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THE ECONOMIC IMPACT OF CLIMATE CHANGE - EVIDENCE FROM GRAPE OUTPUT AND RANDOM FLUCTUATIONS IN WEATHER

Agatha POPESCU[1], Viorica ENACHE[2], Cristina SIMION[3], Alina DONICI[4], Gabriel TABARANU[5]

Abstract. Grape Yield and Quality have been studied for 11 vine types (White Feteasca, Royal Feteasca, Aligote, Sarba, Cabernet Sauvignon, Merlot, Black Babeasca, Black Feteasca, Chasselas Dore, Hamburg Muscat and Black selected Coarna) in close relation to weather conditions in the years 2007 and 2008 at Bujoru Vineyard in the South Eastern Romania. The Index Method, Gain Method, Share Method, Comparison Method have shown the evolution and importance of 22 climate factors and their impact upon grape yield, production and quality. Important differences have been noticed by vine type concerning grape yield and quality. The increased level of climate factors in the year 2008 compared to 2007 determined an increased acidity, grape weight and volume, but a decreased sugar content for almost all the vine types.

Key words: economic impact, climate change, grape, production

1. Introduction

Climate change has a deep impact on physical and biological systems in many regions of the world and this process is expecting to continue in the coming years. According to IPPC Working Group, in the 20th century, the average surface temperatures at world level have increased by 0.6 – 0.9 degrees and in the 21st this warming trend will continue so that in 2010 temperatures will be 1.4 to 5.8 degrees higher than 1990[16].

This world trend varies by region and would lead to changes in the variability of climate and in frequency and intensity of some extreme phenomena.The vulnerability of the bio systems depends on their social, economic and environment conditions. [3, 4, 15].

[1] Prof. Ph D., University of Agricultural Sciences and Veterinary Medicine, Bucharest, Romnania, Full Member of the Academy of Romanian Scientists, (e-mail: agatha_popescu@yahoo.com).
[2]PhD, Senior Researcher, Bujoru Research and Development Station for Viticulture and Vinification, Galatzi County, Romania
[3]Ph.D., Senior Researcher, Bujoru Research and Development Station for Viticulture and Vinification, Galatzi County, Romania
[4]PhD, Researcher, Bujoru Research and Development Station for Viticulture and Vinification, Galatzi County, Romania
[5]PhD, Researcher, Bujoru Research and Development Station for Viticulture and Vinification, Galatzi County, Romania

The impacts of climate change on agriculture will differ by region [5, 11,16].While in some regions agricultural production may decrease, e.g. due to decreasing crop productivity or losses in acreage, in other regions it may benefit from warmer and more humid climate. Producers will respond to climate-induced changes in production conditions by changing their behavior and therefore, lessen direct negative effects and, respectively, strengthen the direct positive ones.

More and more research studies are focused on the assessment of climate change economic effects [3, 4, 5, 8, 11, 15, 16]. Direct climate impacts affecting agricultural production can be modeled as changes in parameter values of production functions or as changes factor endowments. Information on the magnitude of qualitative and quantitative changes in the production function of the agricultural sector can be derived from physical impact studies [5, 8]. Taking into account that climate change has a regional impact, various simulations with regionalized climate economy models have been already carried out [3].Other studies have developed integrated ecological-economic models, encompassing climate scenarios, agro-ecological zoning information, socio-economic drivers as well as world food trade dynamics [8].

World climate change has a deep impact upon viticulture in terms of growing areas, grape production, product quality and efficiency [1, 2]. Predicted changes in the climate of European viticultural regions over coming decades may alter significantly both the spectrum and the distribution of grape varieties currently used [2]. Due to the higher temperatures, the traditional limits for grapevine cultivation are changed and also phenological aspects, grape production and quality as happened in the Western Europe, mainly in France during the last 15 years [6,18]. EXPERT systems have been set up in order to monitories the global climate factors affecting ecological items, vine growing technologies, plant protection and economic performances in the vineyards situated in the hilly areas [18]. Various scenarios for the future global climate change are set up (HadCM3 climate model, general circulation models GFDL, GISS, OSU, UKMO), forecasting an increase of the average global warming by 2.04 ºC in the period 2000-2049 and in Europe by 2.5 ºC- 4.5ºC in summer and by 3.5 ºC - 6 ºC in winter. In such a situation, vine growing could be extended from Northern England to Ukraine and Southern Russia, from Northern Ireland to Southern Denmark. Besides temperature, the environment factors could also affect the vegetation evolution and production [6]. Global warming could determine desertification and affect viticultural ecosystems [6,7]. Grape and wine production in close relationship to economical and financial aspects must not be neglected [9,10, 12,13,14]. Climate change projections are used to produce ‘cost’ impact models and viticulture-suitability maps.

In Romania, climate change impact in viticulture is also approached because viticulturists are facing new climate conditions and they have to adapt their busin ess in consequence. Research results have shown some changes in vine phenology during the vegetation period and also concerning grape yield and quality under various weather conditions [6, 7, 12, 14, 15].

In this context, the paper aims to evaluate the economic impact of climatic change upon grape production and its quality at Bujoru Vineyard situated in the hilly area of Eastern Romania.

2. Experimental Details

The experiments were carried out at Bujoru Research and Development Station, Galatzi County, Romania. A number of 11 vine types were used on a surface of 148 ha as follows: White Feteasca 49 ha, Royal Feteasca 12 ha, Aligote 17 ha, Sarba 11 ha for white wine grapes, Cabernet Sauvignon 5 ha, Merlot 14 ha, Black Babeasca 12 ha, Black Feteasca 1 ha for red wine grapes, Chasselas Dore: 17 ha for white table grapes, Hamburg Muscat 6 ha and Black selected Coarna 4 ha for red table grapes. The soil characteristics were : specific weight 2.65 g/cubic cm, total porosity 54.8 %, air porosity 28.5 %, hygroscopic coefficient 3.43 %, whithering coefficient 611 m^3/ha, field capacity 2,615 m^3/ha, total capacity 6,083 m^3/ha, volumetric weight 1.19 g /cm^3. The following climate factors were analyzed: global, active and useful thermic balance, annual rainfalls and also during the vegetation period, annual average temperature and also average temperature in July, August and September, air minimum temperature, maximum average in August, average temperature in the 1st and 2nd decade of June, wind speed, air moisture, nebulousness, the number of days with maximum temperatures, the length of bioactive period, the real heliothermic index, hydrothermic index, the bioclimate index of vine and oenoclimatic index. Also, the following economic indicators were studied: average and total grape production, grape quality (sugar content, the volume of 100 grape berries, grape average weight).

The following methods were used: ***Index Method*** for analyzing the variability of 22 climate characteristics (marked with X) for the period B - Control year 2007 and C - Experimental year 2008. The individual indices of climate factors were calculated and interpreted according to the formulas: $R_i = XC_i/XB_i$, where: i=1,…,22, if $R_i > 1$, i factor is increasing and if $R_i < 1$, i factor is decreasing and if $R_i = 1$, the i factor is constant ; ***Gain Method***, using the formula: $S_i = R_i - 1$, where S_i = the gain of the i climate factor and R_i, as above; if $S_i > 1$, i factor is increasing ; if $S_i < 1$, i factor is decreasing and if $S_i = 1$, the i factor is constant ; ***Share Method*** for ranking the climate factors based on their importance, using the formula : $P_i = |S_i| * 100 / \Sigma |S_i|$, where P_i = the weight of the climate factor and S_i = the gain of the climate factor; ***Point Method*** for ranking the vine types based

on the grape production and quality; ***Comparison Method*** for analyzing grape production from a year to another and among various types of vine. All the calculations have been done for 1 ha surface, but also for the whole cultivated area for each vine type.

3.Results and Discussions

3.1. Climate Factors.

The weather situation characterized by 22 main climate indicators in the year 2008 compared to the year 2007 is presented in Table 1. In the year 2008, an increased level was noticed for thermic balance, average annual temperature and also temperature in the month of August, the air minimum temperature and the average maximum temperature in August, wind speed, air relative humidity and the bioclimatic index.

Tabel 1. Individual indices, gains and shares of the climatic factors at Bujoru Research and Development Station, Galatzi

Climatic Factor	Individual index of the climatic factor	Gains, S_i	Shares, $P_{i\,\%}$
Global thermic balance (Σt°g)	1.006	0.64	0.303
Active thermic balance (Σt°a)	1.007	0.75	0.355
Useful thermic balance (Σt°u)	1.009	0.91	0.431
Σ annual rainfalls (mm)	0.515	-48.47	22.948
Σ rainfalls during the vegetation period (mm)	0.883	11.47	5.525
Σ sunstroke hours during the vegetation period	0.902	9.79	4.635
Average annual temperature,°C	1.037	3.70	1.752
Average temperature in July,°C	0.854	-14.59	6.907
Average temperature in August, °C	1.015	1.57	0.743
Average temperature in September,°C	0.982	-1.72	0.814
Air Minimum temperature,°C	1.110	7.41	3.508
Maximum average temperature in August,°C	1.045	4.58	2.168
Average temperature in the 1st and 2n decades of June	0.869	-13.10	6.020

Wind speed (km/hours)	1.304	30.43	14.407
Air relative humidity (%)	1.052	5.26	2.490
Nebulousness	1.071	7.14	3.380
Number of days with maximum temperatures > 30 °C	0.787	-21.21	10.042
The length of bioactive period, days	0.994	-0.56	0.265
The real heliothermic index	0.909	-9.09	4.304
Hydrothermic coefficient	0.857	-14.29	67.65
Bioclimatic index	1.026	2.61	1.236
Oenoclimatic index	0.982	-1.73	0.819
		$\Sigma \mid S_i \mid = 211,22$	100.00

The decreasing ranking of the climatic factors is: annual rainfalls, wind speed, the number of days with temperatures higher than 30 °C, average temperature in July and the 1st and 2nd decades of June, hydrothermic index, rainfalls during the vegetation period and heliothermic index. The other climate factors are less important.

In 2008, the annual rainfalls counted for 285.7 mm, by 50 % less than in 2007. During the vegetation period, the rainfalls reached 224. 8 mm in 2008 compared to 254.5 mm in 2007. The sunstroke counted for 1,332.7 hours compared to 1,477.4. The average temperature in July was 24 °C compared to 28.1 °C. The average temperature was 25.9 °C in August and 17.1 °C in September. The minimum temperature was –14.5 °C compared to 13 °C. The maximum temperature in August was 32 °C compared to 30.6 °C in the same month in 2007. The bioactive period has ranged between 177-178 days in the same years. The heliothermic index was 250 in 2008 compared to 275 in 2007. The hydrothermic index was 0.6 in 2008 compared to 0.6 in 2007.The bioclimatic coefficient was 11.8 in 2008 compared to 11.5 in 2007 and the oenoclimatic coefficient was 2.

3.2. Grape Yield.

Grape yield has varied by vine type but also from a year to another because of the different climate conditions (Table 2).

Tabel 2. Grape Yield by vine type in 2007 and 2008 at Bujoru Vineyard

Vine Type	Grape Yield / Position in 2007	Grape Yield / Position in 2008	Yield Gain – kg 2008-2007	Differences % 2008-2007
White Feteasca	5,307/3	8,300/7	2,993	156.39
Royal Feteasca	7,119/1	13,188/1	+6,069	185.25
Cabernet Sauvignon	2,720/9	7,650/10	+4,930	281.25
Muscat Hamburg	1,163/11	11,438/4	+10,267	983.49
Black Coarna	1,350/10	9,010/5	+7,660	667.40
Merlot	2,888/8	8,800/6	+5,912	304.70
Black Babeasca	3,677/5	7,547/11	+3,870	205.24
Black Feteasca	3,515/6	8,000/9	+4, 485	227.59
Chasselas Dore	4,000/4	13,000/2	+9,000	325.00
Aligote	6,290/2	8,200/8	+1,910	130.36
Sarba	3,500/7	11,700/3	+8,200	334.28

In the year 2007, grape yield varied between 1,163 kg ha for Hamburg Muscat type and 7,119 kg/ha for Royal Feteasca. Vine classification based on grape yield is the following one: Royal Feteasca, Aligote, White Feteasca, Chasselas Dore, Black Babeasca, Black Feteasca, Sarba, Merlot, Cabernet Sauvignon and Hamburg Muscat. In the year 2008, grape yield was higher than in 2007 for all the vine types varying between 13,188 kg/ha for Royal Feteasca and 7,547 kg/ha for Black Babeasca, reflecting a favorable influence of the climatic factors. In order, the vine type ranking in 2008: Royal Feteasca, Chasselas Dore, Hamburg Muscat, Black selected Coarna, Merlot, White Feteasca, Aligote, Black Feteasca, Cabernet Sauvignon and Black Babeasca.

3.3. Grape Production.

Grape Production has been determined both by grape yield and the cultivated area by each vine type. In the year 2007, total grape production varied between 260,043 kg at White Feteasca and 3,515 kg at Black Feteasca**.** The hierarchy of the studied types based on grape production was: White Feteasca, Aligote, Royal Feteasca, Chasselas Dore, Black Babeasca, Merlot, Sarba, Cabernet Sauvignon, Muscat Hamburg, Black Coarna Black Feteasca. In 2008, grape production varied between 406,700 kg for White Feteasca and 8,000 kg for Black Feteasca. The decreasing order of the vine types was White Feteasca, Chasselas Dore, Royal

Feteasca, Aligote, Sarba, Merlot, Black Babeasca, Hamburg Muscat, Cabernet Sauvignon, Black Coarna and Black Feteasca (Table 3).

Table 3. Grape Production by vine type in 2007 and 2008 at Bujoru Vineyard

Vine Type	Grape Production/ Position in 2007	Grape Production / Position in 2008	Production Gain – kg 2008-2007	Differences % 2008-2007
White Feteasca	260,043/1	406,700/1	+ 146,657	156.39
Royal Feteasca	85,428/3	158,000/3	+75,572	185.25
Cabernet Sauvignon	13,600/8	38,250/9	+24,650	281.25
Muscat Hamburg	6,978/9	68,620/8	+61,642	983.49
Black Coarna	5,400/10	36,040/10	+30,640	667.40
Merlot	40,432/6	123,200/6	+82,768	304.70
Black Babeasca	44,124/5	90,564/7	+46,440	205.24
Black Feteasca	3,515/11	8,000/11	+4,485	227.59
Chasselas Dore	68,000/4	221,000/2	+153,000	325.00
Aligote	106,930/2	139,400/4	32,470	130.36
Sarba	38,500/7	128,700/5	+90,200	334.28

3.4. Grape Quality

Grape quality has been analysed using the main characteristic parameters: sugar contant, acidity, weight of 100 berries, volume of 100 berries and grape average weight (Tabel 4). Compared to 2007, in 2008 **sugar content** increased by 34 g for Black Babeasca, by 10 g for Royal Feteasca, but it has remained constant for White Feteasca and decreased in case of the other types. **Acidity** increased for Cabernet Sauvignon, Black Babeasca, Hamburg Muscat, Black Coarna, Black Feteasca, Chasselas Dore, Aligote and Sarba, and decreased for Royal Feteasca and Merlot and remained constant for White Feteasca comared to the year 2007. In 2008, **the weight of 100 berries** increased for White Feteasca (+59 g), Royal Feteasca (+64 g), Hamburg Muscat (+91 g), Black Coarna (+ 74 g), Black Babeasca (+ 37 g), Chasselas Dore (+37 g) and Sarba (+ 39 g), while in case of Cabernet Sauvignon, Black Feteasca,Merlot and Aligote it registered a decrease compared to 2007. In 2008, **the volume of 100 berries** increased in case of White Feteasca alba (+ 15 m^3), Royal Feteasca (+ 34 m^3), Hamburg Muscat (+ 100 m^3), Black Coarna (+ 132 m^3), Merlot (+ 6 m^3), Chasselas Dore (+ 43 m^3) and Sarba (+

43 m^3), while for Carbernet Sauvignon, Black Feteasca, Black Babeasca and Aligote decreased compared to 2007.

Table 4. Grape Quality in 2007 and 2008 at Bujoru Vineyard

Vine type	Year	Sugar Content g/l must	Acidity g/l must H2SO4	Weight of 100 berries-g	Volume of 100 berries m^3	Average grape weight - g
White Feteasca	2007	220	3,3	79	84	90
	2008	220	3,3	120	99	90
Royal Feteasca	2007	200	4,3	89	94	89
	2008	210,4	3,64	153,4	120	92
Cabernet Sauvignon	2007	223	2,4	127	95	45
	2008	167,68	6,38	67	60	97
Hamburg Muscat	2007	229	2,35	220	200	80
	2008	195,2	3,52	311,5	300	185
Black Coarna	2007	215	2,69	200	180	102
	2008	154	3,55	274,68	312	300
Merlot	2007	231	3,64	107	82	50
	2008	214	3,30	104	88	85
Black Babeasca	2007	190	3,6	168,5	180	90
	2008	224	4,03	205,64	124	139
Black Feteasca	2007	218	2,56	153	137	59
	2008	213	2,84	97	85	152
Chasselas Dore	2007	206	2,1	120	100	54
	2008	173,2	3,14	157,93	143	103,2
Aligote	2007	212	1,98	140	122	84
	2008	175	3,98	96	92	95
Sarba	2007	243	2,79	110	90	78
	2008	202,8	4,2	149,28	133	155,4

In 2008, **the grape average weight** increased as follows: Black Coarna (+202 g), Hamburg Muscat (+105 g), Black Feteasca (+93 g), Sarba (+77 g), Cabernet Sauvignon (+ 52 g), Black Babeasca (+ 49 g), Chasselas Dore (+49 g), Merlot (+35 g), Aligote (+11 g), Royal Feteasca (+ 3 g). Only White Feteasca remained with the same grape average weight.

3.4. Vine Hierarchization according to Grape Quality

Considering the lowest number of points as the best result, meaning the highest grape quality, the hierarchy of vine types in the decreasing order is Hamburg Muscat, Black Coarna, Black Babeasca, Chasselas Dore, Sarba, Black Feteasca, White Feteasca, Royal Feteasca, Merlot, Aligote, Cabernet Sauvignon (Table 5).

Table 5. Hierarchy of Vine Types based on Grape Quality in 2008 at Bujoru Vineyard

Vine Type	Sugar Content g/l must	Acidity g/l must H2SO4	Weight of 100 berries-g	Volume of 100 berries m^3	Average grape weight g	Total points/ Position
White Feteasca	2	3	7	7	10	29/7
Royal Feteasca	5	5	5	6	9	30/8
Cabernet Sauvignon	10	9	11	11	7	48/11
Hamburg Muscat	7	4	1	2	2	16/1
Black Coarna	11	4	2	1	1	19/2
Merlot	3	3	8	9	11	34/9
Black Babeasca	1	7	3	5	5	21/3
Black Feteasca	4	1	9	10	4	28/6
Chasselas Dore	9	2	4	3	6	24/4
Aligote	8	6	10	8	8	40/10
Sarba	6	8	6	4	3	27/5

Conclusions

The weather conditions have been different in the year 2008 compared to the year 2007. An warming trend has been noticed with a direct impact upon grape yield and mainly upon grape quality.

Compared to 2007, in 2008 a higher level was registered for average annual temperature, average temperature in August, air minimum temperature, maximum average temperature in August, wind speed, air relative humidity and bioclimatic index.

The ranking of the climatic factors according to their importance is: average annual rainfalls, wind speed, number of days with maximum temperatures higher

than 30 °C, average temperature of July, the hydrothermic coefficient, the average temperature in the 1st and 2nd decades of June, rainfalls during the vegetation period, sunstroke hours, real heliothermic index, air minimum temperature, nebulousness, air relative humidity, average temperature in August, annual average temperature, bioclimatic index.

In the year 2008, grape yield was higher than in 2007 for all the vine types varying between 7,547 kg/ha for Black Babeasca and 13,188 kg/ha for Royal Feteasca. Total grape production was also higher, the production gain varying between 883 % for Hamburg Muscat and 30 % for Aligote.

In climate factors of the year 2008 an increased acidity, grape weight and volume, but a decrease in sugar content for almost all the vine types (Black Babeasca, Royal Feteasca, White Feteasca, Hamburg Muscat, Black Coarna, Chasselass Dore, Merlot).

Climate change has to be taken into consideration concerning grape production and quality in close relation to vine type.

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References

[1] Anderson K., C. C. Findley, S.Fuentes, S.Tyerman (2008), Viticulture, Wine and Climate Change,in "Garnaut Climate Change Review",Australia, 2008, www.garnautreview.org.au.

[2] Chiriac Cristina, Influence of climate change upon environment in the Cotnari Vineyard, Annals of Stephan the Great University, Suceava, Romania, XVI, 2007, http:// www. atlas.usv.ro/www/anale/datagrid

[3] Deke O., K..G.Mooss, Christiane Kasten, G.Klepper, Katrin Springer, Economic Impact of Climatic Change: Simulations with a Regionalized Climate Economy Model, Kiel Institute of World Economics, Kiel Working Paper No.1065, p.34-44, Kiel, Germany, 2001

[4] Deschenes O. and M.Greenstone, The Economic Impacts of Climatic Change: Evidence from Agricultural Output and Random Fluctuations in Weather, American Economic Review, 97 (1), 354-385, USA, 2007

[5] Diffenbaugh N.S., Giorgi F., Raymond L. and X.Bi, Indicators of 21st Century socio-climatic exposure, Proceedings of National Academy of Sciences, USA, 104:20195-21198, 2007.

[6] Enache Viorica, Simion Cristina, Donici Alina, Popescu Agatha**,** Aspects of the Desertification risk in the South of Moldova, Romania, Conference on Desertification, Ghent, Belgium, 23 January 2008, "Combating Desertification, Assessment, Adaptation and Mitigation Strategies", p.41-46, UNESCO Chair of Eremology, Ghent, Belgium, 2008

[7] Enache Viorica, Simion Cristina, Donici Alina, Tabaranu G., Popescu Agatha, Research concerning the global climatic changes and their influence on viticultural ecosystem in Dealu Bujorului vineyard, The 3rd International Workshop – Environment/Nutrition/Health relationship in the frame of EU Policy, BENA, www.sia.ugal.ro/bena-workshop/topics.html,The Journal of EPE, www.gen.teithe.gr/-bena, 2009

[8] Gunter Fisher, M.Shah, F.Tubiello, Harrij van Velhizen, Socio-Economic and Climatic Change Impacts on Agriculture: an integrated assessment, 1990-2080, Philosophical Transactions of the Royal Society, http:// rstb. royalsocietypublishing.org, 2005

[9] Hayes Peter, The Climate as a Factor for Wine Valorisation, International Congress of Climate and Viticulture, Zaragoza, Aragon, Spain, 1-10 april, 2007

[10] Jones G.,Climate Change: Observations, Projections and General Implications for Viticulture and Wine Production, Whitman College, W.P.7, http://dspace. lasrworks. org/bitstream

[11] Nordhaus W., Reflection on the Economic of Climate Change, J.of Economic Pespectives, vol.7, No.4, Fall 1993, p.11-25.

[12] Popescu Agatha, Simion Cristina, Tabaran G., Simion Ion, A comparative study concerning the economic efficiency in the producing of high quality grafted vines, Annals of Craiova University, Vol.XIII (XLIX), Craiova, Romania, 2008

[13] Schultz H., Climate Change and Viticulture: A European perspective on climatology, carbon dioxide and UV-B effects. Australian Society of Viticulture and Oenology Inc. Journal of Grape and Wine Research 6(1): 2-12, www.InterScience.Wiley.com, Australia, 2008

[14] Simion Cristina, Enache Viorica, Donici Alina, Popescu Agatha, Research concerning the world climate change upon the vegetative evolution of vine in Dealu Bujorului Vineyard, Romania, 31st World Congress of Vine and Wine, June 15-20, 2008, Verona, Italia, segreteria.scientifica@oiv2008.it

[15] Popescu Agatha, Enache Viorica, Simion Cristina, Donici Alina, Tabaranu G., Research concerning the Economic Impact of Climate Change upon Grape Production, Bulletin UASVM Cluj, 66(1-2), p.366-372, 2009, Cluj Napoca, Romania

[16] xxx Climate Change 2001. 3rd Assessment Report of the Intergovernmental Panel on Climate Change IPCC (WG I and II), Cambridge University Press, Cambridge, UK, 2001