Historical Floras: addressing their genesis in order to be viewed from a modern-day perspective. A case study from Northern Italy

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Abstract

Historical Floras are biodiversity-oriented textual sources, which refer to times when scientific methods were far different compared to the present. They are also geographical documents, as the entire work is referred to a focal region explored by certain collectors and following certain principles, since the taxa recorded are usually accompanied by a description of the locality of the observation. Retrospective georeferencing, as well as taxonomic revision, of the records in historical Floras are however very challenging processes, which are usually not taken into account. As a result, very few global overviews of historical Floras exist to date. In this article we present the analysis of the 7767 floristic records of the late XIX century Flora of the province of Bologna (N-Italy) compiled by Girolamo Cocconi. We processed these records by georeferencing them, whenever possible, to 659 pairs of coordinates and coupling them with the analysis of the collectors involved besides the author, as to provide the spatial and temporal dimension that permits us to further understand the taxonomic information given by the species listed. This allowed us to detect a bias in the exploration of the territory, which depended on accessibility and/or attractivity of the areas for fieldwork and shifted through time as function of the available collaborators who influenced the definition of the floristic pattern of the territory. Finally, we provided a diachronic analysis with the present flora in order to document the most significant land use changes based on selected floristic target groups.

1 INTRODUCTION

Written sources such as books may represent an important source of information when analysing landscape history and transformation (e.g. Fuchs et al. 2015). This is the case in various European countries, where written sources like exploration travel reports, chorographic atlases or Floras cover a time interval of centuries and prove a true cultural heritage for the area of reference (e.g. Rohl 2011).

In this context ancient Floras [1] represent an iconic case of highly valuable cultural and scientific heritage, especially the oldest ones. In Europe, the very first modern Flora is probably the *Synopsis Methodica Stirpium Britannicarum* by John Ray (Online resource 1), which first appeared towards the end of the XVII century (Stace 1989), even if the first place is usually given to Linnaeus' *Flora Lapponica*, published in 1737 (Frodin 2002). But actually, an earlier anticipation was provided by Ray himself with his *Catalogus plantarum circa Cantabrigiam nascentium* (1660), that is, to our knowledge, the first European urban-municipality-countee Flora. Some decades later (e.g. Séguier 1745; Scopoli 1760; Vitman 1773; Buillard 1776; Lamarck 1778), especially during the XIX century, several local or national Floras were published (e.g. Bertoloni 1833-1854; Rostrup 1860; Wilkomm and Lange 1861-1880). Regarding the Italian situation in particular, at least 33 local Floras were published during the boom of floristic exploration from 1849 to the end of the century (Pignatti 1982). Such a flourishing of botanic work was partly favoured by the geographical explorations and the subsequent import of new species from other continents into Europe (Peccenini 1994). On the other hand, it was probably also because of the introduction of the dichotomous keys[2] to identify species, which were extensively used first by Jean-Baptiste de Lamarck in his *Flore Françoise* from 1778 (Comelli 1883; Griffing 2011). The advent of the dichotomous keys is probably a consequence of the continuous increase in the number of species known by the scholars of the time. They allow a sort of hierarchy to be established among morphological traits of the species and thus to overcome the difficulties of the natural system (e.g. Comolli 1834), that considered a multitude of morphological traits, all of them equally important (Stace 1989), and of the long and very detailed descriptions of the species dealt with, typical of the Floras of 1700. In short, dichotomous keys notably simplified the entire identification process, especially for non-professional botanists. Therefore, from mid-1800 onwards, there was a progressive switch from purely descriptive Floras, based on descriptions (e.g. Allioni 1785), to analytical Floras, based on identification keys. Such a transition stimulated also an educational use of the Floras themselves, which were also published with the aim of encouraging young students and citizens to study (or at least to gain interest in) the flora of their territory. Consequently, local and national didactic Floras

1) In this article we use «Flora» (with initial capital letter) to indicate the formally published textual documents containing the lists of species (more or less commented and analysed) of a given territory, «flora» (with lowercase initial letter) to address the ensemble of all plant species (i.e. the floristic heritage) of a territory. The same term, in fact, indicates two quite different concepts. See also Berrens (2019) for further information.

2) Dichotomous keys, in reality, had been already known for various centuries: they are a system inspired by the principles of Aristotelian logic, permitting to reduce to one or few characters, which are assumed to be sufficient and discriminant, the complexity of living beings, with special regard to their identification and description (cfr. Pignatti and Cipriani 2010; Griffing 2011; Fischer 2020).

multiplied in the XIX century (e.g. Gillet and Magne 1861; Caruel 1876, 1883; Pochettino 1878; Bonnier and De Layens 1883; Baroni 1906).

Floras usually consist of plant taxa (species and infraspecies) lists recorded in a given area (Fig. 1), which include also additional information such as place of observation, habitat characteristics, altitude, frequency, phenology (i.e. anthesis period), etc. Normally, they do not only report the species observed during the study period, but also those recorded during previous investigations by other authors. Furthermore, Floras are much more «biodiversity-oriented» than other written sources and refer to times when scientific philosophy was very different compared to the present (Pignatti 1982; Tison and de Foucault 2014). This makes them important reference works for studying floristic, taxonomic, distributional, diachronical, biogeographical, evolutionary questions, or to locate zones of biological interest spatially due to the presence of rare or endangered species (e.g. Funk 1993, 2006; Palmer et al. 1995).

Classical Flora-related studies concern for example the introduction and colonisation dynamics of a neophyte, the variation in frequency or altitudinal range of a species, or the disappearing of certain species from a given area (e.g. Van der Veken et al. 2004; Van Calster et al. 2008; Knapp et al. 2010; Chiarucci et al. 2017).

From a current scientific perspective, historical Floras also show obvious weak points. Traditional floristic research is typically based on an opportunistic approach, which implies potential distortions deriving from particular scientific interests of the time, from the characteristics of the classical floristic research and from the application of current analysis methods to historical data. This fact is well known when speaking of herbarium collections (e.g. Daru et al. 2018), but, to our memory, has never been clearly addressed regarding Floras. In addition, most information is available on paper only, a format which is unsuitable for rapid and statistical coherent data treatments, as required in today's science.

A Flora, however, is also a geographical document, since every species is usually accompanied by the observation place (e.g. in form of textual locality descriptions) and since the entire work is referred to a target region explored with certain criteria by the collectors involved. The information provided by Floras is maximized if the floristic data can be georeferenced by interpreting and converting the heterogeneous textual locality descriptions into geographic coordinates (i.e. retrospective georeferencing; see also e.g. Buldrini et al. 2018, 2019) and applying a spatial measure of uncertainty (e.g. Murphey et al. 2004; Chapman and Wieczorek 2020; Seregin and Basov 2021). Consequently, one may analyse the exploration pattern, the possible presence of exploration attractors for fieldwork, the relationships among the collectors involved, which in turn influence the content of the Flora itself (Fig. 1). Nonetheless, such geographical aspects of the Floras are usually ignored, also because the analysis of this information requires long and time-consuming georeferencing work based on the locality descriptions, thus the studies about quality and quantity of the floristic exploration of a territory are mostly performed following other viewpoints (see e.g. Kier et al. 2005; Chiarucci et al. 2018, 2021). At present, only very few articles dealing with geographical aspects of floristic lists exist (e.g. Viciani et al. 2018, 2021).

In this article, we used the Flora of the province of Bologna, published in 1883 by Girolamo Cocconi (which is already inserted in the Floristic Digital Database of Emilia-Romagna), as a study case for tackling the following research questions:

- what are the principal features of this Flora in terms of quality of the records and taxonomic interpretation of the reported species?
- which are the spatial and temporal exploration patterns applied by the authors within the region of interest and how did Cocconi include the information by both previous and contemporary collectors?
- which is the potential of an ancient Flora in highlighting past landscape features?

To this purpose, first we carefully georeferenced all the cited locations in order to facilitate systematic text and species record research and analysis. For the analysis of specific past landscape features and their evolution, we referred to two target groups of ecologically and/or biogeographically well-characterised species (the hydro-hygrophilous and the allochthonous species) and used them as indicators for assessing and quantifying the environmental transformations and human impacts that occurred in the area since Cocconi's time.

2 MATERIALS AND METHODS

2.1 The author and his Flora

Girolamo Cocconi (Parma, 1824 – Bologna, 1904; Fig. 2) graduated in medicine, veterinary medicine and natural sciences at the University of Parma, where he started to teach veterinary medicine in 1848. He

switched over to the University of Bologna in 1871, where he first became full professor of hygiene and veterinary medicine in 1874 and was later elected director for life of Bologna's *Scuola di Medicina Veterinaria* in 1884. He was well-known for his affiliation to numerous scientific and medical Italian academies, became member of various ministerial commissions for the promotion and development of teaching and for the compilation of the Official Pharmacopoeia, and was finally awarded the title of *Commendatore* (knight commander) of the Crown of Italy for his scientific merits. Pier Andrea Saccardo honoured his memory by naming a genus of fungi *Cocconia* (Brazzola 1905; Béguinot 1931).
Although teaching was his major commitment at the Veterinary Faculty of the university, he wrote various botanical and mycological works, such as a Flora of the forages of the province of Parma (Cocconi 1856), four partial contributions to the Flora of the province of Bologna (Cocconi 1877, 1878, 1879, 1880), followed by several botanical itineraries within the province itself (CAI Bologna 1881) and a complete Flora of the provincial territory (*Flora della provincia di Bologna* here considered – Cocconi 1883 – and thereafter referred to as «the *Flora*»).
The *Flora* summarises all his findings which previously appeared in the partial contributions, together with records by different authors, and represents the attempt to complete what the famous botanist Antonio Bertoloni *senior* (1775-1869) and Giuseppe Bertoloni (1804-1878) could not finalise. The latter, in particular, conceived the idea of using the numerous floristic studies he performed to publish a *Flora escursoria della Provincia di Bologna* (excursion Flora of the province of Bologna), but unfortunately, he died before achieving this goal (Cocconi 1877, 1879). It is fundamental to note that Cocconi's floristic investigations additionally led to the creation of a rich herbarium (Cocconi 1880), whose fate is however unknown to date, apart from some samples kept in the Herbarium Paolucci (University of Ancona).
This *Flora* is an outstanding case study for many reasons. First, it is one of the very first examples in northern Italy of a post-unification local Flora aiming at promoting a larger botanical culture among young (pre-university) students and common citizens. For this purpose, at the beginning of the work some clear and detailed instructions on how to prepare a herbarium and a dichotomous key for species identification are reported. Second, it describes a territory that already shows profound landscape alterations as in many other parts of Europe, such as land reclamation, forest overexploitation, development of railways, mountain exploration and search for thermal and touristic purposes (Bertoloni 1867; CAI Bologna 1881), even if wide areas quite well preserved from a naturalistic viewpoint still persisted. In contrast to many other Floras, in the introduction the author clearly defines and describes the extent of the studied area, giving the readers a precise picture of an urban, periurban and rural European landscape of the XIX century. Cocconi also referred to records from former floristic investigations and took advantage of several collectors, allowing to understand (at least partially) how single floristic records are passed on from one scholar to another.
From a technical viewpoint, the *Flora* is organised according to the system proposed by De Candolle (1818-1821), which at that time was the most modern and widely accepted systematic order, and includes not only native or sub-spontaneous species, but also ornamental species and particularly crop taxa important for industry or agriculture in the late 1800s (Cocconi 1883).

2.2 The study area

As specified by Cocconi himself (1883), the territory covered by the *Flora* encompasses the entire area within the political boundaries of the former province of Bologna (Emilia-Romagna, northern Italy; Fig. 3). Nevertheless, the author, like most contemporaneous botanists (e.g. Gibelli and Pirotta 1883, 1884), followed a naturalistic criterion and paid much more attention to natural rather than to administrative borders, which is standard procedure in floristic research (Pignatti 1982). Consequently, the area examined is larger than the territory comprised within the administrative borders.
From a phytogeographic viewpoint, Emilia-Romagna is a transition area between two bioregions (Dinerstein et al. 2017): the Adriatic Sea and central Mediterranean mixed forests bioregion (part of the Mediterranean subrealm, that covers the Italian peninsula and is characterised by a Mediterranean or oromediterranean vegetation) and the Alps and Po basin mixed forests bioregion (part of the Western Eurasia realm, that covers Northern Italy and is characterised by a continental vegetation of central European or alpine type).
The area covered by the *Flora* shares both these characters, given its position at the centre of the region and its altitudinal extent from the low plain to the subalpine level. Overall, it has an extension of 4096 km ^{2} and ranges from 8 to 1944 m a.s.l. (the peak of the mountain Corno alle Scale). The plain (47% of the area) and the hilly-mountainous part (53%) are clearly defined by the Roman roads *via Claudia* and *via Emilia*, along which the city of Bologna (at that time still surrounded by fortified walls) is located in the middle of the study area. *Circa* 10% of the studied area is currently under the neighbouring province of Modena.

The plain is an alluvial area generated by the River Po and its current and former tributaries, the River Panaro and River Reno, whose substrate is characterised by river sediments of variable granulometry and calcareous soils (Regione Emilia-Romagna 2022). In order to make the region habitable and suitable for agriculture, large-scale hydraulic interventions on the territory were performed between the late Middle Ages and the XVIII century, and others have still been done from 1850 onwards (De La Lande 1769; Bondesan 1990; Dallai et al. 2014). In the late XIX century, the artificial hydrological drainage network was only partially completed (Furlani 2009; Zampighi 2009; Montanari et al. 2022). According to Emilia-Romagna's 1853 land use/land cover map derived from the *Carta Topografica Austriaca* (see Table 1), 157 km ^{2} of the plain were still occupied by wide areas of 1-3 m deep stagnant water (the so-called *valli*). They represented the remnants of a wetland *continuum* called *Valle Padusa*, which in the past centuries extended from the Adriatic coast to the River Panaro and beyond (Soriani 1834). Besides very few spots of *Quercus robur* and *Carpinus betulus*-dominated lowland forests, the vegetation of this part of the study area was characterised by ruderal, disturbance-tolerant and segetal species in the cultivated areas, hydro-hygrophilous species, some of them abundant at times, in the residual marshes (Cocconi 1878) and paddy fields that sometimes replaced parts of the *valli* or the wetlands (Bertoloni 1870; Giacomelli 1987, 1997).
The hilly and mountainous parts are characterised by marked variations in terms of elevation, geology and pedological features. The substrate mainly consists of marl, sandstone, clays and chaotic complexes of various rocks incorporated in a clay matrix (i.e. scaly clays, It.: *argille scagliose*) and notable gypsum outcrops belonging to the Gessoso-Solfifera Formation of Messinian age especially in the eastern part of Bologna (De Waele et al. 2017). Mixed *Quercus* forests belong to the potential natural vegetation up to the submontane belt, whereas *Fagus sylvatica* forests dominate the montane belt, followed by *Vaccinium myrtillus* and *V. gaultherioides* heathlands in the suprasylvatic belt (CAI Bologna 1881).

2.3 Data pre-treatment

2.3.1 Floristic data

The following *Flora*-related information could be extracted as floristic records from Emilia-Romagna's Floristic Digital Database (Regione Emilia-Romagna 2021; hereafter DbER):
- taxon, at the level of species or infraspecies (variety, according to the author of the *Flora*),
- description of the locality (whenever present) where the taxon was observed,
- collector (Cocconi in person or another author by his appointment),
- narrative ancillary data (whenever present) such as presence as a cultivated species and frequency (*rara*, *frequente*, *volgare*, etc.) as indicated by the author himself.

2.3.2 Taxonomic and nomenclatural revision

Each recorded taxon was checked and revised in the light of current taxonomic interpretation, ecology and distribution in the regional territory. After updating the reported nomenclature following Pignatti et al. (2017-2019), taxa that have no longer been observed in Emilia-Romagna since Cocconi's survey and those whose taxonomic interpretation have varied notably have been classified as problematic. For the purposes of the present study, changes in taxonomic interpretation can have two effects: if the herbarium specimen reference is lacking, today it is impossible to fully understand what currently recognised taxon the author had actually observed (e.g. Pignatti and Guarino 2019); on the other hand, the geographical distribution attributed to that taxon can also change, widening or restricting the range and, as a consequence, varying the chorological category. Problematic taxa were thus solved either by assigning them, whenever possible, to the most plausible congeneric or conspecific taxon confirmed in Emilia-Romagna, or discarding them from further processing and analysis. Unfortunately, since the fate of Cocconi's herbarium is currently unknown, a re-examination of the original specimens for clarifying any doubts was impossible; some problems were however solved by consulting other XIX century herbaria available (Herbarium Universitatis Bononiensis – BOLO, then Herbarium Riva and Herbarium Mattei, both preserved in Herbarium Neapolitanum – NAP; Bronzo et al. 2012). The knowledge of today's flora of the province of Bologna is quite accurate, thanks to the DbER and to the work performed by many explorers (see also Pezzi et al. 2021), therefore it was nearly always possible to solve the uncertain cases by assigning the problematic taxa to the most probable one currently ascertained for the regional or provincial flora.
The complete list of the taxa cited in Cocconi's *Flora* together with their current interpretation is available in the DbER and reported in Online resource 2.

2.3.3 Integrating ecological information and defining specific ecological-biogeographic groups

For every retained taxon, life form and chorotype were added following Pignatti et al. (2017-2019) and Ellenberg's bioindication values were attributed as proposed for the Italian flora by Pignatti et al. (2005), Guarino et al. (2012) and Domina et al. (2018).

Secondly, two target ecological-biogeographic groups were defined for the detailed analysis of the landscape evolution: the hydro-hygrophytes and the allochthonous species. The hydro-hygrophytes include all species with Ellenberg's bioindication value for soil humidity U ≥ 7 and are further subdivided into the following three ecological categories:

- hygrophilous species: indicators of humid soils (U = 7 and 8);
- palustrine species: indicators of transitory, but frequent, soil submersion (U = 9 and 10);
- aquatic species: indicators of constant soil submersion (U = 11 and 12).

Allochthonous species were defined based on their origin (archaeophytes or neophytes) and further distinguished according to their present distribution status (casual, naturalised and invasive) as indicated by the Portale della Flora d'Italia (2021). Cryptogenic species, intended as doubtfully allochthonous ones (*sensu* Carlton 1996 and Celesti-Grapow et al. 2010), were computed together with allochthonous species.

Thirdly, in view of the analyses, the chorotypes of both ecological-biogeographic groups were framed into macro-chorotypes. For the hydro-hygrophilous species, this grouping was made according to Pignatti (1982), Poldini (1991), Tomaselli and Gualmini (2000) and Alessandrini et al. (2010):

- Boreal: species of the cold regions of Eurasia and North America;
- Eurasian: species of the temperate and sub-steppe regions of Eurasia;
- European orophytes: species of the mountain ranges of central Europe;
- Southern European orophytes: species of the mountain ranges of southern Europe;
- Mediterranean: species native to the Mediterranean Basin;
- Cosmopolitan: cosmopolitan or sub-cosmopolitan species;
- Exotic: all species which are not native of the Italian territory;
- Endemic: species endemic to the Italian peninsula.

For the allochthonous species, given the presence of many neophytes, further macro-chorotypes were adopted to better illustrate the geographical origin and species ecology, therefore macro-chorotypes were defined as follows:

- Boreal: species of the cold regions of Eurasia and North America;
- Eurasian: species of the temperate and sub-steppe regions of Eurasia;
- Mediterranean: species native to the Mediterranean Basin;
- Palaeotropical: species of the tropical and intertropical regions of Africa and Asia;
- North American: species of the temperate regions of North America;
- Neotropical: species of the tropical and intertropical regions of central and South America;
- South American: species of the temperate regions of South America;
- Pantropical: species native to all tropical regions of the world;
- Cosmopolitan: cosmopolitan or sub-cosmopolitan species.

Fourth, for every taxon featured in the final list, species extinction level (provincial, regional or national) was attributed following Bartolucci et al. (2018) and by means of the authors' expert assessment (AA), based on the floristic records preserved in the DbER. Threat level was evaluated according to the red lists of the European and Italian vascular flora (Bilz et al. 2011; Rossi et al. 2013). The same expert assessment (AA) procedure was applied to assign the current presence in the territory of the species of both target groups , to detect changes in frequency and abundance of the species themselves.

2.3.4 Expliciting the spatial information

We first delimited the reference area of the *Flora* by crosschecking the description provided by the author with the maps of the Istituto Nazionale di Statistica (https://www.istat.it/it/archivio/231601) of administrative divisions available for the years 1881 and 2021. The resulting perimeter roughly corresponds to the province of Bologna's boundaries at that time (Fig. 3), but extends to the natural limits represented by the River

Santerno eastward and the River Panaro westward; eastward it also includes municipalities that became part of the province few years later. To allow us to perform specific geographical analyses, the so obtained study area was subdivided into three different geomorphological and environmental sectors: the city of Bologna, the plain and the hilly-mountainous part.

Next, text-based locality descriptions of each record (whenever present) were associated by one of the authors (GP) to explicit geospatial coordinates with the highest possible precision using a stepwise procedure based on the expert knowledge of the area. Locality descriptions appearing highly heterogeneous (in term of content and format) were first standardised in full observation and consistency with the original terms. Such standardisation also highlighted text strings including more than one toponym, ambiguous toponyms (giving multiple possible interpretations), microtoponyms (i.e. locally used toponyms), as well as inconsistent formatting and misspellings. Geolocalisations were solved case by case, choosing the most suitable option among the available sources, such as georeferenced toponym databases, historical and current topographic maps (Table 1), historical textual sources mainly available in internet (e.g. Google Books), home-grown local people and territorial experts.

The following rules were then applied for the final positioning of the locality point on the maps (see Pezzi et al. 2021). Coordinates of linear-shaped elements (roads, rivers, streams, canals) were positioned in the midst of the feature. If the record was indicated between two different toponyms or in case the author's further indications were unavailable, an intermediate point between the localities was chosen. For the places where there was a parish church, the point was placed on this element, as it can be considered the most stable within the area. For toponyms referring to mountains, the point was placed on top of the mountain. The records referring to polygonal elements (e.g. the *valli* or paddy fields) took the coordinates of the locality of reference. Sometimes it was necessary to give a locality's description to the nearest toponym: this was the case when a locality description was made up of more than one toponym, of which one more precise than the other (and comprising the former), and it was not possible to assign the locality's description to the more precise toponym. Where the textual sources only indicated the area in which the target locality was comprised, the locality itself was matched with the toponym of the whole area.

Further, a radius was associated to each plan coordinates in order to describe the potential geographic extent of the locality, or to measure the uncertainty linked to the georeferencing procedure.

For the reconstructed plan coordinates, the distance from the town centre of Bologna, their positioning in the three defined geomorphological sectors (Bologna town centre, plain, hills and mountains), and the elevation (*z*-coordinate) based on the 5 m grid Digital Elevation Model (DEM) of Emilia-Romagna have been added.

The quality of the georeferencing process was labelled as follows: locality missing in the record; locality not found; locality referred to the nearest toponym. All the standardised georeferenced localities and related ancillary data were integrated back to the original data set.

The entire georeferencing process was performed in QGIS 2.18 (www.qgis.org), using the spatial reference system UTM32N – WGS84.

2.3.5 Collectors data

A careful literature search allowed additional data to be assigned to the collector's characteristics (see Online resource 3), such as background and professional skills (i.e. academic scholar, non-academic botanist, local enthusiast) and registry records (birth and death).

In particular, we used registry data as a proxy of the work period of a certain collector and to understand how contemporary the records are to the data published in the *Flora*. Furthermore, the number of records was assigned to each author whenever they appeared. Through locality georeferencing, we could also examine the various collectors' spatial contribution to floristic exploration and detect the areas of higher record concentration, i.e. those believed to be more interesting from a floristic viewpoint.

2.4 Data analysis

Geographical distribution patterns such as the spatial density of the observation places were analysed using the *Kernel Density* tool of ArcGIS Desktop (vers. 10.8.1) with the following parameters set: 40 m of output raster cell size; 5000 m of search radius (i.e. the search radius within which to calculate density) and a flat earth method (planar). The final map was produced with ArcGIS Pro (vers. 2.6.3). Canonical Analysis (CA) was performed to detect the pattern of collectors in comparison to the detected hotspots of floristic exploration.

Taxa were analysed at species and infraspecies level by grouping them according to their eco-geographical characteristics (e.g. stenomediterranean, arctic-alpine), phytogeographic and conservation interest (endemic, subendemic and extinct) and agricultural importance (cultivated and segetal). A deeper analysis was

performed for the target species (hydro-hygrophilous and alien) with respect to spatial distribution (plain area *versus* hills and mountains), life forms, macro-chorotypes and rarity. Hydro-hygrophytes were also analysed by ecological categories and threat level. This analysis was performed considering the current extent of the Bologna province. When analysing data, if a species is both hydro-hygrophilous and alien, it was considered in both groups.
Statistical elaborations were performed in R version 4.0.4 (R Core Team 2020).

3 RESULTS

3.1 Exploration pattern

Globally, 7767 records (taxon plus toponym) were extracted from the *Flora* (Online resource 2). Among them, 415 lack of a locality description: these records mainly refer to common or very common species, such as the ruderal *Stellaria media*, *Chelidonium majus*, *Echium vulgare*, woody species like *Quercus robur* or *Juniperus communis*, widespread segetal species (e.g. *Agrostemma githago*, *Gladiolus italicus*) and crop plants in some cases widely cultivated (i.e. *Zea mays*, *Solanum lycopersicum*, *S. tuberosum*). In addition, 8 records could not be located and 73 were referred to the nearest toponym. The remaining 7344 records could be referred to 659 standardised georeferenced localities (hereafter localities; see Fig. 4). These localities range from a precise (0.1 km radius) to a vaguely defined point (i.e. an extensive area, up to 40.0 km radius). However, 71.2% of the localities have a radius ≤ 1.0 km and 92.7% are those with a radius ≤ 2.6 km (Fig. 5). Among the localities, 247 are linked to a single record and 16 to more than 100 records (up to 256; see Fig. 4). Localities lay by 75.9% in the hills and mountains, 18.4% in the plain and 5.7% in the Bologna town. The former group of localities is also linked with 79.7% of the floristic records. Some of these localities include completely disappeared ecosystems due to changes in land-use occurred during the XX century (i.e. the *valli*) or destruction during the Second World War.
The locality density estimated by the Kernel density (Fig. 4) ranged from 0 to 2.7 localities/km^2 (mean value: 0.1 localities/km^2) and reveals four hotspots of floristic exploration (Table 2). These areas comprise 63.6% of the georeferenced records, 47.9% of the georeferenced localities, 14 of the 16 localities with at least 100 floristic records. By contrast, they have a total extension of only 280.1 km^2 (6.8% of the entire study area). The richest hotspot in term of records (2108) and localities (173) includes the town of Bologna and its surroundings, up to a distance of 15.4 km and an altitudinal range from 30.8 up to the 390.3 m in the hills. It is interesting to note that most of the localities linked to Bologna refer to the elements of the city walls (e.g. gates) which were demolished in the early XX century. Other hotspots comprise localities at a distance from Bologna between 44.4 and 59.6 km, in the south-western part of the study area. In particular, the localities in the area of Porretta Terme have an altitudinal range from 343.2 to 1470 m a.s.l., whilst Mount Corno alle Scale contains the localities with the highest altitudes: 52.3% of records are comprised between 1600 and 1944 m a.s.l. (i.e. from the timberline upwards, into the subalpine level). Finally, the Montese area includes mainly localities within the province of Modena.
About 27% of the records are referred to collectors other than Cocconi. Globally, contributors are 32, even if a discrete number of floristic records was simultaneously attributed to two authors by Cocconi himself (e.g. Amilcare and Demetrio Lorenzini, Giuseppe and Domenico Riva, Giuseppe Gibelli and Pietro Romualdo Pirotta; see Online resource 3 and Fig. 6). Collectors were academic scholars, professors or directors of botanical gardens (Gibelli, Pirotta, Cavara, Mattei, Savi, etc.), others were undisputed scientific authorities (such as Antonio Bertoloni *senior* or Caruel – Gibelli and Pirotta 1883) or local collectors like pharmacists (Lorenzini, Tassinari), and botany enthusiasts (Breventani, Comelli, Giannitrapani, Saccenti, etc.). However, the major contributors (> 50 records) are principally academic scholars or directors of botanical gardens, such as Antonio Bertoloni *senior* (913 records), Giuseppe Bertoloni (355), the Riva brothers (249), Giuseppe Gibelli and Pietro Romualdo Pirotta (98), Teodoro Caruel (69). Further, the Lorenzini brothers (136) and Cesare Saccenti (77) should be added as the sole non-academic plant collectors among the major contributors. Concerning the timeline, the most ancient records are the 10 by Fulgenzio Vitman and one by Ferdinando Bassi (i.e. *Caldesia parnassifolia*, which was found in the «*wetlands of the Bologna Apennines*» – Cocconi 1883). All the collectors except four are included in the records of the hotspots. Concerning the Bertoloni, 511 out of 913 records for Antonio *senior* are included in the hotspots, whereas for Giuseppe they are 341 out of 355. Furthermore, the records by Antonio *senior* are mainly linked to Bologna (380 records), whereas those by Giuseppe to Porretta Terme (316). Vitman, Savi and Caruel in turn are principally linked with Corno alle Scale (Fig. 7). Most of the records are however due to Cocconi and his contemporary collectors.

3.2 The taxa: general characters and chorological aspects

The floristic dataset consists of 1755 species and 305 infraspecies, corresponding to 1699 species and 92 subspecies currently recognised (on which all subsequent numbers and analyses are based). Besides tracheophytes, 5 species are algae (genera *Chara* and *Nitella*), which were not considered in the present study. As a whole, the taxa occurrence ranges from 1 to 20, with a prevalence (68.5%) of low occurrences (≤ 5). Single occurrences account for 30.0% of the total. The most frequently recorded taxa are *Mentha aquatica* (20 occurrences), *Orobanche gracilis* (19), *Geranium nodosum*, *Trifolium ochroleucum* and *Viola canina* (18).

Problematic taxa are 60 and may refer to possible Cocconi's mistakes (e.g.*Astragalus alpinus*, *Coristospermum ferulaceum*, *Minuartia laricifolia*), to species no longer observed in Emilia-Romagna (such as *Carex disticha* or *Tephroseris longifolia*; in some cases, they are species not confirmed since a long time, but whose ancient presence can not be excluded *a priori*: see for example *Allium carinatum*, *Cynoglossum creticum* and *Equisetum fluviatile*), to species nowadays found only in the Alps or in central-southern Italy (e.g. *Drosera anglica* and *Doronicum orientale*, respectively), or to misinterpretations of the species' past names that make it now impossible to clearly identify the current species (case of *Cardamine pratensis*, *Ranunculus aquatilis*, *R. gracilis*, *Thalictrum flavum*, etc.).

Besides species typical of the mesophilous *Quercus*-dominated or *Fagus sylvatica* forests, which are very common to most parts of continental Europe, the *Flora* reports also species belonging to particular chorological groups, such as:

- stenomediterranean species (< 3%), such as *Allium roseum*, *Asparagus acutifolius*, *Picnomon acarna*, *Quercus ilex* (which at that time grew as a shrub in small groups of individuals, under particular favourable microclimatic conditions);
- arctic-alpine species (< 1%) living in the most elevated parts of the province, in prairies and heaths (e.g. *Anemone narcissiflora*, *Empetrum hermaphroditum* or *Gentiana nivalis*, which was at that time considered very rare) or rocky environments (e.g. *Juncus trifidus*, *Saxifraga paniculata*, *Silene acaulis*);
- species which are endemic to Italy (e.g. *Cirsium bertolonii*, *Globularia incanescens*, *Murbeckiella zanonii*, *Ononis masquillierii*, *Polygala flavescens*) or subendemic (e.g. *Cardamine chelidonia*, *Geranium argenteum*, *Phyteuma scorzonerifolium*), globally accounting for about 2% of the flora.

Cultivated taxa are 122 (Table 3), although some of them may have occurred as casual aliens. Species which were largely cultivated at Cocconi's time were, for example, *Cannabis sativa* (plain part of the study area), *Oryza sativa* (lowlands, near the *valli*), *Castanea sativa* (cultivated even in some kitchen gardens of the city of Bologna), *Solanum lycopersicum* and *S. tuberosum*. To these taxa we add *Morus alba* and *M. nigra*, which were cultivated as fodder crops for silkworms together with *Ulmus minor*, and *Linum usitatissimum* and *Olea europaea*, a stenomediterranean species back then cultivated only in scattered and isolated trees.

Among the segetal species accompanying the cultivations, we mention *Adonis aestivalis*, *Agrostemma githago*, *Anemone coronaria*, *A. hortensis*, *Consolida regalis*, *Cyanus segetum*, *Legousia speculum-veneris*, *Scandix pecten-veneris*, *Papaver rhoeas*, *Turgenia latifolia* and *Vaccaria hispanica*.

Finally, 40 species recorded in the *Flora* are currently declared as extinct on a provincial, regional or national scale. Most of them are hydro-hygrophytes (Table 4), but the list also includes some species of economic and medicinal importance (e.g. *Isatis tinctoria*, *Trigonella foenum-graecum*, *Leonurus cardiaca*, *Styrax officinalis*), the alien and hydro-hygrophilous *Najas graminea*, which the author reported from the paddy fields with the additional comment «*perhaps introduced with the rice cultivation*» (Cocconi 1883) and few hypsophilous species (*Gentiana nivalis*, *Silene acaulis*, *Traunsteinera globosa*, etc.).

3.3 The hydro-hygrophilous species

Hydro-hygrophilous species recorded in the *Flora* are 283 (16.5% of the total species number), subdivided in 169 hygrophilous (59.7%), 70 palustrine (24.7%) and 44 aquatic species (15.5%). Of these 283 species, 59 (20.8%) lack geographical indication: they were either very common species (*Alisma plantago-aquatica*, *Equisetum telmateia*, *Juncus effusus*, *Typha latifolia*, etc.) or cultivated species (*Allium schoenoprasum*, *Oryza sativa*, *Sorghum bicolor*, *Zea mays*). Hydro-hygrophilous species also include 6 alien species (e.g. *Acorus calamus*, *Najas graminea*), 10 cultivated species (*Citrullus lanatus*, *Mentha spicata*, *Oryza sativa*, etc.), 10 ornamental species (*Populus canadensis*, *Salix babylonica*, etc.).

In the plain, the sum of palustrine and aquatic species is nearly equivalent to the number of hygrophilous species (48.9 and 51.1%, respectively), whereas in the hills and mountains the hygrophilous prevail (67.7%; Fig. 8a).

Among the life forms (Fig. 8b), hemicryptophytes clearly dominate in all contexts, but with notable differences between plain (31.6%), hills and mountains (48.8%); similarly, the presence of hydrophytes and helophytes greatly varies between the plain (28.9%), the hills and mountains (11.7%).
Concerning the chorotypes, Eurasian, boreal, cosmopolitan and Mediterranean species are always dominant, but Eurasian and cosmopolitan species are more abundant at low altitudes, whereas boreal and hypsophilous ones are more abundant in the hills and mountains (Fig. 8c). In particular, boreal species (circumboreal and Euro-Siberian) are 19.4% of the chorological spectrum in the plain area and 26.0% in the hills and mountains.
In the *Flora*, 31 species were indicated as frequent and 4 as rare (*Leucojum aestivum*, *Potamogeton perfoliatus*, *Rumex palustris* and *Sonchus palustris*). Among these 31 species, 8 are now rare, for 2 the current presence deserves to be confirmed and 3 formerly rare species are now extinct.
As of today, 63 species (22.3% of the hydro-hygrophilous) are rare, 14 (4.9%) need to be confirmed, 29 (10.2%) are extinct. Among the latter, 2 are extinct all over Italy (*Aldrovanda vesiculosa* and *Caldesia parnassifolia*), 5 are extinct in Emilia-Romagna (*Acorus calamus*, *Hippuris vulgaris*, *Limosella aquatica*, *Ranunculus lingua*, and *Sonchus palustris*, the latter possibly extinct in Italy throughout), whereas the others are extinct on a provincial scale only. Of the extinct species, 12 out of 29 (41.4%) were exclusively recorded in the plain, 9 (31.0%) were found in the hills and mountains exclusively, the others (27.6%) were present throughout the whole territory. The extinct species can be divided into 10 palustrine, 10 aquatic and 9 hygrophilous (Table 4). In the plain, hills and mountains palustrine and aquatic species dominate: 15 species out of 20 in the plain and 11 out of 17 in the hills and mountains. Among them, we find species typical of stagnant oligotrophic waters with a peaty substrate (e.g. *Hottonia palustris*, *Menyanthes trifoliata*), species resisting to a remarkable summer heating (e.g. *Aldrovanda vesiculosa*), or species growing on flooded soils with a good trophic level (e.g. *Caldesia parnassifolia*, *Hippuris vulgaris*, *Oenanthe aquatica*, *O. fistulosa*) or significant nutrient accumulation (*Baldellia ranunculoides*). Various species are also typically found in humid oligotrophic grasslands or peat bogs (*Eriophorum angustifolium*), or humid mesotrophic grasslands (*Anacamptis palustris*, *Leucojum aestivum*, etc.).
Concerning the life forms, 15 species out of 29 are hydrophytes, 6 are hemicryptophytes and 5 geophytes, whereas helophytes and therophytes display a marginal presence only (in terms of number of species, but surely not as land cover importance). In the plain area, hydrophytes and hemicryptophytes dominate (12 and 4 species out of 20, respectively), whereas the most abundant in the hills and mountains are the hydrophytes (8 species out of 17), followed by geophytes and hemicryptophytes (4 and 3 species, respectively). Concerning the chorotypes, Eurasian, boreal and cosmopolitan species dominate in the entire territory (12, 10 and 6 species, respectively), but with noteworthy differences in the distribution between the plain (Eurasian 45.0%, boreal 30.0%, cosmopolitan 25.0%) and the hills and mountains (boreal 47.0%, Eurasian 35.3%, cosmopolitan 11.8%).

3.4 The allochthonous species

The allochthonous species are 123 (7.2% of the total species number), divided in 61 archaeophytes (e.g. *Allium cepa*, *Malus domestica*), 57 neophytes (e.g. *Amaranthus* spp., *Hemerocallis fulva*), 4 cryptogenic (e.g. *Brassica nigra*), 1 generic allochthonous (*Allium ascalonicum*). Even if archaeophytes and neophytes are globally similar in number (Table 5), most of the former correspond to casual and naturalised species, whereas neophytes are largely dominated by invasive ones (87.5%). In the late XIX century, anyway, only 4 currently invasive species were frequent, whereas 14 were cited for not more than 5 localities and 1 was even said to be rare (Table 6). The most recorded species are, in decreasing order, the neophyte *Datura stramonium* and the local allochthonous *Narcissus pseudonarcissus* (12 records each), the archaeophyte *Prunus domestica* subsp. *insititia* (11), the neophytes *Amaranthus retroflexus* and *Narcissus incomparabilis* (8 records each), the archaeophytes *Hyacinthus orientalis*, *Punica granatum* and *Raphanus sativus* and the neophyte *Xanthium spinosum* (7 records each).
13 species were found in Bologna, 34 in the plain, 59 in the hills and mountains. Archaeophytes and neophytes were always present in similar numbers, apart from Bologna town centre (Table 7). 50 species out of 123 (25 archaeophytes, 22 neophytes, 2 cryptogenic, 1 generic allochthonous) lack of a geographical indication, because in most cases they were present only under cultivation and did not tend to naturalise.
67 out of 123 species (50 archaeophytes, 13 neophytes, 3 cryptogenic, 1 generic allochthonous) were cultivated for food and 18 (2 archaeophytes, 16 neophytes) for ornament (but the neophyte *Phytolacca americana* was cultivated for both purposes); 1 was sporadically cultivated as a dyeing plant (*Isatis tinctoria*), whereas the remnant 37 (8 archaeophytes, 28 neophytes, 1 cryptogenic) grew spontaneously in the territory. Among crop species, 6 (4 archaeophytes, 2 neophytes) were cultivated in the plain only (2 of which

in Bologna as well), 14 (13 archaeophytes, 1 cryptogenic) were exclusively cultivated in the hills and mountains (1 of which in Bologna as well), 7 (all of them archaeophytes) were cultivated both in the plain, hills and mountains, 2 (all of them archaeophytes) in all three sectors (Bologna, plain, hills and mountains). Therefore, globally 15 crop species were cultivated in the plain and 23 in the hills and mountains.
Life forms are illustrated in Fig. 9a. Therophytes (i.e. annual species, in most cases typical of disturbed soils) are always dominant, followed by phanerophytes, geophytes and hemicryptophytes (in most cases ornamental species), with small variations in the percentages among the different sectors. Helophytes and hydrophytes are confined to the sole plain zone.
Chorotypes are illustrated in Fig. 9b. Eurasian species are always dominant, making up at least 25% of the spectrum; Mediterranean, palaeotropical, cultivated and temperate America species follow, with values comprised within 10-20% of the spectrum. The species of the Old World vary between 48.8 and 56.6% in the plain, hills and mountains respectively, and are limited to 33.3% within Bologna. The species of the New World vary between 23.6 and 29.8% in the plain, hills and mountains respectively, and reach 41.2% within Bologna.
Concerning the geographical origin of the species, Asian species represent 27.3% of the list, American 24.0%, European 9.9%, African 5.8%. The remnant species have a wide distribution (pantropical, circumboreal, cosmopolitan), are cultivated, or are still of unknown or uncertain origin.
Among the 5 allochthonous species that were common at Cocconi's epoch, 3 neophytes are now invasive (*Amaranthus deflexus*, *A. hybridus* and *Erigeron canadensis*) and 2 naturalised (the neophyte *Digitaria ciliaris* and the archaeophyte *Prunus dulcis*). Today, 4 species are rare (the neophytes *Narcissus medioluteus* and *Tulipa raddii*, the archaeophyte *Punica granatum* and the cryptogenic *Rhus coriaria*) and 6 are extinct (e.g. *Acorus calamus*, *Arachis hypogaea*, *Trigonella foenum-graecum*; see Table 4), whereas in the late XIX century they were cultivated (*A. hypogaea*, *P. granatum* and *T. foenum-graecum*) or somewhere spontaneous or sub-spontaneous (*N. medioluteus*, *R. coriaria*, etc.).

4 DISCUSSION

4.1 Exploration patterns and quality of the data

The *Flora* refers to a territory that goes beyond the administrative borders of the Bologna province back in the day. Indeed, the area studied is much more defined on a geographic and naturalistic basis, also considering changes made on the borders that would have become operational in the near future (i.e. some municipalities of the eastern part annexed to the province of Bologna in 1884). The approach including relevant areas for the reference territory, irrespectively of the administrative units, is common also to other Floras of the same historical period (e.g. Gibelli and Pirotta 1883) and is obviously logical even in a modern perspective (Pignatti 1982).
The resulting floristic records are the product of the joint work by Cocconi and 32 other collectors. When looking at the time span of such records, most ancient ones probably date back to the mid of the XVIII century. Among them, of particular relevance are the record of *Caldesia parnassifolia* by Ferdinando Bassi, who sent Linnaeus the specimen (Managlia and Mossetti 2008; Managlia et al. 2012) and the 10 records by Fulgenzio Vitman, which he published in 1773. Among the most important contributors of the *Flora* we have Antonio and Giuseppe Bertoloni, with records from the 1820s to the 1870s, which were primarily part of the *Flora Italica* (Bertoloni 1833-1854), and the works by Giuseppe Bertoloni such as *Iter in Apenninum Bononiensem* (Bertoloni 1841) and *Vegetazione dei monti di Porretta* (Bertoloni 1867). These records by the Bertoloni, together with the contributions by Bassi and Vitman, might be considered as the *corpus* of historical records of the *Flora*. The other collectors are mainly contemporary to the redaction of the *Flora* and somehow linked to the University of Bologna, either as alumni or as collaborators for Bertoloni and Cocconi. Finally, some records originate from the Flora of the bordering provinces of Modena and Reggio Emilia (Gibelli and Pirotta 1883, 1884), whose authors Cocconi was probably in touch with, which let us suppose similar cultural drivers or even a common genesis of the two works. To sum up, most records of the *Flora* were collected in a period of roughly 60 years, with a peak during the time when Cocconi was a professor in Bologna (from 1871 onwards).
From a geographical standpoint, the exploration effort is unbalanced in favour of the hills and mountains, whereas territories lacking a road network tended to be avoided, for the obvious difficulties of travelling in these areas (cfr. Mattei 1893; Pezzi et al. 2021). Four exploration hotspots can be recognised. The first corresponds to the starting point of the botanical itineraries around Bologna and extends up to the adjacent *Colli Bolognesi* (lit. «the hills of Bologna», roughly ranging from 200 to 400 m a.s.l.). As testified by many

herbarium samples collected by Ulisse Aldrovandi (e.g. Soldano 2000, 2001, 2002), the *Colli Bolognesi* have been known since the Renaissance for their high floristic value. Two other hotspots are situated at a cartographic distance of 40-60 km from Bologna (Bertoloni 1867; CAI Bologna 1881): one coincides with the area of the thermal baths of Porretta and surrounding mountains, the second with the area of the Corno alle Scale massif, both renowned for centuries for their natural and wildlife heritage (cfr. Pezzi et al. 2021). The exploration hotspots also correspond to the areas where data reported by various authors have accumulated over time (Vitman, Bertoloni, Cocconi), confirming botanists' early and notable interest for the biological richness of these sites as well as their medical and cultural importance. Nonetheless, it is due to note that the recent inauguration of the railway from Bologna to Pistoia (opened in 1864) allowed much better access to the most elevated parts of the province. Therefore, the high exploration intensity of the areas of Porretta and Corno alle Scale could be ascribed both to the high interest they generated since the previous centuries and to the great improvement of the travelling conditions.

4.2 The taxa: general characters and chorological aspects

The floristic dataset consists of 1755 species and 305 varieties, which is in line with similar and coeval works such as the Flora of the neighbouring territories of Modena and Reggio Emilia (1871 species and 325 varieties; Gibelli and Pirotta 1883, 1884). Among all taxa recorded in the *Flora*, 38 (of which 30 hydro-hygrophytes) can be declared currently extinct.

The taxonomic problems concerning the interpretation in light of the modern knowledge of the species reported by Cocconi are of different origins. They may be errors by the authors (e.g. *Gentiana pneumonanthe*, *Verbascum samniticum*), species currently interpreted in a different way in comparison to what was done in the late 1800s (e.g. *Cardamine pratensis*, *Ranunculus gracilis*, *R. aquatilis* or *Thalictrum flavum*, which are today intended in a narrower sense or treated as complex of species), or species for which the knowledge of the geographical distribution has varied compared to the author's era, since the floristic exploration of the territory was less complete than today (case of *Carex disticha*, *Drosera anglica*, *Pimpinella tragium*, *Saxifraga caesia*, etc., whose presence is not known in Emilia-Romagna today, but in Cocconi's times they were said to grow also in the Apennines: cfr. Cesati et al. 1868-1886; Bartolucci et al. 2018). The cause of such differences in species interpretation must be searched in the scarcity of reference works available at the time and in the identification obtainable through the Floras of the XIX century (Bertoloni 1833-1854; Passerini 1844; Parlatore 1848-1896; Cesati et al. 1868-1886). In particular, the latter is directly related to the former taxonomic interpretation and knowledge of the geographical distribution, since a Flora is always a subjective interpretation of phenomena and is inevitably a product of the scientific mentality of the author and his time (Pignatti 1982). To better understand Cocconi's choices, one should identify these species with the instruments (microscopes, Floras, keys, etc.) available in the last decades of the XIX century. Anyway, it is not always possible to determine whether we are discussing species which have meanwhile disappeared or erroneous interpretations in light of the current knowledge, due to the fate of his herbarium being unknown, that prevents any verification on the *exsiccata*.

The diversified flora, characterised by the contemporaneous presence of stenomediterranean and arctic-alpine species, proves the high geographical and floristic interest of the small area investigated, which displays different environments and microclimates. Some stenomediterranean species are linked to particular micro-topographic conditions or geological formations, such as the gypsum outcrops (Ferrari 1974; De Waele et al. 2017); the arctic-alpine species, instead, are concentrated and exclusive to the montane and suprasylvatic belt of the Corno alle Scale massif, that is the sole area within the studied territory allowing these microthermal species to grow. Endemic and subendemic species are a marginal presence (2% of the flora) and nearly all are distributed along the Apennines, probably because the province of Bologna does not have geographical barriers that impede the normal dispersal of propagules.

There is a notable number and selected narrative information on crop taxa, allowing to partially reconstruct the agronomic features of the time. We remember for instance the cultivation of *Castanea sativa* trees in some vegetable gardens within Bologna, the wide extent of the cultivations of *Cannabis sativa* in the plain, whereas one century before it was cultivated also in the hills and mountains (Pezzi et al. 2020) , the scattered presence of *Morus* spp. and *Ulmus minor*, which testify a residual but still existing sericulture, and some remnants of *Olea europaea* trees that survived the severe reduction in number caused by the Little Ice Age (Rotondi et al. 2018). On the other hand, new entries such as *Solanum tuberosum* became widespread and cultivated in several varieties, after being highly unwelcome from an agronomical viewpoint just a hundred of years before (a single record for the entire territory at that time; Pezzi et al. 2020). Among formerly cultivated species, we also have to mention those with pharmaceutical uses (e.g. Palma 1964; Gastaldo 1987), that were still present as subspontaneous relictual species, such as *Acorus calamus*, *Leonurus*

cardiaca and *Styrax officinalis*. It is further interesting to note how at Cocconi's epoch also the paddies were rich in autochthonous hydro-hygrophytes, such as *Echinochloa crus-galli*, *Eleocharis palustris*, *Nymphaea alba*, *Nuphar lutea*, *Potamogeton natans* (Bertoloni 1870).
Finally, the agricultural areas were rich in various segetal species, such as *Adonis aestivalis*, *Agrostemma githago*, *Consolida regalis*, *Cyanus segetum*, which are at present extremely sporadic not only in the territory studied, but also in large parts of the southern Po valley (e.g. Ferrari 1980; Piccoli et al. 2014).
All these data contribute to give a picture of an epoch whose socio-economic, climatic and environmental conditions largely differ from those of present days.

4.3 The hydro-hygrophilous species

Floristic data indicate a wide presence of permanent and temporary water bodies in the late XIX century, especially in the plain, where palustrine and aquatic species were almost 50% of the total list of the hydro-hygrophilous species. This is corroborated by the huge number of hydrophytes nearly reaching 25% of the list in the plain, but not exceeding 10% at higher altitudes (Fig. 8b).
The chorological spectrum reveals a considerable presence of microthermal species in the humid areas, both in the plain (19.4%) and in the hills and mountains (26.0%): if this pattern is quite normal in mountainous territories, it is instead worth noting at lower altitudes, since at present boreal species normally are 10% of the spectrum in the Po Plain (Pignatti 1994). These results agree with previous studies performed in the south-eastern Po valley (Buldrini et al. 2013a; Montanari et al. 2020), showing that in the low plain wetlands and hygrophilous habitats microthermal flora can even be 20% of the total list. Anyway, some of the hydro-hygrophilous species recorded by Cocconi in the plain were probably present as glacial relicts (e.g. *Hottonia palustris*, *Menyanthes trifoliata*), since today they are extremely rare at low altitudes and confined only in particular situations, whereas in the late XIX century they were more common, even in other sectors of the Po valley (Romani and Alessandrini 2001; Piccoli et al. 2014).
Among the disappeared species, the most common are aquatic or palustrine, typical of constantly (or at least frequently) flooded areas, where the soil always maintains a notable humidity level (Pignatti et al. 2005). Particularly in the plain, the considerable quantity of palustrine species (28.3% of the total of the hydro-hygrophilous species: see Fig. 8a) indicates a large presence of transition habitats between places which are constantly or frequently submerged and places only flooded on occasion, as indirectly suggested by Cocconi himself, who estimated as widespread species like *Eleocharis palustris*, *Oenanthe fistulosa*, *Rumex hydrolapathum*, typical of environments with very humid and at times asphyctic soils (Pignatti et al. 2017-2019). It is worth noting that, out of 6 species with cosmopolitan distribution, 5 were recorded in the plain (e.g. *Hippuris vulgaris*, *Potamogeton perfoliatus*): in the Po valley, the presence of populations of widely distributed species allowed them to maintain a range continuity within the entire Eurasian continent (Dallai et al. 2014). Land reclamation, hydraulic regulation and agronomic arrangement of the territory caused the progressive disappearance of various species linked to wetlands: the process, probably started during the XVIII century, accelerated and intensified especially from the 1920s onwards (De la Lande 1769; Tinarelli and Tosetti 1998; Buldrini et al. 2013a).
The two species extinct on the Italian level concern both the plain (*Aldrovanda vesiculosa*) and the hills and mountains (*Caldesia parnassifolia*). They are palustrine hydrophytes, with a sub-cosmopolitan distribution, already extinct in some European countries and threatened at various degrees: *A. vesiculosa* is extinct in Italy, France, Austria and Greece and classified as *endangered* on a global scale (Jury 2009; Beretta et al. 2012; Rossi et al. 2013); *C. parnassifolia* is extinct in Italy, but classified as of *least concern* in Europe (Gennai et al. 2012; Rossi et al. 2013), even if its presence is declining everywhere (Dumeige 1995). Both species are listed in Annexes II and IV of the Directive 1992/43 of the European Union and in Annex I of the Convention on the Conservation of European Wildlife and Natural Habitats (Bilz et al. 2011). It is interesting to remember that *A. vesiculosa* was found by Cocconi only in one single place: this fact can lead to believe that it was already very unusual, given its probably very narrow ecological tolerance (Adamec 1995) and since some marshy areas seemed to host mostly common and generalist species (Cocconi 1878). At that time, in fact, notable environmental transformations were ongoing, among them the progressive drainage of the remnant wetland areas of the lowlands: Cocconi was perfectly aware that he was observing a situation already compromised if compared to the previous decades (Cocconi 1877).
Of the 5 extinct species in Emilia-Romagna, 4 were exclusive of the plain. Among them, *Hippuris vulgaris* is classified as *endangered* at the Italian level (Rossi et al. 2013) and is also ascribed to the European red list of vascular plants with the status of *least concern*, together with *Ranunculus lingua* (Bilz et al. 2011).
It is worth mentioning that most of the extinct species were recorded by Cocconi in few places only (Table 4). This is in contrast to what was reported by Buldrini et al. (2014), according to which various hydro-

hygrophytes often were so common to be hardly interesting for the botanists of XIX century. Apparently, all these species were already undergoing a rarefaction process, due to the environment's transformations of that period (cfr. Cocconi 1877; Pezzi et al. 2021): «*if we only visit any of these* [swampy] *areas, we cannot get an adequate concept of the palustrine vegetation of the Province, if all of them have not been studied, each one with its own peculiarities*», also because «*going through these marshes, I noted an increasing transformation of their flora, especially where the drainage works began some years ago; so that certain marshes, that still are in conditions of uncultivated lands,* […] *maintain the characters of the aquatic or palustrine vegetation*», whereas elsewhere «*even if these marshes have a general vegetation character*[3]*, nonetheless certain species prevail in some of them so that to become common, but are rare or completely absent in other areas*» (Cocconi 1878). That being the case, in the Po Plain the phase of most serious population decrease for many hydro-hygrophytes began in the second half of XIX century (at least for certain areas), not at the time of the great economic development after the Second World War as supposed for example by Buldrini et al. (2013b, 2013c) and Conte et al. (2022). Anyway, we must bear in mind that such presence records probably do not represent the entire patrimony of local populations for the above-mentioned species, therefore our conclusions can be biased by the consideration of a subset only of the real number of populations existing at that time.

4.4 The allochthonous species

The quality of the allochthonous species reported by Cocconi clearly identifies a territory already subject to profound transformations and widespread soil tilling, because of the notable presence of species introduced accidentally or for ornamental purposes, already growing as spontaneous in the territory by the late XIX century (29.8% of the list of the allochthonous species). Many of them, such as *Amaranthus deflexus*, *A. hybridus*, *Erigeron canadensis*, are typical of disturbed or ruderal places and were found by Cocconi in great abundance along country roadsides, within the villages, the fields and uncultivated lands. Some of the species which were spontaneous at his time were formerly (or still here and there) cultivated for ornament, for example *Narcissus* spp., *Syringa vulgaris*, *Tulipa* spp. (Cocconi 1883; Fiori 1894); at the end of the XIX century they were naturalised (e.g. Mattei 1893; Pignatti et al. 2017-2019), even if never frequent in the territory. Anyway, the major part of the allochthonous category is composed of food species (55.4%), many of them cultivated in fields and vegetable gardens (*Allium* spp., *Triticum* spp., etc.). Other species, instead, were cultivated at that time, whereas today the cultivation has ceased for many decades: some have in the meantime disappeared from the examined territory (e.g. *Atriplex hortensis*, *Cannabis sativa*) or even from Emilia-Romagna (e.g. *Atriplex sagittata*, *Lagenaria siceraria*); others are frequent in disturbed places, along ditches, abandoned lands, etc. (e.g. *Helianthus tuberosus*, *Prunus cerasifera*; cfr. Pignatti et al. 2017-2019; Portale della Flora d'Italia 2021); others are sporadical, no longer confirmed for the province of Bologna (e.g. *Arachis hypogaea*, *Trigonella foenum-graecum*).

Among the 24 species today classified as invasive on the national level (Portale della Flora d'Italia 2021), we also find species already spreading in the territory by the late XIX century, although not yet invasive: we cite for example *Ailanthus altissima* and *Robinia pseudoacacia*, that now are among the worst invasive species on the European level (e.g. Sheppard et al. 2006; Kleinbauer et al. 2010), even if they are not listed among the invasive species of EU concern (European Commission 2017). According to Cocconi (1883), *A. altissima* was common in a single locality of the plain and *R. pseudoacacia* simply was «*cultivated to make hedgerows and as an ornamental tree in many avenues and public promenades, but here and there spontaneous*». Among the species today listed as invasive (Portale della Flora d'Italia 2021), only *Erigeron canadensis* and (to a lesser extent) *Parthenocissus quinquefolia* were common already in the late XIX century: the others were observed nearly solely in cultivation and the presence records were few (Table 6). In short, at Cocconi's time, nearly all the species today listed as invasive still behaved as casual and only rarely were frequent, probably because of the very diverse environmental and climatic conditions of the territory. In fact, the most frequent species in terms of number of records were *Datura stramonium* and *Narcissus pseudonarcissus* (12 records each), the first typical of ruderal areas and disturbed soils (even in the planitial marshes) and the second widely cultivated in the hills as an ornamental plant (Cocconi 1883), followed by *Prunus domestica* subsp. *insititia* (11 records), commonly cultivated since a very long time, but also

3) At that time, the concepts of habitat and vegetation were not still clearly developed: what now we would call habitat was indicated as «growth station» (It. *stazione*, *stazione di crescita*) and usually intended as one the 24 *stationes plantarum* (that are the diverse environmental situations where plant species can grow) indicated by Linnaeus (1754). Until the mid of the XIX century, the terms «flora» and «vegetation» were indifferently used to address what now we would probably call the vascular plant component of the biosphere (Pavillard 1935; Martins and Batalha 2011).

spontaneous in places far from human settlements (Pignatti et al. 2017-2019) and quite frequent in hilly areas (Cocconi 1883).
The distribution of the allochthonous species also reveals a different distribution of the population with respect to the present: the allochthonous species found in the hills and mountains are 59, whereas in the plain they are only 34. Hills and mountains, in fact, were much more populated than today (Sereni 1961): not by chance, most of the allochthonous species recorded at the higher altitudes were cultivated for food or for ornamental purposes, whereas the typical species of disturbed places (often discretely thermophilous) were few and not rarely linked to agricultural contexts or road margins (*Amaranthus* spp., *Erigeron annuus*, *Sorghum halepense*, *Symphyotrichum novi-belgii*, *Xanthium orientale* subsp. *italicum*). Conversely, the planitial territories, even if impacted by agriculture (as is proved by the 12 species out of 34 cultivated for alimentary purposes), still preserved fairly natural wetlands (Cocconi 1878), as revealed both by the analysis of the hydro-hygrophilous species and by the presence of few hygrophilous allochthonous species such as *Acorus calamus*, *Cyperus glomeratus* and *Najas graminea*, that were found exclusively in the plain.
Overall, the scenario that can be outlined is that of a rural territory, with a presence of residual semi-natural areas, although in regression, and where human impact was still moderate, even if widespread in the entire study area and growing more and more for the progressive economic development of the province of Bologna. In fact, about 70% of the life form spectrum is composed of therophytes and phanerophytes (Fig. 9a), the first ones in many cases cultivated for food (e.g. *Brassica* spp.), the second ones mostly ornamental (e.g. *Broussonetia papyrifera*); the biggest part of the chorological spectrum is made up of species of the Old World despite the notable presence of American ones (Fig. 9b), which reveals traditional agricultural and commercial trading still mostly centred on Eurasia, Europe in particular. The few records of species now disappeared, such as *Acorus calamus*, *Isatis tinctoria* and *Leonurus cardiaca*, which were subspontaneous in the territory studied in the late XIX century, are one of the last memories of ancient cultivations for pharmaceutical or dyeing purposes (e.g. Gastaldo 1987; Pignatti et al. 2017-2019): they can be considered relictual species, whose sporadical, declining presence testifies the progressive transition from a traditional agricultural landscape to a landscape altered by industrialisation and modern specialised agriculture.

5 CONCLUSIONS

In this study, it has been possible to visualise the spatial pattern of the 659 localities and related 7767 floristic records of a late XIX century traditional floristic investigation in the Bologna province for the first time. This allowed us to interpret the data not only in light of the ecological importance of the reported taxa, but also in terms of their spatial distribution. Furthermore, the fact that the *Flora* has been incorporated in the regional floristic database allowed us to precisely illustrate the interpretation problems of past floristic data, especially when considering taxa subject to reclassification and varying interpretation throughout the centuries. In addition, we were able to appreciate the results of a floristic research performed with a similar approach to the current one, but based on former knowledge, culture, travelling conditions and scientific philosophy.
The quality and the informative value of the traditional floristic research depend on the already existing exploration of the territory, on the number and expertise of the persons involved, on the supervision and compiling skills of the authors in harmonising the data collected. The lack of a systematic surveying design (i.e. regular grid of sample points) and the mobility constraints in particular (a still incomplete railway and road network, no paved roads, etc.) caused a spatial bias towards the most accessible and the most valuable sites from the naturalistic point of view. We can easily understand that at the *Flora*'s time a more accurate exploration of the territory would have required a much longer time period, implying therefore the risk to give the study a partially diachronical dimension and potentially compromising the coherence of the floristic picture of the territory.
In brief, the Flora published by Girolamo Cocconi offers not only a good example of a late XIX century flora of a territory which started to experience an increasing human impact, but also an example of the method used in that period for floristic exploration. Spatialising ancient floristic records is a useful way to understand how and how much of the territory has been botanically explored and to improve the use of these records for geographical and diachronical floristic research, also in light of today's scientific practices.
However, it should be noted that the process of parametrising historical textual sources (such as Floras) for analytical and statistical data treatment should still be regarded as *work in progress*. The retrospective georeferencing is an interpretation of a wide format range of locality descriptions, which have to be standardised and transformed into a spatial precisely georeferenced element. Assigning this process to territorial experts notably simplifies the work and assures high quality results. This is also true for the taxonomic aspect of a Flora (i.e. nomenclatural revision and taxa evaluation), which can be best understood

only when a reference herbarium exists. Unfortunately, in spite of their precious contents and their increasing availability as online resources, historical Floras are still not widely used in modern research, for the old-fashioned style or foreign language, the need of a taxonomic revision of the reported species and the necessary georeferencing of the floristic records, the latter in particular being a long and laborious part of the process of analysis.

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Table captions

Table 1 List of data sources used for georeferencing the localities of the *Flora* by Girolamo Cocconi (1883)

Table 2 Exploration hotspots (see also Fig. 3) and related number of records

Table 3 Crop taxa cited in the *Flora*, divided by hierarchically-based categories of use (see UN 2015). Plant nomenclature follows Pignatti et al. (2017-2019) for uniformity reasons with the rest of the taxa. Only taxa indicated by Cocconi as present in cultivation and surely referable to a currently accepted name (*sensu* Pignatti et al. 2017-2019) are reported. In bold: taxa mentioned in the text

Table 4 List of the extinct species. Number of records, altitudinal belts to which they are related in the *Flora* and current extinction level according to Bilz et al. (2011), Rossi et al. (2013) and Bartolucci et al. (2018) are also provided. If a species belongs to a target group it is indicated as follows: hydro-hygrophytes: Aqu. = aquatic, Pal. = palustrine, Hyg. = hygrophilous; allochthonous species: A = archaeophyte, N = neophyte. In bold, cultivated species (see also Table 3). Problematic species are indicated with (*)

Table 5 Distribution of the archaeophytes and neophytes cited in the *Flora* according to their status (casual, naturalised, invasive). Classification follows the Portale della Flora d'Italia (2021)

Table 6 List of the current invasive alien species. Number of records, altitudinal belts to which they are related to in the *Flora* and current status according to the Portale della Flora d'Italia (2021) are also provided. The status at the local scale is based on expert assessment and is referred to the area considered by Cocconi. In bold, cultivated plants (see also Table 3). Ornamental plants as indicated in the *Flora* are marked with (*)

Table 7 Distribution of the allochthonous species in the three territorial sectors considered. Classification follows the Portale della Flora d'Italia (2021)

Figure captions

Fig. 1 Genesis of a Flora: from the context to the outcome

Fig. 2 Girolamo Cocconi (1824-1904) and the title page of the *Flora*. The images are courtesy of the photographic collection by *Accademia delle Scienze dell'Istituto di Bologna* (on the left) and Historical Library *Antonio Bertoloni* - Alma Mater Studiorum Università di Bologna (on the right)

Fig. 3 The spatial cover of the *Flora* by Girolamo Cocconi. The grey line indicates the current border of the province of Bologna. Municipalities added most recently: Tossignano, Fontanelice, Castel del Rio (since 1884), Pieve di Cento (since 1929). Former municipality: Castelfranco Emilia (since 1929). Municipalities that never belonged to the province of Bologna: Montese, Zocca, Guiglia, Nonantola

Fig. 4 Heat map of the localities cited in the *Flora* after the retrospective georeferencing. Red dots indicate localities with more than 100 records. Yellow ramp shows the results of the Kernel density with higher transparency for lower values. Grey line indicates the border of the current Bologna province

Fig. 5 Cumulative curve of the number of localities per each buffer radius

Fig. 6 Collectors reported into the *Flora* ordered by birth-date year. The green band indicates the period from Cocconi's arrival in Bologna University (1871) to the year of the *Flora* publishing (1883). The death-year and the number of records attributed to a contributor are also reported. Importance of the lettering: a) records attributed to Gibelli e Pirotta; b) records attributed to the Lorenzini brothers (Demetrio and Amilcare); c) records attributed to the Riva brothers (Giuseppe and Domenico), which worked together. For further information about the collectors, see Online resource 3

Fig. 7 Exploration hotspots by collectors other than Cocconi. Bcc = Beccari (3 records), Bld = Baldacci (13), Bnc = Bianconi (1), Brt = Bertoloni A. sr. (511), BrtF = Bertoloni G. (341), BrtN = Bertoloni A. jr. (1), Cgn = Cugini (8), Cml = Comelli (7), Crl = Caruel (31), Cvr = Cavara (21), Frn = Farneti (3), Gbl = Gibelli and Pirotta (25), Gdd = Gaddi (1), Gnn = Giannitrapani (4), Gvn = Giovannini (1), Lrn = Lorenzini brothers (87), Mnl = Minelli (2), Mtt = Mattei (2), Prz = Pirazzoli (3), Pzz = Pizzini (1), Riv = Riva brothers (167), Sav = Savi (1), Scn = Saccenti (15), Vtm = Vitman (3), Zff = Zuffi (5). For the collectors see also Fig. 6 and Online resource 3

Fig. 8 Hydro-hydrophytes grouped into ecological categories (a), life forms (b) and chorotypes (c) considering the entire study area, the plain and the hills and mountains. The 3 species found in Bologna are not shown here

Fig. 9 Allochthonous species grouped into life forms (a) and chorotypes (b), considering the entire study area, the plain, the town of Bologna and the hills and mountains. Species with uncertain or unknown chorotype are not shown

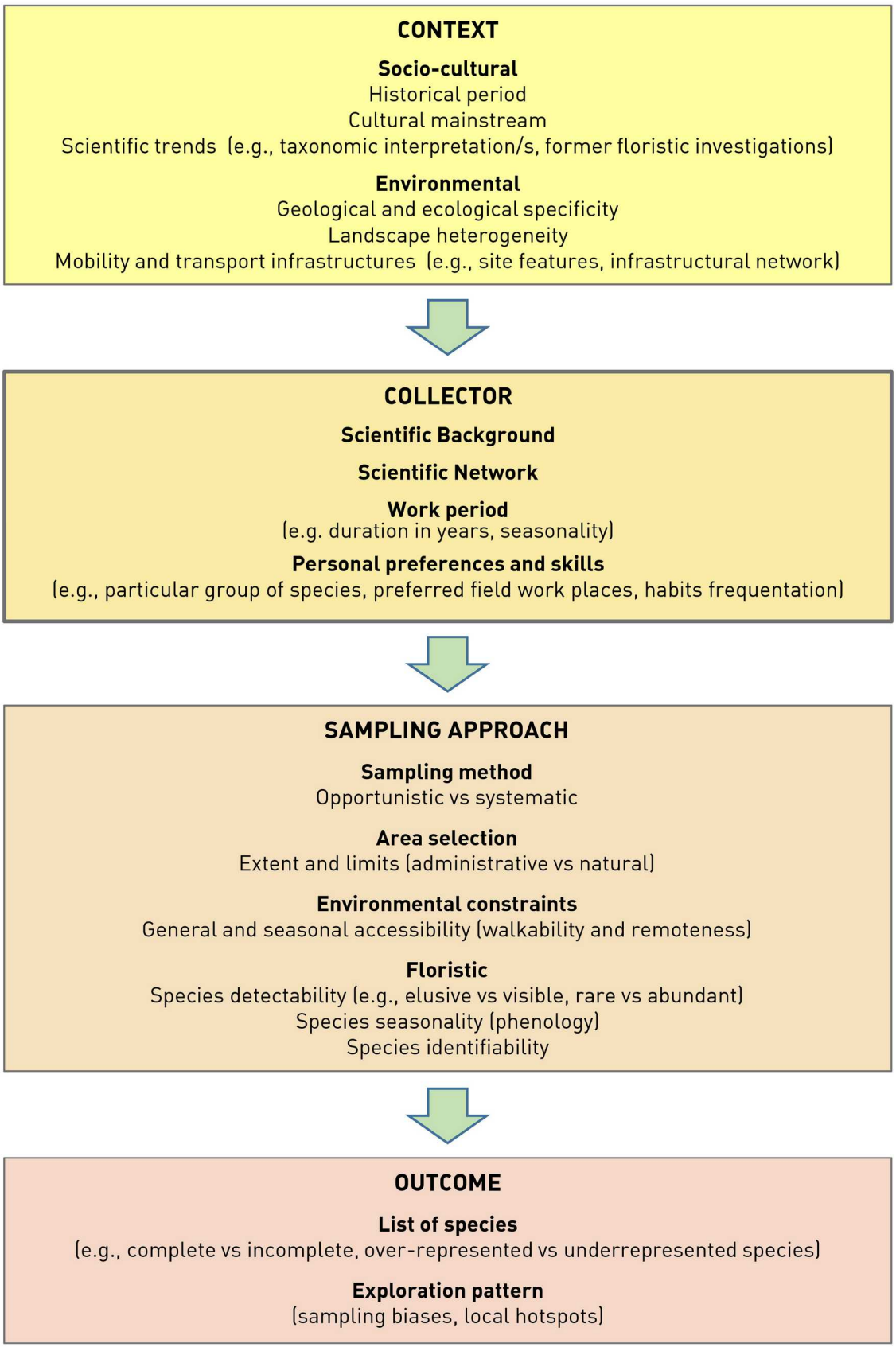
Online resources

Online resource 1 Timeline of the principal changes of the features of Floras from the Renaissance onwards

Online resource 2 List of the species recorded in the Flora of the province of Bologna (Cocconi 1883). For every taxon, ancient name as written by Cocconi, current taxonomic interpretation according to Pignatti et al. (2017-2019), eventual explanatory notes and observation localities as reported on the *Flora* are provided. Critical species are written in bold; in the Taxonomic issues the reasons for treating them as critical are explained

Online resource 3 List of the contributors, besides Girolamo Cocconi, to the Flora of the province of Bologna (1883) and related information

1367 Fig. 1
1368



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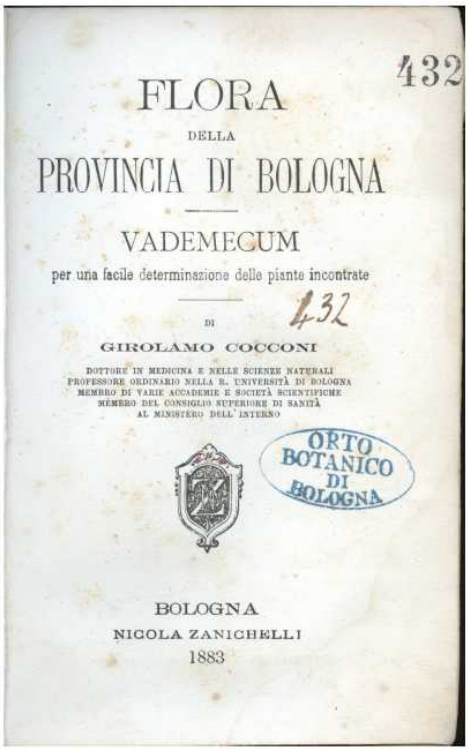
1371



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FLORA

DELLA

PROVINCIA DI BOLOGNA

VADEMECUM

per una facile determinazione delle piante incontrate

DI

GIROLAMO COCCONI

DOTTORE IN MEDICINA E NELLE SCIENZE NATURALI
PROFESSORE ORDINARIO NELLA R. UNIVERSITÀ DI BOLOGNA
MEMBRO DI VARIE ACCADEMIE E SOCIETÀ SCIENTIFICHE
MEMBRO DEL CONSIGLIO SUPERIORE DI SANITÀ
AL MINISTERO DELL' INTERNO

BOLOGNA
NICOLA ZANICHELLI
1883

1373

1374 Fig. 3
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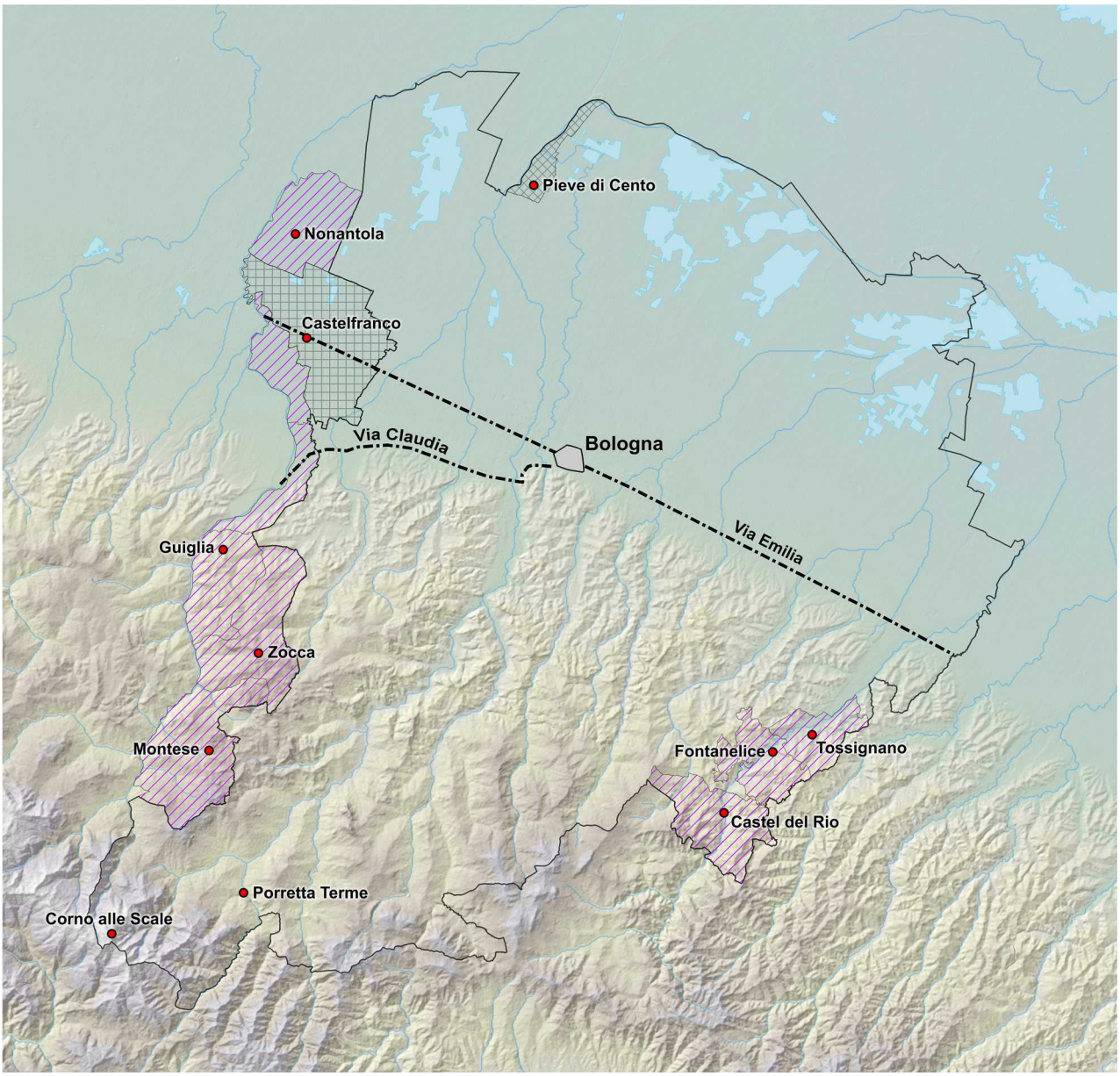

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1378 Fig. 4
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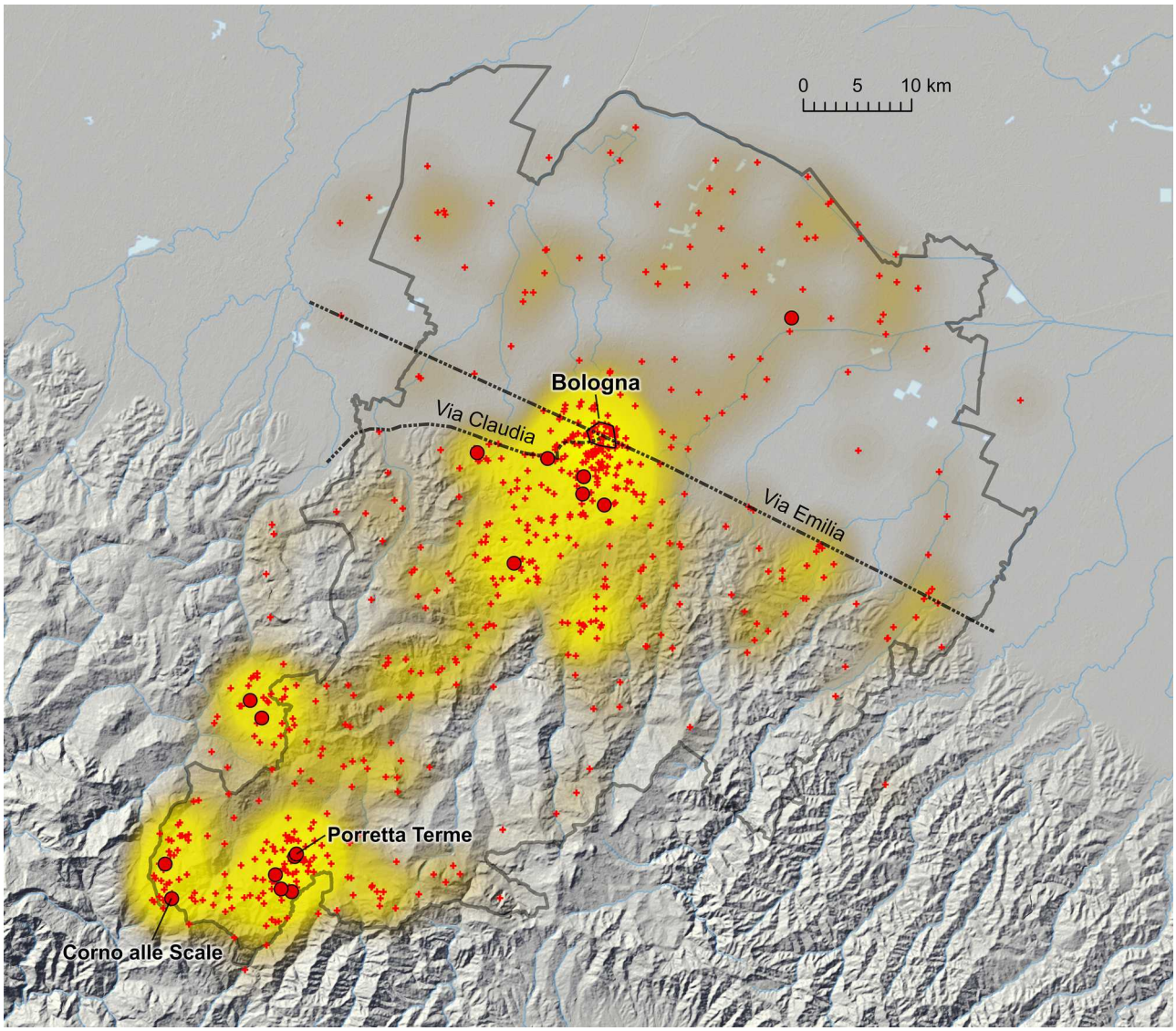

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1382 Fig. 5
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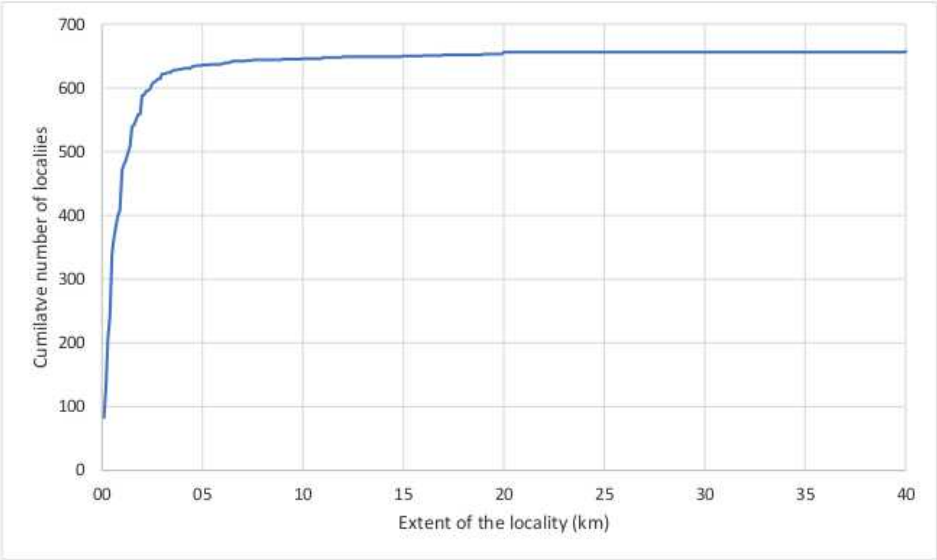

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1386 Fig. 6
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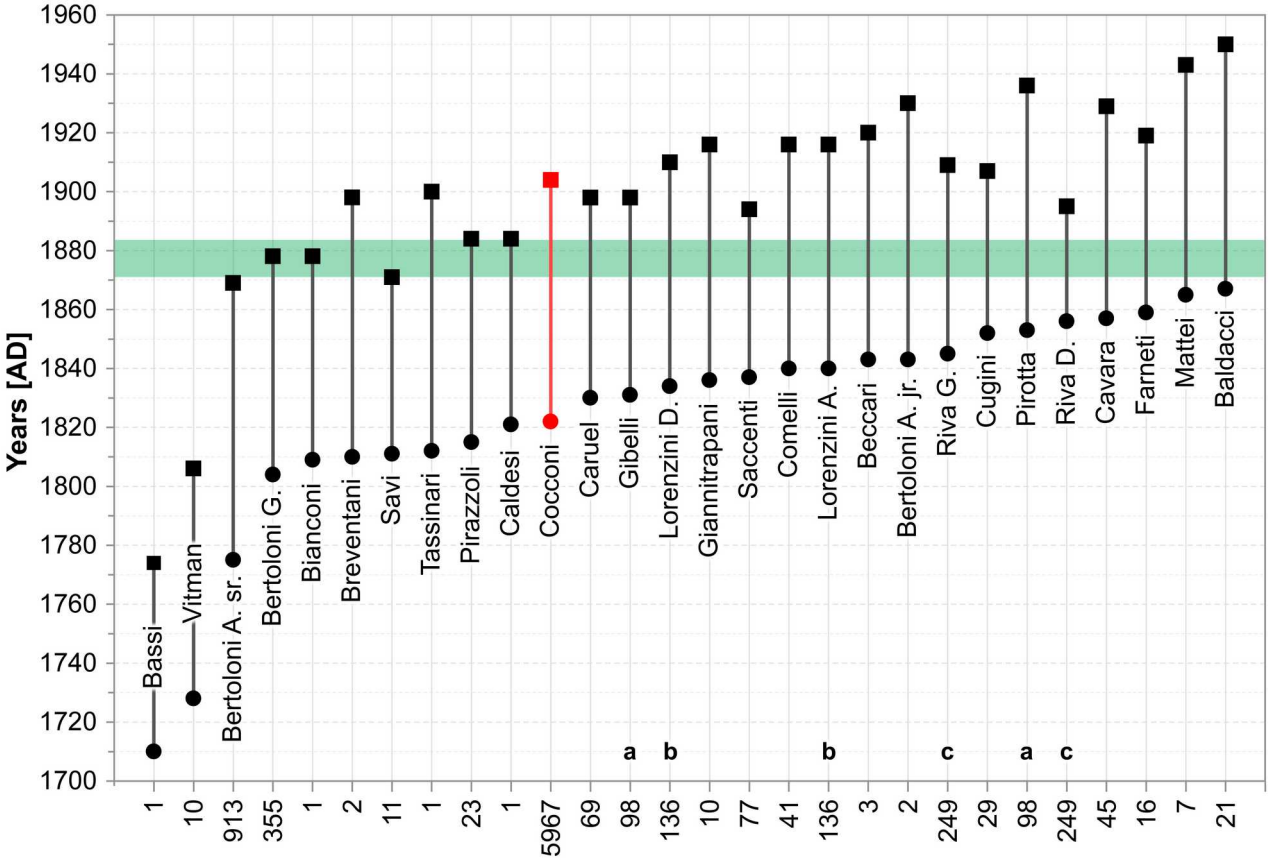

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1390 Fig. 7
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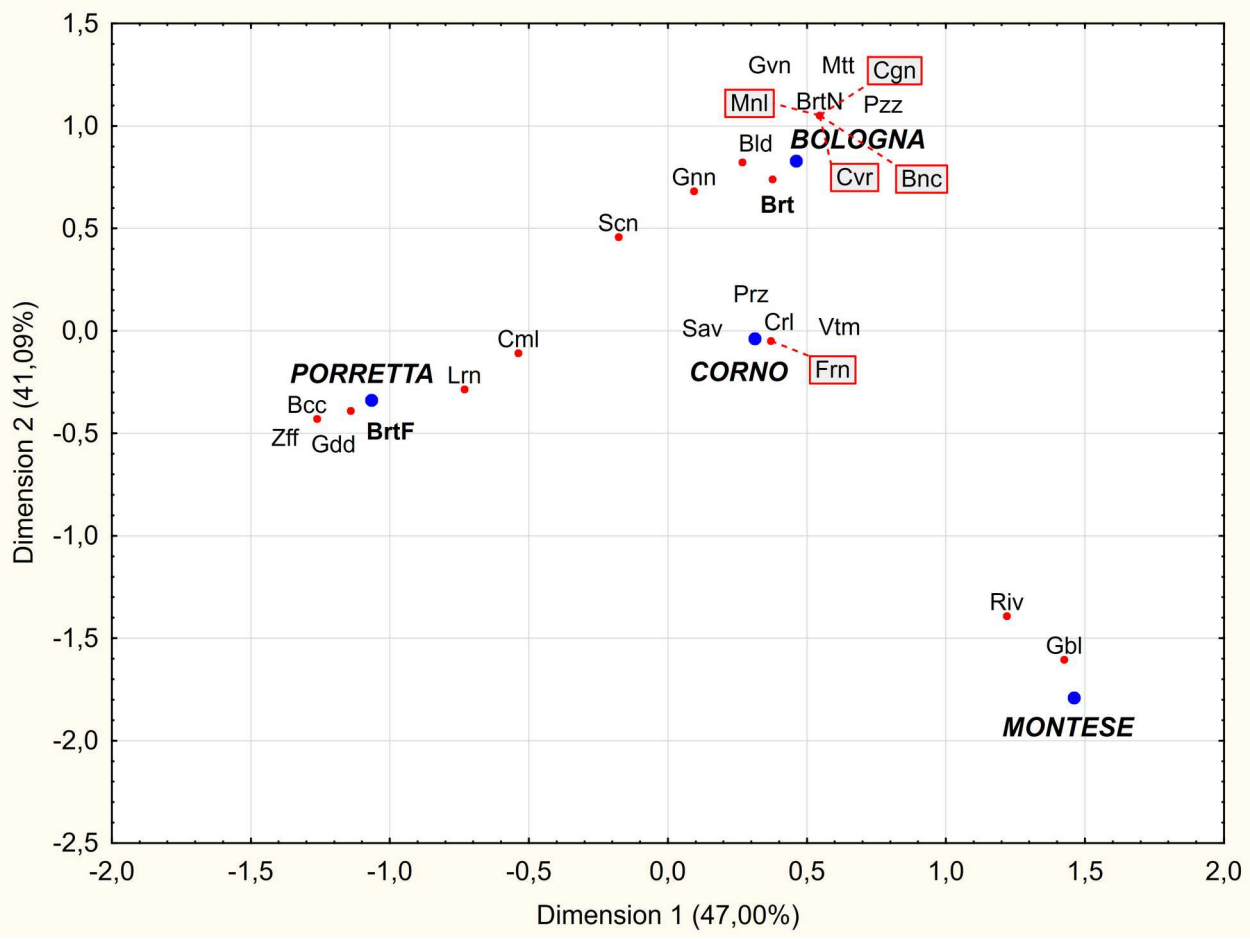

1393

1394 Fig. 8
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1396 a)
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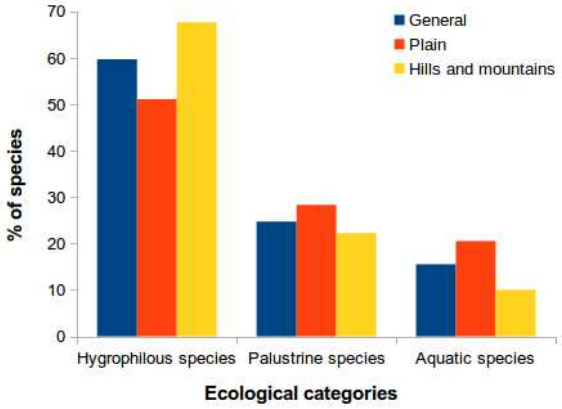
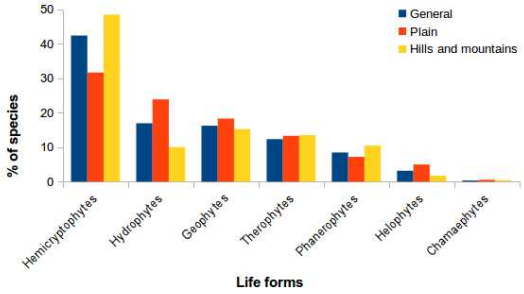


1399 b)
1400



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1403

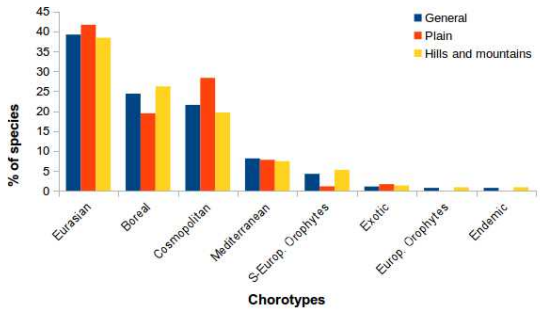

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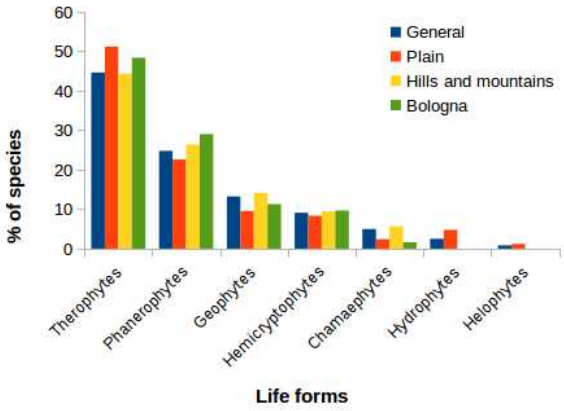
Fig. 9

a)


60
50
40
30
20
10
0
% of species
General
Plain
Hills and mountains
Bologna
Therophytes
Phanerophytes
Geophytes
Hemicryptophytes
Chamaephytes
Hydrophytes
Helophytes
Life forms

b)

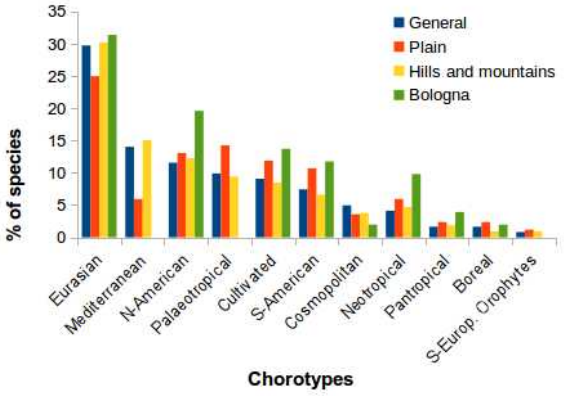

35
30
25
20
15
10
5
0
% of species
General
Plain
Hills and mountains
Bologna
Eurasian
Mediterranean
N-American
Palaeotropical
Cultivated
S-American
Cosmopolitan
Neotropical
Pantropical
Boreal
S-Europ. Orophytes
Chorotypes

Table 1

Source type	Source name	Year	Scale	Available at:
Map	*Carta Storica Regionale (o Carta Topografica Austriaca)*	1853	1:50.000	Geoportale della Regione Emilia-Romagna: https://geoportale.regione.emilia-romagna.it/
	Carta dei dintorni di Bologna	1863	1:10.000	Moka-GIS Regione Emilia-Romagna: http://www.mokagis.it/html/applicazioni_mappe.asp
	Carta IGM di primo impianto	1863-1895	1:100.000	Moka-GIS Regione Emilia-Romagna: http://www.mokagis.it/html/applicazioni_mappe.asp
	Carta Tecnica Regionale	2017	1:5.000	Geoportale della Regione Emilia-Romagna: https://geoportale.regione.emilia-romagna.it/
	Carta topografica d'Italia IGM	various	1:25.000	Portale Cartografico Nazionale: https://www.pcn.minambiente.it/mattm
Toponym layer	*Toponimi d'Italia IGM*	2011	1:25.000	Portale Cartografico Nazionale: https://www.pcn.minambiente.it/mattm
	Database Topografico Regionale (Toponimi)	2017	1:5.000	Regione Emilia-Romagna: https://geoportale.regione.emilia-romagna.it/

Table 2

Hotspot	Area km²	Records n	Localities n	Locality mean altitude (m a.s.l.)				Locality main distance from Bologna city centre (km)			
				min	mean	median	max	min	mean	median	max
Bologna	153.4	2108	173	30.8	121.7 ± 82.5	91.2	390.3	0.0	4.3 ±3.5	3.3	15.4
Porretta Terme	71.3	1399	83	343.2	592.7 ± 263.7	503.8	1470.3	44.4	48.8 ±2.1	48.2	53.9
Corno alle Scale	36.8	664	37	811.9	1331.9 ±363.4	1224.1	1936.0	52.9	56.6 ±1.9	56.7	59.6
Montese	18.7	500	17	509.4	686.7±118.3	685.1	917.6	37.8	39.9 ±1.2	39.9	41.7

1425 Table 3
1426
1427

CEREALS (16)	*Avena sativa* L., *Fagopyrum esculentum* Moench, *Hordeum* spp. (*H. distichon* L., H. *hexastichon* L., *H. vulgare* L. s.s.), ***Oryza sativa* L.**, *Panicum miliaceum* L., *Secale cereale* L., *Triticum aestivum* L., *Triticum aestivum* L. subsp. *spelta* (L.) Thell., *Triticum monococcum* L. subsp. *monococcum* L., *Triticum turgidum* L. subsp. *durum* (Desf.) Husn., *Triticum turgidum* L. subsp. *turgidum* (Desf.) Husn., *Triticum turgidum* subsp. *dicoccon* (Schrank ex Schübl.) Thell., *Zea mays* L.
FRUITS AND NUTS (26)	
Berries	*Fragaria moschata* Weston, *Ribes* spp. (*R. rubrum* L., *R. uva-crispa* L.), *Rubus idaeus* L.
Graped	*Vitis vinifera* L.
Nuts	***Arachis hypogaea* L.**, ***Castanea sativa* Mill.**, *Corylus avellana* L., *Juglans regia* L., *Pinus pinea* L., *Prunus dulcis* (Mill.) D.A. Webb
Pome fruits and stone fruits	*Crataegus azarolus* L., *Cydonia oblonga* Mill., *Ficus carica* L., *Malus domestica* Borkh., *Mespilus germanica* L., *Prunus* spp. (*P. armeniaca* L., *P. avium* L., *P. cerasifera* Ehrh., *P. cerasus* L., *P. domestica* L., *P. persica* (L.) Batsch), *Punica granatum* L., *Pyrus communis* L., *Sorbus domestica* L., *Ziziphus zizyphus* (L.) Meikle
VEGETABLES (37)	
Fruit-bearing vegetables	*Capsicum annuum* L., *Citrullus lanatus* (Thunb.) Matsum. et Nakai, *Cucumis* spp. (*C. melo* L., *C. sativus* L.), *Cucurbita* spp. (*C. maxima* Duchesne, *C. moschata* Duchesne, *C. pepo* L.), *Solanum* spp. (*S. lycopersicum* L., *S. melongena* L.)
Leafy or stem vegetables	*Apium graveolens* L., *Asparagus officinalis* L., *Atriplex* spp. (*A. hortensis* L., *A. sagittata* Borkh.), *Brassica napus* L. (including: cultivar *napobrassica* (L.) Rchb.), *Brassica oleracea* L. subsp. *oleracea* (including: convar. *botrytis* L. cultivar *botrytis* L., convar. *botrytis* L. cultivar *italica* Plenck, convar. *capitata* L. cultivar *capitata* L., convar. *capitata* L. cultivar *sabauda* L.), *Brassica rapa* L. subsp. *rapa*, *Cichorium endivia* L., *Cynara cardunculus* L., *Cynara cardunculus* L. subsp. *scolymus* (L.) Hayek, *Eruca sativa* Mill., *Foeniculum vulgare* Mill., *Lactuca* spp. (*L. sativa* L., *L. serriola* L.), *Lepidium sativum* L., *Spinacia oleracea* L., *Beta vulgaris* L. subsp. *vulgaris*
Root, bulb or tuberous vegetables	*Allium* spp. (*A. ascalonicum* Hort., *A. cepa* L., *A. fistulosum* L., *A. porrum* L., *A. sativum* L.), *Armoracia rusticana* P. Gaertn., B. Mey. et Scherb., *Beta vulgaris* L. subsp. *vulgaris*, *Daucus carota* L., *Daucus carota* L. subsp. *maximus* (Desf.) Ball, *Helianthus tuberosus* L., *Raphanus sativus* L., ***Solanum tuberosum* L.**
LEGUMINOUS CROPS (10)	*Cicer arietinum* L., *Lathyrus* spp. (*L. cicera* L., *L. sativus* L.), *Lens culinaris* Medik., *Lupinus albus* L., *Phaseolus vulgaris* L., *Vicia* spp. (*V. ervilia* (L.) Willd., *V. faba* L.), *Vigna unguiculata* (L.) Walp., *Pisum sativum* L. subsp. *sativum* var. *sativum*
OILSEED CROPS (6)	*Brassica napus* L. (including cultivar *napus*), *Brassica rapa* L. subsp. *sylvestris* (L.) Janch., *Camelina sativa* (L.) Crantz, *Helianthus annuus* L., ***Olea europaea* L.**, *Raphanus sativus* L. var. *oleiferus* Metzg.
OTHER CROPS (27)	
Grasses and other fodder crops	*Morus* spp. (***M. alba* L.**, ***M. nigra* L.**), *Onobrychis viciifolia* Scop., *Pisum sativum* L. subsp. *sativum* var. *arvense* (L.) Gams, *Setaria italica* (L.) P. Beauv., *Trifolium incarnatum* L., ***Trigonella foenum-graecum* L.**, ***Ulmus minor* Mill.**, *Vicia sativa* L.
Medicinal, aromatic, or similar crops	*Allium schoenoprasum* L., *Artemisia absinthium* L., *Brassica nigra* (L.) W.D.J. Koch, *Chamaemelum nobile* (L.) All., *Cochlearia officinalis* L., *Foeniculum vulgare* Mill., *Laurus nobilis* L., *Lavandula angustifolia* Mill., *Mentha spicata* L., *Petroselinum crispum* (Mill.) Fuss, *Salvia sclarea* L., *Satureja hortensis* L., *Thymus vulgaris* L. subsp. *vulgaris*
Fibre crops	***Cannabis sativa* L.**, ***Linum usitatissimum* L.**
Dyeing crops	***Isatis tinctoria* L.**
Other	***Bassia scoparia* (L.) A.J. Scott**, *Lagenaria siceraria* (Molina) Standl., *Sorghum bicolor* (L.) Moench

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Table 4

Species	Records (n.)	Altitudinal belt	Target group		Current extinction level
			Hydro-hygrophytes	Allochthonous	
Acorus calamus L.	1	plain	Pal.	A	regional
Aldrovanda vesiculosa L.	1	plain	Pal.	-	national
Allium angulosum L.	2	hills and mountains	Hyg.	-	provincial
Anacamptis palustris (Jacq.) R.M. Bateman, Pridgeon et M.W. Chase	3	hills and mountains	Hyg.	-	provincial
***Arachis hypogaea* L.**	1	plain	-	N	provincial
Baldellia ranunculoides (L.) Parl.	6	plain, hills and mountains	Aqu.	-	provincial
Caldesia parnassifolia (L.) Parl.	1	hills and mountains	Pal.	-	national
Callitriche brutia Petagna subsp. *hamulata* (W.D.J. Kock) Bonnier et Layens (*)	1	hills and mountains	Aqu.	-	provincial
Callitriche stagnalis Scop. (*)	1	hills and mountains	Aqu.	-	provincial
Carex vesicaria L.	1	plain	Pal.	-	provincial
Cardamine enneaphyllos (L.) Crantz	1	hills and mountains	-	-	provincial
Equisetum fluviatile L. (*)	2	plain, hills and mountains	Pal.	-	provincial
Eriophorum angustifolium Honck.	2	hills and mountains	Aqu.	-	provincial
Gentiana nivalis L.	1	hills and mountains	-	-	provincial
Gentiana pneumonanthe L. (*)	1	hills and mountains	Hyg.	-	provincial
Hippuris vulgaris L.	2	plain	Aqu.	-	regional
Hottonia palustris L.	3	plain, hills and mountains	Aqu.	-	provincial
Kali turgidum (Dumort.) Gutermann	2	plain, hills and mountains	Hyg.	-	provincial
***Isatis tinctoria* L.**	rare	—	-	A	provincial
Leonurus cardiaca L.	3	hills and mountains	-	A	regional (?)
Leucojum aestivum L.	infrequent	plain	Hyg.	-	provincial
Limosella aquatica L.	1	hills and mountains	Hyg.	-	regional
Marsilea quadrifolia L.	1	plain	Pal.	-	provincial
Menyanthes trifoliata L.	2	plain, hills and mountains	Hyg.	-	provincial
Myriophyllum verticillatum L.	7	plain	Aqu.	-	provincial
Najas graminea Delile	1	plain	Aqu.	N	provincial
Oenanthe fistulosa L.	5	plain	Pal.	-	provincial
Oenanthe lachenalii C.C. Gmel.	5	plain	Hyg.	-	provincial
Potamogeton perfoliatus L.	1	plain	Aqu.	-	provincial
Potentilla nitida L.	1	hills and mountains	-	-	regional
Ranunculus flammula L.	1	hills and mountains	Pal.	-	provincial
Ranunculus lingua L.	1	plain	Pal.	-	regional
Rumex hydrolapathum Huds.	common	plain, hills and mountains	Pal.	-	provincial
Sagittaria sagittifolia L.	9	plain, hills and mountains	Pal.	-	provincial
Silene acaulis L.	1	hills and mountains	-	-	provincial
Sonchus palustris L.	1	plain	Hyg.	-	regional (national?)
Styrax officinalis L.	1	hills and mountains	-	-	regional
Traunsteinera globosa (L.) Rchb.	1	hills and mountains	-	-	provincial
***Trigonella foenum-graecum* L.**	1	Bologna, plain, hills and mountains	-	A	regional (?)
Utricularia vulgaris L.	3	plain, hills and mountains	Aqu.		provincial

Table 5

Status	Species category	
	Archaeophytes	Neophytes
Casual	26	14
Naturalised	32	22
Invasive	3	21
Total	*61*	*57*

Table 6

Species	Records (n.)	Geographic sector	Type	Current status	
				national scale	Bologna province
Acer negundo L. (*)	2	Bologna, hills and mountains	neophyte	invasive	invasive
Ailanthus altissima (Mill.) Swingle (*)	4	plain, hills and mountains	neophyte	invasive	invasive
Amaranthus albus L.	4	plain, hills and mountains	neophyte	invasive	naturalised
Amaranthus cruentus L. (*)	2	Bologna, hills and mountains	neophyte	invasive	naturalised
Amaranthus deflexus L.	frequent	—	neophyte	invasive	naturalised
Amaranthus hybridus L.	frequent	—	neophyte	invasive	naturalised
Amaranthus retroflexus L.	8	plain, hills and mountains	neophyte	invasive	naturalised
Amaranthus viridis L.	2	hills and mountains	neophyte	invasive	naturalised
***Bassia scoparia* (L.) A.J. Scott**	4	plain, hills and mountains	neophyte	invasive	casual
Broussonetia papyrifera (L.) Vent. (*)	2	Bologna, hills and mountains	neophyte	invasive	invasive
Cyperus glomeratus L.	1	plain	neophyte	invasive	invasive
Datura stramonium L.	12	plain, hills and mountains	neophyte	invasive	casual
Dysphania ambrosioides (L.) Mosyakin et Clemants	5	plain	neophyte	invasive	naturalised
Erigeron annuus (L.) Desf.	3	plain, hills and mountains	neophyte	invasive	naturalised
Erigeron canadensis L.	very frequent	—	neophyte	invasive	invasive
***Helianthus tuberosus* L.**	—	—	neophyte	invasive	naturalised
***Isatis tinctoria* L.**	rare	—	archaeophyte	invasive	extinct
***Oryza sativa* L.**	2	plain, hills and mountains	archaeophyte	invasive	extinct
Oxalis stricta L.	5	Bologna, plain, hills and mountains	neophyte	invasive	naturalised
Parthenocissus quinquefolia (L.) Planch. (*)	frequent	—	neophyte	invasive	invasive
Phytolacca americana L. (*)	2	Bologna, plain	neophyte	invasive	naturalised
Robinia pseudoacacia L. (*)	—	—	neophyte	invasive	invasive
Sorghum halepense (L.) Pers.	4	plain, hills and mountains	archaeophyte	invasive	invasive
Xanthium spinosum L.	7	plain, hills and mountains	neophyte	invasive	casual

Table 7

Species category	Geographic sector		
	Bologna town	Plain	Hills and mountains
Archaeophytes	4	15	30
Neophytes	9	19	27
Other			2
Total	*13*	*29*	*59*