Detection of Similar Homoclimates by Numerical Analysis

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Abstract

Numerical methods including cluster analysis, similarity measures and other techniques were used to compare climatic data from Bulgarian stations in order to classify them according similar homoclimate. Using Euclidean distance and City-block (Manhattan) distance, data from Bulgaria and states of the USA were analyzed to reveal homoclime. Similarities in conditions for growth and development of crops of these areas were also determined.

Key words: homoclimate, homoclime, cluster analysis, similarity measures.

Introduction

In many fields including agroclimatology, pedology, plant introduction, environmental health and agricultural transfer, detection of areas of similar climate is of significant interest. It helps in solving completely different problems like allocation of appropriate agricultural crops to given areas and evaluation of bioclimatic resources in connection with genetic status of population on certain locations.

Definition of ***homoclime*** (Merriam-Webster): a climatically similar environment; specifically**:** a region climatically similar to another specified region

Several authors have carried out comparisons of climate in different parts of the world. The term "homoclime" is used by Prescot (1938) for areas with similar climate. Others have used the term "homoclimate" (Meigs, 1953). Russell and Moore (1970) give the exact definition of both terms. The term homoclimate refers to two or more stations that possess a similar climate, whereas the term homoclime refers to areas or regions, which possess similar climate. So comparisons are made between meteorological stations and they define homoclimates (Russel, 1982). In the case of considering local conditions on small confined locations we are using term "local homoclimates".

In Bulgaria intensive studies on the climate and climatic regioning have been carried out with reference to global areas as the Balkan Peninsula (Nojarov, 2017) and Bulgaria (Stanev et al., 1991). Most of these studies (CIA, 1943), (Dimitrov, 1968) and (Stanev et al., 1991) provide a common characteristic of the climate in the country. However, no attempt is made to find similarities of different locations in a numerical form. Only Nojarov has made attempt to use method of cluster analysis with Sea Level Pressure data for the period 1950–2012 at 61 stations located in or around the Balkan Peninsula. A

hierarchical clustering technique – average linkage between groups with Pearson correlation for measurement of intervals was employed in the research.

The development of numerical methods for data analysis and computer technique enables to a considerable degree the studies and search for homoclimates. New multivariate statistical methods allow simultaneous consideration of many meteorological parameters for assessment of climate at any one location.

Homoclimate of Bulgarian stations

Climatic data from 114 stations in Bulgaria (Lingova, Kiuchukova, 1979-1982) and Annual Meteorological Books (NIMH, 2011-2017) are used for the present study. Six parameters are considered for all stations on monthly bases (January - December): mean air temperature, absolute maximal and minimal air temperatures, relative humidity, sum of precipitation and wind speed.

For our study we apply joining (tree clustering) Ward's method. This method is distinct from all other methods because it uses an analysis of variance approach to evaluate the distances between clusters. This method attempts to minimize the Sum of Squares of any two (hypothetical) clusters that can be formed at each step. Refer to Ward (1963) for details concerning this method. In general, this method is regarded as very efficient; however, it tends to create clusters of small size.

Euclidean distance measure is used:

$$\text{distance}(x,y) = \{\Sigma_i (x_i - y_i)^2\}^{½}$$

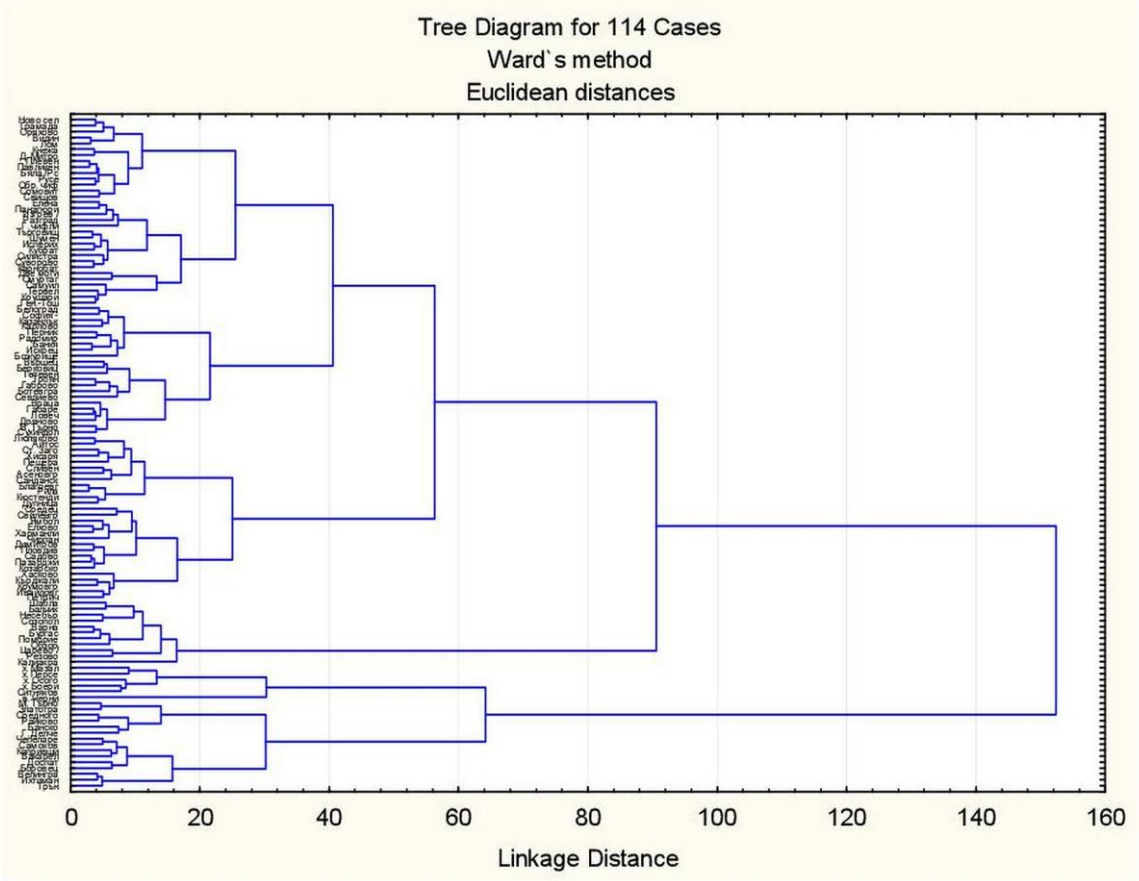

Figure 1. *Graphical presentation of results from cluster analysis.*

The final result consists of five clusters, which combine stations with similar homoclimate.

Cluster 1 contains 13 cases - locations along the Black Sea coast:

Omurtag, Shabla, Kaliakra, Balchik, Gen.-Toshevo, Varna, Burgas, Nessebar, Pomorie, Sozopol, Tsarevo, Rezovo, Obzor.

Cluster 2 contains 49 cases - locations from Danubian plain and middle South Bulgaria:

Novo Selo, Vidin, Gramada, Belogradchik, Lom, Vratsa, Gabare, Knezha, Oryahovo, Pleven, Somovit, D. Mitropolia, Lovech, Sevlievo, Dryanovo, Pavlikeni, Elena, Svishtov, Rousse, Dve Mogili, Obr. Chiflik, Byala/Rs, Targovishte, Razgrad, Samuil, Isperih, Kubrat, Silistra, Shumen, Tervel, Krushari, G. Chiflik, Suvorovo, Karnobat, Sredets, Yambol, Elhovo, Chirpan, Kazanlak, Svilengrad, Harmanli, Dimitrovgrad, Plovdiv, Sadovo, Pazardjik, Radomir, Sofia, Bozhurishte, Botevgrad.

Cluster 3 contains 24 cases - locations from mountainous regions:

Varshets, Berkovitsa, Teteven, Troyan, Gabrovo, Izgrev, M. Tarnovo, Srednogorie, Chepelare, Raikovo, Zlatograd, Dospat, Velingrad, Panagyurishte, Bansko, Pernik, Tran, Bankya, Ihtiman, Koprivshtitsa, Borovets, Samokov, Iskrets, Vakarel.

Cluster 4 contains 6 cases - locations in high mountain areas:

x. Mazalat, x. Persenk, x. Osogovo, Cherni vrah, x. Boerica, Sitnyakovo.

Cluster 5 contains 22 cases - locations in pre-Balkan, sub-Balkan and south-western Bulgaria:

Veliko Tarnovo, Suhindol, Lyulyakovo, Aytos, Sliven, St. Zagora, Haskovo, Kardzhali, Krumovgrad, Ivaylovgrad, Asenovgrad, Karlovo, Hissarya, Kozarsko, Peshtera, Blagoevgrad, Sandanski, Petrich, G. Delchev, Kyustendil, Dupnitsa, Rila.

The results can clearly be displayed on one map of the country.

Homoclime of Bulgaria and USA

We think that in solving different problems like allocation of appropriate agricultural crops, transfer of technology in agricultural practice to given areas and evaluation of bioclimatic resources, it is good to know areas or regions, which possess similar climate. This puts the task of making a comparison of the climate in Bulgaria and that of the states in the United States.

Important factors in the growth and development of crops during the vegetation period are the average daily temperatures and the amount of precipitation during the periods March - June (Tav 3-6, Pav 3-6) and August - November (Tav 8-11, Pav 8-11). For this purpose data from 41 states (U.S. Climate data), compared with the data for Bulgaria from Annual Meteorological Books (NIMH, 2011-2017), were used.

Table 1. *Data from the periods March - June and August - November*

State	Tav 3-6	Tav 8-11	Pav 3-6	Pav 8-11
Alabama	20.125	21.113	111.500	102.250
Arizona	25.388	27.038	9.000	20.750
Arkansas	19.125	20.263	50.000	88.250
California	13.988	15.888	35.500	8.750
Colorado	11.625	13.625	42.500	37.000
Delaware	15.225	17.450	104.500	101.750
Florida	21.263	22.463	128.250	142.500
Georgia	18.875	19.750	100.000	108.500
Idaho	13.050	14.500	29.500	11.750
Illinois	12.875	15.000	92.250	92.250
Indiana	13.313	14.613	101.750	83.750
Iowa	13.488	14.475	100.000	90.250
Kansas	15.450	16.413	103.750	93.750
Kentucky	13.900	15.638	106.250	86.250
Louisiana	22.500	23.463	136.750	131.750
Maryland	16.250	18.538	87.500	95.750
Michigan	11.075	12.988	75.500	76.750
Minnesota	11.600	12.713	78.250	97.500
Mississippi	20.038	20.800	117.500	101.750
Missouri	15.250	16.600	106.000	100.750
Montana	9.625	10.613	34.750	26.250
Nebraska	13.375	14.375	85.500	79.250
New Jersey	14.188	16.588	104.250	100.500
New Mexico	11.888	12.825	25.250	47.250
New York	14.063	16.900	101.250	101.750
North Carolina	17.413	18.238	88.750	92.000
North Dakota	9.163	10.300	49.000	50.750
Ohio	13.838	15.338	106.750	72.750
Oklahoma	18.475	19.650	99.750	88.500
Oregon	12.100	14.013	66.750	33.250
Pennsylvania	14.813	17.050	91.750	94.000
South Carolina	19.675	20.350	88.500	110.000
South Dakota	9.563	10.325	60.750	67.250
Tennessee	19.475	20.325	124.000	92.250
Texas	22.475	23.613	86.000	70.750
Utah	14.300	16.138	49.250	28.500
Virginia	16.750	18.088	94.750	102.750
Washington	11.938	13.563	62.500	40.750
West Virginia	15.200	16.263	103.000	92.750
Wisconsin	10.350	13.338	83.000	85.000
Wyoming	9.088	11.075	47.250	41.000
Bulgaria	12.986	18.562	57.979	53.609

Using these climatic variables, we can calculate the climatic similarity (homoclime) between two areas. Several similarity measures can be applied (Clifford and Williams, 1976). We used Euclidean distance and City-block (Manhattan) distance. Another suitable alternative is Gower's similarity measure (Gower, 1971).

City-block distance = $\frac{1}{m}\sum_{j=1}^{m}\left(\frac{|x_{1j}-x_{2j}|}{x_{1j}+x_{2j}}\right)$;

Gower similarity measure = $1-\frac{|x_{ik}-x_{jk}|}{r_k}$,

where r_k is the range of values for the k-th variable.

The following table presents the results of the analysis representing the states closest to Bulgaria.

Table 2. *Comparison of Bulgaria with the most similar USA states.*

State	Euclidean distances
Bulgaria	0
North Dakota	13
Washington	15
South Dakota	17
Wyoming	19
Colorado	23
Oregon	23
Utah	27

State	City-block (Manhattan) distances
Bulgaria	0
Washington	23
North Dakota	24
South Dakota	28
Oregon	35
Wyoming	35
Colorado	38
Utah	38

The following figure illustrates the similarity of Bulgarian conditions for growth and development of crops with corresponding US states.

Figure 2. *Map of USA showing states with homoclime similar to Bulgaria.*

Here is interesting to show the representation of similarity between countries from Europe and Asia to North America (McCarthy, 2016). It can be seen that the countries of Eastern Europe, to which Bulgaria belongs, have a similar climate with the Northwestern states of America, which confirms our analysis and conclusions.

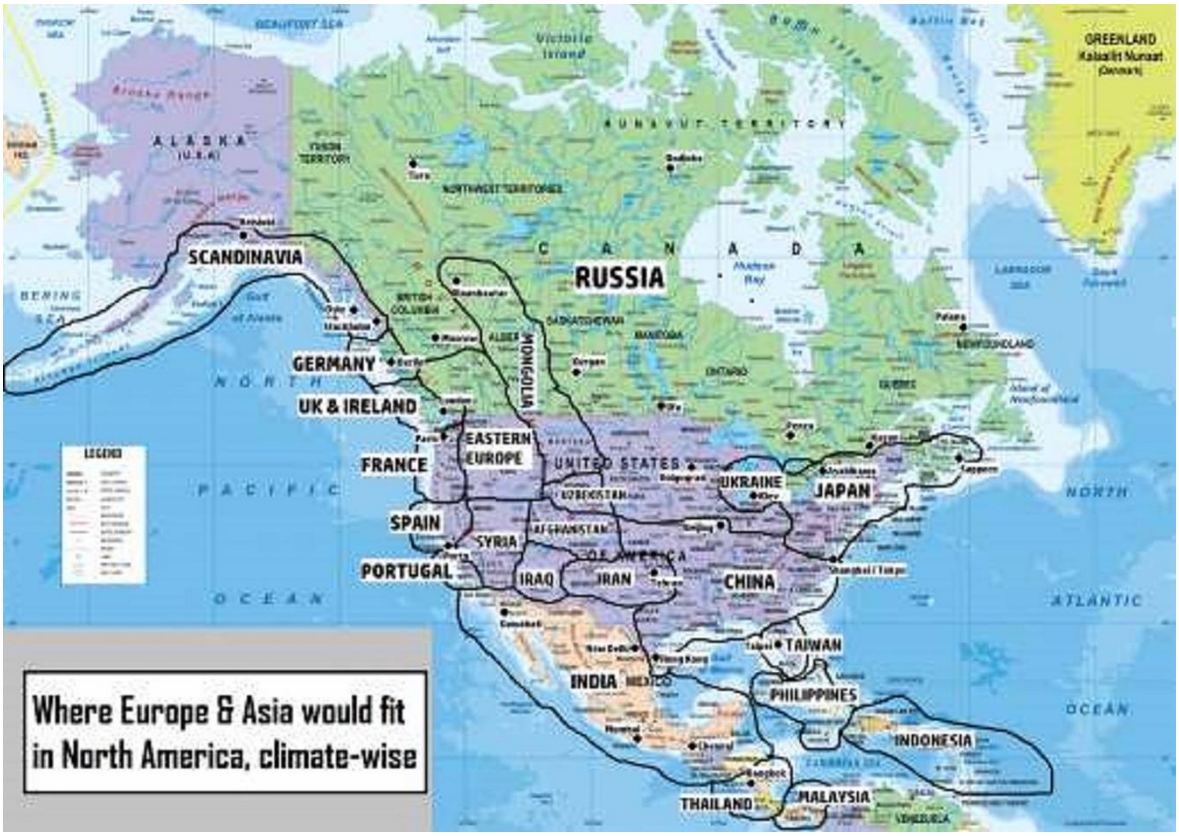

Figure 3. *A climate map comparison of USA, (McCarthy, 2016).*

The climate maps show some countries have what could be called a "climate twin".

Conclusion

The development of a clustering procedure and its application to meteorological data from the station in Bulgaria, provides some insight into the number and position of observation stations that are necessary to monitor adequately the climate of Bulgaria. In the article five clusters are detected and homoclimates in the country are defined.

Precise evaluation of climatically analogous regions in different countries of the world for improvement of cropping practices and introduction of improved crop varieties from one region to another requires realistic computations and detection of homoclime for the crop-growing seasons.

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