Environmental Science and Pollution Research (2019) 26:9908–9915
https://doi.org/10.1007/s11356-019-04214-1

RESEARCH ARTICLE

Orchard management under the effects of climate change: implications for apple, plum, and almond growing

Manuel Alexandru Gitea[1] · Daniela Gitea[2] · Delia Mirela Tit[2] · Lavinia Purza[2] · Alina Dora Samuel[3] · Simona Bungău[2] · Gabriela Elena Badea[4] · Lotfi Aleya[5]

Received: 11 June 2018 / Accepted: 9 January 2019 / Published online: 9 February 2019

Abstract

The authors analyzed certain species and varieties of fruit tree in which applied crop technology is used and also undergoes the effects of climate change. The aim is to extend productive crop varieties, resistant to disease and pests, in order to obtain superior yields. The research was conducted in orchards located in northwestern Romania (on 8.59 ha), intensively cultivated with apple, plum, and almond species. The blooming period of the species and fruit production was studied in 2009, the first year of the farm's commercial production, and then compared to figures from 2016 to see the changes that occurred. Climatic conditions were studied throughout the period of existence of the farm (2002–2016). To determine the influence of the climatic factor on the blooming and production periods, respectively, every year is considered having pre-blooming, blooming, and ripening periods. It was found that climate change influences the annual biological cycle of the trees: the vegetative rest period of the trees shortens, the tree vegetation begins earlier in the spring, and the blooming period is advanced by as much as 10 days compared to normal cultivated varieties. All these factors have direct repercussions on the quantity of production.

Keywords Sustainable production · Climate changes · Agricultural area · Management

Introduction

Over the last century, the European climate has warmed by almost one degree, faster than the globally recorded average. Evidence clearly indicates that almost all natural, biological, and physical processes are reacting to climate changes in Europe and around the world. More than half of Europe's plant species may be threatened with extinction by 2080. Climate changes are expected to reduce access to drinking water, to increase the risk of ecosystem extinction, to reduce biodiversity, and also to increase the number of pests (Metz et al. 2005; European Council 2014; European Commission n.d.).

It is anticipated that almost all of Europe's regions will be negatively affected by future climate changes, which will bring challenges in many economic sectors. The 4th IPCC (Intergovernmental Panel on Climate Change) published a comprehensive summary of the latest results on the various causes of the changes and the immediate or long-term impact based on different scenarios (Metz et al. 2005).

Under Romanian climatic conditions, the most prevalent abiotic stress factors are not only rainfall deficiency or surplus, low temperatures during winter and spring, but also summer heat, hailstorms, insufficient soil fertility, and poor structure (faulty aero hydric regime), to which must be added the biotic stress factors of disease, pests, and competing plants. Concerning precipitation, some regions will be better off than is currently the case, while a reduction in water volume is anticipated in others. The distribution of the general level of exposure to climate change shows that the counties

Responsible editor: Philippe Garrigues

✉ Lotfi Aleya
lotfi.aleya@univ-fcomte.fr

[1] Department of Agriculture, Horticulture, Faculty of Environmental Protection, University of Oradea, 26 Gen. Gh. Magheru Blvd., 410048 Oradea, Romania

[2] Department of Pharmacy, Faculty of Medicine and Pharmacy, University of Oradea, 29 Nicolae Jiga St., 410028 Oradea, Romania

[3] Department of Biology, Faculty of Sciences, University of Oradea, 1 Universitatii St., 410087 Oradea, Romania

[4] Department of Chemistry, Faculty of Sciences, University of Oradea, 1 Universitatii St., 410087 Oradea, Romania

[5] Laboratoire Chrono-Environnement, UMR CNRS 6249, Université de Franche-Comté, F-25030 Besançon, France

(administrative divisions) in the country's extreme northwest, north, and center (Bihor, Timis, Satu Mare, Cluj, Salaj, Alba Iulia, and Hunedoara) fall into high-risk zones. However, the counties with important agricultural areas, located in western and northwestern Romania (Timis and Arad), will be the most exposed, with the maximum risk encountered in Arad County (Meita et al. 2011; Cuculeanu et al. 2012).

The soils of these regions are in a continuous process of accelerated degradation, which inevitably leads to decreased soil fertility. From the degree with which the soil is re-supplied with the main ingredients—nitrogen, phosphorus, potassium, etc.—it is now known that, once lost through erosion, the elements can no longer be restored to their initial form through application of fertilizers. Erosion induces changes in the amount of organic carbon in the upper layer of arable soil, with estimated losses of 22% of organic carbon within the next 50 years, demonstrating that the arable soil, too, is a dynamic ecosystem that is rapidly changing (Doetterl et al. 2012).

The disturbance of the dynamic balance of the soil has important consequences for its evolution. Addition of soluble salts into the soil (through inappropriate mineral or organic fertilizers) results in attacking the accumulated organic dowry of the soil and also in acidification. The irrational use of mineral fertilizers has often led to the pollution of ground and surface waters with nitrates. Previous studies by the authors and others have presented the impacts on the quality and characteristics of agricultural soil (Masu et al. 2013) of unwise management of discharges and wastes: (1) household and institutional (Bungau et al. 2018; Ionescu et al. 2015; Popescu et al. 2016a, b; Rada et al. 2009, 2016; Tit et al. 2016), (2) animal (Burkholder et al. 2007), (3) medical and pharmaceutical (Tit et al. 2016), (4) chemical (Balint et al. 2013; Balint et al. 2014; Diaconu et al. 2010; Dumitrel et al. 2017; Vica et al. 2014), and (5) petroleum (Diaconu et al. 2010).

Adequate education of people in the areas of energy saving and environmental protection also plays an important role in the preservation of the quality of the environment. In addition, entrepreneurs in the field must learn to administer their agro-businesses with environmental quality in mind (Badulescu et al. 2015; Bungau et al. 2014; Popescu et al. 2016a; Prada et al. 2016, 2017).

The objective of this study is to analyze the influence of climate changes on blooming period and fruit production of three fruit trees namely apple, plum, and almond, so as to extend productive varieties resistant to disease and pests in Bihor County (Romania).

Materials and methods

The investigation was conducted on an orchard located in Bihor County, Romania (Latitude: 46° 57′ 55.464″ North, Longitude: 21° 44′ 8.249″ East), which has a surface of 8.59 ha—a compact area—with apple, plum, and almond trees grown within an intensive cultivation system. An illustrated map of the orchard is presented in Fig. 1.

Characteristics of the species' blooming period and fruit production were studied in 2009, the first year of the farm's commercial production, and then compared to figures presenting the same characteristics in 2016. Climatic conditions were studied throughout the farm's period of existence (2002–2016).

To determine climatic factor influence on blooming and production periods, respectively, the year is presented in pre-blooming, blooming and ripening periods. The following observations, determinations, and analyses were made for the studied varieties (Gitea 2008; Martin-Lara et al. 2017; Zavtoni 2017).

Blooming period

The trees were observed on a daily basis; the blooming period was calculated from the date of appearance of the first bloom until the date when the petals had fallen. The average blooming period length was calculated for the total number of years of the study.

Blooming intensity

The orchard was visited daily and blooming intensity was rated on a scale of 0 (zero floral induction) to 5 (maximum floral induction). Observations of bloom intensity were made in the middle of each blooming period, and an average was calculated for the total number of years of the study.

Fig. 1 Map of the studied parcels: 1—plum, 2—apple, 3—almond

Harvesting maturity

Beginning on July 10th every year, each variety was examined, noting the dates, respectively, when the endocarp (1) of the first fruits began to crack and (2) of the last fruits began to unfold. Depending on the cultivated varieties, the data herein represent the study-year averages for the species of almond, apple, and plum. Recordings were made from the emergence of the first ripened fruit to the end of maturation.

Fruit production

To evaluate fruit production, the fruit of 12 trees was completely harvested and weighed in kilograms per tree. The sum of the 12 trees was calculated, and the amount of fruit per variety was determined and reported per hectare.

Farming interventions

Since the establishment of the farm, to date, no chemical fertilizers have been used and no irrigation has been carried out. Orchard maintenance works were different, depending on the stage of tree development, as follows:

- For the first 4 years since planting, the crown was developed for each species. The soil was maintained by repeated works with the milling machine and the disc on the tree intervals, and on each row of trees, the mowing and the weeding were carried out manually.
- From the fifth year of planting, when the trees entered the fruit and made commercial productions, during the vegetative rest period were also made cuttings, phytosanitary treatments, and fertilization with organic fertilizers, which were incorporated into ground. During the vegetation period, the soil was maintained by repeated works with the milling machine and the disc on the tree intervals, and on each row of trees, the millings combined with the mowing were carried out manually.

Phytosanitary treatments and their influence on the fruit quality are detailed elsewhere (Gitea et al. 2018) and can be summarized as follows: treatments were performed at the optimum time, considering tree growth phenophases and appearance of diseases and pests. Additionally, phytosanitary treaty took into account all warning bulletins and forecasts issued by the County Phytosanitary Authority (Gitea et al. 2018).

Statistical analysis

Statistical analysis was performed using SPSS 19. The statistical significance was calculated by the Student's t and χ^2 tests. Statistical significance was assigned at a p value of < 0.05.

Results

Influence of climate changes on blooming period and fruit production

The northwestern part of Romania is a continental climate zone with prolonged droughts and an average annual temperature that has risen by 1 °C over the past 15 years. Some years, in 2007 and 2014, the average annual temperature showed an increase of 2.0 °C and in 2015 of 1.9 °C (Fig. 2). A decrease in rainfall of up to 17 mm was observed over the same period compared to the multiannual averages. In some years, very wide decreases were observed (up to 160–200 mm) (Fig. 3).

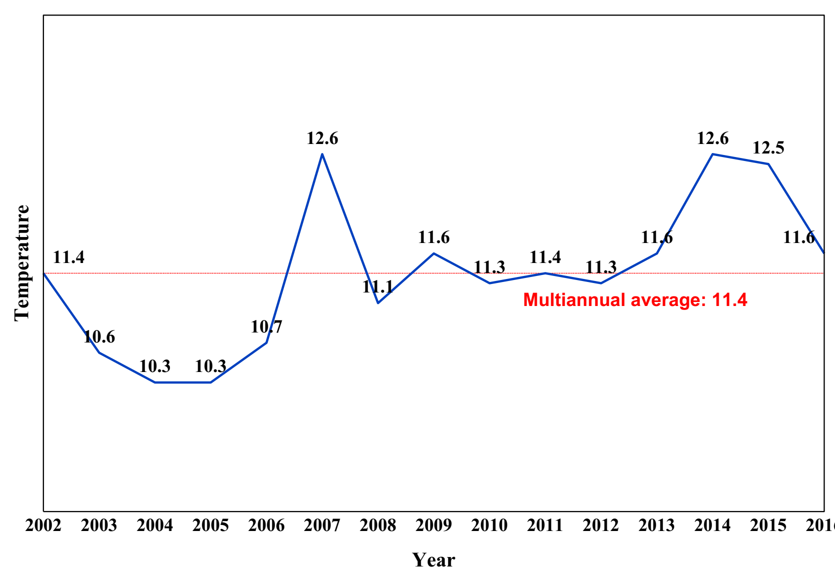

Fig. 2 Evolution of annual temperature in period 2002–2016, versus the multiannual average, in northwestern part of Romania

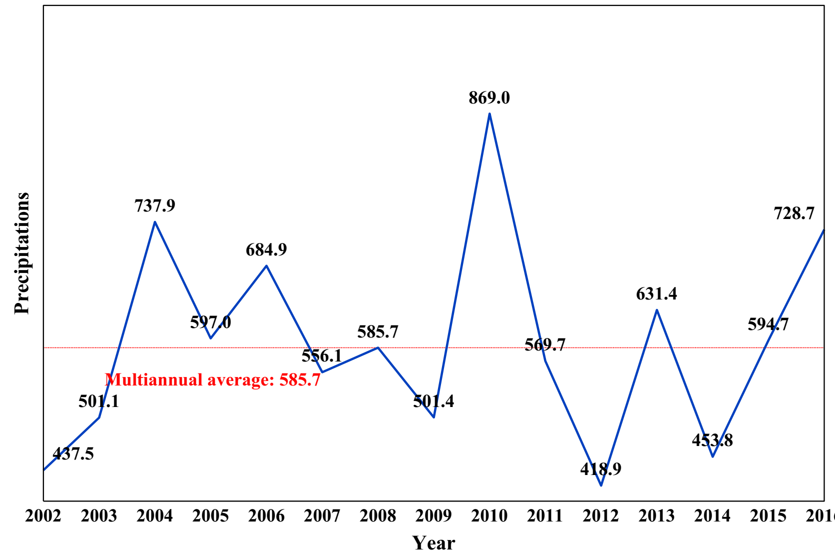

Fig. 3 The evolution of annual precipitations in period 2002–2016, versus the multiannual average, in northwestern part of Romania

Apple culture

For the apple trees, in the blooming period in 2016 as compared to 2009, a 6-day advance was observed in the Golden delicious variety and an advance of up to 10 days in the Golden of Bistrita. No significant differences in temperature were recorded in the October–March pre-blooming period (4.5 vs 4.4 °C, $p > 0.05$) and blooming period (14.4 vs 13.4 °C, $p > 0.05$), but significant differences are observed between the 2 years in the January–March period (1.6 vs 4.4 °C, $p < 0.01$). In terms of precipitation, significant differences are observed between the 2 years, regardless of period ($p < 0.01$) (Table 1).

In comparing apple production from the 2 years, significant differences are recorded in the Florina, Liberty, and Golden delicious varieties ($p = 0.056$, $p = 0.004$, and $p = 0.032$, respectively), but no significant differences for the Golden of Bistrita and Prima varieties ($p = 0.269$ and $p = 0.303$, respectively) (Fig. 4).

Plum culture

In the plum culture, in 2016 compared to 2009, the blooming period records a difference of 8 days for the Centenar and Anna Spath varieties and of 9 days for the Minerva and Stanley varieties. In terms of temperature, no

Table 1 Blooming period of apple varieties

Variety	Year 2009				Year 2016			
	Temp.*	Precip.**	Blooming		Temp.*	Precip.**	Blooming	
			Begin	End			Begin	End
Florina			14-IV	30-IV			06-IV	25-IV
Liberty			12-IV	28-IV			04-IV	20-IV
Golden delicious	4.5[1] 14.4[2]	243.7[1] 13.3[2]	16-IV	30-IV	4.4[1] 13.4[2]	342.4[1] 26.4[2]	10-IV	24-IV
Golden of Bistrita	19.6[3] 11.6[4]	244.4[3] 501.4[4]	16-IV	29-IV	19.9[3] 11.6[4]	359.9[3] 728.7[4]	06-IV	24-IV
Prima			12-IV	26-IV			05-IV	22-IV

Blooming period of apple varieties

[1] Pre-blooming period—October–March

[2] Blooming period—April

[3] Ripening period—May–September

[4] Annual

*Temp.—average temperature by period

**Precip.—total precipitation by period

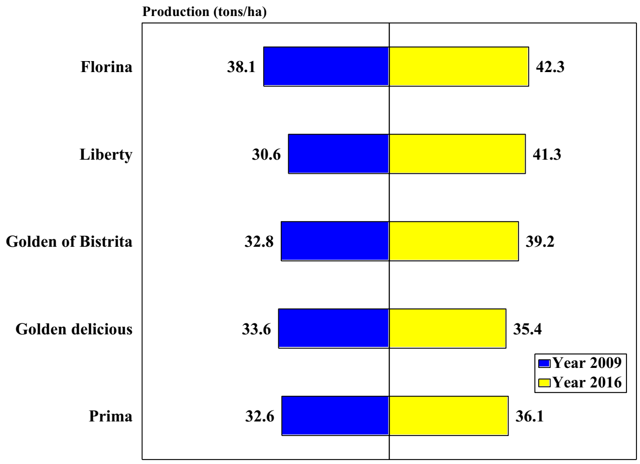

Fig. 4 Fruit production for apple varieties: 2009 comparative with 2016

significant differences are observed between the 2 years, regardless of the vegetation periods or varieties of plum ($p > 0.05$). As for precipitation, significant differences between the 2 years are observed, regardless of the vegetative period or fruit variety ($p < 0.01$) (Table 2). Comparing plum production for the 2 years, no significant differences are observed for any variety ($p = 0.549$ in Minerva, $p = 0.252$ in Centenar, $p = 0.1816$ in Stanley, and $p = 0.227$ in Anna Spath) (Fig. 5).

Almond culture

As for the almond culture, the blooming period in 2016 when compared to 2009 shows a difference of 2 days for the Cristi variety and of up to 10 days for the April variety. No significant differences are observed in terms of temperature in the pre-blooming period (6.2 vs 6.3 °C, $p > 0.05$), but there are significant differences between the 2 years in the blooming period (5.4 vs 6.9 °C, $p < 0.01$). In terms of precipitation, significant differences are observed between the 2 years, regardless of period or almond variety ($p < 0.01$) (Table 3).

In comparing almond production from the 2 years, significant differences appear for all varieties, except Vio and Adeluta ($p < 0.001$ in Sandi, April, Adria, Alexandru and Nicoleta, $p = 0.029$ in Cristi, $p = 0.183$ in Vio, and $p = 0.351$ in Adeluta) (Fig. 6).

Compared to 2009, the 2016 blooming period took place earlier with a number of days differing from species to species and from one variety to another.

Discussion

The obvious climate changes that have occurred throughout the world in the last few years have occurred in northwestern Romania as well. These changes have had a significant

Table 2 Blooming period for plum varieties

Variety	Year 2009				Year 2016			
	Temp.*	Precip.**	Blooming		Temp.*	Precip.**	Blooming	
			Begin	End			Begin	End
Minerva	9.2[1]	341.5[1]	10-IV	21-IV	8.2[1]	402.5[1]	01-IV	12-IV
Centenar	7.1[2]	252.1[2]	12-IV	22-IV	6.1[2]	375.4[2]	04-IV	14-IV
Stanley	5.4[3]	243.7[3]	14-IV	24-IV	4.4[3]	342.4[3]	05-IV	14-IV
Anna Spath	14.4[4]	13.3[4]	10-IV	22-IV	13.4[4]	26.4[4]	02-IV	11-IV
	20.1[5]	146.6[5]			20.1[5]	299.8[5]		
	20.6[6]	236.0[6]			20.3[6]	326.9[6]		
	19.6[7]	244.4[7]			19.9[7]	359.9[7]		
	11.6[8]	501.4[8]			11.6[8]	728.7[8]		

[1] August–March for Minerva
[2] September–March for Centenar and Stanley
[3] October–March for Anna Spath variety
[4] Blooming period—April, ripening period
[5] May–July for Minerva
[6] May–August for Centenar and Stanley
[7] May–September for Anna Spath
[8] Annual
*Temp.—average temperature: pre-blooming period
**Precip.—total precipitation: pre-blooming period

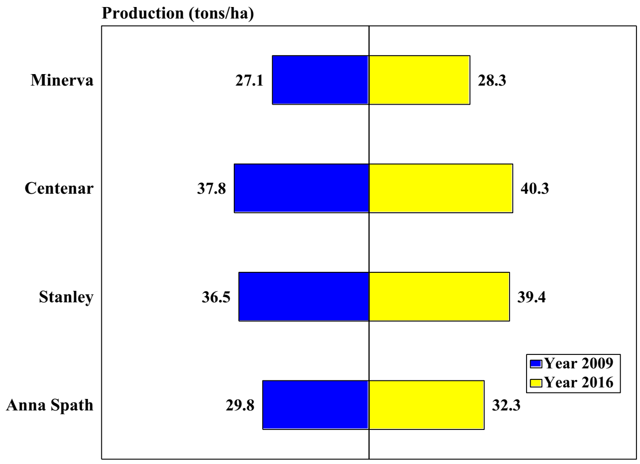

Fig. 5 Fruit production for plum varieties: 2009 comparative with 2016

influence on the annual biological cycle of fruit trees (with direct repercussions on the quality and quantity of fruit yield), especially via the early blooming period of the studied species. To achieve high fruit production yields, the following combination of factors is required: (1) modern technological equipment, (2) hybrids and varieties with high productive potential, (3) modern cropping technologies based on tillage according to fruit tree type, (4) modern methods of irrigation, (5) accentuated chemicalization based on use of both organic and mineral fertilizers, and (6) integrated management of diseases, pests and weeds, all of which imply the preservation of biodiversity and recourse to a skilled workforce.

In addition, soils differ as to their enzyme content since each soil type contains different amounts of organic matter and different organisms, which influence the intensity of biological processes (Cao et al. 2003; Moisa et al. 2018; Yang and Wang 2002). Thus, these soil-level enzymes (soil quality index) directly reflect ground changes (Samuel et al. 2017a, b). Enzymes are directly influenced by environmental conditions so that soil properties and the quality of the entire environment are reflected in the production of fruits, vegetables and other plants and also in the nutrient content of these crops (Bungau et al. 2003; Copolovici et al. 2017a, b; Taschina et al. 2017). Toxicity of microflora and micro-fauna in the soil has also been studied (Kikon and Maiti 2004; Samuel et al. 2018).

In this context, certain aspects of phenophases of tree growth and development (such as almonds, which, due to their early blooming, were sensitive to late spring frosts and thus the trees could grow only in already well-known orchards or in totally new ones) were studied. Spring temperature, now occurring under well-applied crop technology (optimal soil work, fertilizer application, irrigation, phytosanitary treatments), no longer affects the almond production, as the formed fruit resists down to − 2 °C. Production levels are in line with the productive potential of the varieties described in the official catalog of varieties (Popescu et al. 2016b).

All studied species here showed a faster blooming period due to the increase in average monthly temperature during the first 3 months of each year from 2009 to 2016: January 2009 (− 1 °C), January 2016 (− 0.6 °C), February

Table 3 Blooming period for almond varieties

Variety	Year 2009				Year 2016			
	Temp.*	Precip.**	Blooming		Temp.*	Precip.**	Blooming	
			Begin	End			Begin	End
Sandi			17-III	26-III			13-III	20-III
April			30-III	07-IV			20-III	01-IV
Vio			28-III	11-IV			19-III	30-III
Adria	6.2[1] 5.4[2]	191.9[1] 60.2[2]	30-III	09-IV	6.3[1] 6.9[2]	329.5[1] 45.9[2]	21-III	01-IV
Alexandru	19.4[3] 11.6[4]	249.3[3] 501.4[4]	24-III	06-IV	18.9[3] 11.6[4]	353.3[3] 728.7[4]	16-III	26-III
Nicoleta			13-III	28 -III			10-III	22-III
Adeluta			07-III	24-III			04-III	18-III
Cristi			12-III	27-III			10-III	19-III

[1] September–February

[2] Blooming period—March, ripening period

[3] April–August

[4] Annual

*Temp.—average temperature: pre-blooming period

**Precip.—total precipitation

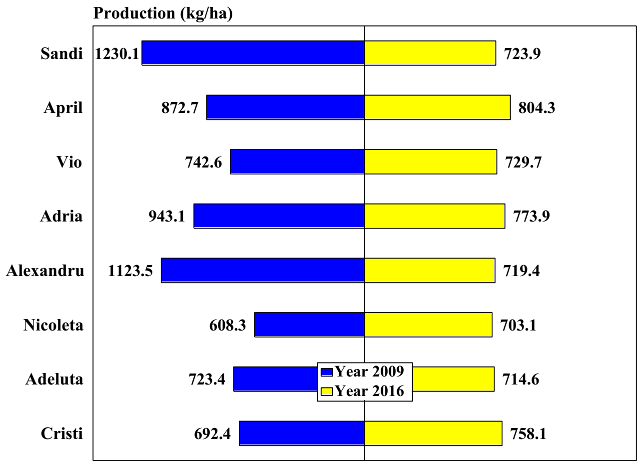

Fig. 6 Fruit production for almond varieties: 2009 comparative with 2016

2009 (0.3 °C), February 2016 (6.8 °C), March 2009 (5.4 °C), and March 2016 (6.9 °C) (Fig. 2), leading the trees out of the vegetative pause and hastening the growth phenophases and annual development. During this period, apple and plum species are in full bloom, while for almond trees, the blooming period has ended and the fruit are already forming. As a result, various diseases appeared, especially moniliasis (*Monilinia laxa*) which causes quantitative loss of flowers and severely affects young branches and fruits in the plum and almond species (Barros et al. 2012; Gitea 2008; Preston and Sandve 2013; Zavtoni 2017). Another disease is scab (*Venturia inaequalis*) causing ultimately total defoliation in apple trees especially in sensitive *Golden delicious*. This intense proliferation of bugs and pests resulted in more frequent pesticide interventions.

Between March and May, as climate is more humid and temperature decreased, treatments were applied to combat apple scab (*Venturia inaequalis*) and diseases such as leaf scars (*Coryneum beijerincki*), moniliasis (*Monilinia laxa*), and blistering leaves (*Taphrina deformans*) for almonds and plums. These treatments were applied repeatedly during the last 3 years (2015–2017) (Gitea et al. 2018).

The results of this study are significant in that they raise the prospect of introducing fruit tree species and their varieties into new agricultural areas, where the climate has become more hospitable to them due to the climate changes now taking place, and where they can be cultivated in soils suitable to their productive potential. An additional aspect of this investigation is the diversification of activities in regions with few economic resources; thus, it offers support to fruit tree growers and investors who can see the introduction of these species to new areas as a business opportunity with a strong commercial potential (the price of almonds is high—about 10€/kg), while simultaneously contributing to environmental protection.

Conclusion

The climate changes have a noticeable influence on the annual biological cycle of trees. Thus, their vegetative rest period shortens, their vegetation begins earlier in spring, and the blooming period is advanced by up to 10 days compared to normal cultivated varieties. All these factors have direct repercussions on the quality and quantity of the yield.

The almond, due to its early bloom, is sensitive to late spring frosts and can only be grown in already well-established agricultural areas but can possibly be expanded to new lands.

Acknowledgements This study is a collaborative effort by the Laboratories from University of Oradea, Romania and the Chrono-Environment Laboratory, CNRS 6249 (National Center for Scientific Research) Besançon, France. We express our appreciation to the editor, Dr. Philippe Garrigues, and to the anonymous reviewers for helping to improve our paper.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

Badulescu D, Bungau C, Badulescu A (2015) Sustainable development through sustainable businesses. An empirical research among master students. J Environ Prot Ecol 16(3):1101–1108

Balint R, Orbeci C, Nechifor G, Plesca M, Ajmone-Marsan F (2013) Effect of redox conditions on the crystallinity of Fe oxides in soil. Rev Chim - Bucharest 64(11):1218–1223

Balint R, Nechifor G, Ajmone-Marsan F (2014) Leaching potential of metallic elements from contaminated soils under anoxia. Environ Sci Process Impacts 16(2):211–219. https://doi.org/10.1039/c3em00546a

Barros PM, Goncalves N, Saibo NJM, Oliveira MM (2012) Cold acclimation and floral development in almond bud break: insights into the regulatory pathways. J Exp Bot 63(12):4585–4596. https://doi.org/10.1093/jxb/ers144

Bungau S, Baldea I, Copolovici L (2003) Determination of ascorbic acid in fruit using a Landolt type method. Rev Chim Bucharest 54(3):213–216

Bungau C, Badulescu A, Badulescu D (2014) Assessing the effectiveness of mobility and study abroad stages during doctoral programs: a case study. In: Proceedings of the 13th European Conference on Research Methodology for Business and Management Studies (Ecrm 2014). London, England, pp 473–476

Bungau S, Tit DM, Fodor K, Cioca G, Agop M, Iovan C, Nistor Cseppento DC, Bumbu A, Bustea C (2018) Aspects regarding the pharmaceutical waste management in Romania. Sustainability 10(8):2788. https://doi.org/10.3390/su10082788

Burkholder JA, Libra B, Weyer P, Heathcote S, Kolpin D, Thorne PS, Wichman M (2007) Impacts of waste from concentrated animal feeding operations on water quality. Environ Health Perspect 115(2): 308–312. https://doi.org/10.1289/ehp.8839

Cao H, Sun H, Yang H, Sun B, Zhao QA (2003) Review: soil enzyme activity and its indication for soil quality. Chin J Appl Environ Biol 9(1):105–109

Copolovici D, Bungau S, Boscencu R, Tit DM, Copolovici L (2017a) The fatty acids composition and antioxidant activity of walnut cold press oil. Rev Chim Bucharest 68(3):507–509

Copolovici L, Timis D, Taschina M, Copolovici D, Cioca G, Bungau S (2017b) Diclofenac influence on photosynthetic parameters and volatile organic compounds emission from Phaseolus vulgaris L plants. Rev Chim Bucharest 68(9):2076–2078

Cuculeanu V, Tuinea P, Balteanu D (2012) Climate change impacts in Romania: vulnerability and adaptation options. Geo J 57:203–209. https://doi.org/10.1023/B:GEJO.0000003613.15101.d9

Diaconu I, Girdea R, Cristea C, Nechifor G, Ruse E, Totu EE (2010) Removal and recovery of some phenolic pollutants using liquid membranes. Rom Biotechnol Lett 15(6):5702–5708

Doetterl S, Van Oost K, Six J (2012) Towards constraining the magnitude of global agricultural sediment and soil organic carbon fluxes. Earth Sur Process Landf 37(6):642–655

Dumitrel GA, Glevitzky M, Popa M, Chirila D, Palea A (2017) Monitoring of lead copper and cadmium contamination level of soil from Zlatna region Romania. J Environ Prot Ecol 18(1):55–62

European Commission (n.d.) Climate change 2020 climate & energy package. https://eceuropaeu/clima/policies/strategies/2020_en. Accessed 28 July 2017

European Council (2014) Conclusions on 2030 climate and energy policy framework Brussels. https://wwwconsiliumeuropaeu/uedocs/cms_data/docs/pressdata/en/ec/145356pdf. Accessed 28 July 2017

Gitea MA (2008) Study of almond elites to obtain new varieties. University of Oradea Ed, Oradea

Gitea MA, Bungau S, Gitea D, Purza L, Nemeth S, Samuel AD, Badea G, Tit DM (2018) The consequences of excessive chemicalization on fruits quality. Rev Chim Bucharest 69(6):1303–1308

Ionescu G, Rada EC, Cioca LI (2015) Municipal solid waste sorting and treatment schemes for the maximization of material and energy recovery in a latest EU member. In: Proc of the 10th International Conference on Environmental Legislation Safety Engineering and Disaster Management. 14(11) 2537–2544

Kikon YY, Maiti CS (2004) Horticulture for sustainable income and environmental protection: advances in horticultural practices fruits and ornamentals. In: Singh VB, Akali Sema K, Alila P (eds) vol 1. Concept Publishing Company, New Delhi, pp 221–223

Martin-Lara MA, Ortuno N, Conesa JA (2017) Volatile and semivolatile emissions from the pyrolysis of almond shell loaded with heavy metals. Sci Total Environ 613-614:418–427

Masu S, Dragomir N, Popa M (2013) Variation of oil products in contaminated soil cultivated with leguminous species. J Environ Prot Ecol 14(3):901–906

Meita V, Petrisor AI, Simion-Melinte CP (2011) Agricultural impact of the exposure to clime change in the Romanian portion of Tisza river basin research. J Agric Sci 43(3):429–436

Metz B, Davidson O, de Coninck HC, Loos M, Meyer LA, IPCC (eds) (2005) IPCC Special Report on Carbon Dioxide Capture and Storage. Prepared by Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge United Kingdom

Moisa C, Copolovici L, Bungau S, Pop G, Imbrea I, Lupitu A, Nemeth S, Copolovici D (2018) Wastes resulting from aromatic plants distillation—bio-sources of antioxidants and phenolic compounds with biological active principles. Farmacia 66(1):289–295

Popescu DE, Bungau C, Prada M, Domuta C, Bungau S, Tit DM (2016a) Waste management strategy at a public university in smart city context. J Environ Prot Ecol 17(3):1011–1020

Popescu M, Ciora M, Theodorescu M, Bran A (2016b) Official catalog of plant varieties in Romania for 2016. In: State institute for variety testing and registration. Complete Ed Bucharest, Bucharest

Prada MF, Popescu DE, Bungau C (2016) Building education source of energy saving in Romania. In: Proc of the 15th national technical-scientific conference on modern technologies for the 3rd millennium. Oradea, Romania, pp 157–162

Prada M, Popescu DE, Bungau C, Pancu R, Bungau C (2017) Parametric studies on European 20-20-20 energy policy targets in university environment. J Environ Prot Ecol 18(3):1146–1157

Preston JC, Sandve SR (2013) Adaptation to seasonality and the winter freeze front. Plant Sci. https://doi.org/10.3389/fpls201300167

Rada EC, Istrate IA, Ragazzi M (2009) Trends in the management of residual municipal solid waste. Environ Technol 30(7):651–661. https://doi.org/10.1080/09593330902852768

Rada EC, Bresciani C, Girelli E, Ragazzi M, Schiavon M, Torretta V (2016) Analysis and measures to improve waste management in schools. Sustainability 8(9):840–852. https://doi.org/10.3390/su8090840

Samuel AD, Brejea R, Domuta C, Bungau S, Cenusa N, Tit DM (2017a) Enzymatic indicators of soil quality. J Environ Prot Ecol 18(3):871–878

Samuel AD, Tit DM, Melinte Frunzulica CE, Iovan C, Purza L, Gitea M, Bungau S (2017b) Enzymological and physicochemical evaluation of the effects of soil management practices. Rev Chim Bucharest 68(10):2243–2247

Samuel AD, Bungau S, Tit DM, Melinte (Frunzulica) CE, Purza L, Badea GE (2018) Effects of long term application of organic and mineral fertilizers on soil enzymes. Rev Chim Bucharest 69(10):2608–2612

Taschina M, Copolovici DM, Bungau S, Lupitu AI, Copolovici L, Iovan C (2017) The influence of residual acetaminophen on beans (*Phaseolus vulgaris* L) plants secondary metabolites. Farmacia 65(5):709–713

Tit DM, Bungau S, Nistor Cseppento C, Copolovici DM, Buhas C (2016) Disposal of unused medicines resulting from home treatment in Romania. J Environ Prot Ecol 17(4):1425–1433

Vica M, Popa M, Dumitrel GA, Glevitzky M, Todoran A (2014) Study on microbiological quality and pollution control of groundwater from different areas in the Alba County Romania. J Environ Prot Ecol 15(1):64–72

Yang WQ, Wang KY (2002) Advances on soil enzymology. Chin J Appl Environ Biol 8(5):564–570

Zavtoni M (2017) State surveillance of the population's health under the conditions of application of pesticides in agriculture. PhD thesis. The National Public Health Center Chisinau