2012 International Conference on Future Environment and Energy
IPCBEE vol.28(2012) © (2012)IACSIT Press, Singapoore

A Climatic Utility Index for the Analysis of the Expected Changes of Cherry and Sour Cherry Production in Central Hungary, Regarding Climate Change

Márta Gaál[1], Károly Szenteleki[1], Zoltán Mézes[2], Réka Homoródi[1+] and Márta Ladányi[1]

[1] Corvinus University of Budapest, H-1118 Budapest, Villányi út 29, Hungary

[2] University of Debrecen, H-4032 Debrecen, Böszörményi út 138., Hungary

Abstract. Production security and risk of a given plant are basically determined by climatic factors the change of which is a great challenge for the growers. This paper focuses on the climatic conditions of cherry and sour cherry production in Central Hungary in three time periods: 1961-1990 as a reference, 2021-2050 as the near future and 2071-2100 for the long-term analysis. A climatic utility index is introduced based on climatic factors and experts' suggestions and calculations. Expected future changes are evaluated by using the predictions of regional climate model RegCM3.1 downscaled to the Carpathian Basin. Results show that in the near future fruit cracking risk of cherry could be higher, but in overall the expected changes are mostly favourable for both cherry and sour cherry production in Central-Hungary. By the end of the century irrigation may be required to maintain the production security and the high standard quality of production. It is also advised to re-evaluate the varieties according to the indicated changes, as a new orchard planted nowadays will have many productive years in the considered future periods.

Keywords: climate change, cherry production, sour cherry production, climatic risk, climatic year types, climatic utility index

1. Introduction

Security of agricultural production is very sensitive to weather and changing climate. However, it is very difficult to express the agriculture related effects of the climate change in numbers and figures, since the soil–plant–atmosphere system is very complex. Crop simulation models were created to give an approximate description of this complex system, and were applied also in Hungary in case of field crops (Fodor and Pásztor, 2010; Erdélyi, 2009).

Another method is the application of climatic indicators defined for certain phenological phases of a given plant (Diós et al., 2009; Ladányi et al., 2010a,b). This kind of examination can be done separately by seasonal effects, but an overall evaluation should be done, too. The climatic indicators can also be related easily to risk values.

The other components of the climate change studies are the climate scenarios. Results from coarse resolution global climate models (GCM) can only be considered as a first-guess of regional climate change consequences of global warming (Bartholy et al, 2009a,b). Regional studies for agricultural purposes are possible since the global models are downscaled by statistical methods to high resolution (10-20 km) data.

One technique that can be used to obtain climate change information at finer scales is the use of nested regional climate models (RCMs) (Torma et al, 2010). Expected regional climate change focused to the Carpathian Basin is modelled by four different RCMs, run by the Department of Meteorology, Eötvös

[+] Corresponding author.
E-mail address: reka.homorodi@gmail.com

Loránd University, Budapest, Hungary (Bartholy et al, 2006; Torma et al., 2008) and by the Hungarian Meteorological Service (Szépszó and Horányi, 2008).

Studies on climate change impacts in agriculture are needed very much in order to find adaptation strategies. It is especially important in case of fruit production, where the change of varieties is slow and the orchards are planted for long time. This paper focuses on the expected climatic conditions and opportunities of cherry and sour cherry production in Central Hungary in the near future (2021-2050) and at the end of the century (2071-2100), compared to the base period of 1961-1990. Cherry production and especially sour cherry production is a very important sector in Hungarian fruit production as there are special and widely known and asked Hungarian varieties with very typical flavour charactesitics as well as macro and microelement content.

2. Materials and methods

2.1. Climate data

Climate data were provided by the Department of Meteorology of the Eötvös Loránd University, Budapest, Hungary. The horizontal grid spacing is 10 km – the highest reached by RegCM3 model – and the database contains daily data of precipitation and temperature for the reference period (1961-1990) and for the future (2021-2050 and 2071-2100) using the A1B scenario. Analyses were carried out characterising each of the 17 local administrative units (LAU 1) of Central-Hungary (i.e. subregions) by one grid point's data.

2.2. Climatic year types and their utility values for cherry and sour cherry production

12 climatic year types were defined by climatic factors, based on experts' suggestions, applied the Delphi method (Dalkey and Helmer, 1963, Linstone and Turoff, 1975). The years not belonging any of the categories (*Tables 1-4*) were defined as the 13th year type called "normal".

In the followings (Table 1-4) 12 climatic year types are grouped according to the precipitation.

Table 1: Extreme dry climatic year types in case of cherry production

Meteorological factors	Extreme dry and extreme cold	Extreme dry and cold	Extreme dry and warm
Precipitation in April	0-15 mm	0-15 mm	0-15 mm
Precipitation in May	0-25 mm	0-25 mm	0-25 mm
Precipitation in June	0-20 mm	0-20 mm	0-20 mm
Tmin January – February	below -25°C exist	below -17°C exist	not below -17°C
Tmin March – April	below -3°C exist	below -1.5°C exist	not below -1.5°C

Table 2: Dry climatic year types in case of cherry production

Meteorological factors	Dry and extreme cold	Dry and cold	Dry and warm
Precipitation in April	15-25 mm	15-25 mm	15-25 mm
Precipitation in May	25-50 mm	25-50 mm	25-50 mm
Precipitation in June	20-40 mm	20-40 mm	20-40 mm
Tmin January – February	below -25°C exist	below -17°C exist	not below -17°C
Tmin March – April	below -3°C exist	below -1.5°C exist	not below -1.5°C

Table 3: Wet climatic year types in case of cherry production

Meteorological factors	Wet and extreme cold	Wet and cold	Wet and warm
Precipitation in April	40-100 mm	40-100 mm	40-100 mm
Precipitation in May	70-180 mm	70-180 mm	70-180 mm
Precipitation in June	80-150 mm	80-150 mm	80-150 mm
Tmin January – February	below -25°C exist	below -17°C exist	not below -17°C
Tmin March – April	below -3°C exist	below -1.5°C exist	not below -1.5°C

Table 4: Extreme wet climatic year types in case of cherry production

Meteorological factors	Extreme wet and extreme cold	Extreme wet and cold	Extreme wet and warm
Precipitation in April	above 100 mm	above 100 mm	above 100 mm
Precipitation in May	above 400 mm	above 400 mm	above 400 mm
Precipitation in June	above 200 mm	above 200 mm	above 200 mm
Tmin January – February	below -25°C exist	below -17°C exist	not below -17°C
Tmin March – April	below -3°C exist	below -1.5°C exist	not below -1.5°C

Next, a climatic utility index value (U) was added to each year type as a weight based on experts' estimates applied again the Delphi method (*Table 5*).

Table 5: Climatic year types and their climatic utility index values (U) for cherry and sour cherry production

Year type	Climatic utility index (U) cherry	Climatic utility index (U) sor cherry
Extreme dry and extreme cold	0.2	0.2
Extreme dry and cold	0.35	0.4
Extreme dry and warm	0.6	0.5
Dry and extreme cold	0.2	0.2
Dry and cold	0.75	0.82
Dry and warm	0.86	0.86
Wet and extreme cold	0.2	0.35
Wet and cold	0.8	0.92
Wet and warm	1	1
Extreme wet and extreme cold	0.2	0.2
Extreme wet and cold	0.55	0.45
Extreme wet and warm	0.6	0.5
Normal	0.88	0.88

2.3. Risk of fruit cracking for cherry production

Cherry production has a specific risk facto, namely the fruit cracking due to the excessive precipitation in the harvest period, resulting decrease of quality and significant yield loss. In some extreme years the cracking damage can cause up to 80-100% loss in sweet cherry and about 40-50% loss in sour cherry orchards (Christiensen, 1996).

According to an earlier study (Szenteleki et al., 2010) harvest period of sweet cherry is considered between 20th of May and 10th of July and four risk factors were calculated for every harvest day using the following algorithm:

- Risk factor R_1: 10-6. days before harvest there is at least 15 mm rainfall observed

once: R_1=0.15; 2 times: R_1=0.4; 3times: R_1=0.7;

- Risk factor R_2: 5-1. days before harvest there is at least 10 mm rainfall is observed

once: R_2=0.2; 2 times: R_2=0.5; 3times: R_2=0.8;

- Risk factor R_3: during harvest there is at least 5 mm rainfall observed

once: R_3=0.8; 2 times: R_3=1.

The overall risk factor is calculated as follows:

$R = \max(R_1+R_2+R_3; 1)$

To obtain the overall production security index (S) of a given year, its climatic utility index value based on the climatic year types must be multiplied with (1- R).

2.4. Statistical comparisons

Statatistical comparisons of the distributions of the year types were executed by Khi-square test. Climatic utility index values were compared with paired t-tests. Normality criterion was checked with Kolmogorov-Smirnov test.

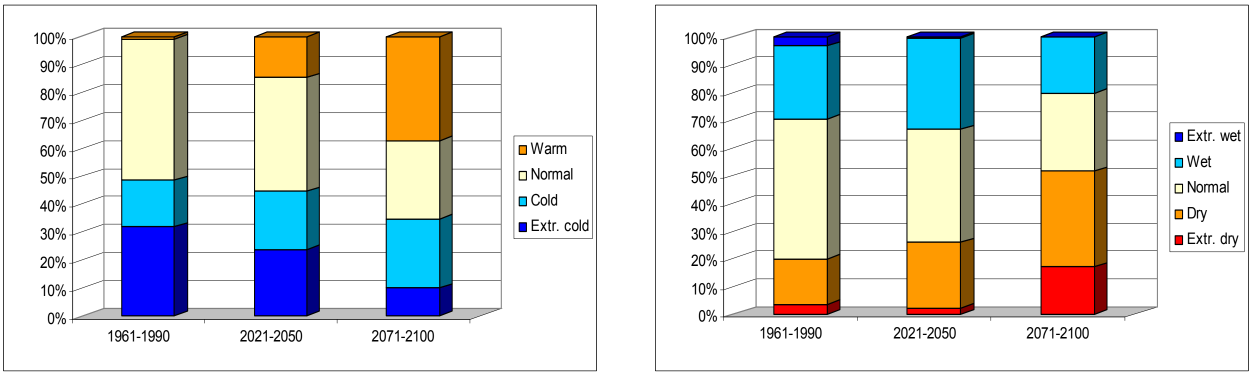
3. Results

3.1. The future predictions of year type distributions based on regional climate model RegCM3.1, compared with the reference period

Statistical comparisons of the expected distributions of the year types in time intervals 2021-2051, 2071-2100 as well as the one of the reference period (1961-1990) were carried out for each of the 17 local administrative units (LAU 1) of Central-Hungary as well as an overall analysis was executed for the whole Central-Hungary region as a complex unit. We give here a short summary of the results.

Comparing the distributions of climatic year types of the three time intervals in Central Hungary region, regarding temperature (Fig. 1a), we can detect significant difference between each of them ($p<0.001$) while a noticable decrease of the extreme cold years together with an increase of warm years can be observed.

The number of cold years is increasing because the formerly extreme cold years become milder (cold year type). Decrease of the number of normal years can be the reason of the increase of frequency of warm years. Overall, a tendentious warming can be observed, which is favourable for quality cherry and sour cherry production. The climatic utility index value of the extreme cold years is very low because of the high risk of winter and spring frost damages. The significant decrease of the extreme cold years indicates the decrease of the frost damage risk, especially in long-term.



(a) (b)

Fig. 1: Distribution of climatic year types regarding temperature (a) and precipitation (b)

However, results call the attention to a very important but rarely mentioned question: the need of re-evaluation of the varieties. The considerably extent of climate change would have a great impact on the time and length of ripening, dormancy and blooming period of cherry varieties. Milder winters can lead to the shortening of the deep-dormancy period, resulting earlier blooming. As a consequence, despite of the milder climate, the risk of spring frost can increase in case of some early and sensitive varieties, too. Changes in the well-known and so far successfully applied blooming time groups and pollination partners are also expected. Re-evaluation of the varieties according to the indicated changes is important in case of planning a new orchard. Counting with a 20-25 year lifetime, orchards planted nowadays will have most of the productive years in the second period examined (2021-2050), already under changed climatic conditions.

In case of precipitation (Fig. 1b) there can again be detected significant differences between each of the the distributions of the year types of the three time intervals in Central Hungary region ($p<0.001$). The number of extreme dry years is insignificant in the reference period and also in the near future, but there is an increase by the end of the century (in every 5-6 years there is one extra dry year expected). There is a continuous increase in the number of dry years and decrease in case of the normal years. In case of the wet years a temporary increase, but in long-term their decrease can be expected. The number of the extreme wet years is very low in all the three periods; moreover, the frequency of this type of years tends to zero.

All together an aridification tendency can be observed, but the dry and warm (U=0.86) as well as the normal (U=0.88) year types are still favourable for both cherry and sour cherry production. However, the significant number of extra dry years at the end of the century is a warning sign. In very dry years the fruit development is not appropriate and adversely affects the fruit size as well as the yield. It calls the attention to the importance of irrigation. Changes are not so drastic that would require immediate investments in existing orchards, but should be considered in the future.

3.2. The future predictions of climatic utility based on regional climate model RegCM3, compared with the reference period

Based on the climatic year types, in most of the sub-regions continuous increase of the expected climatic utility index values can be observed for both cherry and sour cherry production (*Table 6*). However, in short-term, the fruit cracking risk of cherry is higher, so the production security index remains almost the same as in the reference period (*Table 7*). Two reasons can explain the increase of the fruit cracking risk in the near future. One of it is the increase of the number of wet years. At the same time, number of dry years is also higher. If the cherries grow on drier conditions and it becomes rainy just before harvest, cracking damage is higher than in balanced water conditions. Importance of irrigation possibility is great in this point of view and may be justified even in existing young plantations; meanwhile other protection methods are also available (Simon, 2006). The most effective but very expensive protection technique is the plastic rain cover over the trees. Spraying with minerals (calcium) or metallic salts and fruit drying techniques need less investment. Risk of fruit cracking might significantly reduced by adequate irrigation, by means of maintaining balanced water conditions during vegetation period. In long-term, due to the more arid climate, the fruit cracking risk is expected to decrease again, and, compared to the reference period, about 9% increase can be expected in the production security index of cherry.

Table 6: Climatic utility indices for cherry and sour cherry production for the 17 sub-regions of Central-Hungary and for the reference period (1961-1990) as well as for the future time intervals (2021-2050 and 2071-2100), based on regional climate model (RegCM3.1) predictions

Sub-regions of Central Hungary	Cherry Time interval			Sour cherry Time interval		
	1961-1990	2021-2050	2071-2100	1961-1990	2021-2050	2071-2100
1. Aszód	0.62	0.60	0.74	0.65	0.62	0.76
2. Budaörs	0.63	0.72	0.74	0.69	0.74	0.76
3. Budapest	0.70	0.68	0.71	0.72	0.70	0.72
4. Cegléd	0.70	0.73	0.71	0.69	0.73	0.73
5. Dabas	0.68	0.73	0.75	0.67	0.76	0.76
6. Dunakeszi	0.62	0.69	0.73	0.63	0.72	0.75
7. Érd	0.70	0.75	0.70	0.72	0.77	0.72
8. Gödöllő	0.64	0.70	0.76	0.65	0.73	0.76
9. Gyál	0.66	0.77	0.78	0.68	0.79	0.81
10. Monor	0.67	0.64	0.74	0.68	0.66	0.74
11. Nagykáta	0.66	0.68	0.68	0.68	0.72	0.69
12. Pilisvörösvár	0.61	0.69	0.72	0.66	0.73	0.72
13. Ráckeve	0.67	0.76	0.75	0.67	0.78	0.76
14. Szentendre	0.69	0.72	0.74	0.68	0.77	0.76
15. Szob	0.51	0.66	0.74	0.59	0.73	0.75
16. Vác	0.64	0.69	0.73	0.66	0.73	0.75
17. Veresegyháza	0.64	0.67	0.76	0.66	0.70	0.79
Average	**0.65**	**0.70**	**0.73**	**0.67**	**0.73**	**0.75**

Table 7: Cherry production utility in Central Hungary

Period	Climatic utility (U)	Fruit cracking risk (R)	Production security index (S)
1961-1990	0.65	0.05	0.61
2021-2050	0.70	0.11	0.62
2071-2100	0.73	0.05	0.70

The difference of climatic utility is significant for both cherry and sour cherry, compared the values regarding the future time intervals with the ones of the reference period ($p<0.001$). If we compare the utility index values of the two future time scales, the difference is also significant, though the p level is higher: $p<0.05$ for both kinds of fruits.

4. Discussion

Based on the presented results the following conclusions can be drawn concerning the future climatic conditions of cherry production:

- Decrease of the extreme cold and cold year types would have a yield enhancing effect, first of all due to the decrease of the frost damages.
- Increase of the warm year types indicate the improvement in climatic conditions for quality cherry production.
- The precipitation amount in the vegetative period shows a temporary slight increase in short-term, but in long-term tendencies the decrease of it can be observed. It calls the attention that appropriate infrastructure for irrigation may be required in the future. However, the precipitation demand of cherry and sour cherry is not expected to seriously be unsatisfied.
- The uneven distribution of precipitation during the harvesting season initial indicates the increase of yield loss risk caused by fruit cracking of cherry, but in long-term this risk would be moderate. Risk of fruit cracking might significantly reduced by adequate irrigation, so the above mentioned need for irrigation systems is important also in this point of view.
- The serious decrease of the extreme cold years and the increase of warm year types – despite the tendentious aridification – indicate an overall increase of utility values in cherry production and decrease of their variation.
- The rise of the temperature can have effect not only on the growing but also on the post-harvest technology. Even a small rise of temperature increases the risk during post-harvest handling. The transportability and shelf life of cherry fruits depends first of all on the time elapsed between picking and cooling, and the continuous temperature control of the supply chain. In addition, experiences show that fruits harvested on warmer days can store for shorter time as fruits harvested with the same technology but on cooler days.

5. Acknowledgements

This research was supported by the research project TÁMOP 4.2.1/B-09/1/KMR-2010-0005.

6. References

[1] Bartholy, J., Pongrácz, R., Torma, Cs., Hunyady, A. (2006): Regional climate projections for the Carpathian Basin. In: Láng, I. et al. (eds.) Proceedings of the International Conference on Climate Change: Impacts and Responses in Central and Eastern European Countries. Hungarian Academy of Sciences, Hungarian Ministry of Environment and Water, Regional Environment Center for Central and Eastern Europe, Budapest, 55-62. http://ams.confex.com/ams/pdfpapers/147084.pdf. Phoenix, AZ. 5p.

[2] Bartholy, J., Pongrácz, R., Torma, Cs., Pieczka, I., Hunyady, A. (2009a): Regional climate model experiments for the Carpathian basin. 89th AMS Annual Meeting / 21st Conference on Climate Variability and Change.

[3] Bartholy, J., Pongrácz, R., Torma, Cs., Pieczka, I., Kardos, P. Hunyady, A. (2009b): Analysis of regional climate change modelling experiments for the Carpathian basin. International Journal of Global Warming, 1 (No.1-2-3.), pp. 238-252.

[4] Christiensen, J. V. (1996): Rain-induced cracking of sweet cherries: it causes and preventation. In: Webster, A.D., Looney, N.E. (eds.): Cherries: Crop physiology. Production and uses. CAB International, 297-327. pp.

[5] Dalkey, N., Helmer, O. (1963): An experimental application of the Delphi method to the use of experts. Management Science 9(3):458-467.

[6] Diós, N., Szenteleki, K., Ferenczy, A., Petrányi, G., Hufnagel, L. (2009): A climate profile indicator based comparative analysis of climate change scenarios with regard to maize (Zea mays L.) cultures. Applied Ecology and Environmental Research 7(3): 199-214.

[7] Erdélyi, É. (2009): Sensitivity to climate change with respect to agriculture production in Hungary. In: van Henten, E.J., Goense, D., Lokhorst, C. (eds): Precision Agriculture '09. Wageningen Academic Publisher, pp. 559-567.

[8] Fodor, N., Pásztor, L. (2010): The agro-ecological potential of Hungary and its prospective development due to climate change. Applied Ecology and Environmental Research 8(3): 177-190.

[9] Ladányi, M., Persely, Sz., Nyéki, J., Szabó, T., Soltész, M., Szabó, Z. (2010a): Climatic indicators regarding the rest period of sour cherry. International Journal of Horticultural Science 16 (4): 49-52.

[10] Ladányi, M., Persely, Sz., Szabó, T., Szabó, Z., Soltész, M., Nyéki, J. (2010b): Climatic indicator analysis of blooming time for sour cherries. International Journal of Horticultural Science 16 (1): 1-16.

[11] Linstone, A., Turoff, M. (1975): The Delphi method: Techniques and applications. Reading, MA: Addison Wesley.

[12] Simon, G. (2006): Review on rain induced fruit cracking of sweet cherries (Prunus avium L.), its causes and the possibilities of prevention. International Journal of Horticultural Science 12 (3): 27–35.

[13] Szenteleki, K., Gaál, M., Mézes, Z., Soltész, M., Nyéki, J., Szabó, Z. (2010): Correlation of precipitation distribution and quality sweet cherry production. International Journal of Horticultural Science 16(4): 39-43.

[14] Szépszó, G., Horányi, A. (2008): Transient simulation of the REMO regional climate model and its evaluation over Hungary. Idojaras 112(3-4): 213-232.

[15] Torma, Cs., Bartholy, J., Pongrácz, R., Barcza, Z., Coppola, E., Giorgi, F. (2008): Adaptation and validation of the RegCM3 climate model for the Carpathian Basin. Idojaras 112(3-4): 233-247.

[16] Torma, Cs., Coppola, E., Giorgi, F., Bartholy, J., Pongrácz, R. (2010): Validation of a high resolution version of the regional climate model RegCM3 over the Carpathian Basin. Journal of Hydrometeorology 12: 84-100.