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

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6 Fabrizio Buldrini¹, Alessandro Alessandrini², Enrico Muzzi³, Patrik Krebs⁴, Marco Conedera⁴, Giovanna
7 Pezzi¹

8
9 ¹ BIOME Lab – Department of Biological, Geological, and Environmental Sciences, Alma Mater Studiorum
10 Università di Bologna. Via Irnerio 42, 40126 Bologna, Italy

11 ² Independent researcher (ales.alessandrini@gmail.com)

12 ³ Department of Agricultural and Food Sciences, Alma Mater Studiorum Università di Bologna. Viale G.
13 Fanin 44, 40127 Bologna, Italy

14 ⁴ Swiss Federal Institute for Forest, Snow and Landscape Research WSL. Insubric Ecosystems Group, a
15 Ramèl 18, CH-6593 Cadenazzo, Switzerland

16
17
18 **ORCID**

19 Giovanna Pezzi: 0000-0001-9739-3530

20 Fabrizio Buldrini: 0000-0002-0376-6760

21 Enrico Muzzi: 0000-0002-9912-3320

22 Alessandro Alessandrini: 0000-0003-3633-9957

23 Marco Conedera: 0000-0003-3980-2142

24
25
26 **Corresponding author**

27 Fabrizio Buldrini (fabrizio.buldrini@unibo.it)

28
29
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47
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61

62 **Abstract**

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

80 **1 INTRODUCTION**

81 Written sources such as books may represent an important source of information when analysing landscape
82 history and transformation (e.g. Fuchs et al. 2015). This is the case in various European countries, where
83 written sources like exploration travel reports, chorographic atlases or Floras cover a time interval of
84 centuries and prove a true cultural heritage for the area of reference (e.g. Rohl 2011).
85 In this context ancient Floras ¹ represent an iconic case of highly valuable cultural and scientific heritage,
86 especially the oldest ones. In Europe, the very first modern Flora is probably the *Synopsis Methodica*
87 *Stirpium Britannicarum* by John Ray (Online resource 1), which first appeared towards the end of the XVII
88 century (Stace 1989), even if the first place is usually given to Linnaeus' *Flora Lapponica*, published in 1737
89 (Frodin 2002). [But actually, an earlier anticipation was provided by Ray himself with his *Catalogus*](#)
90 [plantarum circa Cantabrigiam nascentium \(1660\), that is, to our knowledge, the first European urban-](#)
91 [municipality-countee Flora.](#) Some decades later (e.g. Séguier 1745; Scopoli 1760; Vitman 1773; Buillard
92 1776; Lamarck 1778), especially during the XIX century, several local or national Floras were published
93 (e.g. Bertoloni 1833-1854; Rostrup 1860; Wilkomm and Lange 1861-1880). Regarding the Italian situation
94 in particular, at least 33 local Floras were published during the boom of floristic exploration from 1849 to the
95 end of the century (Pignatti 1982). Such a flourishing of botanic work was partly favoured by the
96 geographical explorations and the subsequent import of new species from other continents into Europe
97 (Peccenini 1994). On the other hand, it was probably also because of the introduction of the dichotomous
98 keys² to identify species, which were extensively used first by Jean-Baptiste de Lamarck in his *Flore*
99 *Française* from 1778 (Comelli 1883; Griffing 2011). The advent of the dichotomous keys is probably a
100 consequence of the continuous increase in the number of species known by the scholars of the time. They
101 allow a sort of hierarchy to be established among morphological traits of the species and thus to overcome
102 the difficulties of the natural system (e.g. Comolli 1834), that considered a multitude of morphological traits,
103 all of them equally important (Stace 1989), and of the long and very detailed descriptions of the species dealt
104 with, typical of the Floras of 1700. [In short, dichotomous keys notably simplified](#) the entire identification
105 process, especially for non-professional botanists. Therefore, from mid-1800 onward there was a
106 progressive switch from purely descriptive Floras, based on descriptions (e.g. Allioni 1785), to analytical
107 Floras, based on identification keys. Such a transition stimulated also an educational use of the Floras
108 themselves, which were also published with the aim of encouraging young students and citizens to study (or
109 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).

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

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

121 Classical Flora-related studies concern for example the introduction and colonisation dynamics of a
122 neophyte, the variation in frequency or altitudinal range of a species, or the disappearing of certain species
123 from a given area (e.g. Van der Veken et al. 2004; Van Calster et al. 2008; Knapp et al. 2010; Chiarucci et al.
124 2017).

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

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

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

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

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

160

161

162 2 MATERIALS AND METHODS

163

164 2.1 The author and his Flora

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

167 switched over to the University of Bologna in 1871, where he first became full professor of hygiene and
168 veterinary medicine in 1874 and was later elected director for life of Bologna's *Scuola di Medicina*
169 *Veterinaria* in 1884. He was well-known for his affiliation to numerous scientific and medical Italian
170 academies, became member of various ministerial commissions for the promotion and development of
171 teaching and for the compilation of the Official Pharmacopoeia, and was finally awarded the title of
172 *Commendatore* (knight commander) of the Crown of Italy for his scientific merits. Pier Andrea Saccardo
173 honoured his memory by naming a genus of fungi *Cocconia* (Brazzola 1905; Béguinot 1931).
174 Although teaching was his major commitment at the Veterinary Faculty of the university, he wrote various
175 botanical and mycological works, such as a Flora of the forages of the province of Parma (Cocconi 1856),
176 four partial contributions to the Flora of the province of Bologna (Cocconi 1877, 1878, 1879, 1880),
177 followed by several botanical itineraries within the province itself (CAI Bologna 1881) and a complete Flora
178 of the provincial territory (*Flora della provincia di Bologna* here considered – Cocconi 1883 – and thereafter
179 referred to as «the *Flora*»).

180 The *Flora* summarises all his findings which previously appeared in the partial contributions, together with
181 records by different authors, and represents the attempt to complete what the famous botanist Antonio
182 Bertoloni *senior* (1775-1869) and Giuseppe Bertoloni (1804-1878) could not finalise. The latter, in
183 particular, conceived the idea of using the numerous floristic studies he performed to publish a *Flora*
184 *escursoria della Provincia di Bologna* (excursion Flora of the province of Bologna), but unfortunately, he
185 died before achieving this goal (Cocconi 1877, 1879). It is fundamental to note that Cocconi's floristic
186 investigations additionally led to the creation of a rich herbarium (Cocconi 1880), whose fate is however
187 unknown to date, apart from some samples kept in the Herbarium Paolucci (University of Ancona).
188 This *Flora* is an outstanding case study for many reasons. First, it is one of the very first examples in
189 northern Italy of a post-unification local Flora aiming at promoting a larger botanical culture among young
190 (pre-university) students and common citizens. For this purpose, at the beginning of the work some clear and
191 detailed instructions on how to prepare a herbarium and a dichotomous key for species identification are
192 reported. Second, it describes a territory that already shows profound landscape alterations as in many other
193 parts of Europe, such as land reclamation, forest overexploitation, development of railways, mountain
194 exploration and search for thermal and touristic purposes (Bertoloni 1867; CAI Bologna 1881), even if wide
195 areas quite well preserved from a naturalistic viewpoint still persisted. In contrast to many other Floras, in
196 the introduction the author clearly defines and describes the extent of the studied area, giving the readers a
197 precise picture of an urban, periurban and rural European landscape of the XIX century. Cocconi also
198 referred to records from former floristic investigations and took advantage of several collectors, allowing to
199 understand (at least partially) how single floristic records are passed on from one scholar to another.
200 From a technical viewpoint, the *Flora* is organised according to the system proposed by De Candolle (1818-
201 1821), which at that time was the most modern and widely accepted systematic order, and includes not only
202 native or sub-spontaneous species, but also ornamental species and particularly crop taxa important for
203 industry or agriculture in the late 1800s (Cocconi 1883).

205 2.2 The study area

206 As specified by Cocconi himself (1883), the territory covered by the *Flora* encompasses the entire area
207 within the political boundaries of the former province of Bologna (Emilia-Romagna, northern Italy; Fig. 3).
208 Nevertheless, the author, like most contemporaneous botanists (e.g. Gibelli and Pirotta 1883, 1884), followed
209 a naturalistic criterion and paid much more attention to natural rather than to administrative borders, which is
210 standard procedure in floristic research (Pignatti 1982). Consequently, the area examined is larger than the
211 territory comprised within the administrative borders.

212 From a phytogeographic viewpoint, Emilia-Romagna is a transition area between two bioregions (Dinerstein
213 et al. 2017): the Adriatic Sea and central Mediterranean mixed forests bioregion (part of the Mediterranean
214 subrealm, that covers the Italian peninsula and is characterised by a Mediterranean or oromediterranean
215 vegetation) and the Alps and Po basin mixed forests bioregion (part of the Western Eurasia realm, that covers
216 Northern Italy and is characterised by a continental vegetation of central European or alpine type).

217 The area covered by the *Flora* shares both these characters, given its position at the centre of the region and
218 its altitudinal extent from the low plain to the subalpine level. Overall, it has an extension of 4096 km² and
219 ranges from 8 to 1944 m a.s.l. (the peak of the mountain Corno alle Scale). The plain (47% of the area) and
220 the hilly-mountainous part (53%) are clearly defined by the Roman roads *via Claudia* and *via Emilia*, along
221 which the city of Bologna (at that time still surrounded by fortified walls) is located in the middle of the
222 study area. Circa 10% of the studied area is currently under the neighbouring province of Modena.

223 The plain is an alluvial area generated by the River Po and its current and former tributaries, the River
224 Panaro and River Reno, whose substrate is characterised by river sediments of variable granulometry and
225 calcareous soils (Regione Emilia-Romagna 2022). In order to make the region habitable and suitable for
226 agriculture, large-scale hydraulic interventions on the territory were performed between the late Middle Ages
227 and the XVIII century, and others have still been done from 1850 onwards (De La Lande 1769; Bondesan
228 1990; Dallai et al. 2014). In the late XIX century, the artificial hydrological drainage network was only
229 partially completed (Furlani 2009; Zampighi 2009; Montanari et al. 2022). According to Emilia-Romagna's
230 1853 land use/land cover map derived from the *Carta Topografica Austriaca* (see Table 1), 157 km² of the
231 plain were still occupied by wide areas of 1-3 m deep stagnant water (the so-called *valli*). They represented
232 the remnants of a wetland *continuum* called *Valle Padusa*, which in the past centuries extended from the
233 Adriatic coast to the River Panaro and beyond (Soriani 1834). Besides very few spots of *Quercus robur* and
234 *Carpinus betulus*-dominated lowland forests, the vegetation of this part of the study area was characterised
235 by ruderal, disturbance-tolerant and segetal species in the cultivated areas, hydro-hygrophilous species, some
236 of them abundant at times, in the residual marshes (Cocconi 1878) and paddy fields that sometimes replaced
237 parts of the *valli* or the wetlands (Bertoloni 1870; Giacomelli 1987, 1997).
238 The hilly and mountainous parts are characterised by marked variations in terms of elevation, geology and
239 pedological features. The substrate mainly consists of marl, sandstone, clays and chaotic complexes of
240 various rocks incorporated in a clay matrix (i.e. scaly clays, It.: *argille scagliose*) and notable gypsum
241 outcrops belonging to the Gessoso-Solfifera Formation of Messinian age especially in the eastern part of
242 Bologna (De Waele et al. 2017). Mixed *Quercus* forests belong to the potential natural vegetation up to the
243 submontane belt, whereas *Fagus sylvatica* forests *dominate* the montane belt, followed by *Vaccinium*
244 *myrtillus* and *V. gaultherioides* heathlands in the suprasylvatic belt (CAI Bologna 1881).

245 246 **2.3 Data pre-treatment**

247 **2.3.1 Floristic data**

248 The following *Flora*-related information could be extracted as floristic records from Emilia-Romagna's
249 Floristic Digital Database (Regione Emilia-Romagna 2021; hereafter DbER):

- 250 - taxon, at the level of species or infraspecies (variety, according to the author of the *Flora*),
- 251 - description of the locality (whenever present) where the taxon was observed,
- 252 - collector (Cocconi in person or another author by his appointment),
- 253 - narrative ancillary data (whenever present) such as presence as a cultivated species and frequency (*rara*,
254 *frequente*, *volgare*, etc.) as indicated by the author himself.

255 256 **2.3.2 Taxonomic and nomenclatural revision**

257 Each recorded taxon was checked and revised in the light of current taxonomic interpretation, ecology and
258 distribution in the regional territory. After updating the reported nomenclature following Pignatti et al. (2017-
259 2019), taxa *that* have no longer been observed in Emilia-Romagna since Cocconi's survey and those whose
260 taxonomic interpretation have varied notably have been classified as problematic. For the purposes of the
261 present study, changes in taxonomic interpretation can have two effects: if the herbarium specimen reference
262 is lacking, today it is impossible to fully understand what currently recognised taxon the author had actually
263 observed (e.g. Pignatti and Guarino 2019); on the other hand, the geographical distribution attributed to that
264 taxon can also change, widening or restricting the range and, as a consequence, varying the chorological
265 category. Problematic taxa were thus solved either by assigning them, whenever possible, to the most
266 plausible congeneric or conspecific taxon confirmed in Emilia-Romagna, or discarding them from further
267 processing and analysis. Unfortunately, since the fate of Cocconi's herbarium is currently unknown, a re-
268 examination of the original specimens for clarifying any doubts was impossible; some problems were
269 however solved by consulting other XIX century herbaria available (Herbarium Universitatis Bononiensis –
270 BOLO, then Herbarium Riva and Herbarium Mattei, both preserved in Herbarium Neapolitanum – NAP;
271 Bronzo et al. 2012). The knowledge of today's flora of the province of Bologna is quite accurate, thanks to
272 the DbER and to the work performed by many explorers (see also Pezzi et al. 2021), therefore it was nearly
273 always possible to solve the uncertain cases by assigning the problematic taxa to the most probable one
274 currently ascertained for the regional or provincial flora.

275 The complete list of the taxa cited in Cocconi's *Flora* together with their current interpretation is available in
276 the DbER [and reported in Online resource 2](#).

277 278 **2.3.3 Integrating ecological information and defining specific ecological-biogeographic groups**

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

282
283 Secondly, two target ecological-biogeographic groups were defined for the detailed analysis of the landscape
284 evolution: the hydro-hygrophytes and the allochthonous species. The hydro-hygrophytes include all species
285 with Ellenberg's bioindication value for soil humidity $U \geq 7$ and are further subdivided into the following
286 three ecological categories:

- 287
288 - hygrophilous species: indicators of humid soils ($U = 7$ and 8);
289 - palustrine species: indicators of transitory, but frequent, soil submersion ($U = 9$ and 10);
290 - aquatic species: indicators of constant soil submersion ($U = 11$ and 12).

291
292 Allochthonous species were defined based on their origin (archaeophytes or neophytes) and further
293 distinguished according to their present distribution status (casual, naturalised and invasive) as indicated by
294 the Portale della Flora d'Italia (2021). Cryptogenic species, intended as doubtfully allochthonous ones (*sensu*
295 Carlton 1996 and Celesti-Grapow et al. 2010), were computed together with allochthonous species.

296
297 Thirdly, in view of the analyses, the chorotypes of both ecological-biogeographic groups were framed into
298 macro-chorotypes. For the hydro-hygrophilous species, this grouping was made according to Pignatti (1982),
299 Poldini (1991), Tomaselli and Gualmini (2000) and Alessandrini et al. (2010):

- 300
301 - Boreal: species of the cold regions of Eurasia and North America;
302 - Eurasian: species of the temperate and sub-steppe regions of Eurasia;
303 - European orophytes: species of the mountain ranges of central Europe;
304 - Southern European orophytes: species of the mountain ranges of southern Europe;
305 - Mediterranean: species native to the Mediterranean Basin;
306 - Cosmopolitan: cosmopolitan or sub-cosmopolitan species;
307 - Exotic: all species which are not native of the Italian territory;
308 - Endemic: species endemic to the Italian peninsula.

309
310 For the allochthonous species, given the presence of many neophytes, further macro-chorotypes were
311 adopted to better illustrate the geographical origin and species ecology, therefore macro-chorotypes were
312 defined as follows:

- 313
314 - Boreal: species of the cold regions of Eurasia and North America;
315 - Eurasian: species of the temperate and sub-steppe regions of Eurasia;
316 - Mediterranean: species native to the Mediterranean Basin;
317 - Palaeotropical: species of the tropical and intertropical regions of Africa and Asia;
318 - North American: species of the temperate regions of North America;
319 - Neotropical: species of the tropical and intertropical regions of central and South America;
320 - South American: species of the temperate regions of South America;
321 - Pantropical: species native to all tropical regions of the world;
322 - Cosmopolitan: cosmopolitan or sub-cosmopolitan species.

323
324 Fourth, for every taxon featured in the final list, species extinction level (provincial, regional or national) was
325 attributed following Bartolucci et al. (2018) and by means of the authors' expert assessment (AA), based on
326 the floristic records preserved in the DbER. Threat level was evaluated according to the red lists of the
327 European and Italian vascular flora (Bilz et al. 2011; Rossi et al. 2013). The same expert assessment (AA)
328 procedure was applied to assign the current presence in the territory of the species of both target groups, to
329 detect changes in frequency and abundance of the species themselves.

331 2.3.4 Expliciting the spatial information

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

336 Santerno eastward and the River Panaro westward; eastward it also includes municipalities that became part
337 of the province few years later. To allow us to perform specific geographical analyses, the so obtained study
338 area was subdivided into three different geomorphological and environmental sectors: the city of Bologna,
339 the plain and the hilly-mountainous part.
340 Next, text-based locality descriptions of each record (whenever present) were associated by one of the
341 authors (GP) to explicit geospatial coordinates with the highest possible precision using a stepwise procedure
342 based on the expert knowledge of the area. Locality descriptions appearing highly heterogeneous (in term of
343 content and format) were first standardised in full observation and consistency with the original terms. Such
344 standardisation also highlighted text strings including more than one toponym, ambiguous toponyms (giving
345 multiple possible interpretations), microtoponyms (i.e. locally used toponyms), as well as inconsistent
346 formatting and misspellings. Geolocalisations were solved case by case, choosing the most suitable option
347 among the available sources, such as georeferenced toponym databases, historical and current topographic
348 maps (Table 1), historical textual sources mainly available in internet (e.g. Google Books), home-grown
349 local people and territorial experts.
350 The following rules were then applied for the final positioning of the locality point on the maps (see Pezzi et
351 al. 2021). Coordinates of linear-shaped elements (roads, rivers, streams, canals) were positioned in the midst
352 of the feature. If the record was indicated between two different toponyms or in case the author's further
353 indications were unavailable, an intermediate point between the localities was chosen. For the places where
354 there was a parish church, the point was placed on this element, as it can be considered the most stable
355 within the area. For toponyms referring to mountains, the point was placed on top of the mountain. The
356 records referring to polygonal elements (e.g. the *valli* or paddy fields) took the coordinates of the locality of
357 reference. Sometimes it was necessary to give a locality's description to the nearest toponym: this was the
358 case when a locality description was made up of more than one toponym, of which one more precise than the
359 other (and comprising the former), and it was not possible to assign the locality's description to the more
360 precise toponym. Where the textual sources only indicated the area in which the target locality was
361 comprised, the locality itself was matched with the toponym of the whole area.
362 Further, a radius was associated to each plan coordinates in order to describe the potential geographic extent
363 of the locality, or to measure the uncertainty linked to the georeferencing procedure.
364 For the reconstructed plan coordinates, the distance from the town centre of Bologna, their positioning in the
365 three defined geomorphological sectors (Bologna town centre, plain, hills and mountains), and the elevation
366 (z-coordinate) based on the 5 m grid Digital Elevation Model (DEM) of Emilia-Romagna have been added.
367 The quality of the georeferencing process was labelled as follows: locality missing in the record; locality not
368 found; locality referred to the nearest toponym. All the standardised georeferenced localities and related
369 ancillary data were integrated back to the original data set.
370 The entire georeferencing process was performed in QGIS 2.18 (www.qgis.org), using the spatial reference
371 system UTM32N – WGS84.

372 373 **2.3.5 Collectors data**

374 A careful literature search allowed additional data to be assigned to the collector's characteristics (see Online
375 resource 3), such as background and professional skills (i.e. academic scholar, non-academic botanist, local
376 enthusiast) and registry records (birth and death).
377 In particular, we used registry data as a proxy of the work period of a certain collector and to understand how
378 contemporary the records are to the data published in the *Flora*. Furthermore, the number of records was
379 assigned to each author whenever they appeared. Through locality georeferencing, we could also examine
380 the various collectors' spatial contribution to floristic exploration and detect the areas of higher record
381 concentration, i.e. those believed to be more interesting from a floristic viewpoint.

382 383 **2.4 Data analysis**

384 Geographical distribution patterns such as the spatial density of the observation places were analysed using
385 the *Kernel Density* tool of ArcGIS Desktop (vers. 10.8.1) with the following parameters set: 40 m of output
386 raster cell size; 5000 m of search radius (i.e. the search radius within which to calculate density) and a flat
387 earth method (planar). The final map was produced with ArcGIS Pro (vers. 2.6.3). Canonical Analysis (CA)
388 was performed to detect the pattern of collectors in comparison to the detected hotspots of floristic
389 exploration.
390 Taxa were analysed at species and infraspecies level by grouping them according to their eco-geographical
391 characteristics (e.g. stenomediterranean, arctic-alpine), phytogeographic and conservation interest (endemic,
392 subendemic and extinct) and agricultural importance (cultivated and segetal). A deeper analysis was

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

398 Statistical elaborations were performed in R version 4.0.4 (R Core Team 2020).

399

400

401 3 RESULTS

402

403 3.1 Exploration pattern

404 Globally, 7767 records (*taxon* plus toponym) were extracted from the *Flora* (Online resource 2). Among
405 them, 415 lack of a locality description: these records mainly refer to common or very common species, such
406 as the ruderal *Stellaria media*, *Chelidonium majus*, *Echium vulgare*, woody species like *Quercus robur* or
407 *Juniperus communis*, widespread segetal species (e.g. *Agrostemma githago*, *Gladiolus italicus*) and crop
408 plants in some cases widely cultivated (i.e. *Zea mays*, *Solanum lycopersicum*, *S. tuberosum*). In addition, 8
409 records could not be located and 73 were referred to the nearest toponym. The remaining 7344 records could
410 be referred to 659 standardised georeferenced localities (hereafter localities; see Fig. 4). These localities
411 range from a precise (0.1 km radius) to a vaguely defined point (i.e. an extensive area, up to 40.0 km radius).
412 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).
413 Among the localities, 247 are linked to a single record and 16 to more than 100 records (up to 256; see Fig.
414 4). Localities lay by 75.9% in the hills and mountains, 18.4% in the plain and 5.7% in the Bologna town. The
415 former group of localities is also linked with 79.7% of the floristic records. Some of these localities include
416 completely disappeared ecosystems due to changes in land-use occurred during the XX century (i.e. the *valli*)
417 or destruction during the Second World War.

418 The locality density estimated by the Kernel density (Fig. 4) ranged from 0 to 2.7 localities/km² (mean value:
419 0.1 localities/km²) and reveals four hotspots of floristic exploration (Table 2). These areas comprise 63.6% of
420 the georeferenced records, 47.9% of the georeferenced localities, 14 of the 16 localities with at least 100
421 floristic records. By contrast, they have a total extension of only 280.1 km² (6.8% of the entire study area).
422 The richest hotspot in term of records (2108) and localities (173) includes the town of Bologna and its
423 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
424 is interesting to note that most of the localities linked to Bologna refer to the elements of the city walls (e.g.
425 gates) which were demolished in the early XX century. Other hotspots comprise localities at a distance from
426 Bologna between 44.4 and 59.6 km, in the south-western part of the study area. In particular, the localities in
427 the area of Porretta Terme have an altitudinal range from 343.2 to 1470 m a.s.l., whilst Mount Corno alle
428 Scale contains the localities with the highest altitudes: 52.3% of records are comprised between 1600 and
429 1944 m a.s.l. (i.e. from the timberline upwards, into the subalpine level). Finally, the Montese area includes
430 mainly localities within the province of Modena.

431 About 27% of the records are referred to collectors other than Cocconi. Globally, contributors are 32, even if
432 a discrete number of floristic records was simultaneously attributed to two authors by Cocconi himself (e.g.
433 Amilcare and Demetrio Lorenzini, Giuseppe and Domenico Riva, Giuseppe Gibelli and Pietro Romualdo
434 Pirota; see Online resource 3 and Fig. 6). Collectors were academic scholars, professors or directors of
435 botanical gardens (Gibelli, Pirota, Cavara, Mattei, Savi, etc.), others were undisputed scientific authorities
436 (such as Antonio Bertoloni *senior* or Caruel – Gibelli and Pirota 1883) or local collectors like pharmacists
437 (Lorenzini, Tassinari), and botany enthusiasts (Breventani, Comelli, Giannitrapani, Saccenti, etc.). However,
438 the major contributors (> 50 records) are principally academic scholars or directors of botanical gardens,
439 such as Antonio Bertoloni *senior* (913 records), Giuseppe Bertoloni (355), the Riva brothers (249), Giuseppe
440 Gibelli and Pietro Romualdo Pirota (98), Teodoro Caruel (69). Further, the Lorenzini brothers (136) and
441 Cesare Saccenti (77) should be added as the sole non-academic plant collectors among the major
442 contributors. Concerning the timeline, the most ancient records are the 10 by Fulgenzio Vitman and one by
443 Ferdinando Bassi (i.e. *Caldesia parnassifolia*, which was found in the «wetlands of the Bologna Apennines»
444 – Cocconi 1883). All the collectors except four are included in the records of the hotspots. Concerning the
445 Bertoloni, 511 out of 913 records for Antonio *senior* are included in the hotspots, whereas for Giuseppe they
446 are 341 out of 355. Furthermore, the records by Antonio *senior* are mainly linked to Bologna (380 records),
447 whereas those by Giuseppe to Porretta Terme (316). Vitman, Savi and Caruel in turn are principally linked
448 with Corno alle Scale (Fig. 7). Most of the records are however due to Cocconi and his contemporary
449 collectors.

450

451 3.2 The taxa: general characters and chorological aspects

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

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

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

470 - stenomediterranean species (< 3%), such as *Allium roseum*, *Asparagus acutifolius*, *Picnemon acarna*,
471 *Quercus ilex* (which at that time grew as a shrub in small groups of individuals, under particular favourable
472 microclimatic conditions);

473 - arctic-alpine species (< 1%) living in the most elevated parts of the province, in prairies and heaths (e.g.
474 *Anemone narcissiflora*, *Empetrum hermaphroditum* or *Gentiana nivalis*, which was at that time considered
475 very rare) or rocky environments (e.g. *Juncus trifidus*, *Saxifraga paniculata*, *Silene acaulis*);

476 - species which are endemic to Italy (e.g. *Cirsium bertolonii*, *Globularia incanescens*, *Murbeckiella zanonii*,
477 *Ononis masquillierii*, *Polygala flavescens*) or subendemic (e.g. *Cardamine chelidonia*, *Geranium argenteum*,
478 *Phyteuma scorzonrifolium*), globally accounting for about 2% of the flora.

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

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

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

494

495 3.3 The hydro-hygrophilous species

496 Hydro-hygrophilous species recorded in the *Flora* are 283 (16.5% of the total species number), subdivided in
497 169 hygrophilous (59.7%), 70 palustrine (24.7%) and 44 aquatic species (15.5%). Of these 283 species, 59
498 (20.8%) lack geographical indication: they were either very common species (*Alisma plantago-aquatica*,
499 *Equisetum telmateia*, *Juncus effusus*, *Typha latifolia*, etc.) or cultivated species (*Allium schoenoprasum*,
500 *Oryza sativa*, *Sorghum bicolor*, *Zea mays*). Hydro-hygrophilous species also include 6 alien species (e.g.
501 *Acorus calamus*, *Najas graminea*), 10 cultivated species (*Citrullus lanatus*, *Mentha spicata*, *Oryza sativa*,
502 etc.), 10 ornamental species (*Populus canadensis*, *Salix babylonica*, etc.).

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

506 Among the life forms (Fig. 8b), hemicryptophytes **clearly** dominate in all contexts, but with notable
507 differences between plain (31.6%), hills and mountains (48.8%); similarly, the presence of hydrophytes and
508 helophytes greatly varies between the plain (28.9%), the hills and mountains (11.7%).
509 Concerning the chorotypes, Eurasian, boreal, **cosmopolitan** and Mediterranean species are always dominant,
510 but Eurasian and **cosmopolitan** species are more abundant at low altitudes, whereas boreal and hypsophilous
511 ones are more abundant in the hills and mountains (Fig. 8c). In particular, boreal species (circumboreal and
512 Euro-Siberian) are 19.4% of the chorological spectrum in the plain area and 26.0% in the hills and
513 mountains.
514 In the *Flora*, 31 species were indicated as frequent and 4 as rare (*Leucojum aestivum*, *Potamogeton*
515 *perfoliatus*, *Rumex palustris* and *Sonchus palustris*). Among these 31 species, 8 are now rare, for 2 the
516 **current presence deserves to be confirmed** and 3 formerly rare species are now extinct.
517 As of today, 63 species (22.3% of the hydro-hygrophilous) are rare, 14 (4.9%) need **to be confirmed**, 29
518 (10.2%) are extinct. Among the latter, 2 are extinct all over Italy (*Aldrovanda vesiculosa* and *Caldesia*
519 *parnassifolia*), 5 are extinct in Emilia-Romagna (*Acorus calamus*, *Hippuris vulgaris*, *Limosella aquatica*,
520 *Ranunculus lingua*, and *Sonchus palustris*, the latter possibly extinct in Italy throughout), whereas the others
521 are extinct on a provincial scale only. Of the extinct species, 12 out of 29 (41.4%) were exclusively recorded
522 in the plain, 9 (31.0%) were found in the hills and mountains exclusively, the others (27.6%) were present
523 throughout the whole territory. The extinct species can be divided into 10 palustrine, 10 aquatic and 9
524 hygrophilous (Table 4). In the plain, hills and mountains palustrine and aquatic species dominate: 15 species
525 out of 20 in the plain and 11 out of 17 in the hills and mountains. Among them, we find species typical of
526 stagnant oligotrophic waters with a peaty substrate (e.g. *Hottonia palustris*, *Menyanthes trifoliata*), species
527 resisting to a **remarkable** summer heating (e.g. *Aldrovanda vesiculosa*), or species growing on flooded soils
528 with a good trophic level (e.g. *Caldesia parnassifolia*, *Hippuris vulgaris*, *Oenanthe aquatica*, *O. fistulosa*) or
529 **significant** nutrient accumulation (*Baldellia ranunculoides*). Various species are also typically found in
530 humid oligotrophic grasslands or peat bogs (*Eriophorum angustifolium*), or humid mesotrophic grasslands
531 (*Anacamptis palustris*, *Leucojum aestivum*, etc.).
532 Concerning the life forms, 15 species out of 29 are hydrophytes, 6 are hemicryptophytes and 5 geophytes,
533 whereas helophytes and therophytes display a marginal presence only (**in terms of number of species, but**
534 **surely not as land cover importance**). In the plain area, hydrophytes and hemicryptophytes dominate (12 and
535 4 species out of 20, respectively), whereas the most abundant in the hills and mountains are the hydrophytes
536 (8 species out of 17), followed by geophytes and hemicryptophytes (4 and 3 species, respectively).
537 Concerning the chorotypes, Eurasian, boreal and **cosmopolitan** species dominate in the entire territory (12,
538 10 and 6 species, respectively), but with **noteworthy** differences in the distribution between the plain
539 (Eurasian 45.0%, boreal 30.0%, **cosmopolitan** 25.0%) and the hills and mountains (boreal 47.0%, Eurasian
540 35.3%, **cosmopolitan** 11.8%).

541 3.4 The allochthonous species

542 The allochthonous species are 123 (7.2% of the total species number), divided in 61 archaeophytes (e.g.
543 *Allium cepa*, *Malus domestica*), 57 neophytes (e.g. *Amaranthus* spp., *Hemerocallis fulva*), 4 cryptogenic (e.g.
544 *Brassica nigra*), 1 generic allochthonous (*Allium ascalonicum*). Even if archaeophytes and neophytes are
545 globally similar in number (Table 5), most of the former correspond to casual and naturalised species,
546 whereas neophytes are largely dominated by invasive ones (87.5%). In the late XIX century, anyway, only 4
547 **currently** invasive species were frequent, whereas 14 were cited for not more than 5 localities and 1 was even
548 said to be rare (Table 6). The most recorded species are, in decreasing order, the neophyte *Datura*
549 *stramonium* and the local allochthonous *Narcissus pseudonarcissus* (12 records each), the archaeophyte
550 *Prunus domestica* subsp. *insititia* (11), the neophytes *Amaranthus retroflexus* and *Narcissus incomparabilis*
551 (8 records each), the archaeophytes *Hyacinthus orientalis*, *Punica granatum* and *Raphanus sativus* and the
552 neophyte *Xanthium spinosum* (7 records each).
553 13 species were found in Bologna, 34 in the plain, 59 in the hills and mountains. Archaeophytes and
554 neophytes were always present in similar numbers, apart from Bologna town centre (Table 7). 50 species out
555 of 123 (25 archaeophytes, 22 neophytes, 2 cryptogenic, 1 generic allochthonous) lack of a geographical
556 indication, because in most cases they were present only **under** cultivation and did not tend to naturalise.
557 67 out of 123 species (50 archaeophytes, 13 neophytes, 3 cryptogenic, 1 generic allochthonous) were
558 cultivated for food and 18 (2 archaeophytes, 16 neophytes) for ornament (but the neophyte *Phytolacca*
559 *americana* was cultivated for both purposes); 1 was sporadically cultivated as a dyeing plant (*Isatis*
560 *tinctoria*), whereas the remnant 37 (8 archaeophytes, 28 neophytes, 1 cryptogenic) grew spontaneously in the
561 territory. Among crop species, 6 (4 archaeophytes, 2 neophytes) were cultivated in the plain only (2 of which

563 in Bologna as well), 14 (13 archaeophytes, 1 cryptogenic) were exclusively cultivated in the hills and
564 mountains (1 of which in Bologna as well), 7 (all of them archaeophytes) were cultivated both in the plain,
565 hills and mountains, 2 (all of them archaeophytes) in all three sectors (Bologna, plain, hills and mountains).
566 Therefore, globally 15 crop species were cultivated in the plain and 23 in the hills and mountains.
567 Life forms are illustrated in Fig. 9a. Therophytes (i.e. annual species, in most cases typical of disturbed soils)
568 are always dominant, followed by phanerophytes, geophytes and hemicryptophytes (in most cases
569 ornamental species), with small variations in the percentages among the different sectors. Helophytes and
570 hydrophytes are confined to the sole plain zone.
571 Chorotypes are illustrated in Fig. 9b. Eurasian species are always dominant, making up at least 25% of the
572 spectrum; Mediterranean, palaeotropical, cultivated and temperate America species follow, with values
573 comprised within 10-20% of the spectrum. The species of the Old World vary between 48.8 and 56.6% in the
574 plain, hills and mountains respectively, and are limited to 33.3% within Bologna. The species of the New
575 World vary between 23.6 and 29.8% in the plain, hills and mountains respectively, and reach 41.2% within
576 Bologna.
577 Concerning the geographical origin of the species, Asian species represent 27.3% of the list, American
578 24.0%, European 9.9%, African 5.8%. The remnant species have a wide distribution (pantropical,
579 circumboreal, **cosmopolitan**), are cultivated, or are still of unknown or uncertain origin.
580 Among the 5 allochthonous species that were common at Cocconi's epoch, 3 neophytes are now invasive
581 (*Amaranthus deflexus*, *A. hybridus* and *Erigeron canadensis*) and 2 naturalised (the neophyte *Digitaria*
582 *ciliaris* and the archaeophyte *Prunus dulcis*). Today, 4 species are rare (the neophytes *Narcissus medioluteus*
583 and *Tulipa raddii*, the archaeophyte *Punica granatum* and the cryptogenic *Rhus coriaria*) and 6 are extinct
584 (e.g. *Acorus calamus*, *Arachis hypogaea*, *Trigonella foenum-graecum*; see Table 4), whereas in the late XIX
585 century they were cultivated (*A. hypogaea*, *P. granatum* and *T. foenum-graecum*) or somewhere spontaneous
586 or sub-spontaneous (*N. medioluteus*, *R. coriaria*, etc.).

587

588

589 4 DISCUSSION

590

591 4.1 Exploration patterns and quality of the data

592 The *Flora* refers to a territory that goes beyond the administrative borders of the Bologna province back in
593 the day. Indeed, the area studied is much more defined on a geographic and naturalistic basis, also
594 considering changes made on the borders that would have become operational in the near future (i.e. some
595 municipalities of the **eastern** part annexed to the province of Bologna in 1884). The approach including
596 relevant areas for the reference territory, irrespectively of the administrative units, is common also to other
597 Floras of the same historical period (e.g. Gibelli and Pirotta 1883) and is obviously logical even in a modern
598 perspective (Pignatti 1982).

599 The resulting floristic records are the product of the joint work by Cocconi and 32 other collectors. When
600 looking at the time span of such records, most ancient ones probably date back to the mid of the XVIII
601 century. Among them, of particular relevance are the record of *Caldesia parnassifolia* by Ferdinando Bassi,
602 who sent Linnaeus the specimen (Managlia and Mossetti 2008; Managlia et al. 2012) and the 10 records by
603 Fulgenzio Vitman, which he published in 1773. Among the most important contributors of the *Flora* we have
604 Antonio and Giuseppe Bertoloni, with records from the 1820s to the 1870s, which were primarily part of the
605 *Flora Italica* (Bertoloni 1833-1854), and **the** works by Giuseppe Bertoloni such as *Iter in Apenninum*
606 *Bononiensem* (Bertoloni 1841) and *Vegetazione dei monti di Porretta* (Bertoloni 1867). These records by the
607 Bertoloni, together with the contributions by Bassi and Vitman, might be considered as the *corpus* of
608 historical records of the *Flora*. The other collectors are mainly contemporary to the redaction of the *Flora*
609 and somehow linked to the University of Bologna, either as alumni or as collaborators for Bertoloni and
610 Cocconi. Finally, some records originate from the Flora of the bordering provinces of Modena and Reggio
611 Emilia (Gibelli and Pirotta 1883, 1884), whose authors Cocconi was probably in touch with, which let us
612 suppose similar cultural drivers or even a common genesis of the two works. To sum up, most records of the
613 *Flora* were collected in a period of roughly 60 years, with a peak during the time when Cocconi was a
614 professor in Bologna (from 1871 onwards).

615 From a geographical standpoint, the exploration effort is unbalanced in favour of the hills and mountains,
616 whereas territories lacking a road network tended to be avoided, for the obvious difficulties of travelling in
617 these areas (cfr. Mattei 1893; Pezzi et al. 2021). Four exploration hotspots can be recognised. The first
618 corresponds to the starting point of the botanical itineraries around Bologna and extends up to the adjacent
619 *Colli Bolognesi* (lit. «the hills of Bologna», roughly ranging from 200 to 400 m a.s.l.). As testified by many

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

632 633 **4.2 The taxa: general characters and chorological aspects**

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

638 The taxonomic problems concerning the interpretation in light of the modern knowledge of the species
639 reported by Cocconi are of different origins. They may be errors by the authors (e.g. *gentiana*
640 *pneumonanthe*, *Verbascum samniticum*), species currently interpreted in a different way in comparison to
641 what was done in the late 1800s (e.g. *Cardamine pratensis*, *Ranunculus gracilis*, *R. aquatilis* or *Thalictrum*
642 *flavum*, which are today intended in a narrower sense or treated as complex of species), or species for which
643 the knowledge of the geographical distribution has varied compared to the author's era, since the floristic
644 exploration of the territory was less complete than today (case of *Carex disticha*, *Drosera anglica*,
645 *Pimpinella tragioides*, *Saxifraga caesia*, etc., whose presence is not known in Emilia-Romagna today, but in
646 Cocconi's times they were said to grow also in the Apennines: cfr. Cesati et al. 1868-1886; Bartolucci et al.
647 2018). The cause of such differences in species interpretation must be searched in the scarcity of reference
648 works available at the time and in the identification obtainable through the Floras of the XIX century
649 (Bertoloni 1833-1854; Passerini 1844; Parlatore 1848-1896; Cesati et al. 1868-1886). In particular, the latter
650 is directly related to the former taxonomic interpretation and knowledge of the geographical distribution,
651 since a Flora is always a subjective interpretation of phenomena and is inevitably a product of the scientific
652 mentality of the author and his time (Pignatti 1982). To better understand Cocconi's choices, one should
653 identify these species with the instruments (microscopes, Floras, keys, etc.) available in the last decades of
654 the XIX century. Anyway, it is not always possible to determine whether we are discussing species which
655 have meanwhile disappeared or erroneous interpretations in light of the current knowledge, due to the fate of
656 his herbarium being unknown, that prevents any verification on the *exsiccata*.

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

666 There is a notable number and selected narrative information on crop taxa, allowing to partially reconstruct
667 the agronomic features of the time. We remember for instance the cultivation of *Castanea sativa* trees in
668 some vegetable gardens within Bologna, the wide extent of the cultivations of *Cannabis sativa* in the plain,
669 whereas one century before it was cultivated also in the hills and mountains (Pezzi et al. 2020), the scattered
670 presence of *Morus* spp. and *Ulmus minor*, which testify a residual but still existing sericulture, and some
671 remnants of *Olea europaea* trees that survived the severe reduction in number caused by the Little Ice Age
672 (Rotondi et al. 2018). On the other hand, new entries such as *Solanum tuberosum* became widespread and
673 cultivated in several varieties, after being highly unwelcome from an agronomical viewpoint just a hundred
674 of years before (a single record for the entire territory at that time; Pezzi et al. 2020). Among formerly
675 cultivated species, we also have to mention those with pharmaceutical uses (e.g. Palma 1964; Gastaldo
676 1987), that were still present as subspontaneous relictual species, such as *Acorus calamus*, *Leonurus*

677 *cardiaca* and *Styrax officinalis*. It is further interesting to note how at Cocconi's epoch also the paddies were
678 rich in autochthonous hydro-hygrophytes, such as *Echinochloa crus-galli*, *Eleocharis palustris*, *Nymphaea*
679 *alba*, *Nuphar lutea*, *Potamogeton natans* (Bertoloni 1870).

680 Finally, the agricultural areas were rich in various segetal species, such as *Adonis aestivalis*, *Agrostemma*
681 *githago*, *Consolida regalis*, *Cyanus segetum*, which are at present extremely sporadic not only in the territory
682 studied, but also in large parts of the southern Po valley (e.g. Ferrari 1980; Piccoli et al. 2014).

683 All these data contribute to give a picture of an epoch whose socio-economic, climatic and environmental
684 conditions largely differ from those of present days.

685

686 4.3 The hydro-hygrophilous species

687 Floristic data indicate a wide presence of permanent and temporary water bodies in the late XIX century,
688 especially in the plain, where palustrine and aquatic species were almost 50% of the total list of the hydro-
689 hygrophilous species. This is corroborated by the huge number of hydrophytes nearly reaching 25% of the
690 list in the plain, but not exceeding 10% at higher altitudes (Fig. 8b).

691 The chorological spectrum reveals a considerable presence of microthermal species in the humid areas, both
692 in the plain (19.4%) and in the hills and mountains (26.0%): if this pattern is quite normal in mountainous
693 territories, it is instead worth noting at lower altitudes, since at present boreal species normally are 10% of
694 the spectrum in the Po Plain (Pignatti 1994). These results agree with previous studies performed in the
695 south-eastern Po valley (Buldrini et al. 2013a; Montanari et al. 2020), showing that in the low plain wetlands
696 and hygrophilous habitats microthermal flora can even be 20% of the total list. Anyway, some of the hydro-
697 hygrophilous species recorded by Cocconi in the plain were probably present as glacial relicts (e.g. *Hottonia*
698 *palustris*, *Menyanthes trifoliata*), since today they are extremely rare at low altitudes and confined only in
699 particular situations, whereas in the late XIX century they were more common, even in other sectors of the
700 Po valley (Romani and Alessandrini 2001; Piccoli et al. 2014).

701 Among the disappeared species, the most common are aquatic or palustrine, typical of constantly (or at least
702 frequently) flooded areas, where the soil always maintains a notable humidity level (Pignatti et al. 2005).

703 Particularly in the plain, the considerable quantity of palustrine species (28.3% of the total of the hydro-
704 hygrophilous species: see Fig. 8a) indicates a large presence of transition habitats between places which are
705 constantly or frequently submerged and places only flooded on occasion, as indirectly suggested by Cocconi
706 himself, who estimated as widespread species like *Eleocharis palustris*, *Oenanthe fistulosa*, *Rumex*
707 *hydrolapathum*, typical of environments with very humid and at times asphyctic soils (Pignatti et al. 2017-
708 2019). It is worth noting that, out of 6 species with cosmopolitan distribution, 5 were recorded in the plain
709 (e.g. *Hippuris vulgaris*, *Potamogeton perfoliatus*): in the Po valley, the presence of populations of widely
710 distributed species allowed them to maintain a range continuity within the entire Eurasian continent (Dallai
711 et al. 2014). Land reclamation, hydraulic regulation and agronomic arrangement of the territory caused the
712 progressive disappearance of various species linked to wetlands: the process, probably started during the
713 XVIII century, accelerated and intensified especially from the 1920s onwards (De la Lande 1769; Tinarelli
714 and Tosetti 1998; Buldrini et al. 2013a).

715 The two species extinct on the Italian level concern both the plain (*Aldrovanda vesiculosa*) and the hills and
716 mountains (*Caldesia parnassifolia*). They are palustrine hydrophytes, with a sub-cosmopolitan distribution,
717 already extinct in some European countries and threatened at various degrees: *A. vesiculosa* is extinct in
718 Italy, France, Austria and Greece and classified as *endangered* on a global scale (Jury 2009; Beretta et al.
719 2012; Rossi et al. 2013); *C. parnassifolia* is extinct in Italy, but classified as of *least concern* in Europe
720 (Gennai et al. 2012; Rossi et al. 2013), even if its presence is declining everywhere (Dumeige 1995). Both
721 species are listed in Annexes II and IV of the Directive 1992/43 of the European Union and in Annex I of the
722 Convention on the Conservation of European Wildlife and Natural Habitats (Bilz et al. 2011). It is interesting
723 to remember that *A. vesiculosa* was found by Cocconi only in one single place: this fact can lead to believe
724 that it was already very unusual, given its probably very narrow ecological tolerance (Adamec 1995) and
725 since some marshy areas seemed to host mostly common and generalist species (Cocconi 1878). At that time,
726 in fact, notable environmental transformations were ongoing, among them the progressive drainage of the
727 remnant wetland areas of the lowlands: Cocconi was perfectly aware that he was observing a situation
728 already compromised if compared to the previous decades (Cocconi 1877).

729 Of the 5 extinct species in Emilia-Romagna, 4 were exclusive of the plain. Among them, *Hippuris vulgaris* is
730 classified as *endangered* at the Italian level (Rossi et al. 2013) and is also ascribed to the European red list of
731 vascular plants with the status of *least concern*, together with *Ranunculus lingua* (Bilz et al. 2011).

732 It is worth mentioning that most of the extinct species were recorded by Cocconi in few places only (Table
733 4). This is in contrast to what was reported by Buldrini et al. (2014), according to which various hydro-

734 hygrophytes often were so common to be hardly interesting for the botanists of XIX century. Apparently, all
735 these species were already undergoing a rarefaction process, due to the environment's transformations of that
736 period (cfr. Cocconi 1877; Pezzi et al. 2021): «if we only visit any of these [swampy] areas, we cannot get an
737 adequate concept of the palustrine vegetation of the Province, if all of them have not been studied, each one
738 with its own peculiarities», also because «going through these marshes, I noted an increasing transformation
739 of their flora, especially where the drainage works began some years ago; so that certain marshes, that still
740 are in conditions of uncultivated lands, [...] maintain the characters of the aquatic or palustrine vegetation»,
741 whereas elsewhere «even if these marshes have a general vegetation character³, nonetheless certain species
742 prevail in some of them so that to become common, but are rare or completely absent in other areas»
743 (Cocconi 1878). That being the case, in the Po Plain the phase of most serious population decrease for many
744 hydro-hygrophytes began in the second half of XIX century (at least for certain areas), not at the time of the
745 great economic development after the Second World War as supposed for example by Buldrini et al. (2013b,
746 2013c) and Conte et al. (2022). Anyway, we must bear in mind that such presence records probably do not
747 represent the entire patrimony of local populations for the above-mentioned species, therefore our
748 conclusions can be biased by the consideration of a subset only of the real number of populations existing at
749 that time.

750

751 4.4 The allochthonous species

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

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

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

785 spontaneous in places far from human settlements (Pignatti et al. 2017-2019) and quite frequent in hilly areas
786 (Cocconi 1883).

787 The distribution of the allochthonous species also reveals a different distribution of the population with
788 respect to the present: the allochthonous species found in the hills and mountains are 59, whereas in the plain
789 they are only 34. Hills and mountains, in fact, were much more populated than today (Sereni 1961): not by
790 chance, most of the allochthonous species recorded at the higher altitudes were cultivated for food or for
791 ornamental purposes, whereas the typical species of disturbed places (often discretely thermophilous) were
792 few and not rarely linked to agricultural contexts or road margins (*Amaranthus* spp., *Erigeron annuus*,
793 *Sorghum halepense*, *Symphyotrichum novi-belgii*, *Xanthium orientale* subsp. *italicum*). Conversely, the
794 planitial territories, even if impacted by agriculture (as is proved by the 12 species out of 34 cultivated for
795 alimentary purposes), still preserved fairly natural wetlands (Cocconi 1878), as revealed both by the analysis
796 of the hydro-hygrophilous species and by the presence of few hygrophilous allochthonous species such as
797 *Acorus calamus*, *Cyperus glomeratus* and *Najas graminea*, that were found exclusively in the plain.
798 Overall, the scenario that can be outlined is that of a rural territory, with a presence of residual semi-natural
799 areas, although in regression, and where human impact was still moderate, even if widespread in the entire
800 study area and growing more and more for the progressive economic development of the province of
801 Bologna. In fact, about 70% of the life form spectrum is composed of therophytes and phanerophytes (Fig.
802 9a), the first ones in many cases cultivated for food (e.g. *Brassica* spp.), the second ones mostly ornamental
803 (e.g. *Broussonetia papyrifera*); the biggest part of the chorological spectrum is made up of species of the Old
804 World despite the notable presence of American ones (Fig. 9b), which reveals traditional agricultural and
805 commercial trading still mostly centred on Eurasia, Europe in particular. The few records of species now
806 disappeared, such as *Acorus calamus*, *Isatis tinctoria* and *Leonurus cardiaca*, which were subsponaneous in
807 the territory studied in the late XIX century, are one of the last memories of ancient cultivations for
808 pharmaceutical or dyeing purposes (e.g. Gastaldo 1987; Pignatti et al. 2017-2019): they can be considered
809 relictual species, whose sporadic, declining presence testifies the progressive transition from a traditional
810 agricultural landscape to a landscape altered by industrialisation and modern specialised agriculture.

811

812

813 5 CONCLUSIONS

814 In this study, it has been possible to visualise the spatial pattern of the 659 localities and related 7767 floristic
815 records of a late XIX century traditional floristic investigation in the Bologna province for the first time. This
816 allowed us to interpret the data not only in light of the ecological importance of the reported taxa, but also in
817 terms of their spatial distribution. Furthermore, the fact that the *Flora* has been incorporated in the regional
818 floristic database allowed us to precisely illustrate the interpretation problems of past floristic data, especially
819 when considering taxa subject to reclassification and varying interpretation throughout the centuries. In
820 addition, we were able to appreciate the results of a floristic research performed with a similar approach to
821 the current one, but based on former knowledge, culture, travelling conditions and scientific philosophy.
822 The quality and the informative value of the traditional floristic research depend on the already existing
823 exploration of the territory, on the number and expertise of the persons involved, on the supervision and
824 compiling skills of the authors in harmonising the data collected. The lack of a systematic surveying design
825 (i.e. regular grid of sample points) and the mobility constraints in particular (a still incomplete railway and
826 road network, no paved roads, etc.) caused a spatial bias towards the most accessible and the most valuable
827 sites from the naturalistic point of view. We can easily understand that at the *Flora's* time a more accurate
828 exploration of the territory would have required a much longer time period, implying therefore the risk to
829 give the study a partially diachronical dimension and potentially compromising the coherence of the floristic
830 picture of the territory.

831 In brief, the *Flora* published by Girolamo Cocconi offers not only a good example of a late XIX century flora
832 of a territory which started to experience an increasing human impact, but also an example of the method
833 used in that period for floristic exploration. Spatialising ancient floristic records is a useful way to understand
834 how and how much of the territory has been botanically explored and to improve the use of these records for
835 geographical and diachronical floristic research, also in light of today's scientific practices.

836 However, it should be noted that the process of parametrising historical textual sources (such as *Floras*) for
837 analytical and statistical data treatment should still be regarded as *work in progress*. The retrospective
838 georeferencing is an interpretation of a wide format range of locality descriptions, which have to be
839 standardised and transformed into a spatially precisely georeferenced element. Assigning this process to
840 territorial experts notably simplifies the work and assures high quality results. This is also true for the
841 taxonomic aspect of a *Flora* (i.e. nomenclatural revision and taxa evaluation), which can be best understood

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

847

848

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1281

1282 **Table captions**

1283

1284 **Table 1** List of data sources used for georeferencing the localities of the *Flora* by Girolamo Cocconi (1883)

1285

1286 **Table 2** Exploration hotspots (see also Fig. 3) and related number of records

1287

1288 **Table 3** Crop taxa cited in the *Flora*, divided by hierarchically-based categories of use (see UN 2015). Plant
1289 nomenclature follows Pignatti et al. (2017-2019) for uniformity reasons with the rest of the taxa. Only taxa
1290 indicated by Cocconi as present in cultivation and surely referable to a currently accepted name (*sensu*
1291 Pignatti et al. 2017-2019) are reported. In bold: taxa mentioned in the text

1292

1293 **Table 4** List of the extinct species. Number of records, altitudinal belts to which they are related in the *Flora*
1294 and current extinction level according to Bilz et al. (2011), Rossi et al. (2013) and Bartolucci et al. (2018) are
1295 also provided. If a species belongs to a target group it is indicated as follows: hydro-hygrophytes: Aqu. =
1296 aquatic, Pal. = palustrine, Hyg. = hygrophilous; allochthonous species: A = archaeophyte, N = neophyte. In
1297 bold, cultivated species (see also Table 3). Problematic species are indicated with (*)

1298

1299 **Table 5** Distribution of the archaeophytes and neophytes cited in the *Flora* according to their status (casual,
1300 naturalised, invasive). Classification follows the Portale della Flora d'Italia (2021)

1301

1302 **Table 6** List of the current invasive alien species. Number of records, altitudinal belts to which they are
1303 related to in the *Flora* and current status according to the Portale della Flora d'Italia (2021) are also
1304 provided. The status at the local scale is based on expert assessment and is referred to the area considered by
1305 Cocconi. In bold, cultivated plants (see also Table 3). Ornamental plants as indicated in the *Flora* are marked
1306 with (*)

1307

1308 **Table 7** Distribution of the allochthonous species in the three territorial sectors considered. Classification
1309 follows the Portale della Flora d'Italia (2021)

1310

1311 **Figure captions**

1312

1313 **Fig. 1** Genesis of a Flora: from the context to the outcome

1314

1315 **Fig. 2** Girolamo Cocconi (1824-1904) and the title page of the *Flora*. The images are courtesy of the
1316 photographic collection by *Accademia delle Scienze dell'Istituto di Bologna* (on the left) and Historical
1317 Library *Antonio Bertoloni* - Alma Mater Studiorum Università di Bologna (on the right)

1318

1319 **Fig. 3** The spatial cover of the *Flora* by Girolamo Cocconi. The grey line indicates the current border of the
1320 province of Bologna. Municipalities added most recently: Tossignano, Fontanelice, Castel del Rio (since
1321 1884), Pieve di Cento (since 1929). Former municipality: Castelfranco Emilia (since 1929). Municipalities
1322 that never belonged to the province of Bologna: Montese, Zocca, Guiglia, Nonantola

1323

1324 **Fig. 4** Heat map of the localities cited in the *Flora* after the retrospective georeferencing. Red dots indicate
1325 localities with more than 100 records. Yellow ramp shows the results of the Kernel density with higher
1326 transparency for lower values. Grey line indicates the border of the current Bologna province

1327

1328 **Fig. 5** Cumulative curve of the number of localities per each buffer radius

1329

1330 **Fig. 6** Collectors reported into the *Flora* ordered by birth-date year. The green band indicates the period from
1331 Cocconi's arrival in Bologna University (1871) to the year of the *Flora* publishing (1883). The death-year
1332 and the number of records attributed to a contributor are also reported. Importance of the lettering: a) records
1333 attributed to Gibelli e Pirotta; b) records attributed to the Lorenzini brothers (Demetrio and Amilcare); c)
1334 records attributed to the Riva brothers (Giuseppe and Domenico), which worked together. For further
1335 information about the collectors, see Online resource 3

1336

1337 **Fig. 7** Exploration hotspots by collectors other than Cocconi. Bcc = Beccari (3 records), Bld = Baldacci (13),
1338 Bnc = Bianconi (1), Brt = Bertoloni A. sr. (511), BrtF = Bertoloni G. (341), BrtN = Bertoloni A. jr. (1), Cgn =
1339 Cugini (8), Cml = Comelli (7), Crl = Caruel (31), Cvr = Cavara (21), Frn = Farneti (3), Gbl = Gibelli and
1340 Pirotta (25), Gdd = Gaddi (1), Gnn = Giannitrapani (4), Gvn = Giovannini (1), Lrn = Lorenzini brothers (87),
1341 Mnl = Minelli (2), Mtt = Mattei (2), Prz = Pirazzoli (3), Pzz = Pizzini (1), Riv = Riva brothers (167), Sav =
1342 Savi (1), Scn = Saccenti (15), Vtm = Vitman (3), Zff = Zuffi (5). For the collectors see also Fig. 6 and Online
1343 resource 3

1344

1345 **Fig. 8** Hydro-hydrophytes grouped into ecological categories (a), life forms (b) and chorotypes (c)
1346 considering the entire study area, the plain and the hills and mountains. The 3 species found in Bologna are
1347 not shown here

1348

1349 **Fig. 9** Allochthonous species grouped into life forms (a) and chorotypes (b), considering the entire study
1350 area, the plain, the town of Bologna and the hills and mountains. Species with uncertain or unknown
1351 chorotype are not shown

1352

1353 **Online resources**

1354

1355 **Online resource 1** Timeline of the principal changes of the features of Floras from the Renaissance onwards

1356

1357 **Online resource 2** List of the species recorded in the Flora of the province of Bologna (Cocconi 1883). For
1358 every taxon, ancient name as written by Cocconi, current taxonomic interpretation according to Pignatti et al.
1359 (2017-2019), eventual explanatory notes and observation localities as reported on the *Flora* are provided.

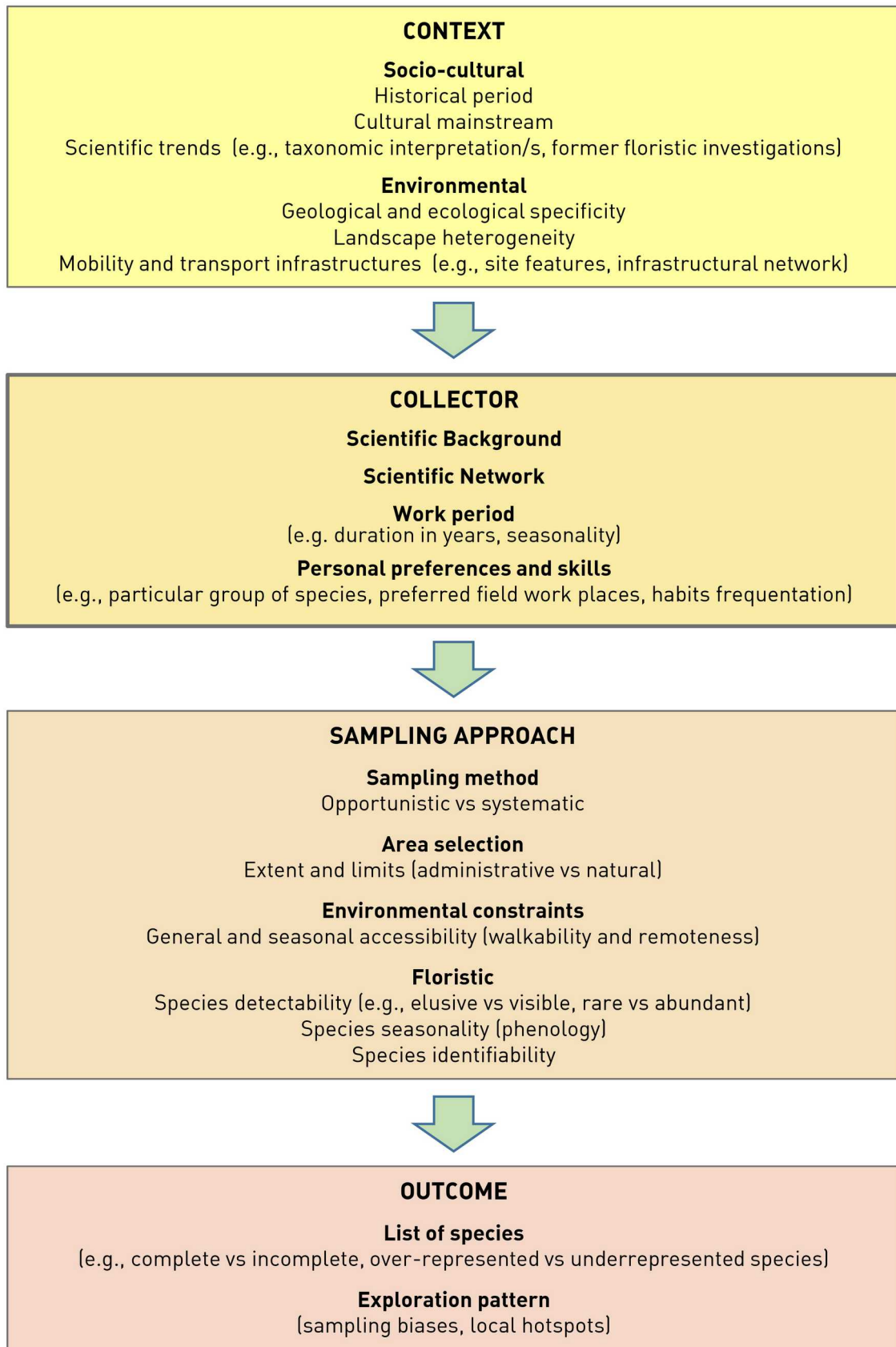
1360 Critical species are written in bold; in the Taxonomic issues the reasons for treating them as critical are
1361 explained

1362

1363 **Online resource 3** List of the contributors, besides Girolamo Cocconi, to the Flora of the province of
1364 Bologna (1883) and related information

1365

1366

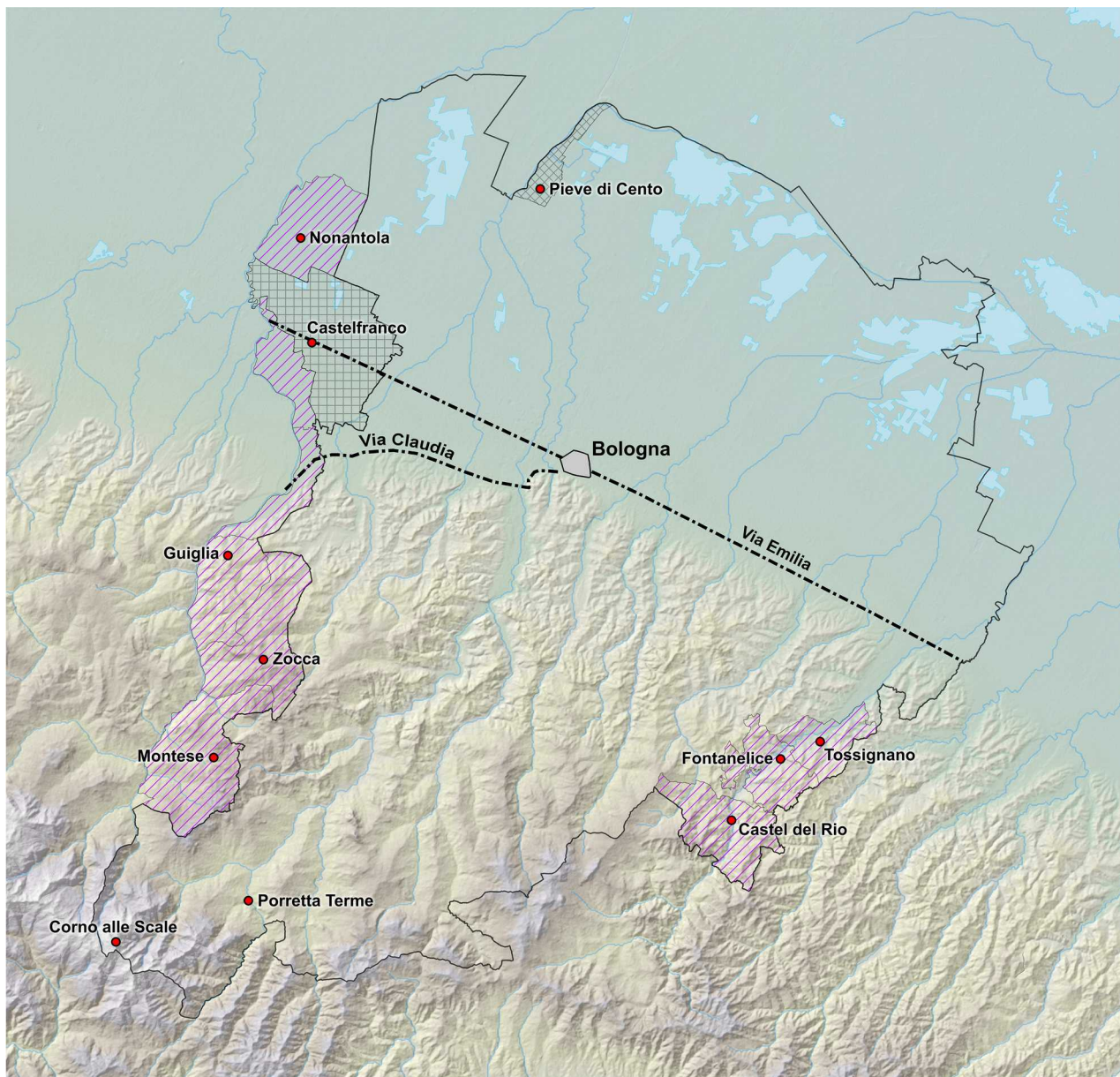


1370 Fig. 2
1371



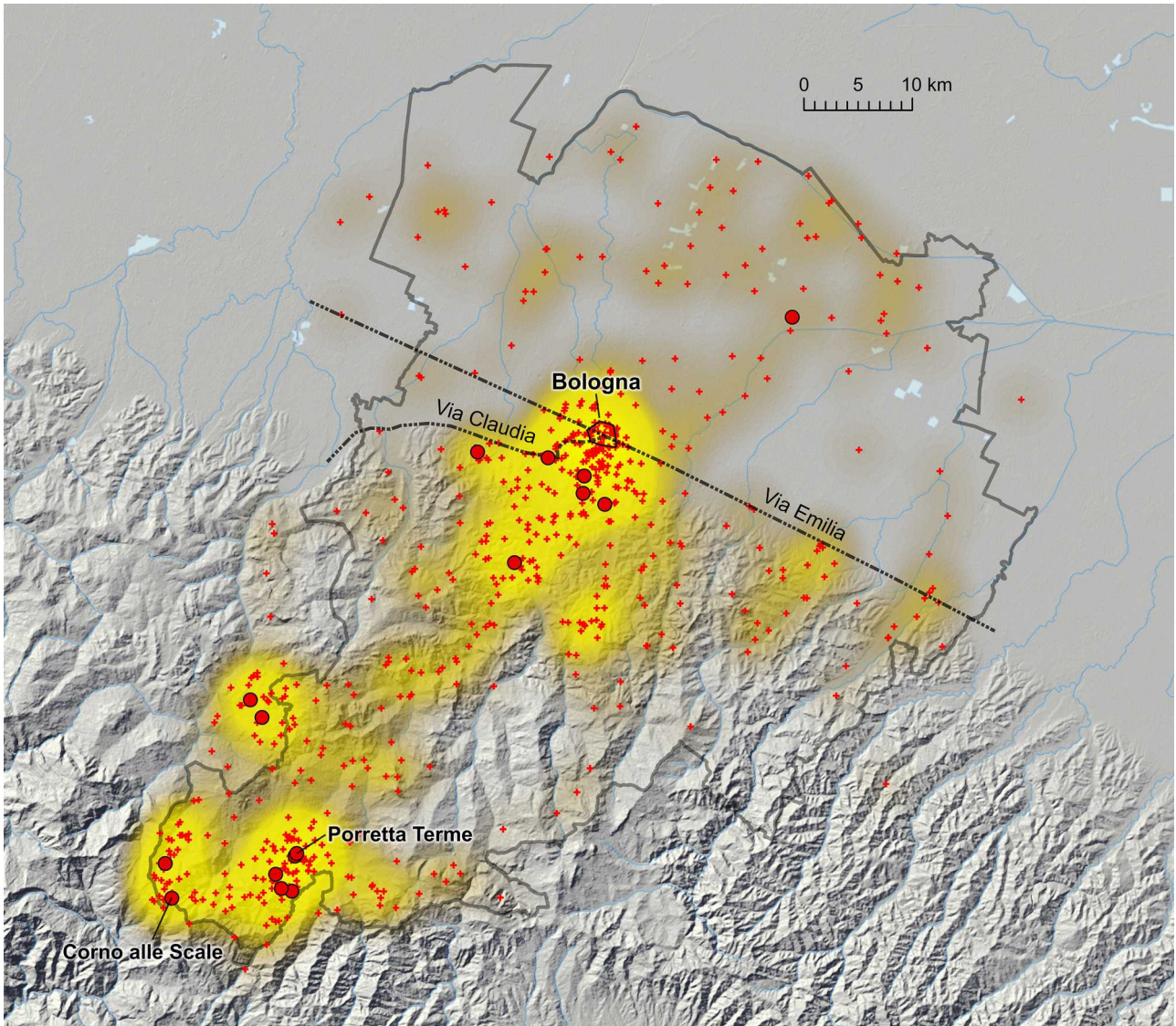
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1374 Fig. 3
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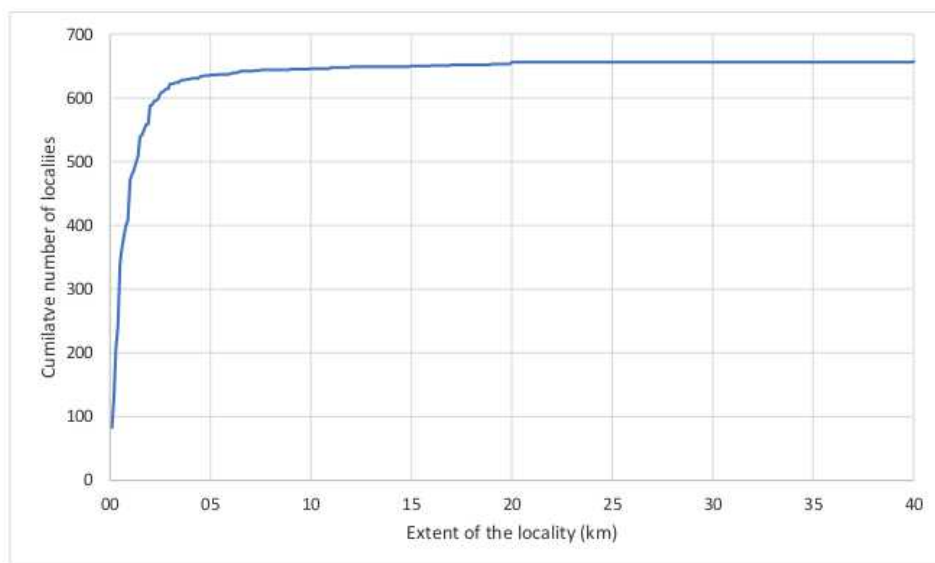
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1378 Fig. 4
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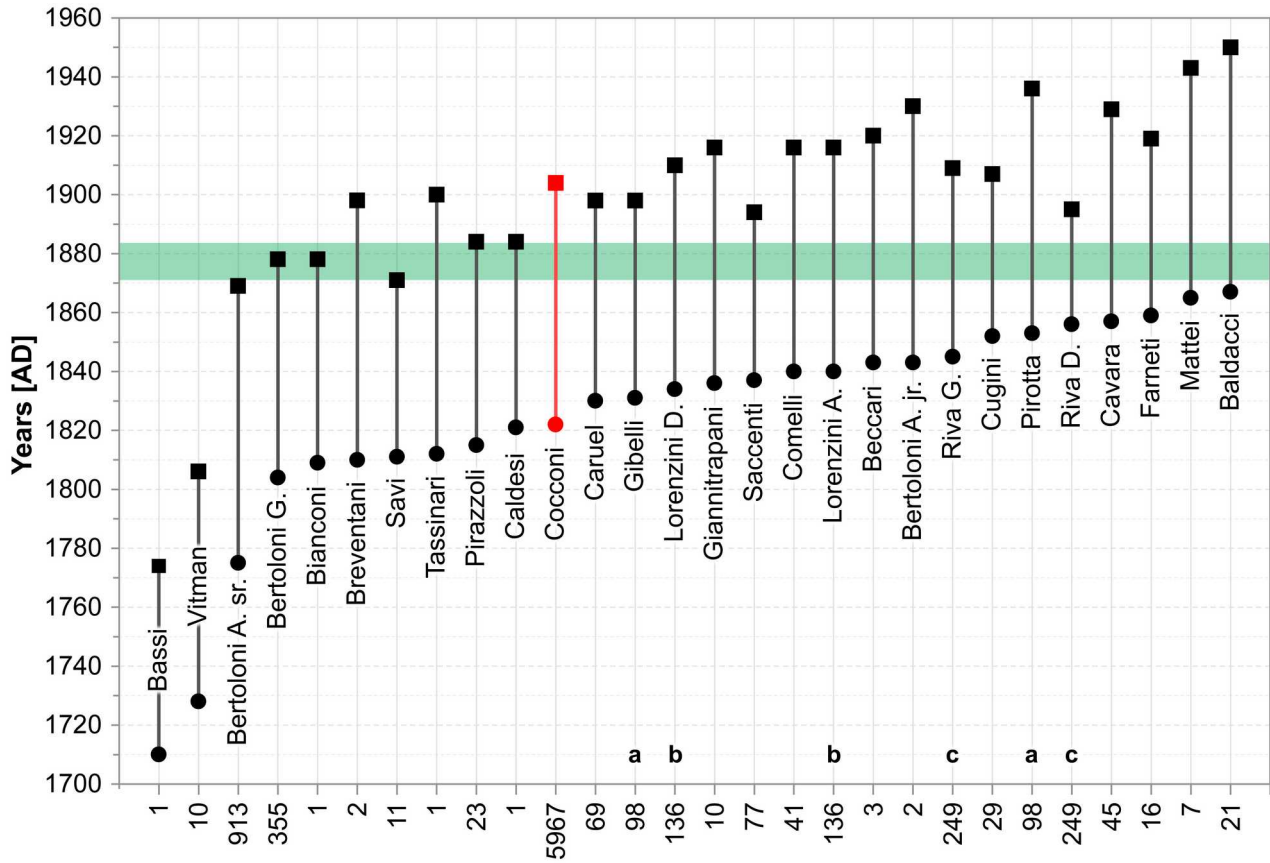
1381

1382 Fig. 5
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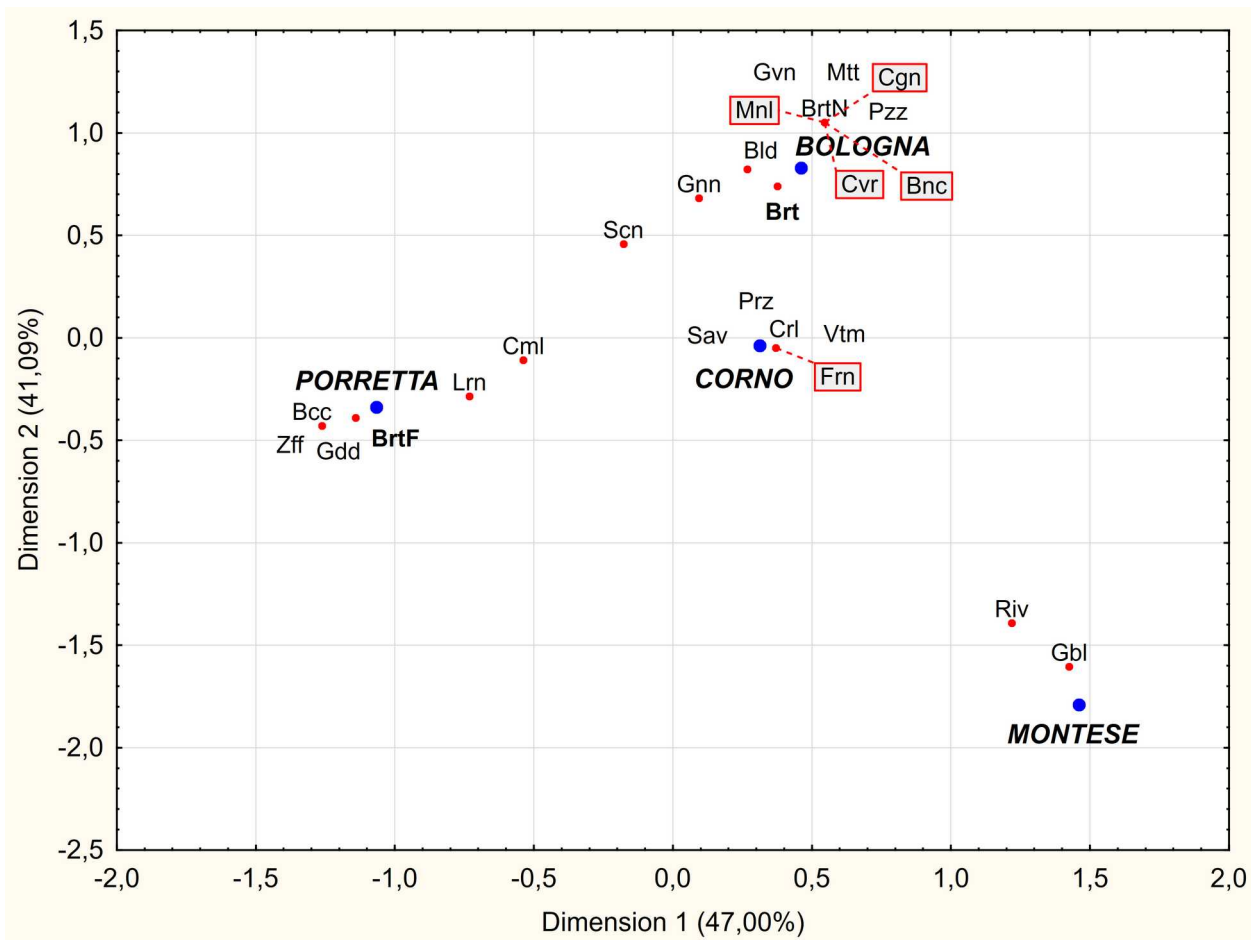
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1386 Fig. 6
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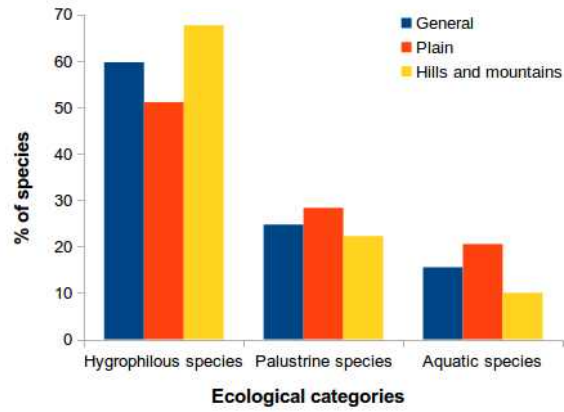
1389

1390 Fig. 7
1391

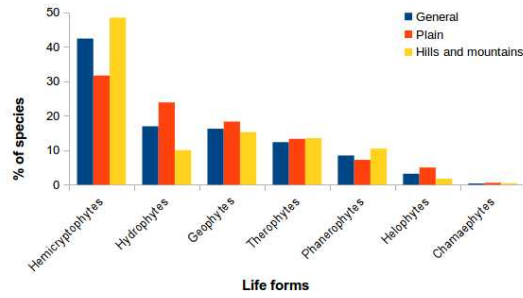


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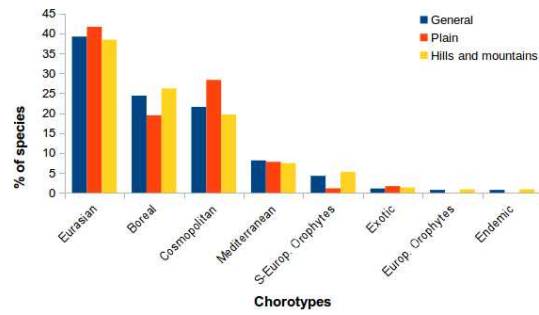
1394 Fig. 8
 1395
 1396 a)
 1397



1399 b)
 1400

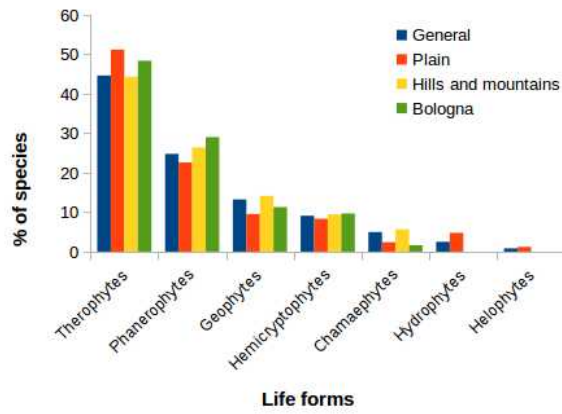


1402 c)
 1403

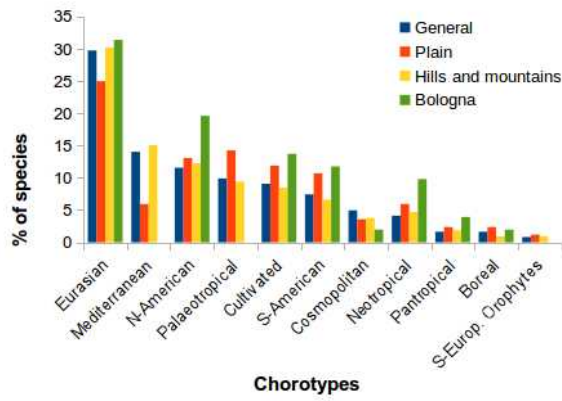


1405

1406 Fig. 9
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 1408 a)
 1409



1411 b)
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1414

1415 Table 1

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

1418

1419

1420 Table 2

1421

1422

Hotspot	Area km ²	Record s n	Localitie s 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

1423

1424

1425 Table 3
 1426
 1427

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

1428
 1429

1430 Table 4
 1431
 1432

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

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 1434

1435 Table 5
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Status	Species category	
	Archaeophytes	Neophytes
Casual	26	14
Naturalised	32	22
Invasive	3	21
<i>Total</i>	<i>61</i>	<i>57</i>

1438
1439

1440 Table 6

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

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1445 Table 7

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

1448