Scientific Research Publishing

Journal of Geoscience and Environment Protection, 2018, 6, 111-124
http://www.scirp.org/journal/gep
ISSN Online: 2327-4344
ISSN Print: 2327-4336

Distribution of *Prunus serotina* Ehrh. in North America and Its Invasion in Europe

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How to cite this paper: Segura, S., Guzmán-Díaz, F., López-Upton, J., Mathuriau, C. and López-Medina, J. (2018) Distribution of *Prunus serotina* Ehrh. in North America and Its Invasion in Europe. *Journal of Geoscience and Environment Protection*, **6**, 111-124.
https://doi.org/10.4236/gep.2018.69009

Received: June 15, 2018
Accepted: September 8, 2018
Published: September 11, 2018

Abstract

Black cherry (*Prunus serotina* Ehrh.) is a native North American plant species. It includes five subspecies and is currently invasive in Europe. Since pre-Hispanic times, black cherry has been known and used by American inhabitants, and its botanical use was reported in the 19th century. The present study describes the taxonomic richness and taxonomic diversity of the species based on data from 554 taxonomically confirmed collection sites. Additionally, 19 climatic parameters were used to estimate the current and future potential distribution patterns of black cherry applying a climate change model to North America and Europe. Regions of northeast Mexico, northwestern Mexico, the Great American Basin, and the Mississippi River-Great Lakes region in the USA are shown as areas where taxa of *P. serotina* are present. The potential distribution model of black cherry in North America shows a continuous pattern starting in the Center of Mexico and following both main Mexican mountain ranges (Sierra Madre Oriental and Sierra Madre Occidental). The pattern extends following two different paths throughout northern Mexico toward the Rocky Mountains and the Appalachians in the USA. Based on the NOAA-CCM3 climatic change model, decreased rainfall in wetlands will result in changes in future patterns in America. When applied to Europe, our model shows more extensive regions and more accurately than previous estimations; thus, the current potential distribution of the species includes important areas in the western part of the continent. The potential effect of climate change on *P. serotina* distribution suggests new and wider areas of possible invasion of this species throughout the continent mainly in France, Germany, and Italy. We suggest take into account the whole American taxa included in this species in the end to study its potential invasion in

Europe and establishing suitable control strategies.

Keywords

Black Cherry, Taxonomic Richness, Taxonomic Diversity, Invasion, Climate Change

1. Introduction

The natural distribution of black cherry (*Prunus. serotina* Ehrh.) extends from the USA to Guatemala [1] [2]. The species is subdivided into five botanical subspecies: *P. serotina* ssp. eximia (Small) Little, *P. serotina* ssp. hirsuta (Elliot) [1], *P. serotina* ssp. capuli (Cav.) McVaugh, *P. serotina* ssp. *serotina* (Ehrh.) McVaugh, and *P. serotina* ssp. virens (Woot & Stand) McVaugh. *P. serotina* ssp. virens includes two botanical varieties: *P. serotina* ssp. virens var. virens McVaugh and *P. serotina* ssp. virens var. rufula McVaugh. These taxa were considered by McVaugh (1951) [1] as relatively separated by geography and having particular morphological characteristics. This classification is based on the hypothesis that the species have their origins in the northeast of the USA, from whence they migrated since the end of the Mesozoic era until the Eocene period due to the effect of glaciations.

According to Popenoe and Pachano (1922) [3], the distribution area of *P. serotina* ranges from California to Florida in the USA, and in Mexico, throughout the western, eastern, and neovolcanic mountain chains: its distribution also includes the area of western Guatemala. The species has adapted to environments in Colombia, Ecuador, Bolivia, North India, and South Brazil [4]. Black cherry adapts well to temperate-cold climates (Cw0, Cw1, Cw2, and Cs) and subtropical climates type A and (A) C. Fresnedo *et al.* (2011) [5] and Avendaño-Gómez *et al.* (2015) [4] indicate that black cherries are distributed from Sonora to Chiapas, in Mexico, mostly in drylands at altitudes from 1000 to 3900 m in the Valley of Mexico, but not in proximity to the coast.

According to Startfinger (2010) [6], Carmenen *et al.* (2016) [7], and Aerst *et al.* (2017) [8], *Prunus serotina* was introduced into Europe in the 17th century as an ornamental species. In the 19th century, the interest in black cherry introduction was focused on forestry, but the endeavor was unsuccessful. In the 20th century, the utility of the species for the forestation of disturbed or degraded areas was employed to improve soils due to the low C/N ratio of its leaves [9]. Thus, black cherry was introduced into Belgium, France, Poland, Germany, Denmark, Norway, Estonia, Lithuania, and Russia [7] [9] [10] [11] [12]. Currently, it has an important presence in Belgium, Poland, Germany, and Denmark, where it has been reported to be an invasive species out of control [9] [11] [12]. For this reason, the recent modeling of the potential distribution of black cherry in Europe has received special attention by geneticists such as Pairon *et al.* (2006)

[13], Pairon *et al.* (2010) [14], and Guzmán *et al.* (2018) [15]; from an ecological point of view, such modeling has been addressed by Carmen *et al.* (2016) [7]. Halarewicz *et al.* (2017) [16] and Aerst *et al.* (2017) [8] sought to predict its invasive ability and analyzed its biological control. The present study aimed to describe, on the one hand, the taxonomic richness and taxonomic diversity of *P. serotina*, and on the other hand, it intended to identify the potential distribution of this species based on data from verified collection sites in its natural distribution area; the data were analyzed using a prospective climate change model for the American continent, where the species is native, and for Europe, where it is invasive.

2. Materials and Methods

2.1. Climate Data

Descriptions of taxonomic richness, taxonomic diversity, and potential distribution were based on georeferenced records from different herbaria: MEXU (UNAM), CHAP (UACh), INBIO (IEB-Bajio, Instituto de Ecología, A. C.), TX-LL (UT-Austin), and BHO (OSU). These data were complemented by consulting the Global Biodiversity Information Facility [17] and using our own collections. **Table 1** shows botanical reports and the number of georeferenced sites of *P. serotina* taxa. Records of *P. serotina* ssp. capuli are related to Mexico only, whereas only *P. serotina* ssp. eximia and *P. serotina* ssp. hirsuta records are related to the USA. Frequently, morphological differences between *P. serotina* ssp. capuli and *P. serotina* ssp. *serotina* were unclear; these records were eliminated from the study data.

2.2. Taxonomic Richness and Taxonomic Diversity

Data from georeferenced sites were analyzed using DIVA-GIS software, version 7.5 [18] to obtain taxonomical richness and taxonomical diversity maps for North America. To calculate the richness estimate, the program used the number

Table 1. Botanical reports and number of georeferenced sites of taxa of *Prunus serotina* Ehnr. in NorthAmerica. Taxonomical classification based on McVaugh (1951).

Taxa	Botanical reports	Georeferenced sites
Prunus serotina ssp. capuli (Cav.) McVaugh	Center and Southern Mexico, Mountain chain of Guatemala	145
Prunus serotina ssp. eximia (Small) Little	Center of Texas	12
Prunus serotina ssp. hirsuta (Ell.) McVaugh	Georgia, Alabama and Florida	55
Prunus serotina ssp. *serotina* (Ehrh.) McVaugh	Northwest USA, Eastern and Western Mountain Chains in Mexico	188
Prunus serotina ssp. virens var. rufula (Wood & Standl.) McVaugh	Southwest of Texas, Arizona and New Mexico. Northeast Mexico	50
Prunus serotina ssp. virens var. virens (Wood & Standl.) McVaugh	Jalisco, Guanajuato and Michoacán, México.	104

of different taxa per each pixel or cell; the diversity estimate was calculated using the Shannon index. In both cases, a point-based procedure was used to link each cell to the next nearby circular cell (circular neighborhood) and create the maps. The properties of the raster were defined to a resolution (size of cells) of 0.5˚.

2.3. Potential Distribution

The current potential distribution of *P. serotina* sites and their potential distribution according to the climate change model were analyzed by climate factor analysis using DIVA-GIS. The program uses a database of 19 temperatures and precipitation variables for each pixel (8 × 8 km) based on the interpolation of the five nearest weather stations; values are corrected for altitude. Given the longitude and latitude of the sites, the program extracts the climatic value of each pixel and builds a matrix of data for processing by factor analysis to describe variation among sites. Through this model, a calculated surface response is constructed by indexing the probability of each pixel in the studied area to belong to the calculated distribution. Limiting factor aggregation criteria were used to define the areas where climate has changed in comparison with the initial set of data. This procedure was based on a proposal by Kiehl *et al.* (1998) [19], parameterized by Govindasamy *et al.* (2003) [20], and included in DIVA-GIS. Essentially, the NOAA-CCM3 model represents a change in climatic parameters based on the increase in the concentration of atmospheric CO_2 over a prospective period ending in 2100 (650 ppm, and temperatures between 1.1˚C - 2.6˚C) using information from 1860 to 2005 [21].

3. Results and Discussion

The pattern of *P. serotina* collection sites in North America is linked to the mountain chains in the region (**Figure 1**). *P. serotina* ssp. *serotina* is the most widely distributed, and its presence is mainly associated with humid regions in the Sierra Madre Oriental, west-central and central Mexico, as well as the central region of the USA, from Missouri to the Appalachian Mountains, as reported by McVaugh (1951) [1], Fresnedo (2011) [5], and Beck (2014) [22]. In Mexico, *P. serotina* ssp. capuli is distributed in both the north and the south, particularly in the western central regions, where is it is often sympatric with *P. serotina* ssp. *serotina* and less frequently allopatric with *P. serotina* ssp. virens var. virens [4] [5]. By contrast, *P. serotina* ssp. eximia is endemic to central Texas, and very particularly in the Edwards Plateau, as reported by McVaugh (1951) [1]. *P. serotina* ssp. hirsuta is mainly distributed in the states of Georgia, Alabama, and Florida. *P. serotina* ssp. virens var. rufula is distributed from southeast Texas to Arizona, the adjacent region of New Mexico, and the southern part of Rocky Mountains, as noted by McVaugh (1951) [1]. *P. serotina* ssp. virens var. virens is distributed in Jalisco, Guanajuato, and especially in the Northwest, in the states of Durango, Sonora, and Chihuahua, as noted by Rzendowski and Calderón de Rzendowski (2005) [2].

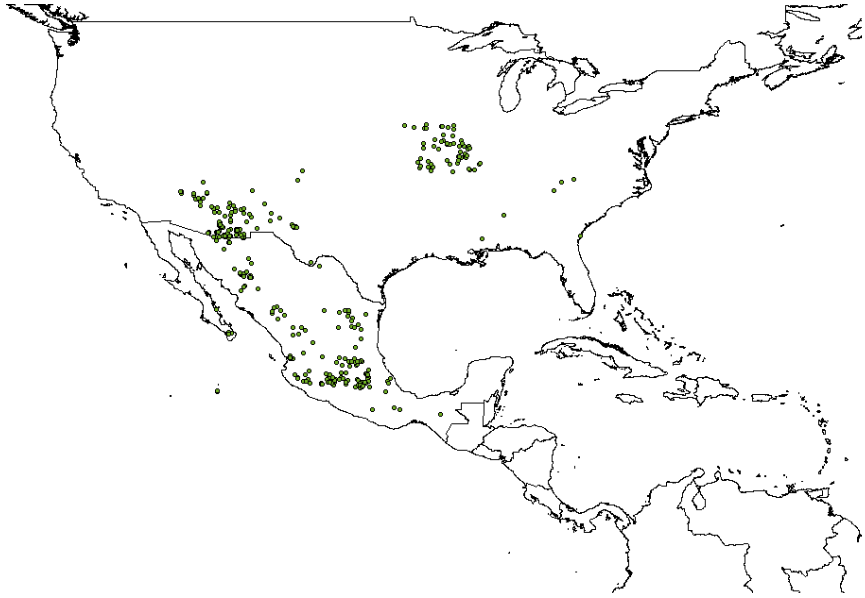

Figure 1. Collecting sites of *Prunus serotina* Ehrh. in North America based on georeferenced records from the MEXU (UNAM), CHAP (UACh), INBIO (IEB-Bajio, Instituto de Ecología, A. C.), TX-LL (UT-Austin), and BHO (OSU) herbaria and, complemented by consulting the Global Biodiversity Information Facility (GBIF, www.gbif.org) and own collections.

3.1. Taxonomic Richness and Taxonomic Diversity

There are three areas In North America where considerable taxonomic richness of *P. serotina* Ehrh. **Figure 2(a)** can be observed; the first area is located near the Mexico-US border, including the Southern Rocky Mountains of New Mexico, Arizona, and the north of Sonora. *P. serotina* ssp. *serotina*, *P. serotina* ssp. virens var. rufula, *P. serotina* ssp. virens var. virens, and sometimes *P. serotina* ssp. capuli are present in this area. The second area presenting considerable taxonomic richness is located in the Sierra Madre Occidental in Durango, Aguascalientes, and Jalisco. Subspecies *P. serotina* ssp. capuli, *P. serotina* ssp. virens var. virens and *P. serotina* ssp. virens var. rufula are present in this second area. The third and most important area of taxonomic richness is located between Nuevo Leon and Tamaulipas, in Mexico. This area comprises the northern end of the Sierra Madre Oriental (known as Sierra del Burro), where subspecies *P. serotina* ssp. capuli, *P. serotina* ssp. *serotina*, *P. serotina* ssp. virens var. rufula, and *P. serotina* ssp. virens var. virens are located. Interestingly, the sympatric distribution of wild subspecies *P. serotina* ssp. *serotina* and the supposedly domesticated subspecies *P. serotina* ssp. capuli raises questions about their being truly different subspecies, as stated by McVaugh (1951) [1] and Rzendowski and Calderón de Rzendowski (2005) [2].

The taxonomic diversity of *P. serotina* is presented in **Figure 2(b)** as a map. This pattern is also similar to the taxonomic richness pattern, with four clearly defined areas. The area of highest taxonomic diversity is located in northern

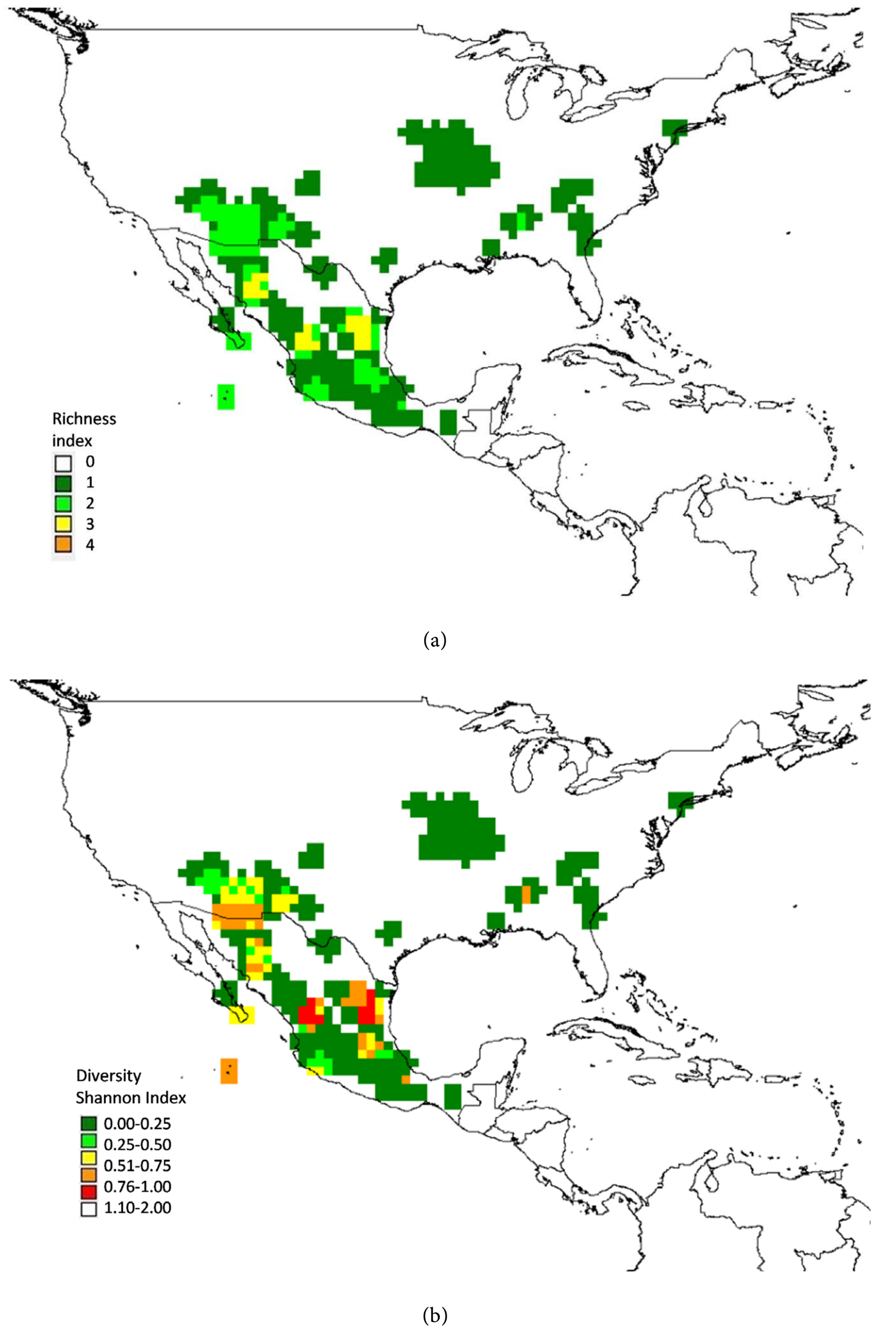

Figure 2. Taxonomic richness (a) and taxonomic diversity (b) of *Prunus serotina* in NorthAmerica calculated from collected sites. The program used the number of different taxa per each pixel or cell to estimate richness index and taxa diversity has been estimated using the Shannon index. The color scale indicates the values of each index.

Mexico, in the so-called Sierra del Burro (Sierra Madre Oriental, Nuevo Leon). A second area is located in the Southern Rocky Mountains in the USA, in Arizona and New Mexico, as well as in part of the Sierra Madre Occidental, in Sonora and Chihuahua (Mexico). A third area, of lower taxonomic diversity, is located in the south of the USA, in the states of Texas and Missouri. A fourth area is associated with the neovolcanic mountain chain in Mexico crossing the states of Michoacán, Queretaro, and Guanajuato.

The results of taxonomic richness and taxonomic diversity presented in the maps in **Figure 1**, showing important areas located in Mexico (western and eastern mountain chains), do not reflect McVaugh's (1952) [23] description of the differences among taxa as a process occurring at the end of the Mesozoic Era and during the Eocene period, when glaciations affected flora patterns in the Nearctic. This author describes the subspeciation path from the northeast part of the USA to southern areas in the USA and Mexico. Although Rohrer (2014) [24] has a new proposal of botanical classification describing four botanical varieties: *P. serotina* var. alabamensis = *P. serotina* ssp. hirsuta, *P. serotina* var. capuli = *P. serotina* ssp. capuli, *P. serotina* var. rufula = *P. serotina* ssp. virens, and *P. serotina* var. *serotina* = *P. serotina* ssp. *serotina* + *P. serotina* ssp. eximia, this author does not describe differences among P. *serotina* ssp. subspecies populations in its extensive area of distribution, and its possible relationship with *P. serotina* ssp. capuli in central Mexico is not mentioned [1]. We are not in a position to suggest a paleoethnobotanical pattern for the history for *P. serotine*, but the high taxonomical richness and taxonomical diversity in both Mexican mountain ranges suggest a review of McVaugh's (1952) [23] descriptions. Interestingly, Guzmán *et al.* (2018) [15] studied 18 populations of the four subspecies and found that ssp. virens had the highest gene diversity. The comparison of genetic diversity across the four subspecies, *P. serotina* ssp. capuli, *P. serotina* ssp. virens, *P. serotina* ssp. *serotina*, and *P. serotina* ssp. eximia, showed that the genetic differentiation (Gst) was even lower (16%) than for the 18 populations, but the genetic differentiation between eximia and the other three subspecies (15%) was higher than the differences among these three (6%).

3.2. Current Potential Distribution in America and Europe

Current potential distribution of *P. serotina* is presented in **Figure 3** as a map of North America and Europe. Two important potential areas can be distinguished on the map of North America: the first area begins in the center of Mexico in the neovolcanic mountain chain, and extends to the western mountains of Michoacán, Guanajuato, Jalisco, Nayarit, Sinaloa, Durango, and Sonora; the area continues in southern Arizona and New Mexico. Subspecies *P. serotina* ssp. capuli, *P. serotina* ssp. *serotina*, and *P. serotina* ssp. virens are predominant in this first area. An interesting point is that the dry and hot area between both mountain ranges in northern Mexico seems to be a natural barrier for black cherry; similarly, an area in the USA where the species is absent is a wetland territory. A major second area of potential distribution for the species is centered in Kansas; the area connects with a zone of medium potential toward Texas and also with a high potential area toward Missouri and the east of the USA. Subspecies *P. serotina* ssp. virens var. virens, *P. serotina* ssp. virens var. rufula, *P. serotina* ssp. *serotina*, *P. serotina* ssp. hirsuta, and the subspecies *P. serotina* ssp. eximia inhabit

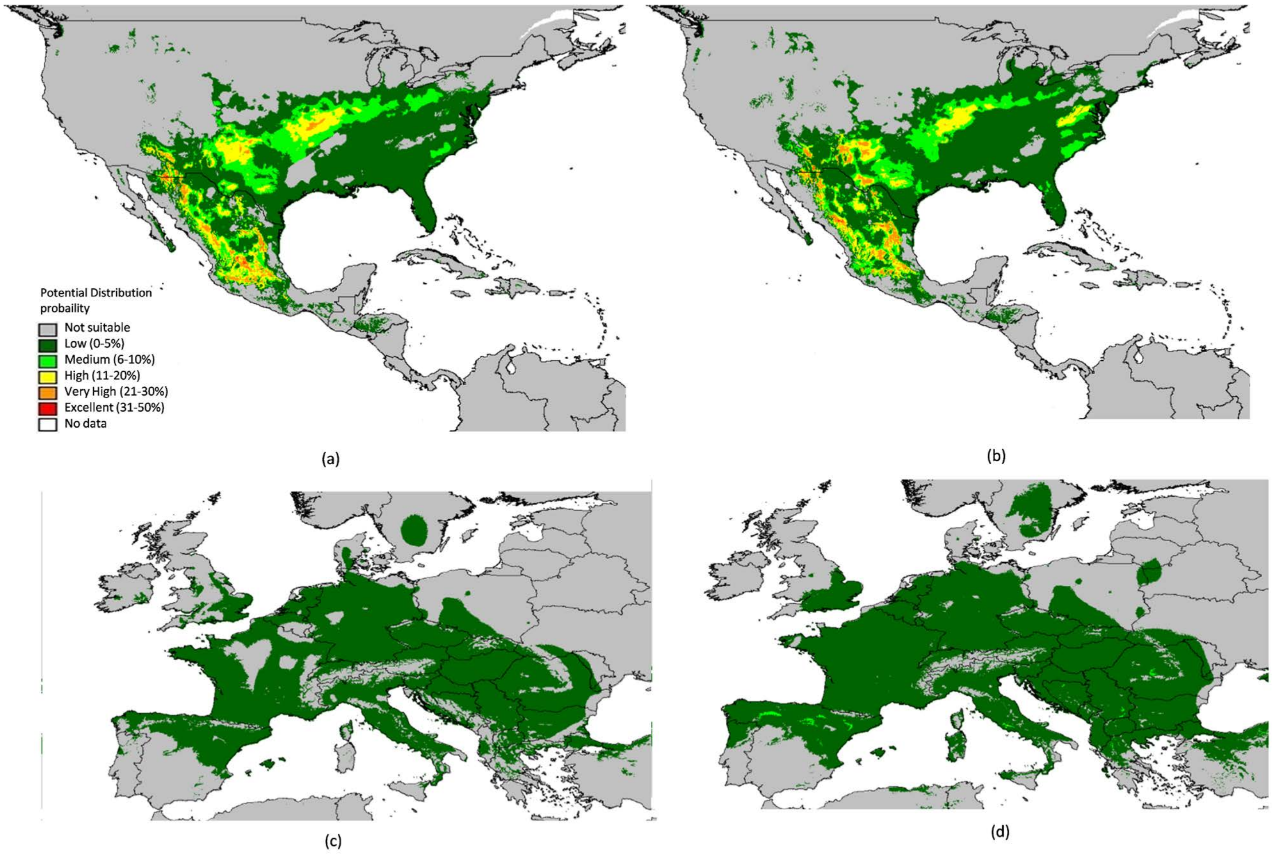

Figure 3. Current potential distribution ((a) and (c)) and climatic change potential distribution ((b) and (d)) of *Prunus serotina* in NorthAmerica and Europe. In both continents patterns are expanded subtly by the effect of climate change (NOAA-CCM3 model used). More information in text.

this area. It is interesting to observe that, as the model suggested, *P. serotina* ssp. eximia is present in the Edwards Plateau in Texas. Comanches had settlements in this area, and Hamel *et al.* (1973) [25] describes how black cherry was used for therapeutic and forestry purposes by the tribe.

The potential distribution in Europe predicted by the model is shown in **Figure 3**. *P. serotina* is relatively widespread in the continent. Its presence is limited by temperature in majority of countries and, particularly in France, precipitation is also a limiting factor. Aerts *et al.* (2017) [8] indicate that the species tolerates a wide range of wetland and dryland conditions in Europe. Apparently, it has a special relationship with sandy and acid soils. Remarkably, even though the species is subdivided into five subspecies and two botanical varieties distributed from the USA to Guatemala, European studies have only taken in account the natural conditions of subspecies *P. serotina* ssp. *serotina*, from the central and northeast areas of the USA, to estimate potential invasion in Europe ([7] [8] [12] [13] [26] but Guzmán *et al.* (2018) [27], studying morphological variability indicated that *P. serotina* ssp. eximia, *P. serotina* ssp. hirsuta and *P. serotina* ssp. *serotina* are distributed in more humid and cold environments, while *P. serotina* ssp. virens prefers drier and warmer environments. Subspecies capuli exhibited the greatest environmental heterogeneity. Some individuals of *P. serotina* in North America are calculated to be 250 years old, whereas specimens in Europe live only 30 years on average. Apparently, as indicated by Deckers *et al.* (2005) [9], black cherry dispersion is favored when the forest is disturbed in this continent; moreover Carmenen *et al.* (2016) [7] proposed an area of potential distribution or niche of invasion by *P. serotina* in Europe larger than in our model of **Figure 3(c)**. These authors suggest that the species is capable of invading virtually all Western Europe. We suppose that the difference in the projections is associated with the sources of information on the presence of the species used by Carmenen *et al.* (2016) [7], who based their prediction model on the little (1971) [28] database, where *P. serotina* is frequently considered as a synonym of *P. virginiana* and *P. alabamensis*. This fact led the author to include areas where *P. virginiana* is present and *P. serotina is* not (north of the USA). In the Europe map, our model matches descriptions by Closset-Kopp *et al.* (2007) [29], Startfinger (2010) [6], and Halarewicz *et al.* (2017) [16], but whether individuals of this species present in Europe are issued from a single taxonomic entity, or from different taxonomic entities introduced at different times remains unsettled, as noted by Pairon *et al.* (2010) [14]. In our opinion, it is hard to believe that all individuals of *P. serotina* currently present in Europe belong to a single taxonomic entity.

Several authors have studied the invasive ability of black cherry in European forests. Deckers *et al.* (2005) [9] confirmed the effects of landscape structure on the occurrence of *P. serotina* in Belgium and suggested dispersal by bird action. Additionally, a decrease in aggregation throughout the plant's life cycle (seedlings and density of young trees) has led to conclusions associated with an allelopathic effect. Godefroid *et al.* (2005) [11] studied the ecological factors affecting the abundance of *P. serotina* in the forests of Belgium and observed a negative correlation between species richness and the abundance of *P. serotina* in forests. According to Closset-Kopp *et al.* (2007) [29], high intensities of light are required from the growth stage of juvenile individuals to maturity and seed production, but Vanhellemont *et al.* (2010) [30] noted that most of the European studies on *P. serotina* were conducted in areas where invasion was intentional, concluding that black cherry could not be considered an invasive aggressor; instead, the authors suggested that perturbations in the forest canopy could accelerate the spread of the species and turn it invasive.

3.3. Potential Distribution of the Species under the NOAA-CCM3 Model

Figure 3(b) shows the *Prunus serotina* Ehrh. potential distribution map for North America under a climatic change scenario and **Figure 3(d)** shows an equivalent projection for Europe. This model was based on the NOAA-CCM3 climatic change model, which includes an estimated variation in climate parameters resulting from a gradual increase in atmospheric CO_2 concentration until 2100 (650 ppm, and temperatures between 1.1˚C - 2.6˚C) [20]. The extension of the potential invasion area of the species is greater than the current area based on information from 1860 to 2005. This can be appreciated as an important extension of the western-central region in the Mexican states of Guanajuato, Jalisco, Michoacan, Queretaro, and the State of Mexico, as well as the northern Mexico region in the states of Durango, Sonora, and Chihuahua. This is a clear sign of the enlargement of arid areas. As noted Guzmán, that increases in temperature will imply altitudinal and latitudinal displacements from currently suitable areas and particularly *P. serotina* ssp. virens has the highest potential for expanding its area of distribution because this subspecies tolerates drought conditions better than the rest. Predicting the possible expansion of *P. serotina* ssp. capuli's potential distribution due to climate change is difficult, since as Rzendowski and Calderon (2005) [2] and Avendaño *et al.* (2015) [4] have noted, this subspecies is still undergoing a domestication process.

The suitable area for black cherries in the USA could also become larger, and this could occur in two directions: the first area of expansion comprises the southern parts of the Rocky Mountains in New Mexico, Arizona, and Colorado, with small portions in Wyoming and Montana, and the second favorable area extends to the southern Appalachian Mountains in Georgia and Tennessee. We assume that *P. serotina* ssp. *serotina*, *P. serotina* ssp. hirsute, and *P. serotina* ssp. eximia will likely colonize these areas. Further to the north, the distribution of *P. serotina* ssp. *serotina*, present in the USA, mainly in the state of Missouri, is projected to enlarge toward the States of Indiana and Ohio on the east, and southwest toward Kansas and Oklahoma, despite its limited genetic variation, as stated by Beck *et al.* (2014) [22]. According to these authors, this subspecies is increasingly being used in forestry.

The projected growth of the species due to climate change in Europe also increased, mainly in France, Germany, and Italy, in areas surrounded by current invasions. In our study, we were also interested in pointing out climatic factors affecting the current potential distribution and those that could affect potential distribution scenarios in the future. Thus, we can see that, currently, mean monthly temperature is the limiting factor of the current invasion of *P. serotina* in southern England (**Figure 4(c)**), but according to the model, the distribution of this species will be greater in the future, limited only by precipitation seasonality (**Figure 4(d)**). Reinhardt *et al.* (2003) [31] report that the species is frequently deemed a "forest plague" in Poland, Germany, Denmark, and the Netherlands. Aerst *et al.* (2017) [8] noted that *P. serotina* is changing nitrogen, phosphorus, and carbon cycles to its own advantage, altering the photosynthetic capacity of the indigenous species; moreover, an uncontrolled invasion of European temperate forests by *P. serotina* would affect the long-term climate change mitigation potential of invaded forests. Evidently, the possible invasion of *P. serotina* will have an economical cost if measures to control it are not put in place [16]. The economic losses in Germany are calculated to be over 25 million EUR; in the Netherlands, the control of this species has cost between 150 and 1500 EUR per hectare each year, according to Startfinger (2010) [6].

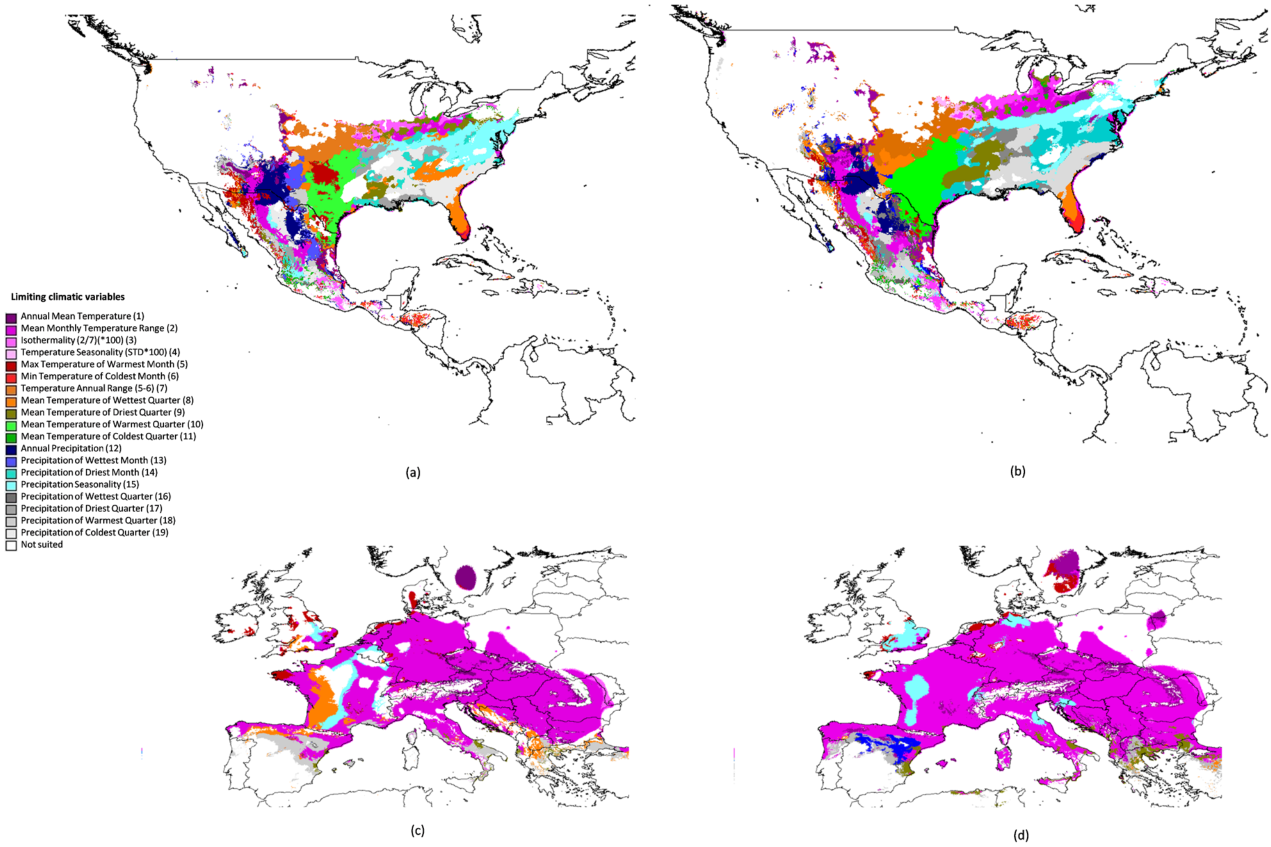

Figure 4. Climatic limiting variables in current potential distribution ((a) and (c)) and climatic change (model CCM3) potential distribution ((b) and (d)) of *Prunus serotina* in NorthAmerica and Europe. 19 climatic parameters were used to estimate the current and future potential distribution patterns of black cherry applying a climate change model to North America and Europe. More information in text.

Diverse eradication strategies have been proposed to control this invasive species [29]. However, they have not become popular because of their high costs, long time for execution, and uncertain success. Finally, it seems that the best method to control it is to assume that *P. serotina* will continue being part of European forests, and that its impact and dominance can be reduced by controlling disturbances in the forest canopy [6] [16] [30].

4. Conclusion

Prunus serotina Ehrh. is a native species of North America that has become invasive in Europe. The present study used data from 554 confirmed collection sites. The taxonomical richness and taxonomic diversity of the plant are described in the first part of this article, and the current potential distribution and future potential distribution of the species have been estimated using 19 climatic parameters. Climate variability data revealed the regions where subspecies of *P. serotina* are mainly distributed are Mexico's northwest, the northwestern part of the Central Mexican Plateau, and regions of the Mississippi River and the Great Lakes. Taxonomic richness and taxonomic diversity show similar patterns, both showing four defined areas. The first area is located in northern Mexico, in the Sierra Madre Oriental (Sierra del Burro) in Nuevo Leon; the second area is located in the southern Rocky Mountains in the USA, in Arizona, New Mexico, and part of the Sierra Madre Occidental in Sonora and Chihuahua (Mexico). A third area presenting lower taxonomic richness and taxonomic diversity is located in the south of the USA, in the States of Texas and Missouri. A fourth area is related to Neovolcanic Mountains in Mexico, in the states of Michoacán, Queretaro, and Guanajuato. The current potential distribution of *P. serotina* in North America shows a continuous pattern starting in the Center of Mexico and following both main Mexican mountain ranges extending to the North and tilting toward the center of the USA and the East of the country. Regions of northeast Mexico, northwestern Mexico, the Great American Basin, and the Mississippi River-Great Lakes region in the USA are shown as areas where the taxa of *P. serotina* are present. According to the maps obtained using our NOAA-CCM3 model, patterns will gradually expand as an effect of climate change. If the current potential species distribution in Europe includes practically all the western part of the continent, the potential effect of climate change suggests that the areas of distribution of the species will expand, especially in France, Germany, and Italy. As species, *P. serotina* seems to be adapted to future possible climatic conditions, the studies of the potential invasion of this species in Europe should take into account the different taxa of the species throughout America in order to achieve more taxonomically accurate conclusions about the behavior and evolution of its invasion in the Old Continent and the potential impacts of climate change.

Acknowledgements

Founds for this investigation were provided by grant CB 2011 169334 of CONACyT, Mexico, and the DCRU of the Autonomous University of Chapingo, Mexico. Special thanks to Dr. Paubelle and his Staff at the facilities of the HCU/Lyon-Sud, France and the CRUCO Staff in Morelia, Mexico.

Conflicts of Interest

The authors declare that they have no conflict of interest.

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