Article

Changes in the Species Composition of Elms (*Ulmus* spp.) in Poland

Anna Napierała-Filipiak ¹, Maciej Filipiak ^{2,*} and Piotr Łakomy ³ ¹ Institute of Dendrology, Polish Academy of Sciences, 62-035 Kórnik, Poland; annafil@man.poznan.pl² Institute of Landscape Architecture, Wrocław University of Environmental and Life Sciences, 50-375 Wrocław, Poland³ Faculty of Forestry, Poznań University of Life Sciences, 60-637 Poznań, Poland; plakomy@up.poznan.pl

* Correspondence: maciej.filipiak@upwr.edu.pl; Tel.: +48-699-117-582

Received: 5 October 2019; Accepted: 9 November 2019; Published: 11 November 2019

Abstract: In nearly 600 randomly selected forest stands including elms (*Ulmus* spp.), we conducted field research to identify them to species level and to find trees showing symptoms of Dutch elm disease (DED). The presented data show that all the 3 native elms (*U. glabra*, *U. laevis*, and *U. minor*) still exist in the whole ranges of their distribution in Poland reported earlier, but their role as forest-forming species has changed. In comparison to published data, the contribution of *U. minor* has markedly decreased, while an increased contribution was observed in the case of *U. laevis*, a species which in the past was predominantly located out of woodland and was rarely cultivated. In mountains, where the most frequent is *U. glabra*, the contribution of elms to forest stands is currently clearly lower than in the lowlands and uplands of Poland. The observed changes most probably result from Dutch elm disease. It cannot be excluded that the changes are at least partly linked with natural correction of forest stand composition modified earlier by human activity (silviculture). In all parts of Poland, trees with symptoms of Dutch elm disease are found, but large-scale decline (of a majority of elm trees) is observed only in about 1.5% of the directly investigated localities.

Keywords: *Ulmus glabra*; *Ulmus minor*; *Ulmus laevis*; Dutch elm disease; alluvial forests

1. Introduction

Three elm species are native to Poland: wych elm (*Ulmus glabra* Huds.), field elm (*U. minor* Mill.), and European white elm (fluttering elm) (*U. laevis* Pall.). *U. glabra* prefers submontane and montane zones. Outside mountainous regions, it usually occurs in mixed stands with the other 2 native elm species, *U. minor* and *U. laevis*. The other 2 species occupy the lowlands and the submontane zone, mostly in river valleys, along streams, in riverine forests, and in forests on sunny slopes (*U. minor*) [1–5]. According to some sources cited above, including the publication by Matuszkiewicz [4], based on extensive phytosociological literature, *U. minor* is regarded as the most important forest-forming elm species in natural forests in the lowlands of Poland, e.g., in the major alluvial forest communities in this region, while *U. laevis* is always an admixture. Overall, in comparison with other tree genera, there are few publications on *Ulmus* spp. Most of them concern various issues more or less associated with the problem of Dutch elm disease (DED) epidemics (e.g., [6–12]). Further on, there are publications on ecophysiology and recently also genetics [13–15]. There is a shortage of publications on the quantitative contribution of individual species to forest stands in a given area.

The rapid decline in interest of elm cultivation was associated with the onset of the epidemic of Dutch elm disease (DED). In Europe, it is caused by two fungal species, *Ophiostoma ulmi* and *O. novo-ulmi*, and spread by bark beetles (subfamily Scolytinae). Fungal spores are transferred from infected trees to healthy ones by young beetles that feed after emergence (before reaching sexual

maturity) in the crowns of elm trees, excavating galleries or cavities in the young bark and wood of shoots. The processes that regulate the current beetle-fungus symbiosis remain poorly understood. The relationships between elm bark beetles and *O. ulmi* s.l. depend on several factors, such as the climatic and environment characteristics, and the interactions between the components of the biotic community [16–19].

DED was first observed in France in 1918, followed by Germany in 1921, and Austria in 1926. In Poland, it was first recorded probably in Katowice in 1927 (although the pathogen was not identified). The occurrence of the pathogen was confirmed in northern Poland in 1932, whereas in Warsaw, in 1935. In the 1950s and 1960s, the disease was reported from all parts of the country and caused substantial losses in urban green areas and on roadsides, but also in forests [20,21]. Apart from the pathogen identified in the 1920s and 1930s, *O. ulmi*, also the more aggressive strain, *O. novo-ulmi*, was observed, but it was confirmed as late in 1978 [22]. The occurrence of both these strains as well as *O. americana* was reported in 2004. However, in studies conducted by our research team, only *O. novo-ulmi* was identified [23].

This paper presents results of our assessment of the contributions of individual elm species to forest stands in various parts of Poland and occurrence of DED symptoms. This study was part of a research programme aimed to investigate the current elm resources in Poland and to form a basis for elm restitution and conservation.

2. Materials and Methods

Poland is divided into 8 forest regions (Figure 1, Table 1), each characterized by relatively uniform physiographic conditions and climate, so we collected data on elms and DED in all the regions [24].

Figure 1. Location of Poland (dark green) on a map of Europe and the studied forest regions (I–VIII, described in Table 1).

Table 1. Characteristics of individual forest regions in Poland [24].

Forest Region	Area (km ²)	Forest Area/Area (%)	Average Annual Temperature (°C)	Growing Season (Days)	Average Annual Rainfall (mm)	Dominant Forest Site Types	Altitude level (m a.s.l.)
I	40,188	28.6	8.5	210–220	550–700	FMCF—31% FCF—28.8% FMDF—17.1% FDF—11%	0–329
II	27,660	33.7	7.5	180–200	550–600	FCF—32.8% FMCF—26% FMDF—13.1% FDF—10.2%	40–150 (one extreme 309 m)
III	71,483	33.2	8.5	210–220	500–570	FCF—53.2% FMCF—19.4% DCF—8.4% FMDF—7.7%	40–220
IV	53,199	21.7	8.0	200–210	500–550	FCF—39.9% FMCF—19.3% FMDF—13% FDF—8.4%	60–235
V	27,202	28.3	8.0	210–220	550–650	FCF—25.8% FMCF—24.1% FMDF—12.7% WMCF—11.4%	100–718
VI	68,522	24.9	8.0	200–210	650	FCF—29.6% FMCF—21.1% FMDF—14.3% FDF—9.3%	150–612
VII	5036	41.3	7.5	190–210	600–700	MMCF—32.1% MMDF—25.9% UMDF—16.2%	200–1602
VIII	19,389	41.4	7.0	180–200	700–900	MDF—54.9% UDF—25.8% MMDF—11.4%	250–2499

DCF—dry coniferous forest; FCF—fresh coniferous forest; FMCF—fresh mixed coniferous forest; FDF—fresh deciduous forest; FMDF—fresh mixed deciduous forest; MDF—mountain deciduous forest; MMCF—mountain mixed coniferous forest; MMDF—mountain mixed deciduous forest; UDF—upland deciduous forest; UMDF—upland mixed deciduous forest; WMCF—wet mixed coniferous forest [24].

Forest plots with elms in Poland were identified, located, and initially described based on forest inventory data, available in a database of the National State Forests Holding, a table of all forest plots including elms during the last forest management survey [25].

Selection of forest stands for this study was carried out in 2013 (the beginning of the study) on the basis of the latest forestry documentation. Forests in Poland are surveyed by foresters continuously, in 10-year cycles, to cover all the forest stands. Hence, the data used as a basis for selection of forest stands with elms were collected in 2004–2013. However, data on individual forest stands were later updated, taking into account new forest surveys conducted by foresters [25].

Forestry documentation usually did not include information on individual species of elm in each of the forest stands. As a result, data on elm species had to be collected directly in the field.

In Poland, forests are divided by a network of treeless lines into administrative units known as forest divisions, covering about 25 hectares each. Those units are composed of irregular smaller units known as forest plots (FPs.), delimited on the basis of factors related to forest stand structure. A forest plot (FP.) is a forest patch uniform in respect of economically important characters (e.g., tree age and species composition), which needs to be managed in a uniform way. It is a basic unit of forest description and forest management planning. Its synonyms are forest subdivision or simply forest stand in jargon. The minimum size of FP. is 1 hectare if the variation of forest units is low and

0.5 hectare if the variation is high. In nature reserves and experimental forests, FP. are delimited irrespective of plot size [26].

The forest plots (FPs.) described above were the basis for distinguishing the elm localities in our study.

In Polish conditions, all forest stands (FPs.) every 10 years are subject to a survey. Special departments (Offices of Forest Management) then investigate directly all the forest plots in a given Forest District, describe the forest stands and make measurements. Thanks to this, each forest stand (FP.) is provided with a detailed description. The description includes the following elements: area, tree species composition, age, forest stand health and technical characters, and tree dimensions of the species accounting about 10% of the canopy. Currently, contributions of individual species are generally determined separately for each layer of the forest stand. It is determined as the percentage contribution of the given species to the total projected crown area in the given layer [26].

The General Directorate of State Forests collects data on forest stands in all forest units in a computer database. A large proportion of the included data (e.g., concerning individual FP. are available on the online Forest Database [27]).

As a result of our application, we received from the Forest Database an Excel spreadsheet with data on all the forest plots where elms were recorded during the last forest survey (about 60,000 records). The spreadsheet included FP. numbers (enabling their unambiguous identification in the field) with data on plot area, forest site type, layers of vegetation, and percentage contribution and age of elm trees. In some cases a FP. appeared in more than one record, because if trees of the same species differ in age more than 20 years on average or form distinct layers, then in the tabulated description the relevant data (mean height, mean breast height diameter, etc.) are recorded separately. However, the data are recorded only if tree crowns of the given species and age group cover at least 10% of plot area. More detailed descriptions of the FP. are available in the online Forest Database [27].

The available data were divided into individual geographical units (forest regions, forest districts) and according to other criteria, such as elm age and percentage contribution to the forest stand (FP.). In each of the 8 investigated forest regions, we selected forest districts located in different parts of the region, preferring those where forest plots (FP.) with variable contributions of elms were located. In total, field work included 67 forest districts located in various parts of Poland. Within individual forest districts, FPs. were basically selected randomly, but with various contributions of elms: 33% of the investigated FPs. were dominated by elm (contribution >50%), in 33% of FPs., elms accounted for 10%–50% of trees, and in the remaining 33% of FPs., the contribution of elms was <10%. We also selected plots (FPs.) so, that half of them were young (up to 50 years old), while the other half were plots with elms older than 50 years.

If during random selection the same plot was selected twice (a rare event), e.g., as a locality of younger elms and of elms older than 50 years, an additional FP. was selected.

In total, for direct field research, we selected in this way 500 FPs., in individual forest regions proportionally to the number of records in the table from the General Directorate of State Forests. In forest regions II, V, and VII, because of additional investigations, the number of FPs was increased by about 100 in total (600 FPs. were investigated directly).

The criteria used in the distinguishing of elms' localities is described below. Each species found in the same forest plot (FP) was treated as a separate locality, even if it was represented by one individual only. This was justified by the fact that currently most of the elm trees in Poland grow singly or in small groups [25]. Besides, several or even single individuals usually indicate that the given species was more numerous there in the past.

Rarely, individuals of the same species within a given forest plot (FPs.) were treated as 2–3 localities, if they formed distinct layers of vegetation: always in the canopy, whereas in the lower layers of vegetation, only if the crowns of elms in the lower layer covered the same or larger area than in the canopy or if their cover exceeded 50% of plot area. If the above criteria were not met, the trees in lower layers were described jointly with trees in the uppermost layer, and that layer determined

their age classification. This was partly due to the fact that in forestry documentation for trees of the same species found in various layers of the same plot (FP.), separate records are created. However, on the other hand, nearly always some elm seedlings are found under the canopy of older trees, but this does not mean that they form a young generation, which in the future will regenerate the existent population. Distinguishing of infrequent seedlings as a separate locality in situations when the given species is already listed in the given plot (FP.) would not be justified. It is assumed that regeneration of a given population is highly probable if the crowns of the lower layer cover a similar or larger area than the cover of tree crowns in the upper layer [26]. In such a situation, uncommon in Polish elms populations (this applied only to 12 directly investigated forest plots), treating the elms in the lower layer as a separate locality was justified in our opinion. Consequently, the total number of localities analysed in this paper was higher than planned initially.

During field survey, we verified the data included in the detailed FP. descriptions, available in offices of individual forest districts and in the online Forest Database [27]. We assessed visually the contributions of elm (percentage contribution of projected crown area in the given layer). First of all, we identified elm species and determined if and to what extent they showed DED symptoms.

Tree age was determined mostly on the basis of data from the detailed descriptions of individual forest plots [27].

Field research was conducted mainly in 2013–2017. DED occurrence was determined on the basis of its commonly known symptoms described e.g., by Hartman et al. [28]: Characteristic withering of leaves, ring-like discolouration within the sapwood, characteristic beetle feeding galleries under the bark of dying trees. From some forest stands, samples were collected and subjected to phytopathological inspection in the laboratory, which usually confirmed the occurrence of pathogenic *Ophiostoma* species, as reported in a separate paper [23].

The assessment of DED symptoms was initially made by all members of our team jointly for consistency. Twigs were collected at each plot from selected trees, mostly in situations when the symptoms were not evident, e.g., only dry, leafless shoots. Samples for phytopathological analyses in the laboratory were randomly collected from individual forest regions.

In this study we took into account only the presence or absence of DED symptoms in a given locality.

Like in respect of percentage contribution, also in respect of DED symptoms, each species was analysed separately. That is why sometimes the same forest plot was classified as a locality affected by DED in one species (e.g., *U. minor*) and simultaneously as a locality without DED symptoms in another elm species (most often *U. laevis*).

Differences in percentage distributions of the analyzed features for individual forest regions were tested using the χ^2 test. The significance of differences between individual species in the percentage of localities with DED symptoms was tested using the Tukey's test. In the analyses, software Statistica version 8.0 (StatSoft Polska Inc., USA) was used. Data in % were transformed before the analysis according to formula of Bliss [29].

3. Results

In the 600 forest plots included in this study, in total 797 localities of the 3 elm species were distinguished: 516 of *U. laevis*, 179 of *U. glabra*, and 102 of *U. minor* (65%, 22%, and 13% of the total, respectively). Table 2 shows data concerning all forest plots with elms, plots selected for this study, and number of distinguished localities of individual species. Special attention was paid to the localities where DED symptoms were observed and to the forest stands (FPs.) dominated by a given elm species. The data are presented separately for 8 forest regions and 2 age groups: younger and older than 50 years.

Table 2. Numbers of elm localities in Poland and of those selected and investigated in the field during this study.

Forest Region	No. of Elm Localities by State Forest Database in 2013 (Localities with the Given Age only)			No. of Selected Forest Plots with Elms	No. of Elm Localities Covered by this Study																	
	<50 Years	>50 Years	<50 years									>50 years										
			<i>U. glabra</i>			<i>U. laevis</i>			<i>U. minor</i>			<i>U. glabra</i>			<i>U. laevis</i>			<i>U. minor</i>				
			T		DED	D	T	DED	D	T	DED	D	T	DED	D	T	DED	D	T	DED	D	
I	4071	4788	70	17	3	2	16	2	9	12	6	1	7	3	1	37	8	15	1	0	0	
II	4730	2862	70	16	4	5	21	3	9	7	2	0	10	2	2	38	10	14	0	0	0	
III	7148	8986	150	13	3	0	55	9	16	31	15	2	2	1	0	92	23	30	3	1	2	
IV	3256	2661	60	5	2	0	21	4	9	15	8	1	0	0	0	43	9	17	0	0	0	
V	4308	4446	110	10	3	0	46	13	18	22	10	3	0	0	0	70	13	27	0	0	0	
VI	2870	3091	60	3	1	1	36	6	10	7	2	1	5	1	0	27	7	10	0	0	0	
VII	248	331	45	24	6	1	1	0	0	1	0	0	18	5	1	4	1	0	0	0	0	
VIII	721	1796	35	24	6	0	4	1	1	2	1	0	25	8	2	5	1	0	1	1	0	
Total	27,352	28,961	600	112	28	9	200	38	72	97	44	8	67	20	6	316	72	113	5	2	2	

T—total; D—forest plots dominated by the individual species of elm; DED—the localities of the individual elm species with the symptoms of DED; <50 years—localities of elm up to 50 years old; >50 years—localities of elm older than 50 years old.

Contributions of individual species to the total number of elm localities in individual forest regions (Figure 2) indicate that *U. laevis* has much more localities than the other species in nearly all forest regions, as it accounts for 59%–81% of all localities. The only exceptions are the mountainous regions VII and VIII, where only *U. glabra* is frequent. Among the localities where elms are dominant species or are on average older than 50 years, percentage contributions of *U. laevis* are even higher (77–96% and 77–100%, respectively).

Figure 2. Percentage contributions of localities of *U. glabra*, *U. laevis* and *U. minor* in individual forest regions: for all localities jointly (a), for localities dominated by elms (b), and for localities where elm trees were older than 50 years (c). The data are broken down by forest regions.

Figure 3 presents percentage contribution of localities with Dutch elm disease to the total pool of investigated localities of individual *Ulmus* spp.

Figure 3. Number of localities of the given species with symptoms of Dutch elm disease and number of localities of this species (expressed as percentage).

Data on percentage contributions of localities with DED symptoms for *U. laevis* and especially *U. minor* in mountainous regions (VIII, and particularly VII) should be treated as rough estimates because of the small number of localities (3 and 1 localities, *U. minor*).

The data presented in Table 3a–c suggest that three groups of regions with a similar contribution of individual elm species can be distinguished. The first group consists of regions I and II, located in the north of Poland. They are distinguished by the greater share of *U. glabra* and slightly less dominance of *U. laevis*. Certain similarities to these regions are shown by the upland region VI (3c). However, in general (all plots jointly and plots dominated by elms) this region is similar to the group of lowland regions III, IV, and V (3a and 3b), distinguished by clear *U. laevis* domination. The third group of regions is composed of the above-mentioned mountainous regions VII and VIII. They are distinguished by the dominance of *U. glabra* and by the low participation of *U. laevis* and especially *U. minor*. Data from Figure 3 and Table 3d suggest no significant differences in DED occurrence in the different regions. Localities of *U. laevis* with some trees showing DED accounted in individual forest regions (excluding mountainous regions VII and VIII) for 20%–22% of the total number of investigated localities of this species. The corresponding values for *U. glabra* and *U. minor* were 25%–40% and 29%–47%. The mean values of 21%, 32.5% and 38%, respectively, differ statistically (Tukey's test, $p < 0.05$).

Table 3. Values of χ^2 test for differences in percentage distributions of the analyzed features for individual forest regions.

Forest Region	I	II	III	IV	V	VI	VII	VIII
a—All Localities Jointly								
I		2.982	12.044	19.780	19.780	2.024	87.409	88.206
II	2.982		10.702	13.464	13.464	1.079	92.565	98.040
III	12.044	10.702		5.128	5.128	14.565	131.660	131.418
IV	19.780	13.464	5.128		0	17.391	138.983	144.828
V	19.780	13.464	5.128	0		17.391	138.983	144.828
VI	2.024	1.079	14.565	17.391	17.391		87.155	92.797
VII	87.409	92.565	131.660	138.983	138.983	87.155		3.124
VIII	88.206	98.040	131.418	144.828	144.828	92.797	3.124	
b—Localities Dominated by Elms								
I		9.618	11.536	10.549	10.756	2.824	163.636	69.800
II	9.618		32.331	29.087	30.690	19.537	125.203	39.111
III	11.536	32.331		1.418	0.307	4.698	200	102.848
IV	10.549	29.087	1.418		0.421	4.245	200	101.767
V	10.756	30.690	0.307	0.421		4.140	200	102.299
VI	2.824	19.537	4.698	4.245	4.140		184.615	88.030
VII	163.636	125.203	200	200	200	184.615		3.124
VIII	69.800	39.111	102.848	101.767	102.299	88.030	3.124	
c—Localities where Elm Trees were Older than 50 Years								
I		1.858	12.515	16.004	14.434	12.355	76.154	56.678
II	1.858		15.222	19.110	16.111	10.578	74.040	56.122
III	12.515	15.222		0.321	0.250	0.321	128.215	105.454
IV	16.004	19.110	0.321		0.376	4.159	134.983	111.912
V	14.434	16.111	0.250	0.376		2.086	131.550	108.930
VI	12.355	10.578	0.321	4.159	2.086		121.932	100.962
VII	76.154	74.040	128.215	134.983	131.550	121.932		2.667
VIII	56.678	56.122	105.454	111.912	108.930	100.962	2.667	
d—Localities with Dutch Elm Disease								
I		2.079	0.039	1.931	0.392	2.044	65.102	1.362
II	2.079		2.213	3.987	1.501	0.131	48.997	6.735
III	0.039	2.213		1.429	0.247	2.036	64.955	1.292
IV	1.931	3.987	1.429		0.863	2.977	62.507	3.039
V	0.392	1.501	0.247	0.863		1.129	59.742	2.447
VI	2.044	0.131	2.036	2.977	1.129		48.569	6.519
VII	65.102	48.997	64.955	62.507	59.742	48.569		79.735
VIII	1.362	6.735	1.292	3.039	2.447	6.519	79.735	

bold values—indicate statistically significant differences ($p < 0.05$).

Trees with DED symptoms were also recorded in all parts of Poland, but in most of the investigated forest stands one to several dozen trees were affected by the disease, and large-scale decline (a majority of elm trees showing DED symptoms) was observed only in 9 localities (1.5%).

4. Discussion

The presented data show that in spite of the long-term impact of DED, all of the 3 analysed elms are found in all parts of Poland.

The majority of the examined elm trees represented *U. laevis*, i.e., a species that was not commonly grown in forests in the past [5] and silvicultural literature cited. This species clearly dominates in most parts of Poland, particularly in forest regions III (Wielkopolska-Pomerania), IV (Mazovia-Podlasie),

V (Silesia), and VI (Małopolska). This species prevails especially in older forest stands and in forest stands dominated by elms.

Similarly, *U. minor* is distributed throughout Poland, except for the highest parts of the mountains. Large specimens and forest stands dominated by this species are very rare.

U. glabra has maintained its dominant position in mountainous regions. However, a strong impact of DED on this species is evidenced by a markedly lower proportion of elms per unit of forest area in mountainous regions (virtually no forest stands dominated by elms in this region), and very few older trees in non-mountainous forest stands. Higher contributions of this species outside mountains were recorded in the forest regions with higher numbers of forest sites on slopes, i.e., in the northern forest regions I and II, shaped by the last glacial period, and forest region VI, located in the south, in the belt of uplands dissected by gullies.

Published data indicated that in comparison with the 1970s, the number of forest stands dominated by elms has increased [25,30]. The percentage of localities with DED symptoms in individual forest regions is very similar (Figure 3, Table 3d). Nevertheless, relatively, the least damaged species is *U. laevis*. The currently observed clear dominance of *U. laevis* in a larger part of Poland, especially with regard to older trees and localities with a higher contribution of elms, also suggests a markedly stronger impact of DED on two other species. According to the literature [2,4], *U. laevis* in non-mountainous parts of Poland should be less common than *U. minor* in both anthropogenic communities and in nearly natural vegetation. According to Matuszkiewicz [4], in alluvial forests, the ratio of the two species should be about 1:4 or even 1:8. It should be noted that the literature data on which Matuszkiewicz (l.c.) was based, originated mainly from the second half of the 20th century. Presumably the remarkable change in their proportions is due to DED. *U. minor* is the elm species considered to be the most susceptible to DED, while *U. laevis* is considered to be the less impacted since the beetle vectors of this disease colonize trees of this species less commonly [31]. It is noteworthy, however, that the dominance of *U. minor* in forest stands on potential sites of lowland alluvial forest in Poland [2,4], contrasts with some published reports from other countries, both from the East and from the West of Europe [1,32–34], which suggest that the most typical elm species of alluvial forests is *U. laevis*. Nevertheless, it cannot be excluded that the contribution of *U. minor* to alluvial forests was artificially increased before the DED epidemics. In the case of fungal diseases transmitted by insect vectors, the effectiveness of the transmission often depends on tree condition. Bark beetles (*Scolytus* spp.), as secondary pests, prefer weaker trees [35]. The artificial elevation of the contribution of *U. minor* on alluvial sites could be a factor that slightly increased the impact of the pathogen on the species, although it probably was not a dominant factor.

According to Mackenthun [36,37], in Saxony, humans destroyed about 90 fertile alluvial forests where percentage contributions of elms were the highest. Probably a similar trend was observed all over West and Central Europe because forests of this type grow on very fertile alluvial soils, which are very attractive to agriculture. Data presented by Matuszkiewicz [38] indicate that in Poland only about 3% of fertile elm-ash forests are left, i.e., even less than in Saxony. However, it must be noted that currently over two-thirds of elms are scattered on more numerous non-alluvial sites, mostly in oak-hornbeam forests [25].

As mentioned above, in current forest practice, individual elm species are often not distinguished, although it is easy to identify *U. laevis* during seed collection. Due to this, in some regions, an increased contribution of one species can be accidental, but it should not be assumed that this applies to the whole country. The dominance of *U. laevis* in Saxony's alluvial forests was reported also by Mackenthun [36,37], whereas in riverine forests in the Oder (Odra) valley in western Poland, by Danielewicz [39].

To present properly the problems linked with DED, many factors must be taken into account, e.g., plot area, size of the local population, number and percentage of trees with DED symptoms, percentage of crown involvement, coexistence of several species of elms within one plot, occurrence of elms in neighbouring forest plots, size of the forest complex, forest site type, and differences between regions.

These relationships will be discussed separately, in at least one publication. Here we would like to draw attention to two interesting findings linked with changes in dominance structure of elm resources: (1) DED is still observed throughout the country; and (2) *U. laevis* is significantly less affected by the disease than the other species.

Author Contributions: Conceptualization, A.N-F., M.F., P.Ł.; methodology, A.N-F., M.F.; software, A.N-F., M.F., P.Ł.; validation, M.F., P.Ł.; formal analysis, A.N-F., M.F.; investigation, A.N-F., M.F., P.Ł.; resources, A.N-F.; data curation, A.N-F., M.F., P.Ł.; writing—original draft preparation, A.N-F., M.F.; writing—review and editing, A.N-F., M.F.; visualization, A.N-F.; supervision, A.N-F.; project administration, A.N-F.; funding acquisition, A.N-F.

Funding: This study was supported by the National Science Centre, Poland, grant No. 2011/01/B/NZ9/02883 “Assessment of the present population size, distribution, and condition of elms (*Ulmus* spp.) in Poland.” and the Institute of Dendrology, Polish Academy of Sciences, Kórnik, Poland.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

- Richens, R.H. *Elm*; Cambridge University Press: Cambridge, UK, 1983.
- Boratyńska, K.; Sekiewicz, M.; Boratyński, A. Morfologia, systematyka, zmienność i rozmieszczenie geograficzne [Morphology, systematics, variability and geographical distribution]. In *Wiązy [Elms]*; Bugała, W., Boratyński, A., Iszkuło, G., Eds.; Bogucki Wydawnictwo Naukowe: Poznań, Poland, 2015; pp. 24–52.
- Collin, E.; Bozzano, M. Implementing the dynamic conservation of elm genetic resources in Europe: Case studies and perspectives. *iForest Biogeosci. For.* **2015**, *8*, 143–148. [[CrossRef](#)]
- Matuszkiewicz, J.M. Rola wiązków w zespołach roślinnych Polski [The role of the elms in plant associations in Poland]. In *Wiązy [Elms]*; Bugała, W., Boratyński, A., Iszkuło, G., Eds.; Bogucki Wydawnictwo Naukowe: Poznań, Poland, 2015; pp. 181–235.
- Filipiak, M.; Napierała-Filipiak, A. Zarys ekologii [Outline of ecology]. In *Wiązy [Elms]*; Bugała, W., Boratyński, A., Iszkuło, G., Eds.; Bogucki Wydawnictwo Naukowe: Poznań, Poland, 2015; pp. 133–181.
- Martin, J.A.; Esteban, L.G.; De Palacios, P.; Solla, A.; Gil, L. Bordered pit and ray morphology involvement in elm resistance to *Ophiostoma novo-ulmi*. *Can. J. For. Res.* **2009**, *39*, 420–429. [[CrossRef](#)]
- Solheim, H.; Eriksen, R.; Hietala, A.M. Dutch elm disease has currently a low incidence on wych elm in Norway. *For. Pathol.* **2011**, *41*, 182–188. [[CrossRef](#)]
- Martín, J.A.; Sobrino-Plata, J.; Rodríguez-Calcerrada, J.; Collada, C.; Gil, L. Breeding and scientific advances in the fight against Dutch elm disease: Will they allow the use of elms in forest restoration? *New For.* **2018**, *50*, 183–215. [[CrossRef](#)]
- Urban, J.; Dvořák, M. Sap flow-based quantitative indication of progression of Dutch elm disease after inoculation with *Ophiostoma novo-ulmi*. *Trees* **2014**, *28*, 1599–1605. [[CrossRef](#)]
- Menkis, A.; Östbrant, I.L.; Wågström, K.; Vasaitis, R. Dutch elm disease on the island of Gotland: Monitoring disease vector and combat measures. *Scand. J. For. Res.* **2016**, *31*, 237–241. [[CrossRef](#)]
- Flynn, L.E.; Mitchell, F.J.G. Comparison of a recent elm decline with the mid-Holocene Elm Decline. *Veg. Hist. Archaeobot.* **2018**, *28*, 391–398. [[CrossRef](#)]
- Martin, J.A.; Solla, A.; Ruiz-Villar, M.; Gil, L. Vessel length and conductivity of *Ulmus* branches: Ontogenetic changes and relation to resistance to Dutch elm disease. *Trees* **2013**, *27*, 1239–1248. [[CrossRef](#)]
- Del Puerto, M.M.; García, F.M.; Mohanty, A.; Martín, J.P. Genetic Diversity in Relict and Fragmented Populations of *Ulmus glabra* Hudson in the Central System of the Iberian Peninsula. *Forests* **2017**, *8*, 143. [[CrossRef](#)]
- Gong, J.; Zhang, Z.; Zhang, C.; Zhang, J.; Ran, A. Ecophysiological Responses of Three Tree Species to a High-Altitude Environment in the Southeastern Tibetan Plateau. *Forests* **2018**, *9*, 48. [[CrossRef](#)]
- Sepúlveda, P.; Johnstone, D.M. A novel way of assessing plant vitality in urban trees. *Forests* **2019**, *10*, 2. [[CrossRef](#)]
- Brasier, C.M. *Ophiostoma novo-ulmi* sp. nov., causative agent of the current Dutch elm disease pandemics. *Mycopathologia* **1991**, *115*, 151–161. [[CrossRef](#)]

17. Santini, A.; Montaghi, A.; Vendramin, G.G.; Capretti, P. Analysis of the Italian Dutch Elm Disease Fungal Population. *J. Phytopathol.* **2005**, *153*, 73–79. [CrossRef]
18. Solla, A.; Dacasa, M.C.; Nasmith, C.; Hubbes, M.; Gil, L. Analysis of Spanish populations of *Ophiostoma ulmi* and *O. novo-ulmi* using phenotypic characteristics and RAPD markers. *Plant Pathol.* **2008**, *57*, 33–44. [CrossRef]
19. Santini, A.; Faccoli, M. Dutch elm disease and elm bark beetles: A century of association. *iForest Biogeosci. For.* **2015**, *8*, 126–134. [CrossRef]
20. Mańka, K.; Sobiczewski, P.; Mańka, M.; Fiedorow, Z. *Fitopatologia Leśna [Forest Pathology]*; PWRiL: Warszawa, Poland, 2005.
21. Grzywacz, A. Ważniejsze choroby infekcyjne. In *Wiązy [Elms]*; Bugała, W., Boratyński, A., Iszkuło, G., Eds.; Bogucki Wydawnictwo Naukowe: Poznań, Poland, 2015; pp. 324–367.
22. Mańka, K.; Bałazy, S.; Chwaliński, K.; Michalski, J. Odporność wiązków w Poznaniu i okolicy na holenderską chorobę wiąz [Elm resistance to Dutch elm disease in Poznań and the surrounding area]. *Zesz. Probl. Postępów Nauk Rol.* **1978**, *198*, 251–265.
23. Łakomy, P.; Kwaśna, H.; Kuźmiński, R.; Napierała-Filipiak, A.; Filipiak, M.; Behnke, K.; Behnke-Borowczyk, J. Investigation of *Ophiostoma* population infected elms in Poland. *Dendrobiology* **2016**, *76*, 137–144. [CrossRef]
24. Zielony, R.; Kliczkowska, A. *Regionalizacja Przyrodniczo-Leśna Polski 2010 [Natural-Forest Regionalization of Poland 2010]*; CILP: Warszawa, Poland, 2012.
25. Napierała-Filipiak, A.; Filipiak, M.; Jaworek, J. Rozmieszczenie zasobów drzew z rodzaju wiąz (*Ulmus* spp.) w lasach Polski w świetle dokumentacji leśnej [Distribution of elms (*Ulmus* spp.) in Polish forests according to the forestry inventory]. *Sylvan* **2014**, *158*, 811–820.
26. Jaszczak, R.; Magnuski, K. *Urządzanie Lasu [Forest Inventory]*; Wydawnictwo Uniwersytetu Przyrodniczego: Poznań, Poland, 2010.
27. Forest Data Bank. Available online: <https://www.bdl.lasy.gov.pl/portal/> (accessed on 9 November 2019).
28. Hartmann, G.; Nienhaus, F.; Butin, H. *Farbatlas Waldschäden: Diagnose von Baumkrankheiten*; Eugen Ulmer KG: Stuttgart, Germany, 2007.
29. Snedecor, G.W.; Cochran, W.G. *Statistical Methods*, 6th ed.; The Iowa State University Press: Ames, IA, USA, 1976; pp. 327–329.
30. Napierała-Filipiak, A.; Filipiak, M.; Łakomy, P.; Kuźmiński, R.; Gubański, J. Changes in elm (*Ulmus*) populations of mid-western Poland during the past 35 years. *Dendrobiology* **2016**, *76*, 145–156. [CrossRef]
31. Pajares, J.A.; Martín-Benito, D.; García-Vallejo, M.C.; López, D. Triterpenes in elms in Spain. *Can. J. For. Res.* **2005**, *35*, 199–205.
32. Pogrebnik, P. *Podstawy Typologii Leśnej [Basics of Forest Typology]*; PWRiL: Warszawa, Poland, 1961.
33. Li, M.; Lopez, R.; Venturas, M.; Pita, P.; Gordaliza, G.G.; Gil, L.; Rodríguez-Calcerrada, J. Greater resistance to flooding of seedlings of *Ulmus laevis* than *Ulmus minor* is related to the maintenance of a more positive carbon balance. *Trees* **2015**, *29*, 835–848. [CrossRef]
34. Venturas, M.; Fuentes-Utrilla, P.; López, R.; Perea, R.; Fernández, V.; Gascó, A.; Guzmán, P.; Li, M.; Calcerrada, J.R.; Miranda, E.; et al. *Ulmus laevis* in the Iberian Peninsula: A review of its ecology and conservation. *iForest Biogeosci. For.* **2015**, *8*, 135–142. [CrossRef]
35. Mańka, M. *Choroby Drzew Leśnych [Diseases of Forest Trees]*; PWRiL: Warszawa, Poland, 2011.
36. Mackenthun, G.L. The role of *Ulmus laevis* in German floodplain landscapes. *For. Syst.* **2004**, *13*, 55–63.
37. Mackenthun, G.L. Elm Losses and their Causes over a 20 Year Period—A long-term Study of *Ulmus* in Saxony, Germany. In Proceedings of the Third International Elm Conference, Florence, Italy, 9–11 October 2013.
38. Matuszkiewicz, J.M. *Zespoły Leśne Polski [Forest Plants Communities in Poland]*; Wydawnictwo Naukowe PWN: Warszawa, Poland, 2002.
39. Danielewicz, W. *Ekologiczne Uwarunkowania Zasięgów Drzew i Krzewów na Aluwialnych Obszarach Doliny Odry [Ecological determinants of the range of trees and shrubs in the alluvial areas of the Oder valley]*; Wydawnictwo Uniwersytetu Przyrodniczego: Poznań, Poland, 2008.