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Historical and Contemporary Herbaria as a Source of Data in Plant Taxonomy and Phytogeography Research: An Example from Poland

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Abstract: The art of drying plants has a long tradition. It was already known in the Middle Ages as a form of documenting flora. It began to develop more intensively in Europe in the 16th century. This method of documenting plant collections quickly gained recognition among scientists. Its role and importance has changed throughout historical periods. The current study presents a short history and resources of Polish and European herbaria against the background of world data. It primarily focuses on indicating their contemporary importance in research in plant taxonomy and geography, as well as on the current situation of herbaria and problems identified using the example of Polish herbaria.

Keywords: plant collections; herbarium data; taxonomy; phytogeography; herbarium specimens

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1. Introduction—An Outline of the History and Status of Herbarium Resources

The art of plant drying began to spread in Europe in the 16th century. It was initiated by the Italian physicist and botanist Luca Ghini from Bologna and his students, Andrea Cesalpino and Ulisses Aldrovandi. The plant collections created in this way in the form of herbaria were called dry gardens (*hortus siccus*) [1–3]. The oldest European herbaria preserved to the present day include the herbarium of Farncesco Petrollini (formerly known as "Cibo herbarium", 1550, Rome), Luca Ghini's students Ulysses Aldrovandi (1551–1586, Bologna) and Andrea Cesalpino (1563, Florence), the herbaria of Jean Girault (1558, Paris), and Kaspar Ratzenberger (1555–1592, Kassel) [3,4]. This method of documenting plant collections quickly gained recognition among scientists. The oldest European collections that were gathered by institutions, rather than by private individuals, belong to the Herbarium of the University of Bologna (1568). One of the oldest and largest in Europe is the herbarium of the Botanical Garden in Leiden in the Netherlands, founded in 1575 and currently comprising approximately 5 million specimens. Another is the herbarium of the Natural History Museum in Paris, founded in 1653 and currently holding more than 8 million specimens [5].

Representatives of the aristocracy, doctors, pharmacists, and teachers were responsible for creating ancient herbaria in Europe and Poland. The first known Polish herbaria included the plant collections of Anna Wazówna, sister of King Sigismund III Vasa, dating back to the turn of the 16th and 17th centuries. Her herbarium was destroyed during World War II. The oldest herbarium in Poland is the herbarium of the Italian physician Silvius Boccone, initiated in 1674, which is kept in the Natural History Museum in Wrocław [2,6]. The National Library in Warsaw houses the herbarium of the Prussian botanist–pastor Georg Andreas Helwing (1666–1748), collected at the turn of the 17th and 18th centuries. It is one of the oldest preserved herbaria of dried plants in Poland. This two-volume work, with almost 700 pages, is located in the National Library in Warsaw and is available on the Internet. These types of archives were called *herbaria viva*—living herbaria, because they contained real plants, not their images. The oldest collection in the herbarium of the Institute of Botany W. Szafer PAN in Kraków (KRAM V) is the herbarium of J. Jundziłł (1794–1877), a professor at the University of Vilnius. It consists of 7318 specimens (including 6249 vascular plants) arranged in 40 herbarium boxes and 5 fascicles. Jundziłł's collection comes from the vicinity of Kaunas (Lithuania) and was collected in the years 1825–1832. The herbarium of Jundziłł contains the oldest specimens in KRAM V—51 sheets collected by J.G. Forster (1754–1794) during J. Cook's (1772–1775) expedition to South Africa and 29 sheets by H.E. Gilibert (1741–1814), consisting of specimens without descriptions [7].

The next stage in the development of herbaria is associated with the establishment of natural history departments in university centers in the 18th century. The creation of scientific herbarium collections can be dated from this period.

Currently, herbaria are an integral part of scientific and research institutions conducting botanical research and disseminating knowledge in this field. They operate at universities, research and development institutes, botanical gardens, and nature museums [8,9]. In 1959, "INDEX HERBARIORUM—The Herbaria of the World" was created by the New York Botanical Garden in the USA [5]. There are approximately 4000 registered worldwide herbaria (approximately 3000 of which are active) in 180 countries, storing approximately 390 million herbarium specimens documenting vegetation of the Earth over the last 400 years [5].

There are approximately 700 herbaria in Europe, comprising approximately 175 million plant specimens [5]. The total number of scientific herbaria in Poland is over 60 [10], including 32 listed in the Index Herbariorum [5] (Figure 1). The resources of Polish herbaria include over 5 million specimens of vascular plants and bryophytes.

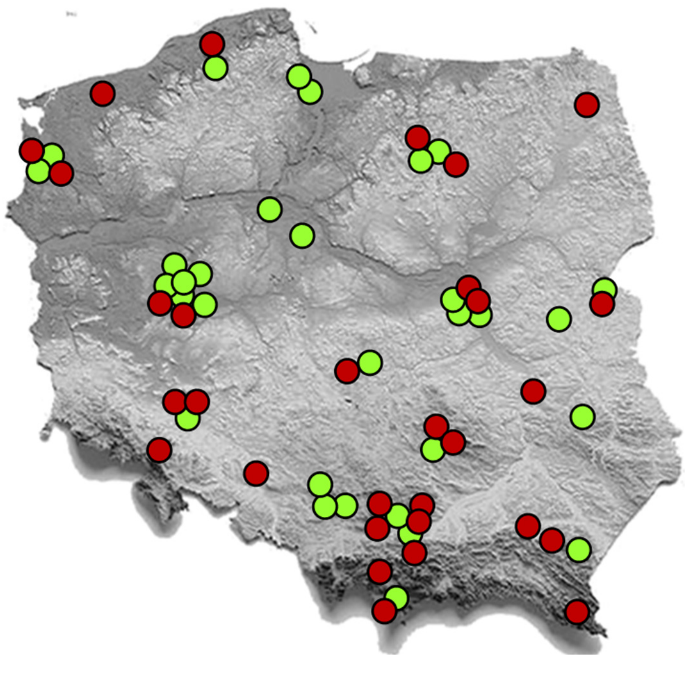


Figure 1. Distribution of scientific herbaria in Poland (green dot—Polish herbaria listed in the Index Herbariorum [5]; red dot—Polish herbaria listed only in Polish Herbaria [10]).

Botanical collections gathered in the form of herbaria, in addition to their documentary and historical value, have scientific significance [11]. They are used, among other ways, in research on plant taxonomy and systematics, floristics, morphology, phenology, ecology and phytogeography, constituting a source of information on the distribution of plant species in the world and changes in plant cover over the years [12–17].

Herbarium collections containing nomenclature types of described taxa, enabling comparative research and taxonomic revisions, are of particular taxonomic value. In recent years, resources consisting of hundreds of millions of herbarium specimens are finding new applications in science, thanks to new techniques such as digital images of herbarium specimens and artificial intelligence techniques enabling the preliminary recognition of species and their features [18].

The revision of herbarium materials of many plant species has allowed the development of their current distribution maps. Nowadays, herbarium documentation is an important supplement to the data used to model natural phenomena and forecast changes in the ranges of plant species in the future [19,20]. Currently, other new possibilities are being investigated of using data documented in the form of herbarium specimens collected in specific conditions of time and space [14,21–23].

The traditional role of herbaria in scientific research was recently summarized by Heberling et al. [15] and Davis [9]. At the same time they pointed to new and innovative functions of herbaria in the future. Davis [9], highlighting the current revolutionary changes in the use of herbaria in basic and applied sciences, forecasted their development towards the creation of the 'herbarium of the future' (or the 'global metaherbarium') which "will be the central element guiding the exploration, illumination, and prediction of plant biodiversity change in the Anthropocene".

The present study aims to illustrate and document the importance of herbarium collections in contemporary plant taxonomy and geography research using the example of the regional (national) and local collections in Poland, as well as giving an indication of the main problems they face.

2. Materials and Methods

This research study was conducted based on a literature search which, among other criteria, covered the last 200 years based on: titles of studies, keywords, quotations, abstracts, available databases, and websites. The subjects of interest were monographs, monograph chapters and articles published in Polish and foreign journals.

The analyses covered studies relating to Poland and individual regions and included the terms: 'vascular plants/species', 'flora', 'vegetation', 'plant community', 'plant taxonomy', 'phytogeography', 'plant distribution', and also 'herbarium', 'plant collections', 'notes/floristic records', 'materials for flora', 'new species in flora', 'new site(s)', 'protected and endangered plants', 'alien plant species', 'invasive plants', 'herbarium data', and 'herbarium specimens' in Polish or their English equivalents in their titles and/or keywords. Publications selected on this basis were then analyzed in terms of the use of herbarium materials in specific studies [24–29].

Previously collected data in the form of databases and lists of publications, some of which were prepared as part of completed projects, were also used [17,30,31]. Information contained in publications [27,31–37] and on the websites of individual herbaria/institutions, together with our own data and experience, were used to assess the condition of botanical collections and the situation of herbaria in Poland.

A plant collection gathered in the Scientific Herbarium of the University of Silesia in Katowice (KTU) was used to illustrate the presented results. The Herbarium, currently named after Prof. Krzysztof Rostański, Ph.D., began operating in 1972, and in 1974 was entered into the international list of scientific herbaria in the world—"Index Herbariorum"—where it obtained a unique acronym—KTU [17,38]. The oldest specimens of the collection of the Scientific Herbarium of the University of Silesia in Katowice (KTU) come from the second half of the 19th century (Austria, Tirol—*Dianthus sylvestris* VULF., *Ranunculus seguieri* VILL.), which were added to the collection as a private gift.

3. Results

3.1. The Importance of Herbarium Collections in Taxonomic Research—Using a Local Example

Comparative research and taxonomic revisions in Poland are made possible primarily by herbarium collections containing nomenclature types of particular genera, e.g., *Aconitum* [39–41], *Amaranthus* [42], *Cerastium* [43], *Crataegus* [44], *Dryopteris* [45], *Erysimum* [46], *Fumaria* [47], *Oxalis* [48], *Rubus* [49,50], and *Valeriana* [51]. The critical revision of the genus

Rubus carried out in the first study was based primarily on old herbarium material [49], while the next one was supplemented with new herbarium material collected during field research [50].

Professor Krzysztof Rostański's research on European taxa of the genus *Oenothera*, which lasted over 40 years, resulted in the creation of the largest collection of this genus in Europe (Table 1). This collection, gathered in the Scientific Herbarium of the University of Silesia in Katowice (KTU) numbers over 12,000 herbarium sheets. On the basis of this collection (and other source materials) scientific research has been carried out on the taxonomic diversity and distribution of the *Oenothera* species in Europe [52,53]. The collection itself includes several dozen nomenclature types of various ranks (Table 2, Figures 2 and 3).

Table 1. Estimated number of *Oenothera* genus specimens in selected herbaria in Europe (based on scientific contacts with Herbaria from 2005–2010).

Herbarium Acronym	Institution	City–Country	Number of *Oenothera* Specimens
KTU	University of Silesia in Katowice	Chorzów–Poland	12,000
G	Conservatoire et Jardin Botaniques de la Ville de Genève	Geneva–Switzerland	2500
K	Royal Botanic Gardens Kew	London–UK	1500
W	Naturhistorisches Museum Wien	Wien–Austria	1000
H	Botanical Museum	Helsinki–Finland	933
S	Swedish Museum of Natural History	Stockholm–Sweden	900
KRAM	W. Szafer Institute of Botany, Polish Academy of Sciences	Kraków–Poland	865
JE	Friedrich Schiller University Jena	Jena–Germany	700
LOD	University of Lodz	Łódź–Poland	546
MSK	National Academy of Sciences of Belarus	Minsk–Belarus	411
BRNU	Masaryk University	Brno Bohunice–Czech Republic	400
MW	Moscow State University	Moscow–Russia	350
MA	Real Jardín Botánico	Madrid–Spain	346
WA	University of Warsaw	Warszawa–Poland	283
HAL	Martin-Luther-Universität	Halle–Germany	150
BC	Institut Botànic de Barcelona	Barcelona–Spain	148
PAD	Università degli Studi di Padova	Padova–Italy	139
KR	Staatliches Museum für Naturkunde Karlsruhe	Karlsruhe–Germany	120
TRH	Norwegian University of Science and Technology	Trondheim–Norway	85
MFU	Museo Friulano di Storia Naturale	Udine–Italy	76
SAV	Slovak Academy of Sciences	Bratislava–Slovakia	71
WI	Vilnius University	Vilnius–Lithuania	62
BOLO	Università di Bologna	Bologna–Italy	54

Table 2. Nomenclature types of the *Oenothera* species in the collections of the KTU Herbarium.

Species Name	Type Status
Oenothera acerviphila ROSTAŃSKI	HOLOTYPUS, ISOTYPUS
Oenothera acutifolia ROSTAŃSKI	LECTOTYPUS
Oenothera britannica ROSTAŃSKI	HOLOTYPUS, ISOTYPUS
Oenothera cambrica ROSTAŃSKI	HOLOTYPUS, ISOTYPUS, PARATYPUS
Oenothera cambrica ROSTAŃSKI var. *impunctata* ROSTAŃSKI	HOLOTYPUS, PARATYPUS
Oenothera carinthiaca ROSTAŃSKI	HOLOTYPUS, ISOTYPUS, PARATYPUS
Oenothera coronifera RENNER	NEOTYPUS, LOCO CLASSICO
Oenothera depressa GREENE for. *angustifolia* ROSTAŃSKI	HOLOTYPUS, ISOTYPUS, PARATYPUS
Oenothera drawertii RENNER ex ROSTAŃSKI	ISOTYPUS
Oenothera hassica ROSTAŃSKI *nom. prov.*	HOLOTYPUS
Oenothera hoelscheri RENNER ex ROSTAŃSKI	HOLOTYPUS, ISOTYPUS
Oenothera hoelscheri RENNER ex ROSTAŃSKI var. *albinervis* ROSTAŃSKI	ISOTYPUS, PARATYPUS
Oenothera hoelscheri RENNER ex ROSTAŃSKI var. *rubricalyx* ROSTAŃSKI	HOLOTYPUS, ISOTYPUS, PARATYPUS
Oenothera issleri RENNER ex ROSTAŃSKI	ISOTYPUS
Oenothera issleri RENNER ex ROSTAŃSKI var *silesiacoides*	ISOTYPUS
Oenothera italica ROSTAŃSKI et SOLDANO	HOLOTYPUS, ISOTYPUS
Oenothera jueterbogensis HUDZIOK	TOPOTYPUS
Oenothera ligerica DESCHÂTRES & R.JEAN	ISOTYPUS
Oenothera marinellae SOLDANO	TYPUS (AUCT.)
Oenothera moravica JEHLIK	ISOTYPUS
Oenothera oehlkersi KAPPUS	NEOTYPUS
Oenothera ploompuui ROSTAŃSKI	PARATYPUS
Oenothera pycnocarpa ATK. & BARTL.	ISOTYPUS
Oenothera rostanskii JEHLIK	ISOTYPUS, PARATYPUS
Oenothera royfraseri GATES	ISOTYPUS
Oenothera rubricaulis KLEB.	ISONEOTYPUS
Oenothera rubricaulis KLEB. var. *longistylis* GUTTE et ROSTAŃSKI	ISOTYPUS
Oenothera schnedleri ROSTAŃSKI *nom. prov.*	HOLOTYPUS
Oenothera sesitensis SOLDANO	TYPUS (AUCT.)
Oenothera slovaca JEHLIK et ROSTAŃSKI	ISOTYPUS
Oenothera stucchii SOLDANO	ISOTYPUS,
Oenothera suaveolens DESF. ex PERS.	TYPUS (AUCT.)
Oenothera subterminalis GATES	NEOTYPUS
Oenothera tacikii ROSTAŃSKI	ISOTYPUS
Oenothera turoviensis ROSTAŃSKI	ISOTYPUS
Oenothera wienii RENNER ex ROSTAŃSKI	HOLOTYPUS, ISOTYPUS, PARATYPUS
Oenothera wratislaviensis ROSTAŃSKI	ISOTYPUS
Oenothera × *casimiri* ROSTAŃSKI	HOLOTYPUS
Oenothera × *rigirubata* RENNER ex GUTTE et ROSTAŃSKI	ISOTYPUS, PARATYPUS, TYPUS
Oenothera × *saxonica* GUTTE ex ROSTAŃSKI	ISOTYPUS

The geographical and genetic center of *Oenothera* L. was originally in America, from where in different times and manners the representatives of this genus made their way to various continents and islands of the earth. In the flora of Europe and in Eastern Europe too, there are four groups of species defined by their origin [52]:

- ornamental plants introduced to European gardens in the past (e.g., *Oenothera fruticosa* L., *Oe. tetragona* ROTH., *Oe. macrocarpa* NUTT., *Oe. glazioviana* MICHELI);
- epoecophytes of the North American origin (e.g., *Oenothera canovirens* STELLE, *Oe. depressa* GEENE, *Oe. pycnocarpa* ATKINSON & BARTLET, *Oe. subterminalis* GATES)
- European species, whose origin is controversial and uncertain, because their occurrence in America has not been confirmed (e.g., *Oenothera ammophila* FOCKE, *Oe. biennis* L. s.str., *Oe. rubricaulis* KLEB., *Oe. suaveolens* DESF EX. PERS.)

- species of hybridogenous origin occurring in Europe, as a cross between European species and American newcomers (e.g., *Oenothera fallax* RENNER—*Oe. glazioviana* × *biennis*; *Oe. wienii* RENNER EX ROSTAŃSKI—*Oe. rubricaulis* × *depressa*)

In the last paper published by Prof Rostański, summarizing research on genus *Oenothera* in Europe, 61 species and permanent hybrids of *Oenothera* were described [53].

Figure 2. *Oenothera cambrica* ROSTAŃSKI—Holotype from the collection of KTU Herbarium.

Figure 3. *Oenothera depressa* GREENE for. *angustifolia* Rostański—Isotype from the collection of KTU Herbarium.

3.2. The Use of Herbarium Collections in Research in the Field of Phytogeography

The revision of herbarium materials for many plant species allowed the development of current maps of their distribution in Poland [28,29]. In the first edition of the Distribution

Atlas of Vascular Plants in Poland (ATPOL), prepared on the basis of approximately 4,500,000 floristic dates collected in the data bank of the flora, herbarium data were used to a limited extent [28]. The number of items of herbarium data used in ATPOL reaches 3.6%. However, for a large group of critical taxa, such as *Alchemilla*, *Oenothera*, *Potamogeton* and *Rubus*, maps (cartograms) were prepared almost exclusively based on the herbarium data. The study's authors also pointed out significant limitations in the use of herbarium data, related at that time to the need to devote a huge amount of work to verifying these materials and entering the data into the database.

The second edition of the Atlas (ATPOL), which was significantly supplemented based on current and verified data, also uses herbarium data. Many maps in this edition were changed after specialists identified herbarium material from Poland (Figure 4). These maps include, among others, species from the Orobanchaceae family [29].

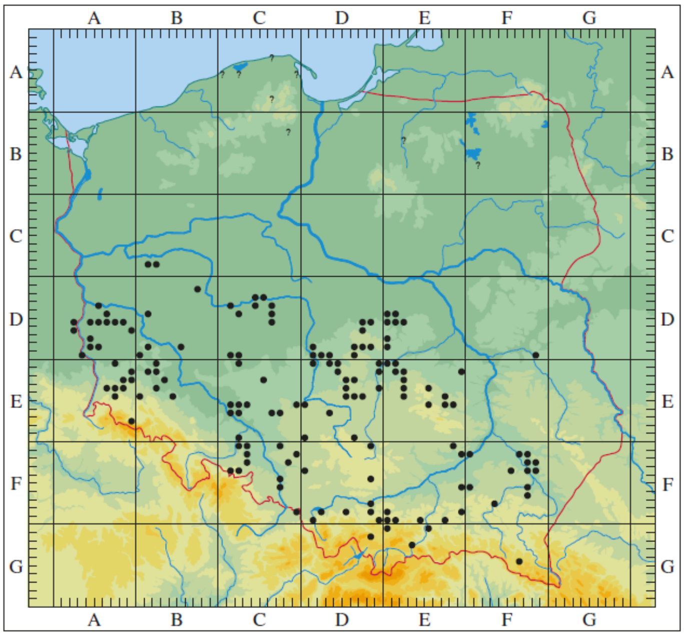


Figure 4. Revision of herbarium material of many plant species allowed the development of current distribution maps in Poland. An example is *Aphanes inexspectata* W. Lippert [29]. Explanations of symbols: •—station of species; ?—doubtful station.

Herbarium data (including private herbaria) are used especially in regional and local studies, enabling analyses of changes in the flora of the studied areas over time [54–61]. Urban flora have a special place in these studies, especially those taking into account changes over time. Such studies, using herbarium data, have been published for several large cities in Poland, such as Warsaw [62,63] and Poznań [64–66]. At the same time, a large part of the floristic data collected during field work has been documented with herbarium specimens deposited in regional herbaria. This provides the possibility of comparative research in the future, e.g., ref. [67]—3000 collected herbarium sheets; ref. [68]—6410 herbarium sheets; ref. [66]—4300 herbarium sheets. Furthermore, a lack of herbarium specimens makes it impossible to verify the correctness of the plant species designation, and therefore the correctness of the data provided. In recent decades, the development of modern tools in the field of spatial information systems has allowed the collection of natural history data, including botanical data, in databases. These databases contain data documented by herbarium material. Regional databases allow for a systematic assessment of the degree to which the vascular plant flora has been researched. An example is the information on the flora of vascular plants in the Silesian Voivodeship collected in the Flora Silesiana database (the database of the herbarium of the University of Silesia in Katowice) [27].

Herbarium data were used in a study devoted to endangered, rare, relic and endemic plant species in Poland in the form of red books—both national [69,70] (Figure 5) and regional [71,72].

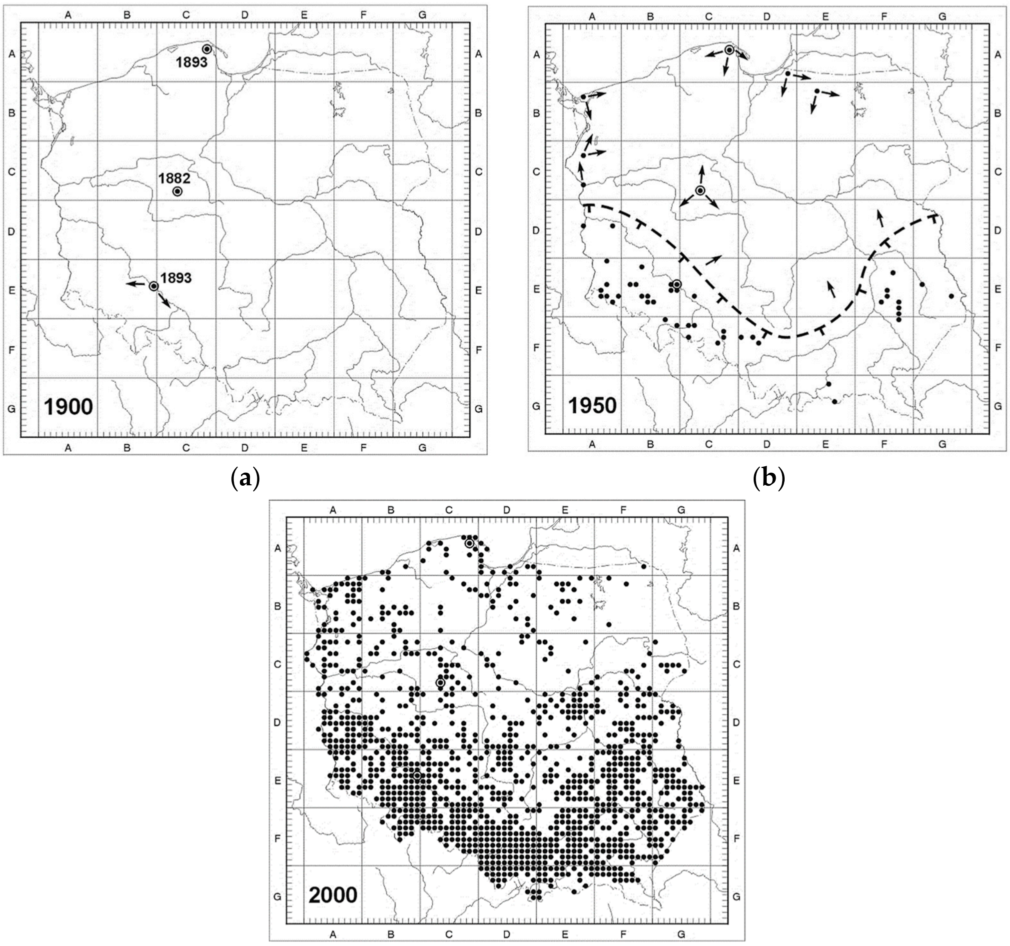
Figure 5. A specimen of *Euphorbia epithymoides* L. from KTU Herbarium (1990). In Poland, the species is at risk of extinction (VU) [73]; however, at the same time, it is indicated as a taxon of uncertain status in Polish flora [74]. The species are found in the Silesian Upland in the southern part of the country on hills made of Triassic limestone [73].

Herbarium collections also contain documentation of new plant species recorded in Poland for the first time [75–80] (Figure 6).

(**a**) (**b**)

Figure 6. Specimens as a documentation of new plant species recorded in Poland from KTU Herbarium (1999–2001): (**a**) *Reynoutria* × *bohemica* CHRTEK & CHRTKOVA, (**b**) *Eleusine indica* (L.) GAERTNER.

Herbarium collections as an important source of data made it possible to supplement maps of the occurrence of species of alien origin spreading in Poland [81–87] and have also allowed for the reconstruction of probable directions of range expansion (Figure 7).



(**c**)

Figure 7. Changes in the distribution range of *Reynoutria japonica* HOUTT. in Poland in subsequent periods of time [88]: (**a**) First recorded localities: 1—Gniezno, West Poland, ATPOL raster CC83 (Cybichowski herbarium specimen, POZ 1882); 2—Darzlubie, North Poland, ATPOL raster CA48 [89]; 3—Wrocław, West Poland, ATPOL raster BE49 (Baenitz, herbarium specimen, WU 1893), (**b**) Subsequent phases of spread 1950—occupation of new localities, predominantly in the southern part of Poland, (**c**) The current distribution of *Reynoutria japonica* is an effect of a fast spread rate, especially in river valleys where it forms copact monospecific phytocoenoses which often occupy extensive areas in the habitats of former willow-poplar forests and thickets. It also occurs commonly in urban areas and railway territory [28]. Symbols: ◉—first recorded locality; ↗↘ —directions of further spread; ╱‾‾╲—occupation of new localities, predominantly in the southern part of Poland.

Archival herbarium collections make it possible to identify the first (historical) records confirming the occurrence of a specific species in the area analyzed. It is worth noting that, in the case of 174 species for which historical data about the first sites in Poland have been collected, 58 come from herbarium materials and the oldest from the first half of the 19th century. An example illustrating the use of this type of data, allowing for the reconstruction of the formation and changes in the ranges of occurrence of plant species is studies on the anthropogenic changes (so-called synatropization) of the flora and vegetation [88].

3.3. Current Situation of Herbaria in Poland

Currently, the activities of Polish herbaria operating at scientific institutions are based on statutory financing of their activities. These are modest financial resources that usually enable these institutions to survive. Herbaria mainly document scientific works concerned with assessing national and regional flora resources. An important part of these activities is also documenting global flora resources and making collections available (for taxonomic research) and inter-herbarium exchange of plant collections (national, international). It is also worth mentioning the important role of herbaria in phylogeographic and phylogenetic research and providing specimens for molecular research. In addition, an important task of herbaria is to store specimens documenting special scientific achievements.

What is particularly important in the activities of herbaria is the continuous verification of specimens, especially critical taxa, in taxonomic revisions. It is necessary to constantly update the collection database using the appropriate scope of information (including georeferencing) and to have data sharing tools (hardware and software).

The proper operation of the herbarium requires an appropriate team of qualified employees and guaranteed financial resources. Financial security for the statutory activities of parent institutions (universities, museums, scientific institutes) is often the only source of financing. Occasional grants and various projects, often quite modestly financed, are mainly aimed at modernizing and supplementing equipment and databases (e.g., The National Biodiversity Information Network, The Global Biodiversity Information Facility) [90–92].

However, there is a problem with the availability of qualified botanists, who should be responsible not only for managing herbaria but also for the continuous maintenance and care of botanical collections. Hence, the questions that are often left unanswered include:

- Who should be the manager (curator) of a scientific herbarium collection? Should we educate staff in this direction?
- Who will take over responsibility for the collections of scientific herbaria in the country in the future?
- Who can act as a collection guardian, and who can be an employee of the scientific herbarium?
- Should activities of the scientific herbarium count as scientific achievements (and how)?

These and other questions remain without a clear answer for now. However, there are threats resulting from such a situation, such as the liquidation of the collection (for various reasons, including institutional ones), the constant reduction and ultimately lack of financing of herbaria, as well as the "physical" reconstruction of the institution and the lack of a worthy place for the collection in the new conditions. Finally, there is a generational change of staff, a change in research directions and a deficit or complete lack of specialists (taxonomists, botanists, etc.). This may lead to the loss of importance of the herbarium, both nationally and globally.

4. Discussion

The role and importance of scientific herbaria cannot be overestimated. In addition to their historical value and role in taxonomy, based on plant morphology, herbarium specimens are showing promise in many other areas, especially in the case of innovative research programs assessing intra- and inter-specific changes resulting from climate change [93].

Yet, with over 390 million specimens worldwide [94], herbaria are often overlooked as rich repositories for trait data, and even extensive trait databases. Various authors [22] indicate that features from the herbarium cannot always be used interchangeably with features measured in fresh tissues due to their shrinkage. However, trait data from herbaria still have the potential to significantly expand the temporal, geographic, and taxonomic scope of global trait databases.

Herbarium specimens continue to play a key role in taxonomy, floristics, and species identification, as well as acting as scientific tokens [95], and in education and dissemination of scientific research results [93,96,97]. For example, field research and taxonomic revisions of species and hybrids of the genus *Oenothera* conducted in many European regions and herbaria led by Professor Krzysztof Rostański resulted in permanent traces in the literature and checklists of the flora of many European countries, such as Great Britain [98], Germany [99], Scandinavia [100] and Eastern European countries [52].

Current research on the genus *Oenothera* is resulting in changes to the names of some *Oenothera* taxa. Published studies of taxonomical revision and validation of the names were created with the use of herbarium specimens of the KTU Herbarium [101–105].

Climate change will strongly influence species distributions in the forthcoming decades [106]. Reliable herbarium data made available in an open system, thanks to modern tools, allow researchers to model changes in the ranges of specific plant species in response to forecasted climate change. Such models or forecasts are particularly important today because the ecological consequences of the projected shrinkage of the range of (mainly woody) plant species are important from an economic point of view. They are serious for forest management and especially for nature conservation in Europe [107]. What is more, climate change and biological invasions are both listed among the factors threatening global biodiversity [108], which allows us to assume that future climate change may significantly increase the vulnerability of the Polish territory to invasions by alien species [109].

The increasing number of publications regarding the contemporary use of herbarium data strongly suggests that we have entered a new era of specimen use [16,21,110–112].

Currently, herbarium documentation can be used in research in critical or poorly described taxa, especially in connection with new research tools and techniques (e.g., DNA analysis, electron microscopy—SEM, 3D imaging) [21,101–105,113]. For this reason, it is important to properly secure the plant collection, ensure appropriate conditions for its storage, and ensure that a correct description of a herbarium specimen is prepared via the herbarium label and information in the database.

According to Hedrick et al. [114] the online mobilization of specimens via digitization—the conversion of specimen data into accessible digital content—has greatly expanded the use of natural history collections across scientific disciplines. Therefore, it is important to make regional and local collections available in this way. In Poland, such initiatives have been undertaken as part of regional and national projects aimed at digitizing collections and making them available through the Polish Biodiversity Information Network (KSIB) and, ultimately, the Global Biodiversity Information Facility (GBIF) [8,92]. The IMBIO project (on integration and mobilization of data on biotic diversity of Eucaryota in resources of Polish scientific institutions) digitized over 570,000 herbarium specimens stored in the scientific herbaria of a dozen scientific institutions, universities and natural museums [8]. The IMBIO project covered selected collections or their parts deposited in the KTU Scientific Herbarium. A total of 63,100 specimens were digitized [17,115,116], including the *Oenothera* collections described above [117]. The database records associated with each specimen received a unique identifier, the so-called 2D matrix code, and was characterized based on nearly 40 identified attributes. Additionally, 6000 moss records from the KTU-B herbarium were transferred to the IMBIO database [17,118]. Making the remaining part of the herbarium collections available in Polish herbaria requires the continuation of digitization activities and supplementing the database, which largely depends on the financial capabilities of individual scientific institutions.

Digitization of herbarium collections as a tool for global taxonomic analyses provides the possibility of open access to plant specimens from different parts of the world for taxonomic and phytogeographical research, which is arousing the interest of researchers from all over the world [119–123]. The possibility of financing this type of research may enable national and international projects, as well as the creation of scientific networks (e.g., KSIB in Poland).

5. Conclusions

Gathering herbarium collections was and is an important documentation of aspects of botanical research, such as taxonomy and phytogeography. Old herbarium specimens (over 100 years old) are often the basic source of knowledge about the morphology and distribution of taxa, including critical taxa and hybrids.

Herbarium materials may constitute interesting material for modern genetic and phylogenetic research, shedding light on previously unsolved taxonomic and phytogeographical problems.

The ongoing digitization of herbarium collections in Poland, making them available and transferring data to databases, either global (e.g., GBIF, GRIIS), national (KSIB) or thematic (e.g., EASIN), will allow existing knowledge to be supplemented and, above all, will facilitate access to reliable sources of data that were previously difficult to access.

Due to the system of formal authorization, staffing, and size of collection resources, database resources of national herbaria are diverse. It is necessary to create an integrated system of cooperation, data flow and mutual support of institutions collecting botanical data in the form of scientific herbaria.

In individual countries, it is possible and important to develop strategies for financing and treating plant collections as a type of "national heritage".

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