Annals. Food Science and Technology
2009

STUDY OF THE EFFECTS OF CLIMATE CHANGE IN THE ORCHARDS AND WINE GROWING AREAS BY GENERATION OF THE TYPICAL METEOROLOGICAL YEAR - TMY AND USING CLUSTER ANALYSIS

Armeanu Ileana[1], Petrehus Viorel[2], Radu Raluca[3]
[1]University of Agronomical Sciences and Veterinary Medicine, 59 Marasti Boulevard, Sector 1, Bucharest, Romania,
[2] Technical University of Civil Engineering , Buchares, Romania
[3] National Meteorological Administration, Bucharest, Romania
iarmeanu@gmail.com

Abstract

Typical meteorological year was firstly produced in USA at Sandia Laboratories [1] and revised in the next years [2]. These techniques are based on the Finkelstein-Schafer (FS) statistics [3]. In this paper we apply aspects of the FS statistics to produce a typical meteorological year based on data sets from the Romanian fruit trees in Baneasa Region for a sample of 30 years with complete daily observations for (in between) 1977-2006 period and from the wine growing area Valea Călugărească for a sample of 15 years. The results emphasize considerations about the local effects of climate changes for these regions. The program for TMY generation was coded in Scilab and finally we used a nonlinear projection model of cluster analysis to compare the months of the TMY in order to distinguish climatologic changes in both regions. For comparison was used the year 2007, being the second year of obsevatins in POMOSAT-2006 and IMEV-2006 grants. The mains agro climatic indicators used for comparation was daily mean air temperature, extreme temperatures, length of the vegetation period, the quantity of precipitation, the monthly mean amplitude of the air temperature.

Keywords: Finkelstein-Schafer statistics, concordance tests, agroclimatic indicators, temperature, precipitation, vegetation period.

1. INTRODUCTION

TMY is commonly used in building energy systems simulations and in assessments of wind and solar energy systems performance. Also it is used in the modeling of agricultural systems and the dispersion of air pollutants and in simulations of microenvironment greenhouses in agriculture and solar desalination systems.

This paper describes the procedures as well as the observations regarding the generation of a typical meteorological year for the fruit trees and wine culture areas and also presents a variant of a typical meteorological year based on the data measured at the meteorological stations: (of) Băneasa-Bucharest and Valea Călugărească situated in Southern part of Romania, using a sample of 30 years with complete observations, respectively a sample of 15 years.

The weights of the eco-climatic characteristics used in the study are similar to those used by the American standards TMY and they are adapted following the consultations with specialists from fruit and wine growing field. The approach uses a statistical method introduced by J.M. Finkelstein, R.E. Schafer in Improved Goodness-of-Fit Tests (Biometrika, 58(3), (1971), pp. 641-645), a well known and largely used method to generate a typical meteorological year.

The calculation program was written in Scilab software because it offers a large number of routines for manipulating large blocks of data, sorting routines, mathematical calculations etc., all accessible following simple instructions and available free of charge at www.inria.fr.

This paper is a continuation of analysis of our previous work [4], with addition of cluster analysis method based on nonlinear projection with an extension of area under study. This work was supported by POMOSAT and IMEV grants from the Ministry of Education and Research of Romania.

2. MATERIALS AND METHODS

2.1. The Filkenstein-Schafer statistics

The measure of the goodness of fit proposed by Filkenstein and Schafer is some kind of distance between cumulative distribution functions of two random variables. For continuous random variables with cumulative distribution functions F_1 and F_2 we define a "distance" between them as

$$FS(F_1,F_2)=\frac{1}{2}\int_{-\infty}^{\infty}|F_1(t)-F_2(t)|d(F_1(t)+F_2(t))$$

$$=\int_{-\infty}^{\infty}|F_1(t)-F_2(t)|dF_1(t)=\int_{-\infty}^{\infty}|F_1(t)-F_2(t)|dF_2(t)$$

From this definition it follows:

i. $FS(F_1,F_2)\geq 0$ and it is zero if and only if $F_1\equiv F_2$

ii. $FS(F_1,F_2)=FS(F_2,F_1)$

iii. $FS(F_1,F_2)\geq\frac{1}{2}(\max|F_1-F_2|)^2$

Unfortunately the triangle rule is not true for FS. Even so, the iii) property shows that if a sequence $(F_n)_{n\in N}$ of continuous cumulative distribution functions is a Cauchy sequence with respect to FS, then the sequence is Cauchy with respect to the true distance $\max|F_1-F_2|$ whence the limit exists and is a continuous cumulative distribution function. This "distance" can be used as a measure of the closeness of the two random variables.

In our case we have a meteorological characteristic daily or hourly measured for many years for which we can make various cumulative distribution functions. To compare them we use the proposed by Filkenstein and Schafer statistics (see [3]) which is analogous to the FS above but for discrete random variables.

Depending on the activity domain, some climate characteristics are more important than others. The importance of a single characteristic in construction of a typical meteorological year was measured through weighted characteristics. In our model, we have considered different characteristics and corresponding weights: solar radiation = 0.4, mean air temperature = 0.2, maximum air temperature = 0.1, minimum air temperature = 0.1, mean relative humidity = 0.1 and precipitation = 0.1.

We used a sample of 15 years in the V. Calugareasca region with complete observations in between 1990-2006 except for 1999-2000. We eliminated 29th of February from leap years, so that we had for 15 years of observations a number of 15 x 365=5475 days.

In the Baneasa region we have a large sample of 30 years in between 1977-2006 with 30 X365 = 10950 daily observations.

2.2. The construction of a typical meteorological year

We used the methodology for calculating a typical meteorological year presented in [1] or [2]. The main steps are as follows:

1. Those characteristics which presents the highest interest for a certain activity field are considered.
2. The typical year is not built from data resulted by averaging the measurements on many years, but each month of a typical year is a true (effective) month from one of the considered years to build the typical year. In order to choose this typical month, for example January, for each meteorological characteristic, denoted c), the empirical cumulative distribution function with data of all January months from the used sample was built (denoted with CDF_c=cumulative distribution function for the indicator c) called also the distribution for long term. The empirical cumulative distribution functions were built also for each January considered separately ($CDF_{c,i}$ where i is the year index). Typical month of January will be considered from indexed year i for which the distance Filkenstein-Schafer between CDF_c and $CDF_{c,i}$ is the smallest. This distance is defined by $FS_{c,i}=\frac{1}{n}\sum_{j=1}^{n}|CDF_c(x_j)-CDF_{c,i}(x_j)|$, where n is the number of days of a month (thus the number of data on which $CDF_{c,i}$ was built, x_j, represents the daily means from a month, so that the values from CDF_c and $CDF_{c,i}$ have jumps, and i is the year's index whom month is

considered. In order to take in account as much as meteorological characteristics a weighting of these distances is done, with the weights W_c, and the smallest averaged distance $WFS_i = \sum_c W_c \cdot FS_{c,i}$ indicates that the typical month comes from the year i.

Those representative months are concatenated and smoothed for the transition between two months. To smooth the data at the transition between two months which can be months of different years, we used a moving average between 3 neighbor's data with the weights w=[0.3, 0.4, 0.3].

The program was coded in Scilab and follows the steps 1, 2, 3, from TMY2 method described above. The typical months for this period were found as following:

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baneasa	1995	1981	1982	1977	2006	1985	2004	1993	1977	1998	1999	1978
Valea Calugareasca	1992	1994	2006	1992	2005	1994	2004	2006	2004	2005	1997	1994

3. RESULTS AND DISCUSSION

3.1. The principals agro climatic indicators

Air temperature constitues an essential climatic element with a basic influence on the vegetation. The accumulated data during long periods of time allows to remark the thermic regime, respectively the particularities of the diurnal and the annual cycle of air temperature in different regions which are included in the representative area of the respectively meteorological station.

The data used in the analysis were measured to Baneasa (near Bucharest) at the meteorological station with geographical coordinates latitude 44° 29' N, longitude 26° 04' E, and Valea Calugareasca (near Ploiesti) stations situated at latitude 44° 57' N, longitude 26° 09' E, just inside the chosen area of study for POMOSAT and IMEV projects. For comparison was used the year 2007, being the second year of POMOSAT-2006 and IMEV-2006 grants.

The daily mean temperatures for the TMY are less than those of the year 2007 especially between January and August (Fig. 1).

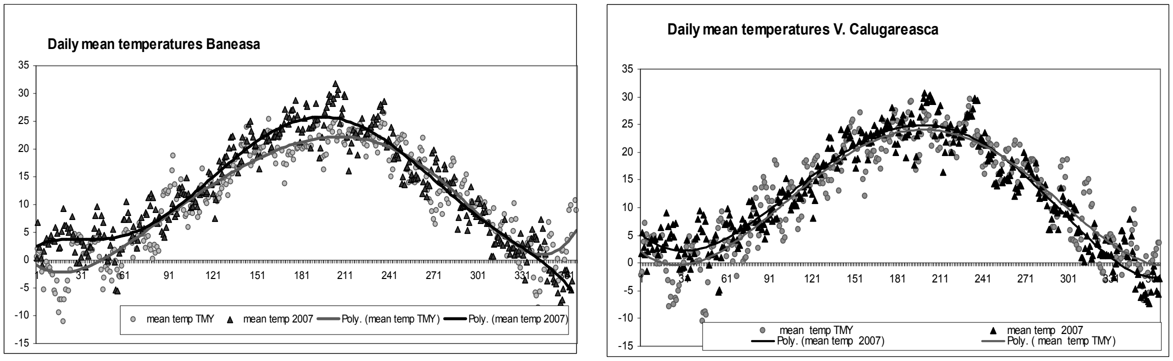


Fig. 1. Daily mean temperature

The temperature mean in Baneasa region is about 10.76± 8.99^{0}C in TMY, respectively 12.2± 9.41 ^{0}C in 2007. At V. Calugareasca station the general mean of temperature is 11.91± 9.51^{0}C in TMY, respectively 12.23 ± 9.45 ^{0}C in 2007 (bigger variability in 2007).

Useful information on thermal potential of a region is offered by the frequency of characteristic days. Four types of characteristic days are defined two of them are specific for warm season: summer days, when maximum temperature is bigger than 25^{0}C, tropical days when maximum temperature is $\geq$ 30^{0}C and other two specific for cold season: frost days when minimum temperature is ≤ 0 ^{0}C, and freezing days when temperature is ≤ -10^{0}C. The available data did not contain information about temperature by night. In the Baneasa region in the typical meteorological year (TMY) were observed 107 summer days and 47 winter days, in comparison with the year 2007 when were recorded 127 summer days and 107 winter days. Totally there are 154 situations of extreme values in TMY and 234 in 2007 (the bigger variability we were discussing about, is a typical aspect of global warming on the fruit growing ecosystem) (Fig.2).

The same characteristic seen in V. Calugareasca area shows 83 summer days and 82 winter days in TMY, in comparison with 2007, where we found 119 summer days and 109 winter days.

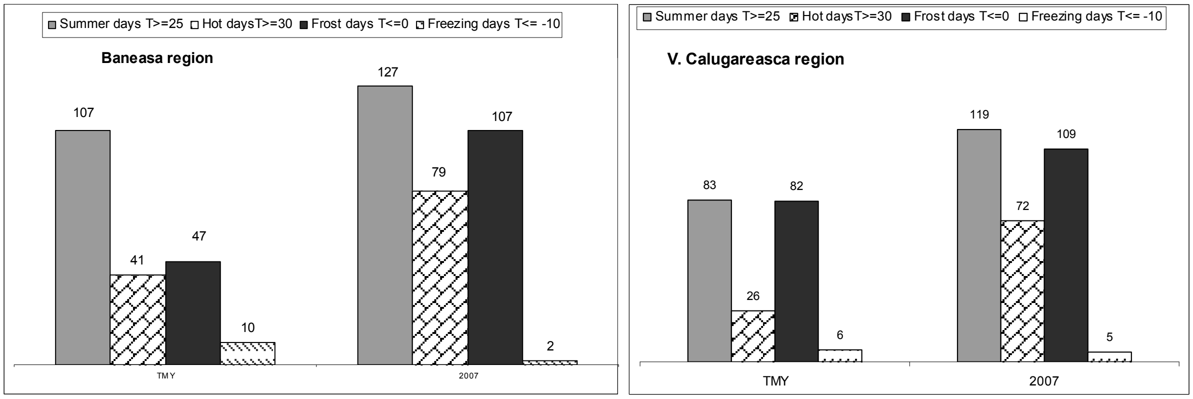


Fig. 2. Extreme temperatures

If we denote p_1, respectively, p_2 the probability of having a day with extreme temperatures in TMY, respectively in 2007 and we propose the verification of the hypothesis $H_0: p_1 = p_2$ with the alternative $H': p_1 \neq p_2$, this can be done with the help of statistics

$$Z = \frac{\frac{X_1}{n_1} - \frac{X_2}{n_2}}{\sqrt{\hat{p}(1-\hat{p})\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \sim N(0,1)$$

When the hypothesis is true, the common value of $p_1$and p_2 is replaced with the estimation:

$$\hat{p} = \frac{X_1 + X_2}{n_1 + n_2} = \frac{234 + 154}{2 \cdot 365} = \frac{388}{730} = 0.5315 \text{ and}$$

$$Z = \frac{\frac{234}{365} - \frac{154}{365}}{\sqrt{0.5315 \cdot (1 - 0.5315)\left(\frac{2}{365}\right)}} = 5.934 > 3.29$$

As consequence, the nule hypothesis is rejected, the difference between p_1 and p_2 is statisticaly very significant.

Thus, there can be identified the first and the last day from the year with the temperature equal or bigger than a certain threshold, for example 8 degrees Celsius, the length of the interval as well as the number of degrees over the threshold accumulated in that interval. The threshold of 8 degrees Celsius includes **the vegetation period** of many thermophilic species.

For the Baneasa region, this is between 27th of March and 4th of November during 217 days for TMY with a sum of 3718.83^{0}C in comparison with 2007 when the vegetation period is of 195 days, between 2nd of April and 13th of October, with a sum of 3884.8 ^{0}C.

In the region V. Calugareasca the vegetation period is between 23rd of April and 16th of October during 177 days with a sum of 3554^{0}C in TMY in comparison with the year 2007 when the vegetation period is between 4th of April and 13th of October, during 193 days with an amount of 3817^{0}C. An effect of the warming is clearly indicated in the Fig. 3. The warm summer determines in the vegetation period of 2007 a bigger sum of temperatures. The difference between TMY and 2007 is not statistically significant, concerning the length of the interval and the cumulated temperatures value as well.

The quantity of precipitation constitutes as the air temperature an essential element for the development of the vegetation and especially for the agriculture. For the Banesa region the yearly mean quantity of precipitation doesn't exceed 564.6 mm in the analyzed TMY, and 530.6 mm in 2007. For V. Calugareasca region, the altitude and the nearby mountains have influenced a quantity of 696 mm in TMY and much less in 2007, respectively 593 mm. The differences between TMY and 2007 are not, however, statistically significant.

One remarks the alternation of months between rich and poor in precipitation quantities. When this rule is not respected, one remarks floods.

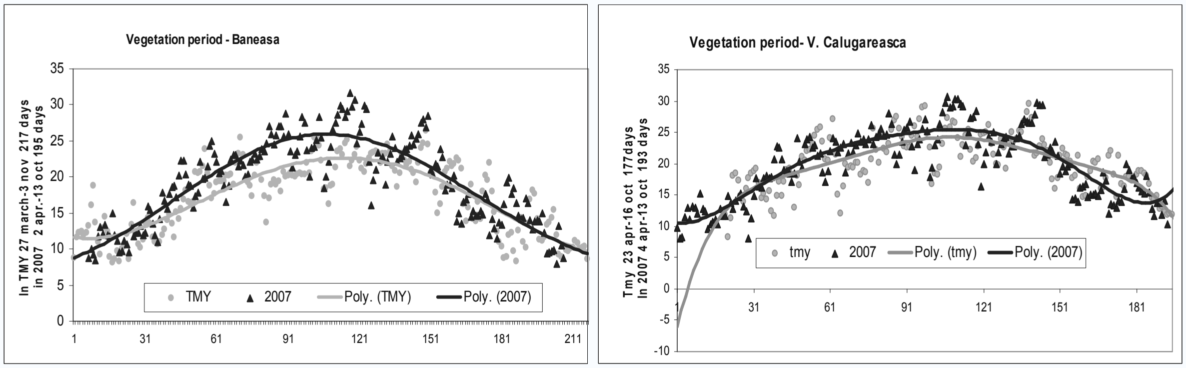
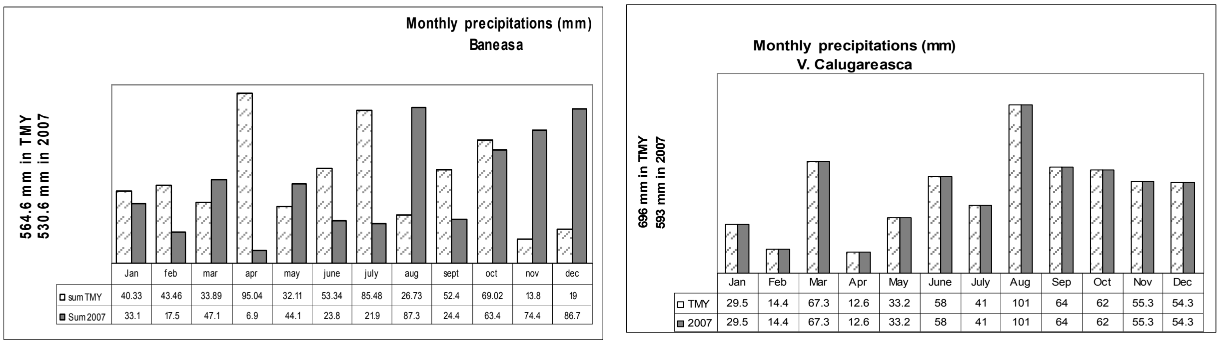


Fig. 3 The vegetation period

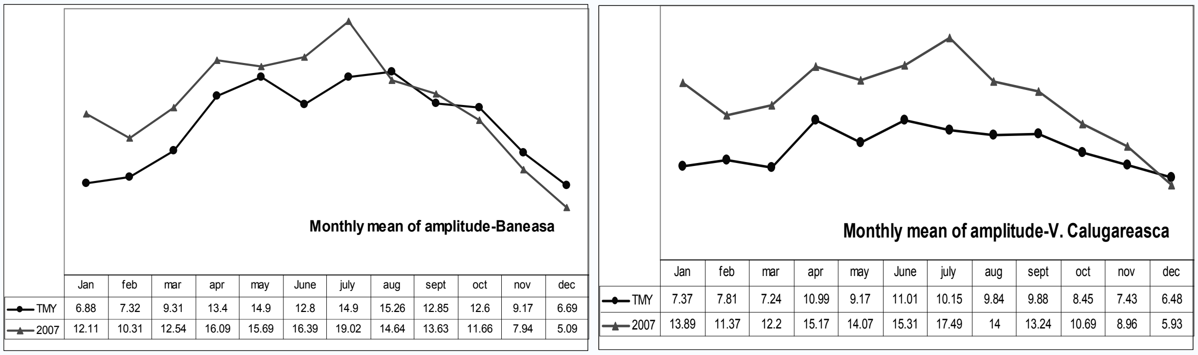
The monthly mean of air temperature amplitude in TMY, of about 11.24 ^{0}C in Baneasa and 8.81^{0}C in V. Calugareasca is specific for some regions characterized by continental climate. The highest monthly mean of amplitude is registered in July in both region, and the lowest monthly mean is registered in December. The major role of the atmospheric circulation in showing the extreme values is underlined by the distribution of the extreme values along the year.



	Jan	feb	mar	apr	may	june	july	aug	sept	oct	nov	dec
☐ sum TMY	40.33	43.46	33.89	95.04	32.11	53.34	85.48	26.73	52.4	69.02	13.8	19
▨ Sum 2007	33.1	17.5	47.1	6.9	44.1	23.8	21.9	87.3	24.4	63.4	74.4	86.7

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
☐ TMY	29.5	14.4	67.3	12.6	33.2	58	41	101	64	62	55.3	54.3
▨ 2007	29.5	14.4	67.3	12.6	33.2	58	41	101	64	62	55.3	54.3

Fig. 4 . Monthly precipitations (mm)



	Jan	feb	mar	apr	may	June	july	aug	sept	oct	nov	dec
TMY	6.88	7.32	9.31	13.4	14.9	12.8	14.9	15.26	12.85	12.6	9.17	6.69
2007	12.11	10.31	12.54	16.09	15.69	16.39	19.02	14.64	13.63	11.66	7.94	5.09

	Jan	feb	mar	apr	may	June	july	aug	sept	oct	nov	dec
TMY	7.37	7.81	7.24	10.99	9.17	11.01	10.15	9.84	9.88	8.45	7.43	6.48
2007	13.89	11.37	12.2	15.17	14.07	15.31	17.49	14	13.24	10.69	8.96	5.93

Fig. 5. Monthly mean of air temperature amplitude

The monthly means of the temperature amplitudes underline the big variability of the air temperature for the year 2007, the amplitudes are constanly bigger the ones from TMY in V. Calugareasca and till August in Baneasa.

This climatologic indicator has special importance in trees culture, being responsible for the colour of the fruits. In the both regions, the values of amplitudes are increased till July and decreased during cold season. The yearly mean of amplitude in 2007 is 12.92 ^{0}C in Baneasa, respectivly 12.7 ^{0}C in V. Calugareasca region.

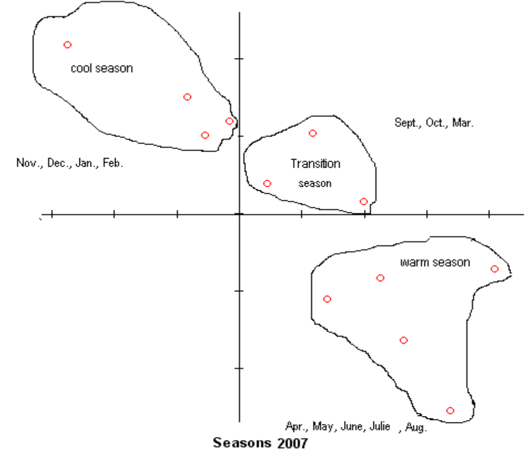


Fig. 6. The clusters of the 2007's months

Finally we used a nonlinear projection model of cluster analysis to compare the months of the TMY in order to distinguish climatologic changes in both regions. As climatologic characteristics we used the mean temperature, the relative humidity, the quantity of precipitations, solar radiation and the temperature amplitude.

The analysis emphasizes three clusters of months (three possible seasons). A cold season (November, December, January and February), a warm season (April, May, June, July, August) and the intermediate season (March, September, October) (Fig. 6).

4. CONCLUSIONS

1. The daily mean temperatures values of 2007 are above those of TMY in both regions between January and August and very similar for the other months. A common characteristic is a big variability of the air temperature; that is a typical indication of the warming of the orchard ecosystem.
2. The cluster analysis emphasizes a new consequence of climatologic changes: we have not the traditional four seasons. The cold and warm seasons tend to be of about 4-5 months with two transition periods of 1-2 months.
3. The number of days of the year 2007 with extreme temperatures differs significantly from the similar number of TMY.
4. The difference between TMY and 2007 is not statistically significant concerning the length of the vegetation period, as well as the value of the cumulated temperatures.

   We remark consecutive days with mean temperatures above 8^{0}C from the beginning of April until the middle of October.

5. REFERENCES

[1]. William Marion, Ken Urban 1995. User's Manual for TMY2s Typical Meteorological Years. National Renewable Energy Laboratory, Golden, Colorado.

[2]. Wilcox S. and Marion W.,2008, User's Manual for TMY3 Data Sets, Technical Report, National Renewable Energy Laboratory-NREL/TP-581-43156.

[3]. J.M. Finkelstein; R.E. Schafer. 1971. Improved Goodness-of-Fit Tests. Biometrika. 58(3): 641-645.)

[4]. Armeanu Ileana, Stanica Florin, Petrehus Viorel - Constructing a typical meteorogical year -TMY for the fruit trees area Voinesti and the effects of global warming on the fruit growing ecosystem -8 th International Symposium on Modeling in Fruit Research and Orchard Management Wädenswil Switzerland 1-5 July 2007.