atmosphere

Article

Adaptability of *Prunus cerasifera* Ehrh. to Climate Changes in Multifunctional Landscape

Djurdja Petrov [1],*, Mirjana Ocokoljić [1], Nevenka Galečić [1], Dejan Skočajić [1] and Isidora Simović [2]

1 University of Belgrade - Faculty of Forestry, Kneza Viseslava 1, 11030 Belgrade, Serbia; mirjana.ocokoljic@sfb.bg.ac.rs (M.O.); nevenka.galecic@sfb.bg.ac.rs (N.G.); dejan.skocajic@sfb.bg.ac.rs (D.S.)
2 BioSense Institute, University of Novi Sad, Dr Zorana Djindjića 1, 21000 Novi Sad, Serbia; isidora.simovic@biosense.rs
* Correspondence: djurdja.stojicic@sfb.bg.ac.rs; Tel.: +381-1130-53814 or +381-1125-45485

Abstract: Urban trees play a vital role in mitigating climate changes, maintaining the sustainability of ecosystems. This study focuses on the assessment of the resilience of cherry plums to climate changes, a fruit-bearing species that offers diverse ecosystem services within multifunctional urban and suburban landscapes. This study examines flowering and fruiting in the context of climate characteristics, expressed through the Day of the Year (DOY), Growing Degree Days (GDDs), and a yield over 17 consecutive years. The results indicate significant shifts in the DOY but not in the GDD, apart from the end of flowering. The onset of flowering was earlier and the end postponed, extending the phenophase by an average of 4 days. The cherry plum's yield was unaffected by climate changes, including extreme events like a late-spring frost. The stability of the cherry plum was confirmed by the phenological patterns of the bullace (cherry plum and blackthorn hybrid) exhibiting repeated flowering in the warmest year of 2023. The cherry plum is an adaptive species, with a high adaptability to a changing climate and a high resistance to late-spring frosts; thus, it is a favorable choice in urban design and planning, demonstrating resilience to climate shifts and thriving in polluted urban environments. It is especially appreciated for multiple ecosystem services: biodiversity conservation in natural and semi-natural areas, yielding good provisions in challenging environments, and the preservation of ornamental values through an extended flowering phenophase.

Keywords: phenology; fruit-bearing trees; cherry plum; ecosystem services; DOY; GDD; landscape design; resilience

check for updates

Citation: Petrov, D.; Ocokoljić, M.; Galečić, N.; Skočajić, D.; Simović, I. Adaptability of *Prunus cerasifera* Ehrh. to Climate Changes in Multifunctional Landscape. *Atmosphere* **2024**, *15*, 335. https://doi.org/10.3390/atmos15030335

Academic Editor: Andreas Matzarakis

Received: 26 January 2024
Revised: 27 February 2024
Accepted: 5 March 2024
Published: 8 March 2024

1. Introduction

Urban greenery needs to fulfill multiple ecosystem roles nowadays, as we are facing severe changes in the climate [1], a lack of food [2], and air pollution [3–5]. Apart from the existential needs of the population, the species needs to be adaptive to climate changes and needs to realize its full aesthetical and ecological potential amid the challenging environmental conditions in urban areas. Landscape design, management, and planning are especially challenging since species must be appropriate for the location from both the ecological and aesthetic perspectives [6–9]. Realizing full ecological potential within certain aesthetic preferences assumes species adaptability to climate changes that are specific to a given locality [10]. Despite the high survival rate of urban trees, there might be significant differences in health and vigor in individuals [11]. In one study, the environmental importance of fruit-tree species was considered in Serbia and Montenegro due to their ecological and biological characteristics that are favorable due to their quality and high nutritional value and, thus, economic value [12]. The researchers included several species from the *Prunus* genus, among which was *Prunus cerasifera* Ehrh. Another research showed that semi-cultivated *Prunus cerasifera* Ehrh. represents a significant reservoir of genetic diversity and resilience to climate change, showcasing substantial possibilities for selective breeding and utilization [13].

Prunus cerasifera Ehrh. (cherry plum) is an autochthonous species with a highly expressed polymorphism of characteristics [14] and is one of the oldest and most widely spread fruit species in the natural population of Serbia [15]. It is also among the most commonly used species in urban areas in Serbia, as well as in other cities [16], and other authors cite cherry plums to be found by the roads, bounds, individually, or in groups [14]. Plum is ranked as the second-most important fruit-tree crop in the temperature climate from the point of view of production [17] but is also common in Serbia in natural and urban settings, as it is adaptive to low temperatures and is resistant to various diseases, providing a good yield and fruits of various size and quality [18–20]. Furthermore, previous research [21] analyzed the "dual evaluation" of species in terms of ecosystem service functions in residential areas and found that the cherry plum is characterized by the ability to serve as a carbon sink in urban areas without being affected and is among the top species in doing so. Many studies estimate the mitigation potential of urban species and list *Prunus cerasifera* Ehrh. high on the list for carbon sequestration [16] and heavy-metal-accumulation capacity [22,23], making it the suitable choice of urban planners for multifunctional landscapes. The cherry plum is a very useful agricultural plant that is cultivated for commercial purposes. The fruits of this species are food for humans, from consumption to making alcoholic beverages, but they are also food for animals [24–26]. Small trees and shrubs are an integral part of forest communities that contribute to biodiversity [27,28]. The cherry plum, as a small tree, is a very important element in the formation of stories. It grows on the edges of forests, builds thickets, and represents important habitats for rodents and insects and for nesting birds [29]. The lightly fragrant flowers of the cherry plum are very important for pollinators and other insects and are an important source of nectar in early spring. It is also an ornamental species, and its application in landscape architecture and design must not be neglected due to the decorativeness of this early-flowering species. Decorative plants represent an important element in the urban environment, which, in addition to having a positive effect on the quality of the environment and carbon absorption, have an impact on the aesthetics of the space, landscaping, as well as the well-being of citizens [30–32]. When properly applied, the known data on flowering phenology could lead to a reduction in the costs of maintaining green areas with the appropriate choice when choosing plant material [33]. The flowering of *Prunus cerasifera* Ehrh. thus influences all the aforementioned ecosystem services (Figure 1), and its shifts due to climate changes are of major importance for mitigation in urban areas.

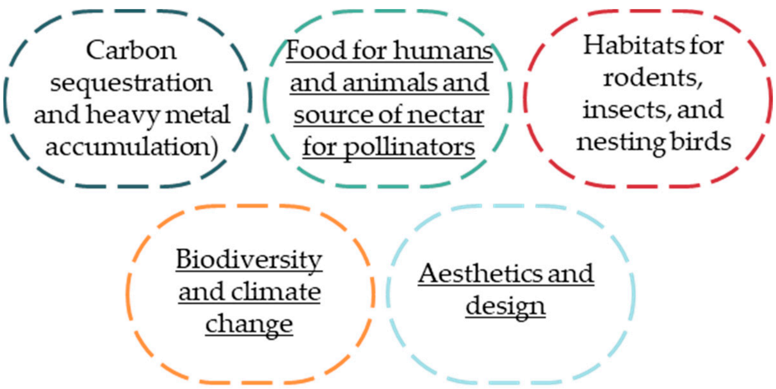


Figure 1. Ecosystem services of *Prunus cerasifera* Ehrh., with the underlined topics covered in this paper.

The main indicator of ecosystem adjustments to climate changes are shifts in phenology [34], and its changes have serious implications for biodiversity [35] and ecosystem production [36]. For many years, the impact of climate changes on plant phenology has been the focus of studies worldwide [37–45]. Some authors [46] indicate that in addition to phenology, climate changes also affect the physiology and distribution of species and the composition and dynamics of biocenosis. Shifts to earlier developments of phenophases, as well as the duration of phenological events, affect biodiversity, habitat sustainability, and ecosystem services [35,36,47–49], but they also provide feedback regarding climate changes [50]. The phenology of cherry plums is important from two perspectives, as it is a part of the multifunctional landscape in our study: as a part of natural and semi-cultivated populations due to biodiversity and an improvement of the environmental quality in urban and suburban areas and as a fruit-bearing and ornamental species. One study [51] dealt with the systems of the vulnerability of species, habitats, or ecosystems to climate changes and concluded that projections allow managers to develop new regulations and management practices in accordance with changed conditions. It is very important to conserve individual species, as well as to identify groups of species that are resistant or sensitive to future climate-change scenarios, in order to understand how phenological mismatches can affect community dynamics, ecosystem services, and conservation over time [52]. Other studies regard the cherry plum as an agricultural species [53], address policies, and examine the weather risk in agriculture based on the Weather Insurance Index as an innovative tool to facilitate the fight against climate changes in agriculture. Horticulture would benefit from using high-yielding cultivars in urban landscapes, especially in terms of ecology and economy, if the species would be appropriately chosen according to soil and climatic requirements. In terms of climate factors, it was found that *Prunus cerasifera* Ehrh. is mostly affected by the flowering intensity and minimum air temperature during flowering, and spring frosts are especially important [54]. Another research [55] proved that the capacity of the cherry plum to withstand cold in the winter is highly dependent on temperature variations, highlighting autumn and the beginning of winter as the crucial period for the species to prepare for the winter season. Climate change, increasing spring temperatures, and increasing temperature variations affect phenology, which, in most species, leads to a greater risk of damage from spring frosts [56,57]. Apart from other factors, such as a high temperature and lack of water, urban trees are affected by excessive light that influences phenophases and photosynthesis. Genotypes of *Prunus cerasifera* Ehrh. with red leaves that are very common in urban settings in Belgrade are better adjusted to extra lighting, as the anthocyanins significantly influence the duration of phenophases, which is of utter importance for both ecosystem services and urban greening [58].

The aim of our study is to detect the most important climatic factors that are decisive for the flowering phenophase of *Prunus cerasifera* Ehrh. and to analyze their relation to shifts in flowering and fruit abundance that are detrimental to the ecosystem services the cherry plum provides.

2. Materials and Methods

The research area is a multifunctional landscape within the suburban region of the southwestern municipality of Čukarica, located in the city of Belgrade, Serbia. This area spans 2155 hectares and encompasses elevations ranging from 66.3 m to 87.9 m (Figures 2 and 3). The spatial distribution of elements was determined using satellite maps, as the remote sensing of phenology has been conducted in Serbia before [59], cartographic materials, planning documents, and on-site field research.

2.1. Habitat Characteristics

From a spatial perspective, the research area has two distinct characteristics. In the northeastern part, it serves as a connection between residential areas situated north of Makiško polje, above the Sava highway, and the right bank of the Sava River. In the southwestern part, it acts as a link between two significant transportation hubs: the bypass highway and the Belgrade marshaling station. This area encompasses various land uses: (i) the public infrastructure—road network (3.12%)—areas for infrastructure facilities and complexes (1.29%), green areas (13.64%), forests (13.04%), water areas (1.24%), and areas for sports facilities and complexes (0.69%); and (ii) areas of other uses, including housing (0.21%), commercial facilities (3.6%), economic zones (0.42%), and agricultural areas (62.36%). According to some researchers [60], within this area, there exists a historical example of late 19th-century industrial architecture: the "Belgrade Waterworks" complex, located at Vodovodska Street 158, dates back to 1892. This complex was expanded in 1906–1907 to meet the growing demand for water supply in Makiško polje, making it a vital part of the city's water infrastructure. This area belongs to the alluvial plain of the Sava River, separated by a steep section from the Sava Terrace and intersected by the Železnička River and several canals. Within the boundaries of the study area are two hydrogeological collectors. The lower collector, within the alluvial–lacustrine, sandy pebble deposits, overlays impermeable alluvial–diluvial–marly clays. The upper groundwater collector was formed within alluvial sand–gravel formations.

Figure 2. The research area— the municipality of Čukarica (Belgrade, Serbia).

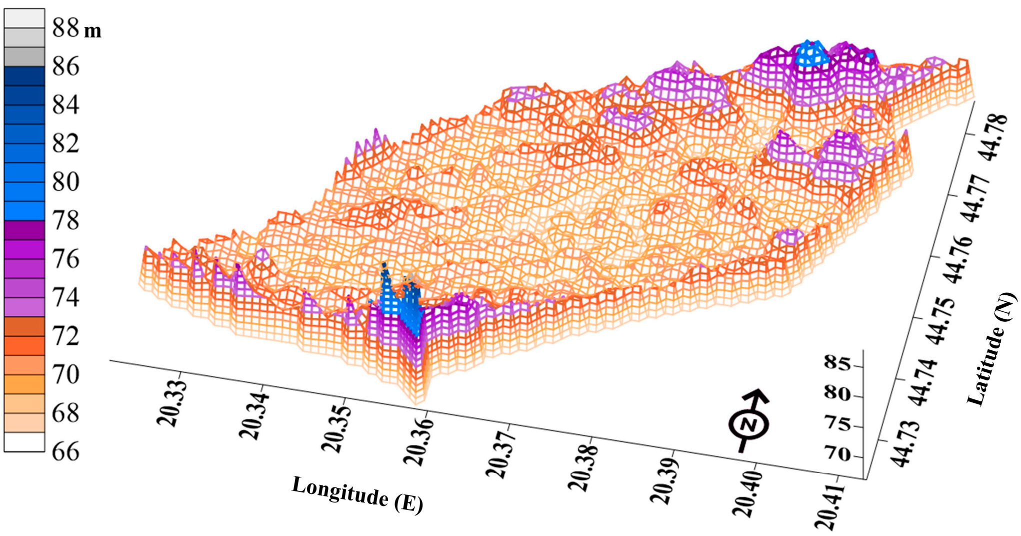


Figure 3. A 3D surface plot of the relative relief values derived over the study area.

Surface water, created by flooding and torrents, penetrates the ground vertically but at a notably slow pace. During extreme climatic events, all stormwater ultimately accumulates in the lowest section of the alluvial area. The limited permeability of the loose sediments leads to occasional flooding (up to 74 m above sea level) and causes the site to remain waterlogged for most of the year [61].

As per some authors [62], the terrain consists of Quaternary formations, including alluvial sediments and alluvial lake sediments, as well as Tertiary formations, such as the marl–carbonaceous complex. The research area is not within the spatial scope of the ecological network, nor is it within the protected area for which the protection procedure has been implemented or initiated. There are no recorded natural assets, as specified in the Decision of the Institute for Nature Protection of Serbia 2977/3, dated 14.11.2018. Nevertheless, this area is spatially connected to the ecologically significant area of the "Confluence of Sava and Danube" [63]. Consequently, it holds natural value, as it serves as a connecting element within an ecologically important corridor of international significance, playing a vital role as a biotope in species migration and biodiversity preservation. Additionally, it is a fundamental component of the city's future green infrastructure, offering ecological and recreational potential for residents and contributing aesthetic and ambient values. This area hosts a variety of woody plant species, particularly those capable of withstanding prolonged surface-water retention, such as hygrophilous forest edifiers [64]. Within this multifunctional landscape, mosaic-distributed populations of cherry plums, with a significant number of trees, were selected, covering a total of 0.3% of the study area, which corresponds to 6465 hectares, and the populations of cherry plum occupy a mere 0.0004% of this space, totaling 0.009 hectares.

2.2. Phenology

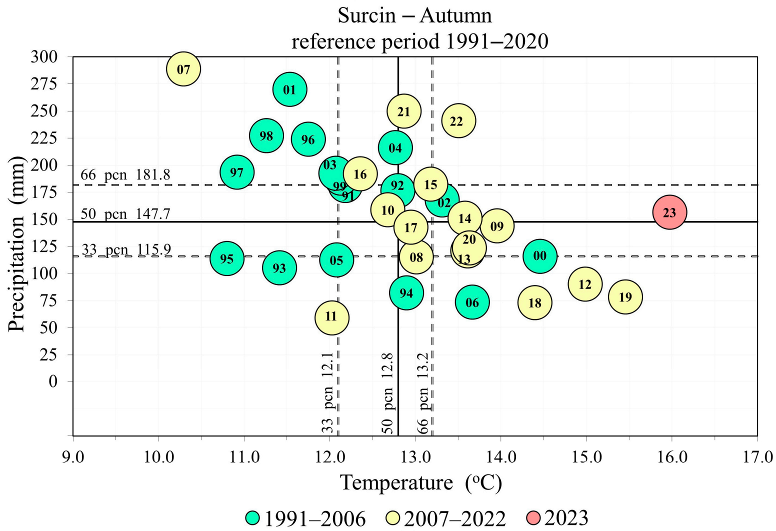
To assess the adaptability of *Prunus cerasifera* Ehrh. (cherry plum) to climate changes between 2007 and 2023, an extended BBCH scale, a scale of developmental phenological phases of the plant, was utilized for monitoring the phenological stages of cherry-plum flowering at the population level, as suggested by previous authors [65]. The extended BBCH scale includes the following stages: the beginning of flowering—BF (more than 10% of the flowers opened)—full flowering—FF (more than 50% of the flowers opened)—and the end of flowering—EF (more than 80% of the flowers opened). During the 17-year period, the phenophase of fruit ripening at the population level was observed: the phenophase of fully ripe fruits—FRs (fruit shows a fully ripe color, and fruit abscission begins)—was monitored. The fruit yield was evaluated by quantifying phenological observations on a five-point scale [66], where 0 is a tree without fruit (0% of branches bearing fruit); 1—a small number of fruits ($\leq$20%); 2—a low number of fruits (>20$-\leq$40%); 3—a moderate number of fruits (>40$-\leq$60%); 4—abundant fruits (>60$-\leq$90%); and 5—the maximum number of fruits (>90%). In addition to the cherry plum, the flowering phenophase of a hybrid species known as bullace, which spontaneously emerged from a cross between *P. cerasifera* Ehrh. and *P. spinosa* L., was monitored for control purposes. Observations were conducted visually every other day across the entire research area. The recorded dates were then converted into the day of the year (DOY), with DOY 1 corresponding to 1 January. The temperature sums, i.e., the cumulative growth degree days (GDDs), using a temperature threshold of 5 °C for moderate continental climate conditions [67], were calculated based on a previously proposed method [68]. The GDD is the accumulation of temperatures above a predetermined limit, and it represents the sum of temperature differences between the mean daily air temperature and the biological minimum air temperature [69]. This method is adequate because for research, degree days are more suitable than calendar days, since the development of plants does not follow dates but the accumulation of heat above a specific temperature limit (threshold), below which, if the temperature drops, growth and development stop. For most plant taxa that grow in conditions of a moderate continental climate, a limit of 5 °C (Tt) is taken [67–69], as was also used in our work. The data presented in this study represent the mean values gathered from 12 populations of the common cherry plum and 2 populations of the bullace within the research area. The statistical analysis, conducted using the XLSTAT 2020 software package, included descriptive statistics and Spearman's correlation coefficient (ρ). Hourly and daily climatic data from the weather station in Surčin (44°47′54.44″ N; 20°27′53.35″ EGr) were obtained from the RHMZ [70]. These data were employed due to the similarity of environmental conditions to determine the influence of climatic parameters. Statistical climatological methods of percentiles and associated terciles (RHMZ) were applied, where nth signifies the value below which "n" percent of the data, previously sorted in ascending order, is located. The term "normal" in this context refers to the climatological standard normal of the analyzed parameter for the reference period of 1991–2020.

The ArcGIS/ArcMap 10.3 and Surfer 22 software packages were used for data processing.

3. Results

The analysis of the phenological characteristics confirmed that the flowering period of the researched populations of cherry plums occurred exceptionally early, making them vulnerable to potential damage from spring frosts. Flowering and fruit ripening exhibited variations contingent upon environmental conditions, as noted by other authors [71]. The phenophases were particularly influenced by year × climate variable interactions over the 17-year span of research. Figure 4a–d illustrate the average seasonal air temperatures and precipitation levels during the research period from 2007 to 2023 (for autumn, from 2007 to 2022), in comparison to the reference period of 1991–2020.

The earliest onset of flowering before 2023 was recorded in 2007 and 2016 (DOY: 53), when seasonal (winter) air temperatures and precipitation (Figure 4b) were around the upper tercile (2007) and below the lower tercile (2016). The latest BF was recorded in 2009 (DOY: 84), when air temperatures were significantly above the upper tercile, and precipitation was below the lower tercile. In the period spanning from 2007 to 2023, the years with the latest beginning of flowering, including 2018 (characterized by notably high air temperatures, ranking as the highest in the 17-year series and by precipitation levels near the lower tercile boundary), exhibited the shortest flowering phenophase, lasting only 17 days. The longest flowering phenophase (35 days) was recorded in 2008, which, according to the seasonal map, in terms of precipitation, is identical to the year in which the length of flowering was the shortest. Although the air temperatures were lower in 2008, they still exceeded the upper tercile threshold. Considering the aforementioned analysis and the fact that 2023 displayed the earliest onset of flowering (DOY: 51), graphs were created to illustrate the average monthly air temperatures and monthly precipitation for February and March during the research period from 2007 to 2023, as shown in Figure 5a,b. These figures are provided in relation to the reference period of 1991–2020.



(a)

Figure 4. *Cont.*

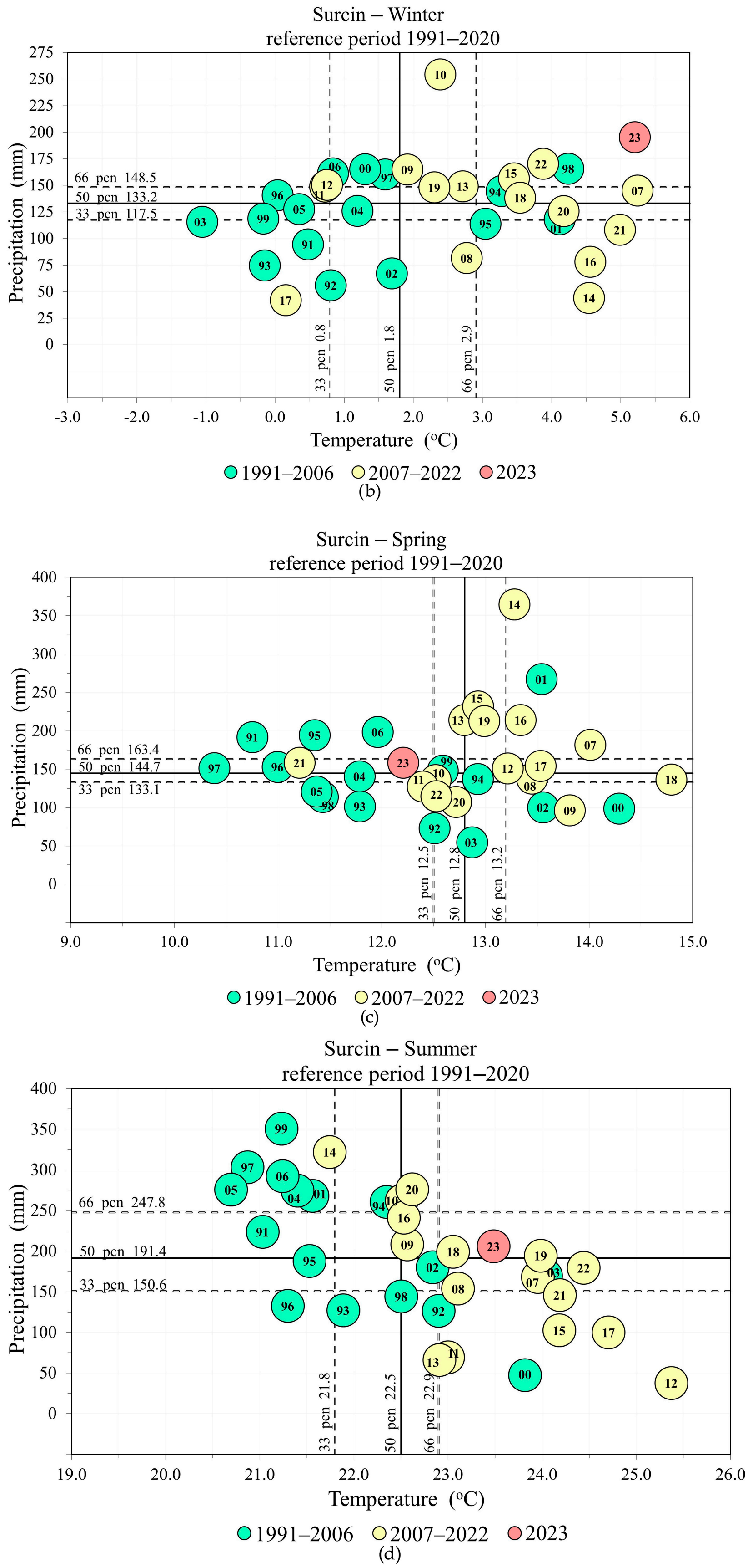


Figure 4. Mean seasonal air temperature and total precipitation for autumn (**a**), winter (**b**), spring (**c**), and summer (**d**) and their respective terciles for Belgrade (black lines correspond to the percentiles of the reference period), in the research period, in relation to the reference period 1991–2020.

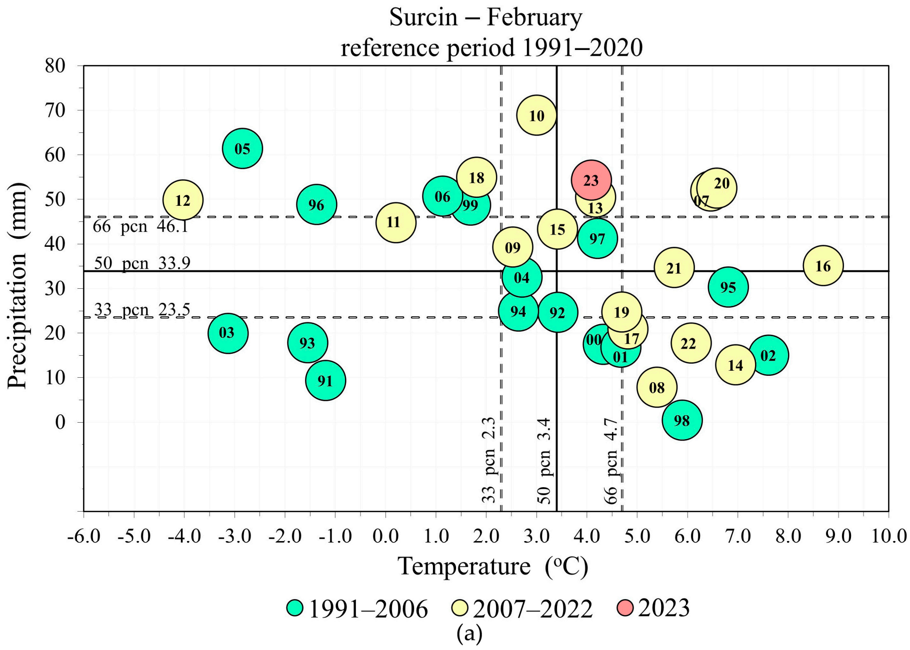
In Figure 5a, it is shown that February 2023 had an air temperature close to the upper tercile, while the precipitation was significantly above the upper tercile. At the beginning of the month, cold and changeable weather prevailed, and from the middle of the first decade, there was dry and warm weather (RHMZ). This weather pattern triggered the earliest onset of flowering in a 17-year series. Namely, the winter ranked as the second warmest in Belgrade since 1887, with a record-low number of frosty days (RHMZ). In March 2023, the air temperature exceeded the upper tercile limit, while precipitation levels remained within the range of average values (Figure 5b). This resulted in the occurrence of the end of flowering (EF) on the 79th DOY. March 2023 was characterized by warm temperatures and average rainfalls, according to percentile and tercile calculations (RHMZ). However, April 2023 was notably cold and ranked as the sixth wettest month, according to RHMZ. In April, a sudden drop in the temperature of the 98th DOY was recorded. At the beginning of April, the maximum height of the snow cover was recorded since the beginning of measurements in Belgrade. A climatic anomaly occurred in the period from 3 March to 7 April, as maximum temperatures were consistently below the normal minimum temperatures for those specified dates in the reference period of 1991–2020. Taking into account the weather events during 2023, it was expected that there would be no fruiting of cherry plums. Surprisingly, all cherry-plum populations yielded their maximum harvest (grade 5) in 2023, just as they had in the preceding 16 years.

For all the observed flowering phenophases, decreasing DOY trends were determined, which confirms that flowering started and ended earlier during the 17 years of research (Figure 6). While there is a 33-day absolute difference between the earliest and latest beginning of flowering (BF), the trend analysis revealed that, in the last 17 years, cherry-plum flowering has shifted to start 15 days earlier and end 11 days earlier within the research area. The recording of BF was noted after the accumulation of heat sums ranging from 85.5 °C (in 2010, DOY: 78) to 138.4 °C (in 2016, DOY: 53). The current 2023 BF began after the accumulation of 93.0 °C (DOY: 51) and ended after the accumulation of 204.0 °C (DOY: 79) (Figure 7). The mean value of the accumulated heat for BF in the period 2007–2023 is 116.1 °C. The calculated GDDs are variable but consistently close, irrespective of the DOY. The linear trends for BF and EF (Figures 6 and 7) confirm that the shift in the DOY for these phenophases does not significantly impact heat accumulation. In other words, these phenophases consistently occur within certain thresholds of accumulated heat, as illustrated in Figure 7. A decrease in the accumulated heat was recorded for EF, which confirms the linear trend, and is attributed to extreme climatic events in previous years. Therefore, a comparative analysis of the temperatures and precipitation levels with GDDs was conducted using Spearman's coefficients, revealing a significant positive correlation of the GDD with the air temperature and precipitation levels, ranging from 0.951 to 0.966. The Spearman correlation coefficient values (Figure 8) demonstrate a significant positive correlation between the DOY and the flowering phenophases (0.983 and 0.800) as well as an influence of the BF GDDs on EF GDDs (0.841).

Descriptive statistics were used to assess the trends, specifically examining the impact of climatic variables on the adaptability of cherry plums within a multifunctional landscape (Table 1). The mean value indicates the phenological patterns of flowering, and the standard deviation is the deviation from the mean values, providing insights into the shifting of the cherry plum's flowering phenophases.

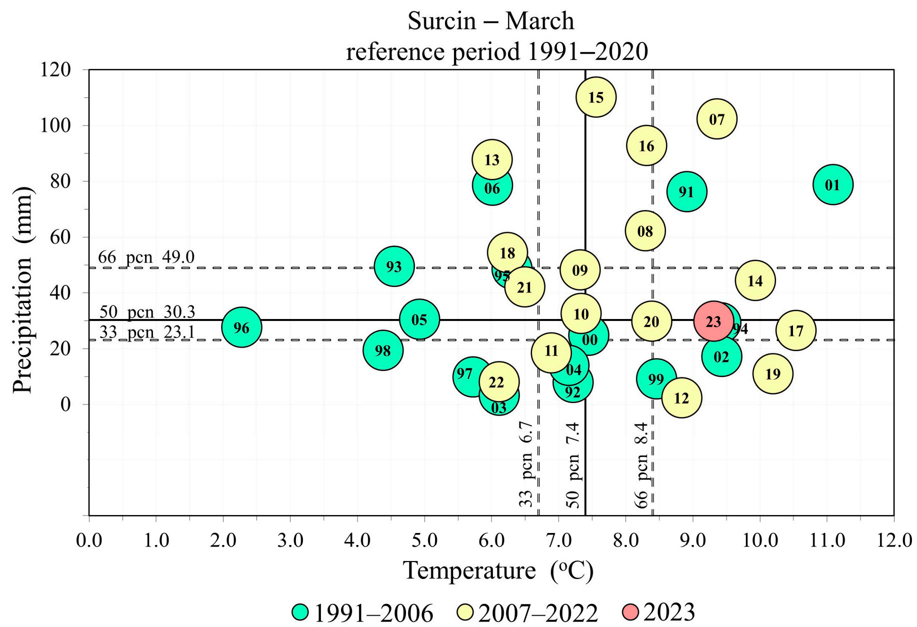
A MultiFunctional Landscape: Phenology of Cherry Plum and Bullace during 2023

Considering the primary goal of this research, which is to assess the resilience of the cherry plum under changing climate conditions, the phenological characteristics of the bullace were also monitored in parallel. During the 17 consecutive years, the cherry plum did not have a repeated flowering, while the bullace displayed a repeated flowering occurrence in the current year, 2023. The phenogram for both species, in 2023, is presented in Figure 9. At the beginning of September, full leaf shedding was observed, followed by an entirely distinct flowering and the initiation of leafing and shoot growth in the bullace in both populations, during October, with a fruiting in November and a small number of fruits—the yield was marked as 2 in both of the bullace populations. On 16 November, a sporadic flowering, in parallel, was noted, as was a significant growth of shoots (the average growth of fully leafed shoots on this day, for both populations, was 9.2 cm). At the end of October, the cherry plum had a complete leaf mass that had just begun to transition in color, a characteristic of the period preceding leaf shedding, and by the end of autumn, full leaf shedding was noted. This confirmed its high adaptability to climatic variations (Table 2). September 2023 had a mean air temperature of 21.9 °C, which deviated from the norm of the reference period, being higher by 4.2 °C and 3.8 °C compared to the research period. According to the percentile method, most of September was in the warm and very warm category. At the beginning of the second and third decades, the temperatures were in the extremely warm category, and at the beginning of the month and in the middle of the second and third decades, it was in the normal category. A heatwave was recorded in the period of September 9–13. There were 27 summer and 9 tropical days during this month. On September 25, the highest daily amount of precipitation of 30.6 mm was measured. October 2023 was the warmest October since measurements were made at the Surčin station, with an average air temperature of 17.02 °C, which deviated from the reference period, i.e., it was higher by 4.25 °C and 4.05 °C compared to the research period. The record-high minimum and maximum air temperatures were recorded, especially in the last decade of October. There was also a heat wave from 20 to 24 October. According to the percentile method, at the beginning and in the middle of October, temperatures were in the normal category, and on October 16 and 17, it was cold, while for the rest of the month, it was in the categories of warm to extremely warm. There were 9 summer days and 1 tropical day during the month. There were no frosty days. November had a mean air temperature of 9.0 °C, which deviated from the reference period, i.e., it was higher by 1.6 °C and 0.8 °C compared to the research period. There were no heat waves, nor summer and tropical days, but there were 5 frosty days. According to the percentile method of mean daily temperatures, during most of the first and middle of the second decade, they were in the warm category, while the rest of the month was in the normal category. November 2023 had the most precipitation since measurements were taken (RHMZ, https://www.hidmet.gov.rs/ciril/meteorologija/klimatologija_produkti.php accessed on 10 January 2024).



(a)

Figure 5. *Cont.*



(b)

Figure 5. Mean monthly air temperature and sum of precipitation for February (**a**) and March (**b**) and their corresponding terciles for Belgrade (black lines correspond to the percentiles of the reference period), in the research period, in relation to the reference period 1991–2020.

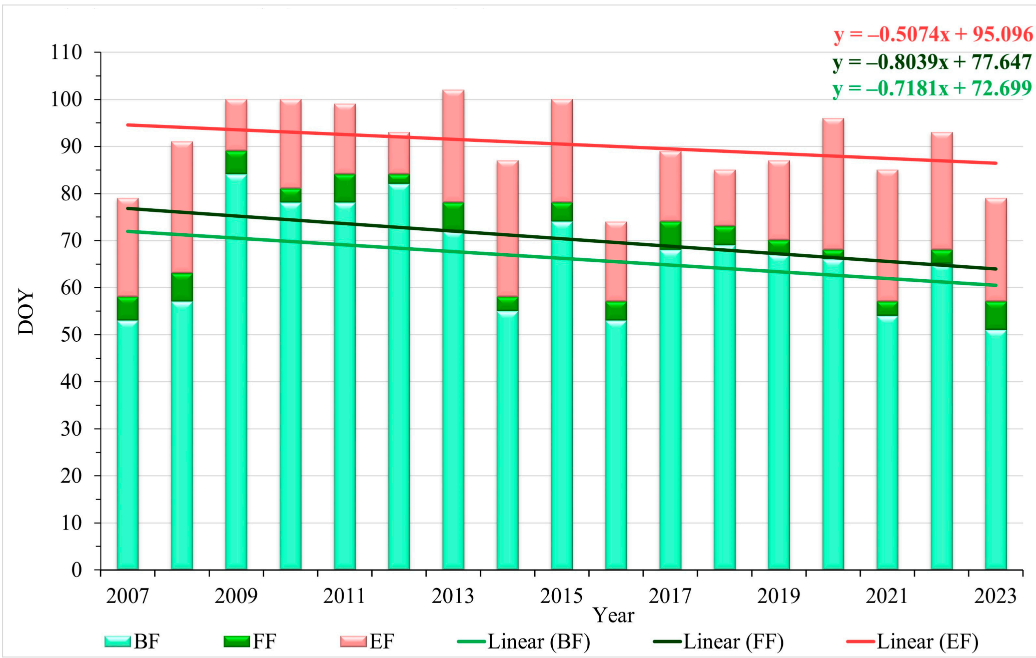


Figure 6. The DOY, for the period of 2007–2023, for the beginning of flowering (BF), full flowering (FF), and the end of flowering (EF) and associated linear trends.

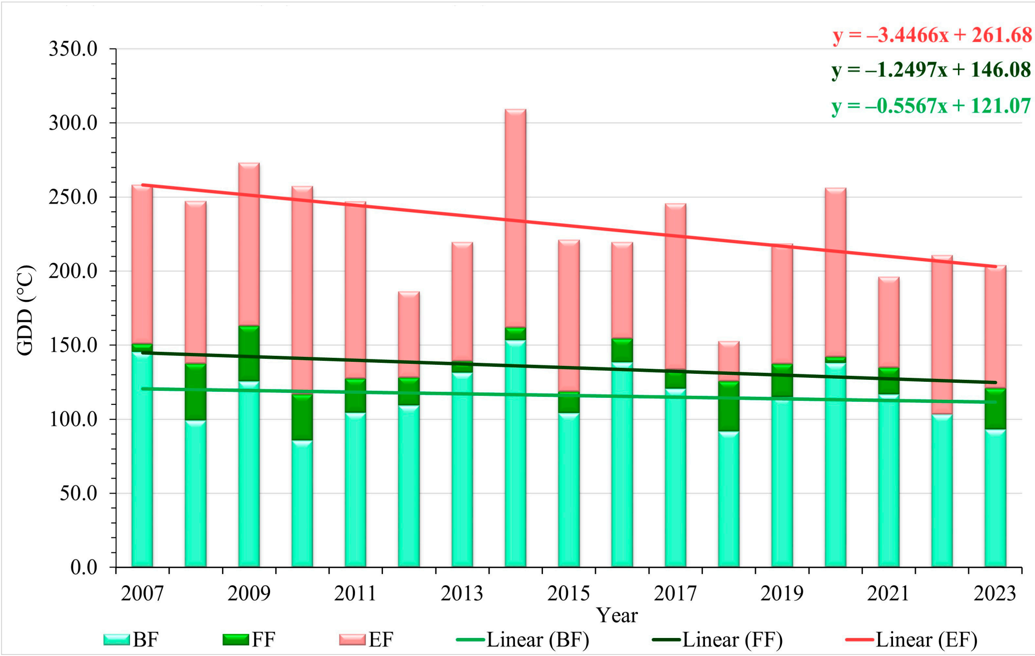


Figure 7. GDDs (°C), for the period of 2007–2023, for the beginning of flowering (BF), full flowering (FF), and the end of flowering (EF) and associated linear trends.

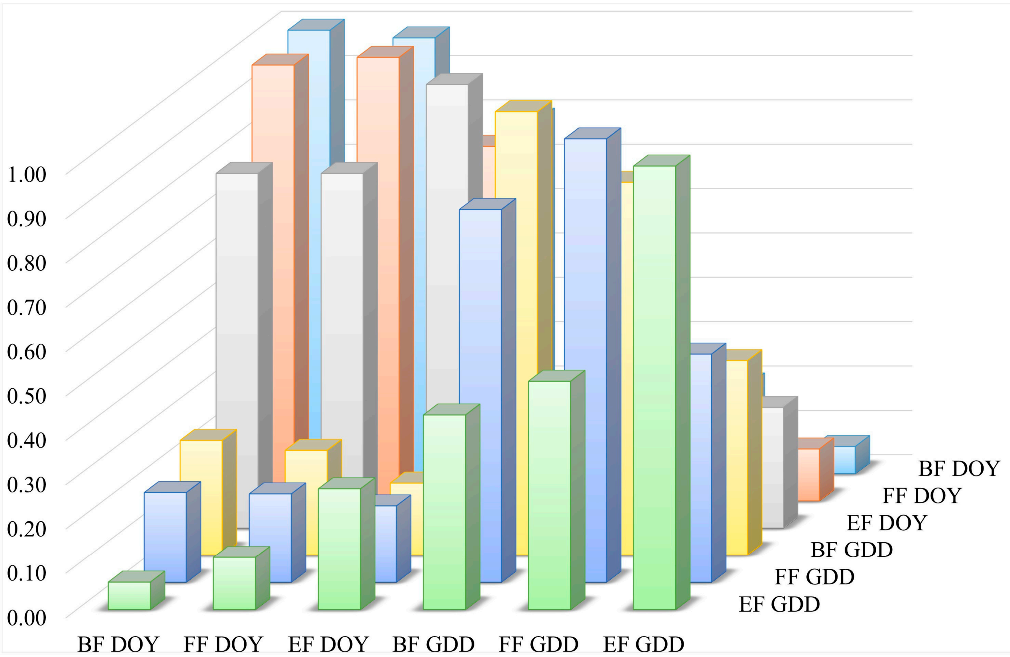


Figure 8. Graphic representation of Spearman's correlation coefficients for the DOY and GDDs for cherry plums, for the period of 2007–2023, in the study area.

Table 1. Descriptive statistics for the investigated parameters of cherry plums.

Parameter	BF DOY	FF DOY	EF DOY	BF GDD	FF GDD	EF GDD
Minimum	51.000	57.000	74.000	85.529	103.173	152.667
Maximum	84.000	89.000	102.000	153.082	162.887	309.247
Range	33.000	32.000	28.000	67.553	59.715	156.581
1st Quartile	55.000	58.000	85.000	103.115	125.548	210.594
Median	67.000	70.000	91.000	114.788	134.595	221.087
3rd Quartile	74.000	78.000	99.000	131.219	141.786	256.229
Mean	66.235	70.412	90.529	116.062	134.837	230.662
Standard deviation (n)	10.547	10.505	8.197	19.367	15.704	35.722
Variation coefficient (n)	0.159	0.149	0.091	0.167	0.116	0.155
Kurtosis (Pearson)	−1.263	−1.287	−0.919	−0.996	−0.508	0.110
Standard error (Kurtosis (Fisher)	1.063	1.063	1.063	1.063	1.063	1.063

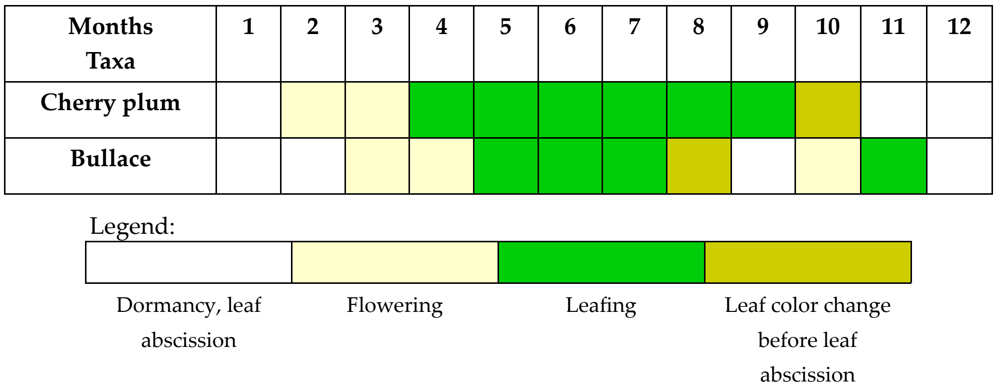


Figure 9. A phenogram of the cherry plum and bullace from January to November 2023 in the study area.

Table 2. Climatic variables for the reference period of 1991–2020, research period, and for 2023 and their deviations from the reference period for the temperatures (°C) and precipitation levels (%) for the Surčin weather station based on hourly and daily data (source: RHMZ).

Mean Air Temperature (°C)													
Months Period	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	$\bar{x}$
Tmean 1991/2020	1.0	3.0	7.5	12.9	17.6	21.4	23.3	23.2	18.0	12.8	7.4	2.2	12.5
Tmean 2007/2022	1.8	4.2	8.0	13.5	17.8	22.2	24.1	24.0	18.6	13.0	8.2	3.3	13.2
Tmean 2023	5.1	4.1	9.3	10.6	16.8	21.2	25.3	23.8	21.9	17.02	9.0	5.9	14.2
Deviation Tmean 2023 from the reference period	4.2	1.6	2.0	−3.0	−1.2	−0.9	2.0	0.7	4.2	4.25	1.6	3.8	1.7
Deviation Tmean 2023 from period 2007–2022	3.4	0.4	1.7	−3.6	−1.2	−1.5	1.2	−0.1	3.8	4.05	0.8	2.7	1.7
Mean maximum air temperature (°C)													
Tmax 1991/2020	4.5	7.4	12.9	18.4	23.2	26.9	29.0	29.3	24.1	18.5	11.9	5.5	17.6
Tmax 2007/2022	5.3	8.6	13.2	19.1	23.2	27.5	29.8	30.1	24.5	18.5	12.7	6.6	18.3
Tmax 2023	8.7	9.0	14.8	15.5	22.0	26.0	31.0	30.0	28.3	23.4	13.4	10.4	19.4
Deviation Tmax 2023 from the reference period	4.2	1.6	2.0	−2.9	−1.2	−0.9	2.0	0.7	4.2	4.9	1.5	4.9	1.7
Deviation Tmax 2023 from period 2007–2022	3.4	−0.4	1.7	−3.6	−1.2	−1.5	1.2	−0.1	3.8	4.9	0.7	3.8	1.1

Table 2. *Cont.*

Mean Air Temperature (°C)													
Months Period	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	$\bar{x}$
Mean minimum air temperature (°C)													
Tmin 1991/2020	−2.3	−1.0	2.6	7.1	11.8	15.4	16.8	16.9	12.6	7.9	3.6	−0.9	7.5
Tmin 2007/2022	−1.6	0.1	3.1	7.4	12.1	16.2	17.6	17.5	13.1	8.2	4.4	0.2	8.2
Tmin 2023	2.5	0.0	4.0	5.8	11.9	16.1	18.7	18.0	15.8	11.4	4.9	1.9	9.2
Deviation Tmin 2023 from the reference period	4.2	1.6	2.0	−3.0	−1.2	−0.9	2.0	0.7	4.2	3.4	1.3	2.8	1.7
Deviation Tmin 2023 from period 2007–2022	3.4	0.4	1.7	−3.6	−1.2	−1.5	1.2	−0.1	3.8	3.2	0.5	1.7	1.1
Total and mean amounts of precipitation (mm)													
Period	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	∑
Prec 1991/2020	42.4	34.0	41.7	47.4	68.1	80.1	58.2	54.0	56.0	50.7	45.5	48.3	626.4
Prec 2007/2022	44.9	38.2	48.4	40.4	82.5	74.2	51.0	45.3	52.3	50.0	48.5	50.0	625.8
Prec 2023	71.6	54.4	29.9	58.6	70.1	102.0	43.4	60.6	46.9	16.8	93.0	31.6	678.9
Deviation Prec 2023 from the reference period	69	60	−28	24	3	27	−25	12	−16	−67	104	−35	8
Deviation Prec 2023 from period 2007–2022	59	43	−38	45	−15	37	−15	34	−10	−66	92	−37	8

A strong seasonality of the bullace is evident. Specifically the phenological patterns were influenced by variations in the climatic parameters within a multifunctional landscape, as stated by previous authors [72]. While flowering and other phenological patterns of the cherry plum exhibit associations with these variations, it is worth noting that phylogeny has a more pronounced impact on this correlation. According to some researchers [73], these findings can be attributed to a complex interplay of abiotic and biotic factors, taking into account the historical evolutionary strategies of cherry-plum development.

4. Discussion

This study examines the changes in phenology during the 17-year period of urban and suburban cherry-plum populations with a special focus on flowering and fruiting as the prerequisite for the yield and reach of its full vegetative potential in abiotic stress caused primarily by climate change. Although some studies suggest a 70% survival of urban tree species [1], the vitality of species varies among various locations within the city. Thus, it is necessary to inform decision makers of species-specific and climate-specific characteristics to allow for the maximal provision of urban greenery to ecosystem services. *Prunus cerasifera* Ehrh. populations, in our research, are located in a research area that has two distinct characteristics: one is characterized by a predominantly residential area, while the other is mainly an agricultural area but includes public infrastructures, such as roads and other facilities. As this area does not belong to any protected category, it is important to rely on resistant, native-to-semi-cultured species to contribute to biodiversity conservation and the provision of the stepping stones to the species inhabiting the protected area of the confluence of Sava and Danube. Thus, *Prunus cerasifera* Ehrh. was chosen, as the literature suggested it is resistant to dominant stressors in this area—air pollutants—and is adaptive to climate change. The cherry plum showed an air-mitigation potential that was among the species with the best health conditions in a previous study [21] and a good adaptive capacity for the climate and air-pollution projections for the next 20 years. It is also appreciated for its carbon sequestration potential [16] and its capacity to accumulate heavy metals [22,23]. In our research, the cherry plum occupies both positions: (a) in private gardens, where its main role is providing yields and food for people and animals; and (b) in roadside solitaires and groups, where its resistance to air pollution and the accumulation of carbon and heavy metals is of the utter importance. Other mechanisms of its suitability for urban planning are its high photosynthetic values in urban areas [16], and it was named the most suitable species used as a biomonitor, according to previous researchers [74]. Habitat sustainability and important phenological stages are affected by climate changes [49]. Ecosystem responses to climate changes and urbanization are clearly seen in phenological changes [75], which can further affect the ecological and physiological processes of plants, such as production, evapotranspiration, and plant development—plant fitness.

Our research identifies biotic and environmental factors that significantly affect the phenology and productivity of cherry-plum trees (*Prunus cerasifera* Ehrh.). Species from the genus *Prunus* L. are cosmopolitan, encompassing 340 officially accepted species of the cherry plum (*Prunus cerasifera* Ehrh.) native to West Asia, the Balkans (Serbia, Romania, Bulgaria, and Greece), and the Caucasus [26,76,77]. The species is highly resistant, especially to frost, and has shown a great power of adaptability, which is why it is used as a rootstock for grafting, breeding, and genetic resources [26,78–81]. Some authors [54] also indicate the high resistance of different cultivars of the cherry plum to frost, based on research in Crimea. Others [82] point out that the cherry plum is a very resistant species, which does not have many requirements and whose production and cultivation do not have a bad impact on the environment.

A study [54] determined that the main factors limiting productivity in cherry-plum cultivars were the flowering intensity and minimum air temperature during flowering as well as spring frosts. Our results suggest that *Prunus cerasifera* Ehrh. as well as the bullace (*P. cerasifera* Ehrh. × *P. spinosa* L.) are adaptive species maintaining abundant fruiting, despite their cited susceptibility to late-spring frosts (which occurred from 3 March to 7 April in 2023). However, an early frost in autumn affected the repeated fruiting in the bullace that was noted after the second flowering in the same year. Namely, the yield was significantly lower compared to the previous 16-year period. The phenological characteristics of the species previously revealed that the blossoming period varied among genotypes, although they were all very early flowering and were at the risk of spring-frost damage [83]. Late-spring frosts lead to ecological and economic losses, because plants are vulnerable in the spring period when temperatures are below 0 °C [84], which places the cherry plum high on the priority list for urban use, as our research showed that no fruiting was affected by late-spring frosts. The findings of previous studies prove that with different mechanisms of adaptation and changes in the physiological processes of plants, the risk could be reduced, which was observed in *Prunus cerasifera* Ehrh. What was observed in our research was that spring phenologies took place earlier, especially in those years when the risk of late-spring frosts increased. Another explanation for the cherry-plum resilience to spring frosts in our study could be that the winter-cold resistance of plums is significantly influenced by temperature fluctuations, especially the autumn and early winter when they prepare for dormancy, as cited in previous research [55]. September in Belgrade was warm with no extreme fluctuations in temperatures. One study [85], in neighboring Romania, specifies 21–25 March and 21–25 April as the most critical intervals for late frosts to affect fruit trees and notices the higher values of the probabilities of damage occurrence for the early cultivars. However, the probability of damage occurrence by late-spring frosts was only less than 3%.

Phenology has an important place in current scenarios of global-change research due to its role in monitoring and predicting the recurrence of life-cycle events [52]. Monitoring phenology, as well as phenological modeling, is of great importance in terms of making decisions about agricultural practices in growing agricultural trees [86,87]. The research on plant phenology in urban environments is the basis for predicting future plant phenology in cities where air temperatures are increasingly altered [88]. Using surveillance cameras in urban areas, the phenology of several species was studied, among them the cherry plum, and determined that the results of the phenological projections were in accordance with the phenological observations conducted in the field [89,90]. Only in Ukraine in 2019, when the winter temperatures were unusually high, the repeated flowering of cherry plum was recorded [91], while in our research, the repeated flowering of bullace was recorded only in 2023.

Another research on the cherry plum of various age points that air temperatures and precipitation in April and August have the biggest correlation with the phenological occurrences [92]. April 2023 in Belgrade did not significantly deviate in precipitation from other 16-year observations nor from the 1991–2020 period, but phenophases were still shifted. Similar to our results, research in Slovakia [93], Iran [24], and Taiwan [83] noted that temperature changes led to earlier onset of cherry plum phenophases. Urban and suburban cherry-plum populations in Romania along with 9 other species were shifted to earlier phenophases according to some [94]. Research on the phenology of cherry plum carried out in Turkish Anatolia in the period from 1995 to 1997 shows that the time of full flowering was from 8–15 March and from 20–28 March, similar to our results while fruit ripening began in mid-May and early June [95]. A study on the flowering and fruiting phenology of certain cultivars of the cherry plum, carried out in Iran [24], cites 21 March for BF, which is the 80th DOY. Fruiting started in the first decade of July. All 17 years of our research showed that the flowering of the basic form, in most cases, occurred significantly earlier than the early flowering varieties of cherry plums in Iran. In the year of 2023, in Belgrade, the beginning of flowering was at the 51st DOY, and in 2009, when, in Belgrade, cherry plums started flowering at the 84th DOY (the latest), this was only 4 days later than in Iran. The median onset of flowering for all the 17 years was 67, which is 13 days earlier than the study in Iran. Some researchers [92] followed the air temperature and precipitation in April and August due to the influence on the flowering and fruiting of cherry plums and cited an average of a DOY of 91.5 as the beginning of flowering. These flowering data show that cherry plums in Hungary flowered more than a month later compared to the earliest flowering period in our study. According to previous research in Romania [33], the beginning of the flowering of cherry plums was 15 March (74th DOY). The duration of flowering was 29 days when the average air temperature was 9.69 °C. Some researchers [96] also studied the phenology of 10 ornamental woody species, including cherry plums, among others, which bloomed in Romania 2 days apart in urban and rural areas (5 km from the center), that is on the 80th DOY and the 82nd DOY when converted to the DOY, as in our research. This is 13 days later than our observation. Another research [83] investigated hybrids of the cherry plum and apricot and noted that the beginning of flowering is in March (14 to 29), i.e., the 73rd to the 88th DOY, which is a 21-day difference compared to the median of our survey. Thus, we can conclude that the onset of the flowering phenophase in Belgrade is significantly earlier than in neighboring countries. The research from Montenegro examined twenty cultivars of *Prunus cerasifera* Ehrh. and concluded that the onset of flowering was in the last five days of March and in the first twelve days of April and lasted 9 to 14 days [17]. These findings are closer to our observations. We observed an increase in the length of the vegetation season, which was registered before as well [97]. In Romania, the shortest duration from bud-breaking to the end of blossoming was in *P. cerasifera* Ehrh. from 15 March to 15 April. In 2023, in Belgrade, the flowering phenophase lasted 28 days (the 51st DOY to the 79th DOY). In a 17-year period, the onset of the flowering was earlier by 15 days, while the end was earlier by 11 days, which leads us to an extended flowering phenophase, as cited by other researchers who noticed that, regardless of the species or phenological phase, the urban environment accelerates the beginning of phenological phases [94].

A long time-series analysis, such as that of our research, could show clear trends of the changes in phenology and could contribute to the informed planning of urban species. We analyzed the shifts regarding the day of the year (DOY) as well as the GDD (growth degree day) and found that accumulated heat was less affected than the DOY in regard to the flowering phenophase. Other findings suggest that the predicted warming in the future may result in a slowdown in the advance of the spring phenology of woody plants [98]. As in previous studies, our findings suggest that the need for a cold climate is the main factor that determines the flowering time [99,100], which is an important agronomic feature for seed and fruit development in species of fruit trees in temperate areas. Our results show that the GDD is highly correlated with temperature and precipitation levels. The phenology and fruiting of cherry plums are often the focus of research, as different cultivars and hybrids of the cherry plum and other *Prunus* L. are stable, more adaptable, and, therefore, are more profitable crops than others in a changing climate [101]. To increase the economic efficiency of the horticultural industry, it is necessary to introduce high-yielding cultivars and to consider scientific grounds for their placement in specific soil and climatic conditions. The aim of the present research is to focus on those environmental factors that significantly affect the flowering and productivity of cherry-plum trees (*Prunus cerasifera* Ehrh.). Some research [54] also addresses the minimum air temperature during flowering as the factor that affects the productivity of cherry plums, which is in accordance with our findings that highlight the importance of the temperature, as the DOY was more affected than the GDD during the 17-year period.

The adaptability of the cherry plum to climate changes in our research indicates that the species does not require too much cost and provides many benefits in the city (ecosystem services). As in another research [102], cherry plums could be suggested for more frequent use in the arrangement of the urban environment. Due to its sustainability, it is appropriate for urban planning, while maintaining its decorative and ecological values in changed climatic conditions, as authors have previously suggested [103]. The use of *Prunus cerasifera* Ehrh., and especially purple cultivars for urban greening, has a very important place, as it shows great resistance to the negative conditions of climate changes and urbanization and is a prerequisite for environmental sustainability [32]. In the urban and suburban areas of Belgrade, there is a common presence of cultivars with anthocyanins that determine the morpho-anatomical, biochemical, and physiological effects of the phenology in climate changes [58]. The same study compared green-leaved to red-leaved cultivars and found that the presence of anthocyanins promotes a delayed leaf senescence (a 4-week-longer leaf lifespan), which is a well-appreciated feature in the context of urban greening. Our research encompasses phenophases at the population level; therefore, the next step could be to compare the differences in phenology in the cherry plum and its purple cultivar. Tolerance to abiotic stresses is a very important feature of urban plant materials, especially trees, as environmental conditions in cities are significantly altered due to global climate change. The purple cultivars of the cherry plum are particularly resistant to drought stress, as indicated by previous researchers [33]. Therefore, in the context of landscape architectural planning and design, it is necessary to monitor the adaptation and resistance of plants to stresses, as well as to know their vulnerability, when choosing the species for the design. Also, studying the phenology of fruit-bearing species, in relation to ecological factors, helps in researching their adaptation to climate change. If there are extended spring phenophases, such as the number of days of flowering, this can, on the other hand, positively affect pollination and provide a longer period that is favorable for bee flight [33]. Knowing the sensitivity of plants is very important for making decisions about creating varieties that are able to adapt to climate change. The temperature sensitivity of the red-leaved cherry-plum cultivar was a focus of research for some authors [98], who concluded it was almost constantly under changed elevated-temperature conditions for all phases, except for flower opening. Temperature sensitivity was only strong during the opening of flower buds. At a temperature of 10 °C, the buds of the cherry plum spread apart, while with the passage of time, the fruits matured more slowly. The cherry plum showed the least temperature sensitivity among the different phenophases.

In order to avoid extreme events, it is necessary that the development of adaptation strategies to climate changes be oriented towards the use of cultivars that are resistant to change factors, as well as the harmonization of phenology with those new environmental conditions [104]. The same authors quantified the changes in carbon uptake through assessments of phenological changes occurring in temperate forests. Since the cherry plum in our research also occupies positions on the roadside, its capacity for carbon uptake is also an important characteristic, especially if we take into account that in our location, the cherry plum is next to the road that connects two important ecosystems in terms of biodiversity, one being the confluence of the Sava to the Danube River. Adaptations and an increased carbon input through the process of photosynthesis due to earlier spring phenophases were determined, which will have a positive effect, as global warming will occur more slowly. As a result, the increase in areas under the greenery, as well as the extension of the vegetation period, have an impact on the longer uptake of carbon [105,106]. *Prunus cerasifera* Ehrh. stands out as the species that covers more than one ecosystem service: it is a fruit-bearing species with fruits that can be used as food for both humans and animals and can be processed into a variety of products; it is adaptable to climate changes with unaffected fruit production, despite the shifts in the flowering phenophase; and it is highly ornamental, with the ability to mitigate the carbon sequestration and heavy metals in polluted environments.

5. Conclusions

In the period of 2007 to 2023, significant climate changes occurred, marked by alterations in air temperatures, precipitation patterns, and occurrences of extreme events, such as autumnal summer and tropical days and late (spring) and early (autumn) frosts. The adaptability of *Prunus cerasifera* Ehrh. (cherry plum), as a fruit-bearing species, was evaluated for its potential in urban design and planning, focusing on the phenological aspects of flowering and fruiting. The cherry plum demonstrated a robust capacity to withstand these climate variations.

The analysis of the flowering phenophase, assessed through both the DOY and GDD, revealed that the onset of flowering occurred, on average, 15 days earlier, with the end of flowering being 11 days earlier compared to the reference period. Thus, the flowering phenophase was extended for 4 days in total. Despite these shifts, fruit abundance remained unaffected, with all fruits receiving a maximal rating of 5 on the scale, even in the presence of late frosts in March and April. A linear trend in the DOY indicated earlier appearances of BF, FF, and EF, despite a 33-day difference between the earliest and latest flowering phenophases. Conversely, the GDD exhibited stability, indicating consistent heat-accumulation requirements for initiating subphases in flowering. The GDD correlated with air temperatures and precipitation levels, aligning with prior research, even though the earliest and latest flowering occurrences transpired amid similar precipitation levels.

In 2023, autumn fluctuations were extreme, bringing increased precipitation levels, more summer and tropical days, late (spring) and early (autumn) frosts, and a snow cover in spring. Despite these challenging weather conditions, the cherry plum consistently delivered unchanged ecosystem services, with a maximum yield and extended flowering contributing to prolonged ornamental values, thus exhibiting a resilience to early frosts. The only registered repeated flowering, fruiting, and the growth and leafing of shoots were observed in a hybrid of the cherry plum—bullace—lasting until the early frost in autumn 2023. However, the late-spring frost was detrimental to the repeated fruiting in the bullace in November, contributing to its decreased yield. The populations in urban and suburban areas, in natural and semi-natural habitats, demonstrated an equal resilience to climate changes. The cherry plum's ability to thrive in urban environments positions it as a suitable species for urban design in multifunctional landscapes, offering benefits such as biodiversity conservation, air-pollution mitigation, and climate-change adaptation.

Author Contributions: Conceptualization, D.P., M.O., N.G., D.S. and I.S.; methodology, D.P., M.O., N.G., D.S. and I.S.; formal analysis, D.P. and M.O.; investigation D.P., M.O., N.G., D.S. and I.S.; resources, D.P., M.O., N.G., D.S. and I.S.; data curation D.P. and M.O.; visualization, N.G. and D.S.; writing—original draft preparation, M.O., D.P. and I.S.; writing—review and editing D.P., M.O. and I.S.; supervision, M.O. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by The Ministry of Education, Science and Technological Development, which finances the scientific research of the University of Belgrade, the Faculty of Forestry on the basis of an agreement of the following realization number: 451-03-65/2024-03/200169.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The climatology data are freely available at https://www.hidmet.gov.rs/eng/meteorologija/klimatologija_produkti.php (accessed on 10 January 2024) The data from the Republic Hydrometeorolgical Service of Serbia, which cannot be published, was accessed multiple times.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. IPCC. *Summary for Policymakers: Synthesis Report—Climate Change 2023—Synthesis Report*; Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change; IPCC: Geneva, Switzerland, 2023; pp. 1–34.
2. Randall, T.; Cousins, A.L.; Neilson, L.; Price, M.; Hardman, C.A.; Wilkinson, L.L. Sustainable food consumption across Western and Non-Western cultures: A scoping review considering the theory of planned behavior. *Food Qual. Prefer.* **2024**, *114*, 105086. [CrossRef]
3. Shahid, M.; Dumat, C.; Khalida, S.; Schreck, E.; Xiong, T.; Nabeel, N.K. Foliar heavy metal uptake, toxicity and detoxification in plants: A comparison of foliar and root metal uptake. *J. Hazard. Mater.* **2017**, *325*, 36–58. [CrossRef]
4. Cetin, M.; Onac, A.K.; Sevik, H.; Sen, B. Temporal and regional change of some air pollution parameters in Bursa. *Air Qual. Atmos. Health* **2019**, *12*, 311–316. [CrossRef]
5. Qarri, F.; Lazo, P.; Stafilov, T.; Bekteshi, L.; Baceva, K.; Marka, J. Survey of atmospheric deposition of Al, Cr, Fe, Ni, V, and Zn in Albania by using moss biomonitoring and ICP-AES. *Air Qual. Atmos. Health* **2014**, *7*, 297–307. [CrossRef]
6. Zhang, S.; Song, H.; Li, X.; Luo, S. Urban Parks Quality Assessment Using Multi-Dimension Indicators in Chengdu, China. *Land* **2024**, *13*, 86. [CrossRef]
7. Song, P.; Gao, L. Landscape design of colleges based on the concept of ecological protection-taking Jilin Communications Polytechnic as an example. *Int. J. Phytoremediat.* **2024**, *26*, 314–323. [CrossRef]
8. Smithwick, E.A.H.; Baka, J.; Bird, D.; Blaszscak-Boxe, C.; Cole, C.A.; Fuentes, J.D.; Gergel, S.E.; Glenna, L.L.; Grady, C.; Hunt, C.A.; et al. Regenerative landscape design: An integrative framework to enhance sustainability planning. *Ecol. Soc.* **2023**, *28*, 5. [CrossRef]
9. Wang, H.; Tassinary, L.G.; Newman, G.D. Developing the health effect assessment of landscape (HEAL) Tool: Assessing the health effects of community greenspace morphology design on non-communicable diseases. *Landsc. Urban Plann.* **2024**, *244*, 104990. [CrossRef]
10. Roman, L.A.; McPherson, E.G.; Scharenbroch, B.C.; Bartens, J. Identifying common practices and challenges for local urban tree monitoring programs across the United States. *Arboric. Urban For.* **2013**, *39*, 292–299. [CrossRef]
11. Martin, M.P.; Simmons, C.; Ashton, M.S. Survival is not enough: The effects of microclimate on the growth and health of three common urban tree species in San Francisco, California. *Urban For. Urban Green.* **2016**, *19*, 1–6. [CrossRef]
12. Ognjanov, V.; Cerović, S. Selection and utilization of minor fruit tree species. *Acta Hortic.* **2004**, *663*, 569–574. [CrossRef]
13. Cosmulescu, S.N.; Ionica, M.E.; Mutu, N. Evaluation on the genetic diversity of phenotypic traits in myrobalan plum (*Prunus cerasifera* Ehrh.). *South-West J. Hortic. Biol. Environ.* **2018**, *9*, 25–34.
14. Nikolić, D.; Rakonjac, V. Divergence of myrobalan (*Prunus cerasifera* Ehrh.) types on the territory of Serbia. *Genetika* **2007**, *39*, 333–342. [CrossRef]
15. Mišić, P.D. Gene banks and preselection in fruit plants. *Genetika* **1983**, *15*, 361–368.
16. Baraldi, R.; Chieco, C.; Neri, L.; Facini, O.; Rapparini, F.; Morrone, L.; Rotondi, A.; Carriero, G. An integrated study on air mitigation potential of urban vegetation: From a multi-trait approach to modeling. *Urban For. Urban Green.* **2019**, *41*, 127–138. [CrossRef]
17. Šebek, G. The phenological and pomological traits of autochthonous plum cultivars in the area of North Montenegro. *Acta Sci. Pol. Hortorum Cultus* **2016**, *15*, 45–63.
18. Milutinovic, M.; Nikolic, D. Genetical variability of myrobalan (*Prunus cerasifera*) seedlings. *Acta Hortic.* **1994**, *359*, 217–224. [CrossRef]
19. Ogašanović, D.; Korać, M.; Miletić, R.; Milutinović, M.; Mišić, P.D.; Miranović, K.; Nikolić, M.; Ognjanov, V.; Paunović, S.A.; Tešović, Ž.; et al. Genetic resources of the most important fruit tree species of FR Yugoslavia. [Genetički resursi važnijih vrsta voćaka SR Jugoslavije]. *Savremena Poljoprivreda* **1997**, *46*, 161–173. (In Serbian)
20. Božović, Đ.; Jaćimović, V. Resistance to low temperatures, causing disease and pests of isolated genotypes of sedge (*Prunus cerasifera* Ehrh.) in the area of upper Polimlje. [Otpornost na niske temperature, prouzrokovače bolesti ištetotičine izdvojenih genotipova džanarike (*Prunus cerasifera* Ehrh.) u području gornjeg Polimlja]. *Zbornik Naučnih Radova sa XVII Savetovanja Agronoma, Veterinara i Tehnologa* **2003**, *9*, 185–191. (In Serbian)
21. Li, Q.; Zhu, Y.; Zhu, Z. Calculation and Optimization of the Carbon Sink Benefits of Green Space Plants in Residential Areas: A Case Study of Suojin Village in Nanjing. *Sustainability* **2023**, *15*, 607. [CrossRef]

22. Zhang, B.; Feng, Q.; Xue, Y.; Liu, D.; Zhao, C.; Yan, S.; Li, J. Accumulation characteristics, seasonal changes, and source analysis of heavy metals in major greening tree species on common highways in Fuzhou, China. *Chin. J. Appl. Environ. Biol.* **2022**, *28*, 1199–1208. [CrossRef]
23. Turkyilmaz, A.; Sevik, H.; Cetin, M.; Ahmaida Saleh, E. Changes in Heavy Metal Accumulation Depending on Traffic Density in Some Landscape Plants. *Pol. J. Environ. Stud.* **2018**, *27*, 2277–2284. [CrossRef]
24. Ganji Moghaddam, E.; Hossein Ava, S.; Akhavan, S.; Hosseini, S. Phenological and pomological characteristics of some plum (Prunus spp.) cultivars grown in Mashhad, Iran. *Crop Breed. J.* **2011**, *1*, 105–108. [CrossRef]
25. Milošević, T.; Milošević, N. Plum (*Prunus* spp.) Breeding. In *Advances in Plant Breeding Strategies: Fruits*; Al-Khayri, J., Jain, S.M., Johnson, D.V., Eds.; Springer: Cham, Switzerland, 2018; Volume 3, pp. 165–215. ISBN 978-3-319-91943-0.
26. Butac, M. Plum Breeding. In *Prunus*; Küden, A., Küden, A., Eds.; IntechOpen: London, UK, 2020; ISBN 978-1-83962-608-1. [CrossRef]
27. Halpern, C.B.; Spies, T.A. Plant Species Diversity in Natural and Managed Forests of the Pacific Northwest. *Ecol. Appl.* **1995**, *5*, 913–934. [CrossRef]
28. Carey, A.B. Biocomplexity and restoration of biodiversity in temperate coniferous forest: Inducing spatial heterogeneity with variable-density thinning. *Forestry* **2003**, *76*, 127–136. [CrossRef]
29. Czortek, P.; Adamowski, W.; Kamionka-Kanclerska, K.; Karpińska, O.; Zalewski, A.; Dyderski, M. Patterns of *Prunus cerasifera* early invasion stages into a temperate primeval forest. *Biol. Invasions* **2023**, *26*, 633–647. [CrossRef]
30. Zuo, J.; Zhao, Z.Y. Green building research–current status and future agenda: A review. *Renew. Sustain. Energy Rev.* **2014**, *30*, 271–281. [CrossRef]
31. Radutoiu, D.; Stefanescu, D.M. Aesthetics of ruderal vegetation in the urban and peri-urban areas of Oltenia (Romania). *Ann. Univ. Craiova Agric. Mont. Cadastre Ser.* **2017**, *XLVII*, 223–228.
32. Lo Piccolo, E.; Landi, M. Red-leafed species for urban "greening" in the age of global climate change. *J. For. Res.* **2021**, *32*, 151–159. [CrossRef]
33. Cosmulescu, S.; Buican Stanciu, A.; Ionescu, M. The influence of temperature on phenology of ornamental woody species in urban environment. scientific papers. *Sci. Pap. Ser. B Hortic.* **2020**, *64*, 61–67.
34. Richardson, A.D.; Anderson, R.S.; Arain, M.A.; Barr, A.G.; Bohrer, G.; Chen, G.; Chen, J.M.; Ciais, P.; Davis, K.J.; Desai, A.R.; et al. Terrestrial biosphere models need better representation of vegetation phenology: Results from the North American Carbon Program Site Synthesis. *Glob. Chang. Biol.* **2012**, *18*, 566–584. [CrossRef]
35. Burkle, L.A.; Marlin, J.C.; Knight, T.M. Plant-pollinator interactions over 120 years: Loss of species, co-occurrence, and function. *Science* **2013**, *339*, 1611–1615. [CrossRef]
36. Xia, J.; Niu, S.; Ciais, P.; Janssens, I.A.; Chen, J.; Ammann, C.; Arain, A.; Blanken, P.D.; Cescatti, A.; Bonal, D.; et al. Joint control of terrestrial gross primary productivity by plant phenology and physiology. *Proc. Natl. Acad. Sci. USA* **2015**, *112*, 2788–2793. [CrossRef]
37. Fitter, A.; Fitter, R.; Harris, I.; Williamson, M. Relationships between first flowering date and temperature in the flora of a locality in central England. *Funct. Ecol.* **1995**, *9*, 55–60. [CrossRef]
38. Menzel, A. Trends in phenological phases in Europe between 1951 and 1996. *Int. J. Biometeorol.* **2000**, *44*, 76–81. [CrossRef]
39. Rötzer, T.; Chmielewski, F.M. Phenological maps of Europe. *Clim. Res.* **2001**, *18*, 249–257. [CrossRef]
40. Sparks, T.H.; Menzel, A. Observed changes in seasons: An overview. *Int. J. Climatol.* **2002**, *22*, 1715–1726. [CrossRef]
41. Vitasse, Y.; Porté, A.J.; Kremer, A.; Michalet, R.; Delzon, S. Responses of canopy duration to temperature changes in four temperate tree species: Relative contributions of spring and autumn leaf phenology. *Oecologia* **2009**, *161*, 187–198. [CrossRef]
42. Beaubien, E.; Hamann, A. Spring Flowering Response to Climate Change between 1936 and 2006 in Alberta, Canada. *BioScience* **2011**, *61*, 514–524. [CrossRef]
43. Stojicic, Đ. The Impact of Environmental Factors on Flowering of Woody Species from Magnoliophyta group in Belgrade. Ph.D. Thesis, Univerzitet u Beogradu—Šumarski Fakultet, Belgrade, Serbia, 2014; p. 243. (In Serbian).
44. Wang, H.; Zhong, S.; Tao, Z.; Dai, J.; Ge, Q. Changes in flowering phenology of woody plants frm 1963 to 2014 in North China. *Int. J. Biometeorol.* **2019**, *63*, 579–590. [CrossRef]
45. Ocokoljić, M.; Petrov, Đ.; Galečcić, N.; Skočajić, D.; Košanin, O.; Simović, I. Phenological Flowering Patterns of Woody Plants in the Function of Landscape Design: Case Study Belgrade. *Land* **2023**, *12*, 706. [CrossRef]
46. Parmesan, C.; Yohe, G. A globally coherent fingerprint of climate change impacts across natural systems. *Nature* **2003**, *421*, 37–42. [CrossRef]
47. Hamann, A.; Wang, T. Potential effects of climate change on ecosystem and tree species distribution in British Columbia. *Ecology* **2006**, *87*, 2773–2786. [CrossRef]
48. Qiu, J.; Carpenter, S.R.; Booth, E.G.; Motew, M.; Zipper, S.C.; Kucharik, C.J.; Loheide, S.P., II; Turner, M.G. Understanding relationships among ecosystem services across spatial scales and over time. *Environ. Res. Lett.* **2018**, *13*, 054020. [CrossRef]
49. Preve´y, J.S.; Parker, L.E.; Harrington, C.A. Projected impacts of climate change on the range and phenology of three culturally-important shrub species. *PLoS ONE* **2020**, *15*, e0232537. [CrossRef]
50. Richardson, A.D. Climate change, phenology, and phenological control of vegetation feedbacks to the climate system. *Agric. For. Meteorol.* **2013**, *169*, 156173. [CrossRef]

51. Bagne, K.; Friggens, M.; Finch, D. *A System for Assessing Vulnerability of Species (SAVS) to Climate Change*; General Technical Report RMRS-GTR-257; U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: Fort Collins, CO, USA, 2011; p. 28.
52. Morellato, L.P.C.; Alberton, B.; Alvarado, S.T.; Borges, B.; Buisson, E.; Camargo, M.G.G.; Cancian, L.F.; Carstensen, D.W.; Escobar, D.F.E.; Leite, P.T.P.; et al. Linking plant phenology to conservation biology. *Biol. Conserv.* **2016**, *195*, 60–72. [CrossRef]
53. Dalhaus, T.; Musshoff, O.; Finger, R. Phenology Information Contributes to Reduce Temporal Basis Risk in Agricultural Weather Index Insurance. *Sci. Rep.* **2018**, *8*, 46. [CrossRef]
54. Grigoriev, A.; Lukicheva, L.; Korzin, V.; Gorina, V. Biotic and abiotic factors limiting the productivity of *Prunus cerasifera* subsp. *macrocarpa* (Ehrh.) Erem. et Garcov. *Acta Hortic.* **2021**, *1322*, 193–200. [CrossRef]
55. Duchovskis, P.; Stanys, V.; Sasnauskas, A.; Bobinas, C. Cold resistance of *Prunus domestica* L. and *Prunus cerasifera* Ehrh. in Lithuania. *Acta Hortic.* **2007**, *734*, 299–303. [CrossRef]
56. Augspurger, C.K. Reconstructing patterns of temperature, phenology, and frost damage over 124 years: Spring damage risk is increasing. *Ecology* **2013**, *94*, 41–50. [CrossRef]
57. Ru, X.; Jiang, Y.; Luo, Q.; Wang, R.; Feng, X.; Wang, J.; Wang, Z.; Li, M.; Qu, Z.; Su, B.; et al. Evaluating late spring frost risks of apple in the Loess Plateau of China under future climate change with henological modeling approach. *Sci. Hortic.* **2023**, *308*, 111604. [CrossRef]
58. Landi, M.; Lo Piccolo, E.; Pellegrini, E.; Agati, G.; Giordano, C.; Giordani, T.; Lorenzini, G.; Malorgio, F.; Massai, R.; Nali, C.; et al. The use of red species for urban "greening" in the age of climate change. *Agrochimica* **2019**, 157–161.
59. Simović, I.; Šikoparija, B.; Panić, M.; Radulović, M.; Lugonja, P. Remote Sensing of Poplar Phenophase and Leaf Miner Attack in Urban Forests. *Remote Sens.* **2022**, *14*, 6331. [CrossRef]
60. Available online: http://www.sllistbeograd.rs/pdf/2020/153-2020.pdf (accessed on 18 September 2023).
61. Available online: https://www.srbijavode.rs/images/dokumenti/vodoprivredna_osnova_republike_srbije.pdf (accessed on 18 September 2023).
62. Anđelković, M. *Geology of the Wider Area of Belgrade 4—Paleogeography [Geologija Šire Okoline Beograda 4—Paleogeografija]*; Zavod za Regionalnu Geologiju i Paleontologiju: Belgrade, Serbia, 1989. (In Serbian)
63. Direkcija za Građevinsko Zamljište i Izgradnju Beograda. *General Urban Plan of Belgrade, "Official Gazette of the City of Belgrade", Number 11/16*; Direkcija za Građevinsko Zamljište i Izgradnju Beograda: Belgrade, Serbia, 2016.
64. Teofilović, A.; Cvejić, J.; Jovanović, S.; Lakušić, D.; Tutundžić, A.; Mitrović, M.; Čavić, K.; Jeftić, N.; Glamočić, B.; Vasiljević, N.; et al. *Mapping and Evaluation of Belgrade Habitats. Results of the Project "Belgrade Green Regulations—Phase III"*; Electronic Edition; Secretariat for Environmental Protection of Belgrade: Belgrade, Serbia, 2008; Volume 1, pp. 1–112.
65. Meier, U. *BBCH-Monograph. Growth Stages of Plants [Entwicklungsstadien von Pflanzen. Estadios de las Plantas. Stades De Développement des Plantes]*; Blackwell Wissenschafts-Verla: Berlin, Germany; Vienna, Austria, 1997; p. 622.
66. Stilinović, S. *Semenarstvo Šumskog i Ukrasnog Drveća i Žbunja*; OOUR Institut za Šumarstvo Šumarskog Fakulteta u Beogradu: Belgrade, Serbia, 1985; p. 399.
67. Vučetić, V. Secular trend analysis of growing degree-days in Croatia. *Idojaras* **2009**, *113*, 39–46.
68. WMO. *State of the Global Climate 2021: WMO Provisional Report*; WMO No. 1290; World Meteorological Organization (WMO), World Climate Data and Monitoring Programme: Geneva, Switzerland, 2021; p. 57. Available online: https://library.wmo.int/doc_num.php?explnum_id=10859 (accessed on 18 September 2023).
69. Lalić, B.; Ejcinger, J.; Dalamarta, A.; Orlandini, S.; Firanj Sremac, A.; Paher, B. *Meteorology and Climatology for Agronomists. [Meteorologija i Klimatologija za Agronome]*; Univerzitet u Novom Sadu—Poljoprivredni Fakultet: Novi Sad, Serbia, 2021; p. 219. (In Serbian)
70. Available online: https://www.hidmet.gov.rs/ciril/meteorologija/klimatologija_godisnjaci.php (accessed on 1 November 2023).
71. Glowacka, A.; Sitarek, M.; Rozparaa, E.; Podwyszynska, M. Pomological characteristics and ploidy levels of Japanese plum (*Prunus salicina* Lindl.) cultivars preserved in Poland. *Plants* **2021**, *10*, 884. [CrossRef]
72. Silva, I.A.; Da Silva, D.M.; De Carvalho, G.H.; Batalha, M.A. Reproductive phenology of Brazilian savannas and riparian forests: Environmental and phylogenetic issues. *Ann. For. Sci.* **2011**, *68*, 1207–1215. [CrossRef]
73. CaraDonna, P.J.; Inouye, D.W. Phenological responses to climate change do not exhibit phylogenetic signal in a subalpine plant community. *Ecology* **2015**, *96*, 355–361. [CrossRef]
74. Sevik, H.; Cetin, M.; Ozel, H.B.; Pinar, B. Determining toxic metal concentration changes in landscaping plants based on some factors. *Air Qual. Atmos. Health* **2019**, *12*, 983–991. [CrossRef]
75. Ding, H.; Xu, L.; Elmore, A.J.; Shi, Y. Vegetation Phenology Influenced by Rapid Urbanization of The Yangtze Delta Region. *Remote Sens.* **2020**, *12*, 1783. [CrossRef]
76. Ocokoljić, M.; Petrov, Đ. *Decorative Dendrology. [Dekorativna Dendrologija]*; Univerzitet u Beogradu—Šumarski Fakultet: Belgrade, Serbia, 2022; p. 409. (In Serbian)
77. POWO Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet. 2023. Available online: https://www.plantsoftheworldonline.org (accessed on 28 November 2023).
78. Hartmann, W.; Neumüller, M. Plum Breeding. In *Breeding Plantation Tree Crops: Temperate Species*; Jain, S.M., Priyadarshan, P.M., Eds.; Springer: New York, NY, USA, 2009; Volume 6, pp. 161–231.

79. Wang, Y.X.; Chen, X.; Zhang, Y.; Chen, X. Antioxidant activities and major anthocyanins of myrobalan plum (*Prunus cerasifera* Ehrh.). *Food Sci.* **2012**, *77*, 388–393. [CrossRef] [PubMed]
80. Fanning, K.J.; Topp, B.; Russell, D.; Stanleyd, R.; Netzel, M. Japanese plums (*Prunus salicina* Lindl.) and phytochemicals—Breeding, horticultural practice, postharvest storage, processing and bioactivity. *J. Sci. Food Agric.* **2014**, *94*, 2137–2147. [CrossRef]
81. Slepneva, T.; Makarenko, S. Economic and biological evaluation hybrids of *Prunus cerasifera* Ehrem. var. *pissardii* Bail. in conditions of the Southern Urals. *BIO Web Conf.* **2020**, *24*, 00082. [CrossRef]
82. Dunaevskaya, E.V.; Gorina, V.M.; Melkozerova, E.A.; Khetagurov, K.M.; Kozyrev, A.K. *Prunus cerasifera* Ehrh. fruits are a source of biologically active substances and high-quality feedstock for Food for Specific Health Use. *E3S Web Conf.* **2021**, *282*, 04008. [CrossRef]
83. Shamsolshoara, Y.; Seied, M.; Gharesheikhbayat, R.; Pirkhezri, M.; Davoodi, D. Phenological, morphological, and pomological characterizations of three promising plum and apricot natural hybrids. *Taiwania* **2021**, *66*, 466–478. [CrossRef]
84. Lhotka, O.; Brönnimann, S. Possible Increase of Vegetation Exposure to Spring Frost under Climate Change in Switzerland. *Atmosphere* **2020**, *11*, 391. [CrossRef]
85. Chitu, E.; Sumedrea, D.; Paltineanu, C. Phenolocial and climatic simulation of the late frost damage in plum orchard under the climate conditions of Romania. *Acta Hortic.* **2008**, *803*, 139–146. [CrossRef]
86. Yaacoubi, A.E.; Oukabli, A.; Hafidi, M.; Farrera, I.; Ainane, T.; Cherkaoui, S.I.; Legave, J.M. Validated model for apple flowering prediction in the Mediterranean area in response to temperature variation. *Sci. Hortic.* **2019**, *249*, 59–64. [CrossRef]
87. Vujadinović Mandić, M.; Vuković Vimić, A.; Ranković-Vasić, Z.; Ðurović, D.; Ćosić, M.; Sotonica, D.; Nikolić, D.; Ðurđević, V. Observed Changes in Climate Conditions and Weather-Related Risks in Fruit and Grape Production in Serbia. *Atmosphere* **2022**, *13*, 948. [CrossRef]
88. Jochner, S.; Menzel, A. Urban phenological studies—Past, present, future, Environmental Pollution. *Environ. Pollut.* **2015**, *203*, 250–261. [CrossRef]
89. Deng, L.; Shen, W.; Lin, Y.; Gao, W.; Lin, J. Surveillance Camera-Based Monitoring of Plant Flowering Phenology. In *Geo-Spatial Knowledge and Intelligence, Proceedings of the 4th International Nonference on Feo-Informatics in Resource Management and Sustainable Ecosystem, GRMSE 2016, Hong Kong, China, 18–20 November 2016*; Yuan, H., Geng, J., Bian, F., Eds.; Part of the Communications in Computer and Information Science; Springer: Singapore, 2017; 698p, p. 698. [CrossRef]
90. Deng, L.; Lin, Y.; Yan, L.; Tesfamichael, S.; Billen, R.; Yao, Y.; Yao, W.; Chen, X.; Fang, X.; Wang, C.; et al. Urban plant phenology monitoring: Expanding the functions of widespread surveillance cameras to nature rhythm understanding. *RSASE Remote Sens. Appl. Soc. Environ.* **2019**, *15*, 100232. [CrossRef]
91. Didukh, Y.P.; Kucher, O.O.; Zavialova, L.V. Phenological reaction of vascular plants to the extreme thermal regime in autumn–winter of 2019 in Ukraine. *Ukr. Bot. J.* **2020**, *77*, 143–155. [CrossRef]
92. Surányi, D. Phenological and flower morphological studies on different plum and prune cultivars. *Int. J. Hortic. Sci.* **2013**, *19*, 43–52. [CrossRef]
93. Zverko, J.; Vido, J.; Škvareninová, J.; Škvarenina, J. *Early Onset of Spring Phenological Phases in the Period 2007–2012 Compared to the Period 1931–1960 as a Potential Bioindicator of Nvironmental Changes in the National Nature Reserve Boky (Slovakia)*; Rožnovský, J., Litschmann, T., Eds.; Mendel a Bioklimatologie: Brno, Czech Republic, 2014; Volume 9, pp. 3–5. ISBN 978-80-210-6983-1.
94. Buican Stanciu, A.; Ionescu, M.; Cosmulescu, S.N. The influence of urban conditions on the phenology of some ornamental species. *Biharean Biol.* **2021**, *15*, 75–79.
95. Onal, K. Collecting and evaluation of myrobalan plum (*Prunus cerasifera* Ehrh.) from southeast Anatolia. *Plant Genet. Resour. Newsl.* **1998**, *115*, 49–50.
96. Buican Stanciu, A.; Ionescu, M.; Cosmulescu, S.N. Spring phenology of some ornamental species, as an indicator of temperature increase in the urban climate area. *Not. Sci. Biol.* **2021**, *13*, 11007. [CrossRef]
97. Robeson, S.M. Increasing growing-season length in Illinois during the 20th century. *Clim. Chang.* **2002**, *52*, 219–238. [CrossRef]
98. Wang, H.; Zexing, T.; Wang, H.; Ge, Q. Varying temperature sensitivity of bud-burst date at different temperature conditions. *Int. J. Biometeorol.* **2021**, *65*, 357–367. [CrossRef]
99. Egea, J.; Ortega, E.; Martínez-Gómez, P.; Dicenta, F. Chilling and heat requirements of almond cultivars for flowering. *Environ. Exp. Bot.* **2003**, *50*, 79–85. [CrossRef]
100. Ruiz, D.; Campoy, J.A.; Egea, J. Chilling and heat requirements of apricot cultivars for flowering. *Environ. Exp. Bot.* **2007**, *61*, 254–263. [CrossRef]
101. Nečas, T.; Rampáčková, E.; Göttingerová, M.; Kiss, T.; Ondrášek, I. Evaluation of non-traditional plum cultivars for growing in the Czech conditions. *Acta Hortic.* **2021**, *1322*, 113–124. [CrossRef]
102. Nguyen, A. *A Benefit–Cost Analysis of Ten Urban Landscaping Trees in Berkley*; CA Drubin/Barnes Lab: Berkeley, CA, USA, 2005; pp. 1–26.
103. Karlović, K.; Jeran, N.; Dujmović Purgar, D.; Židovec, V.; Bolarić, S.; Vokurka, A. Sustainable landscaping with Prunus. *Acta Hortic.* **2020**, *1288*, 75–84. [CrossRef]
104. Keenan, T.; Gray, J.; Friedl, M.; Toomey, M.; Bohrer, G.; Hollinger, D.; Munger, J.W.; O'Keefe, J.; Schmid, H.P.; Wing, I.S.; et al. Net carbon uptake has increased through warming-induced changes in temperate forest phenology. *Nat. Clim. Chang.* **2014**, *4*, 598–604. [CrossRef]

105. Churkina, G.; Schimel, D.; Braswell, B.H.; Xiao, X. Spatial analysis of growing season length control over net ecosystem exchange. *Glob. Chang. Biol.* **2005**, *11*, 1777–1787. [CrossRef]
106. Dragoni, D.; Schmid, H.P.; Wayson, C.A.; Potter, H.; Grimmond, C.S.B.; Randolph, J.C. Evidence of increased net ecosystem productivity associated with a longer vegetated season in a deciduous forest in south-central Indiana, USA. *Glob. Chang. Biol.* **2011**, *17*, 886–897. [CrossRef]