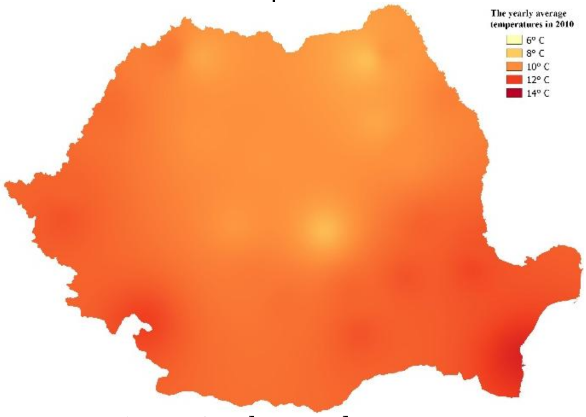

Figure 9. The yearly average

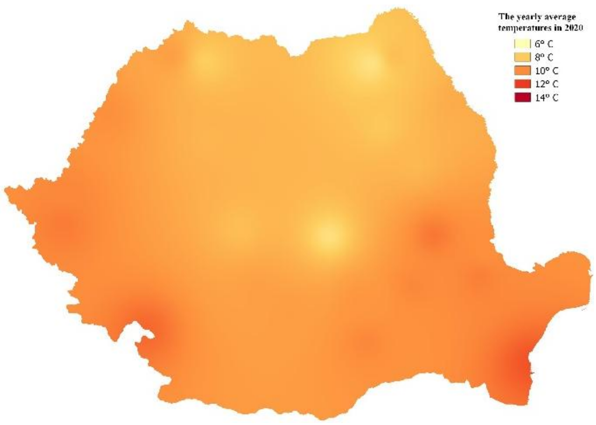

Figure 10. The yearly average temperatures in 2020

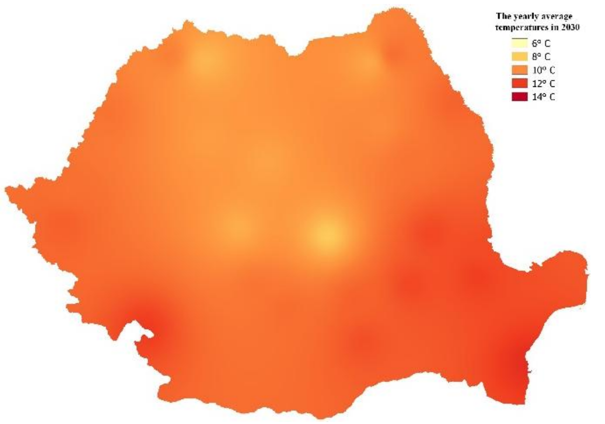

Figure 11. The yearly average temperatures in 2030

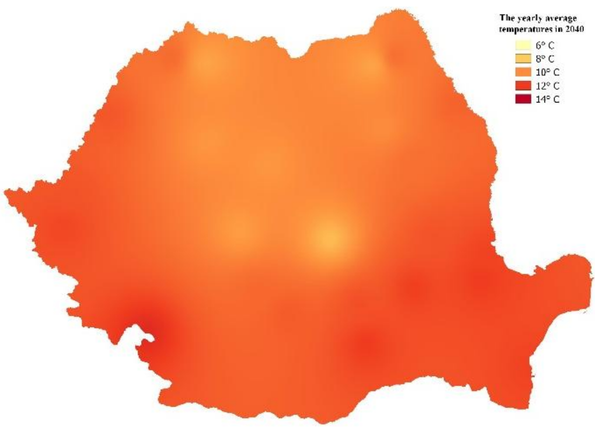

Figure 12. The yearly average temperatures in 2040

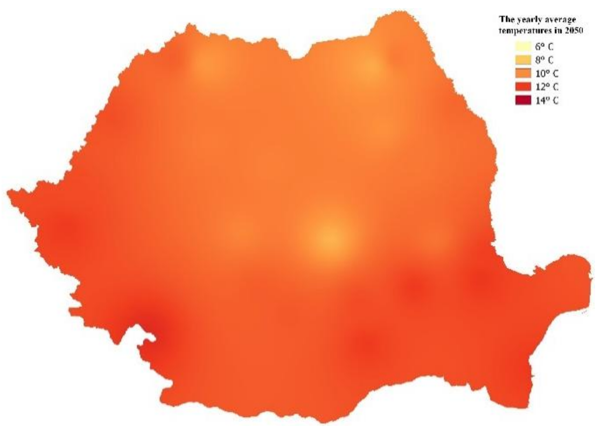

Figure 13. The yearly average temperatures in 2050

From the analysis of the resulting figures it can be seen that from 1961 to 1990 the yearly average temperatures are on a downward slope, and from 1990 to 2050, these register increases throughout the country.

6. Conclusions

The Romania's specific climate is a temperate continental one, in which the monthly average temperatures vary between 22° C and 24° C during the summer, respectively between -3° C and -5° C during the winter.

The method used to predict the values of yearly average temperatures has the disadvantage that when we have positive and negative values, “aberrant” values may result from the forecast. Therefore, this method is not good for predicting monthly average temperature values.

This is due to the fact that incorrect values of the variability index result from the calculation of successive averages.

Instead, for the polar or equatorial areas, where the monthly average temperatures record only negative or positive values, the method will give good results for the monthly predictions, too.

From the evolution of the yearly average temperatures, there is a tendency to increase them on average, by 2° C, throughout the country, from 1990 to 2050.

This could be due to the industrial development, the increase of the cars number, the old technologies used before 1990, which have become very polluting, as well as the uncontrolled deforestation.

7. References

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