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# The weed vegetation of the bean “Fagiolo Cannellino di Atina” and the red pepper “Peperone di Pontecorvo” PDO crops (Latium, central Italy)

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## Abstract

The weed vegetation of the bean “Fagiolo Cannellino di Atina” (*Phaseolus vulgaris* L.) and the red pepper “Peperone di Pontecorvo” (*Capsicum annuum* L.) PDO (Protected Designation of Origin) crops was surveyed by means of 16 relevés, sampled in four farms of southern Latium during July 2019. The relevés were subjected to multivariate analysis, which revealed that the two crops are weeded by vegetation types referable to two different subassociations of *Panico-Polygonetum persicariae* (*Spergulo-Erodion*, *Eragrostietalia*, *Digitario-Eragrostietea*). Namely, communities colonizing bean fields, which are more mesophilous and richer in Eurasian taxa, are ascribable to the subassociation *sorghetosum halepensis*. Communities colonizing red pepper fields, which are more thermophilous and richer in Mediterranean taxa, are ascribable to the subassociation *cyperetosum rotundi*. Floristic, structural, and chorological features of the communities are discussed in relation to environmental factors and agricultural management.

## Keywords

Agroecosystems, Arable weeds, Bean, Biodiversity, *Digitario-Eragrostietea*, Phytosociology, Protected Designation of Origin, Red Pepper

## Introduction

Plant species that grow in arable land are among the most characteristic elements of agroecosystems. They consist of pioneer, wide-ranging, mostly annual species (Holzner 1978, 1982). Due to the competition that they exert towards crops, the fight against plants spontaneously colonizing cultivated fields is as old as agriculture itself. Nevertheless, arable weeds have been acknowledged, in recent years, for the benefits they provide in agricultural ecosystems. In fact, their presence considerably increases the biodiversity of arable land, also by supporting pollinators and birds (Marshall et al. 2003; Storkey 2006; Petit et al. 2011; Bretagnolle and Gaba 2015).

Shifts from traditional, extensive to modern, intensive agriculture had a relevant negative impact on arable weed biodiversity in Europe, which suffered a decline in quantity and quality (Storkey et al. 2012; Richner et al. 2015). Arable weed communities suffered a decrease in species

richness and a banalization of their floristic composition, through the increase in generalist taxa (Meyer et al. 2013; Arslan 2018; Fanfarillo et al. 2019a). This implied not only a decrease of environmental sustainability, but even troubles from an agronomic perspective. In fact, species-rich arable weed communities are less competitive and less harmful for the crop. The massive usage of herbicides and chemical fertilizers caused through the years the selection of few but very competitive species, which cause major damages to crops (Storkey and Neve 2018). Thus, the interest in the knowledge of arable weed vegetation considerably increased in the last years, both for agronomic and environmental reasons.

In climates with a cold season, the weed communities of summer crops are very different from those of winter crops. They include a much higher proportion of neophytes and cosmopolitan taxa (Lososová et al. 2004; Brullo and Guarino 2007; Abbate et al. 2013). In Italy, summer-annual crops like maize and sunflower are usu-

ally grown under intensive agriculture and host very impoverished weed communities, due to herbicide spraying (Fanfarillo et al. 2019a).

The Protected Designation of Origin (PDO) mark identifies a European product that only originates in a specific place and whose quality and features are due to a particular geographical environment, with its natural and human factors. The production, processing, and preparation of PDO products take place in a defined geographical area and are in line with the established production protocols (European Commission 2019). This makes PDO products emblematic of European traditional agriculture.

Latium region, in central Italy, hosts a high number of PDO products. The “Fagiolo Cannellino di Atina” (*Phaseolus vulgaris* L., bean) and “Peperone di Pontecorvo” (*Capsicum annuum* L., red pepper) obtained the PDO mark in 2010. Both of them are grown within a few hundreds of square kilometres in the Province of Frosinone, in the southern part of the region. Given the absence of information on the weed vegetation of PDO crops in Italy and the opportunity to study summer arable weed communities under traditional agricultural management provided by these two crops, we aimed at carrying out a phytosociological survey on their weed vegetation in four selected farms.

## Materials and methods

### Study areas

The two study areas are located in the Province of Frosinone (southern Latium, central Italy), in the surroundings of Atina (beans) and Pontecorvo (red peppers) (Fig. 1).

The production area of Atina bean is located in the middle Comino Valley, at elevations around 400 m a.s.l. The area is crossed by the Melfa and Mollarino rivers. The phytoclimate is Temperate Submediterranean (Pesaresi et al. 2017). Soils are alluvial loamy, with a neutral reaction (Hengl et al. 2017). Along the courses of Melfa and Mollarino rivers, the potential natural vegetation is constituted by hygrophilous woods with *Salix alba*, *S. purpurea*, *Populus* spp. and *Quercus robur* (*Fraxino-Quercion roboris*, *Salicion albae*). These are replaced, on the gentle slopes further from the waterbodies, by mesophilous *Quercus cerris* woods (*Daphno laureolae-Quercetum cerridis*) (Blasi 2010).

The production area of Pontecorvo red pepper lies in the lower Liri Valley, at elevations around 50 m a.s.l. The main waterbody is the Liri River. The phytoclimate is Temperate Submediterranean, close to the contact with the Mediterranean region (Pesaresi et al. 2017). As in Atina, soils are alluvial loamy and have a neutro-alkaline reaction (Hengl et al. 2017). Hygrophilous woods, along waterbodies (*Fraxino-Quercion roboris*, *Salicion albae*),

and mesophilous *Quercus cerris*-*Q. frainetto* woods, in less humid sites (*Malo florentinae-Quercetum frainetto*), represent the potential natural vegetation (Blasi 2010).

### Agricultural management

Both beans and red peppers are summer-annual crops and are grown with traditional methods of low-input agriculture. Each farmer was asked to compile a questionnaire about the agricultural management, his relationship with arable plants, and some personal piece of information.

According to the production protocols, both crops need irrigation. Chemical weeding and fertilization are not allowed for beans. On the contrary, these practices can be carried out in red pepper crops, if needed. Crop rotation is facultative for bean crops, whereas it is mandatory for red pepper ones, which cannot follow themselves or other Solanaceae before three years.

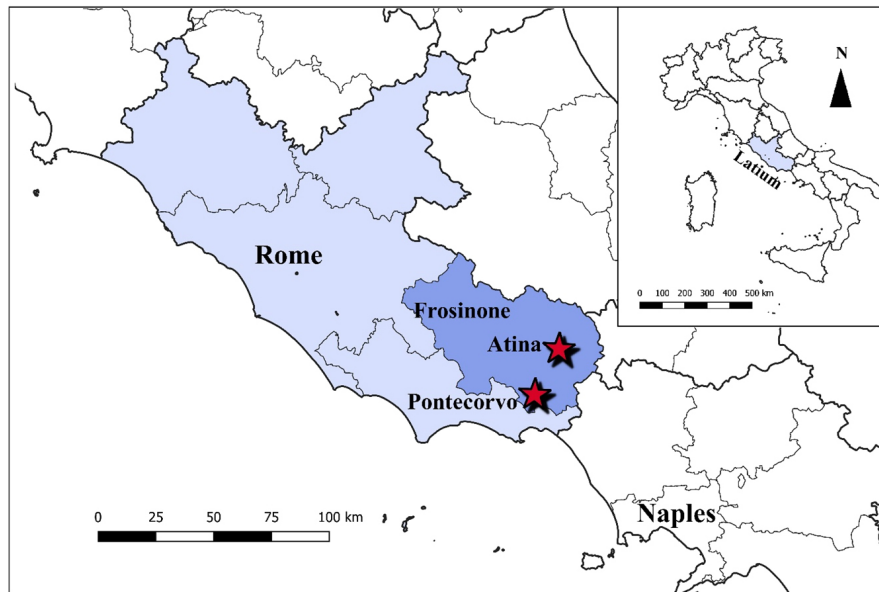
### Vegetation survey

In late spring 2019, we contacted the owners of 14 certified PDO bean and red pepper farms. Two bean and two red pepper producers were available to collaborate. The survey was carried out in July 2019. The vegetation sampling was carried out by means of fixed area plots of 1×16 m<sup>2</sup>, oriented along crop rows (Chytrý and Otýpková 2003; Güler et al. 2016). One plot was placed in the centre of each cultivated field. In red pepper farms, we also surveyed three fields that were in their rest year. All the occurring plant species were recorded and cover values were attributed according to the Braun-Blanquet scale (Braun-Blanquet 1964). We surveyed seven red pepper and nine bean fields, carrying out 16 relevés.

The collected specimens were identified according to Pignatti et al. (2017–2019). The taxonomic nomenclature was then updated according to Bartolucci et al. (2018) and Galasso et al. (2018), and their respective following updates. The syntaxonomic nomenclature follows the original authors for associations and subassociations and Mucina et al. (2016) for higher-rank syntaxa. We proposed corrections of names according to the rules of the International Code of Phytosociological Nomenclature (Weber et al. 2000). Species were attributed to syntaxa according to the original authors for associations and subassociations, and to Biondi et al. (2014) and Mucina et al. (2016) for higher-rank syntaxa.

### Statistical analyses

We performed a modified TWINSpan classification analysis of the relevés in the program JUICE (version 7.0.227 – Tichý 2002), using default settings (five pseudospecies cut levels: 0, 2, 5, 10, 20; minimum group size



**Figure 1.** Location of the study areas in Latium and location of Latium in Italy.

= 5) and total inertia as a dissimilarity measure. For the ordination of the relevés, we carried out a NMDS analysis using the function `isoMDS` in the mass package of R project (dissimilarity measure: Bray-Curtis) (Venables and Ripley 2002).

We calculated life form and chorological spectra for each cluster resulting from the classification. Life forms and chorotypes follow Pignatti et al. (2017–2019). Archaeophytes, neophytes, and cryptogenic species are according to Bartolucci et al. (2018) and Galasso et al. (2018), and their respective following updates.

## Results

### Agricultural management and farm histories

All the farmers carried out agricultural practices in line with the production protocols of each crop. All the interviewees declared to perceive arable weeds as a problem for production, with special regards to *Cirsium arvense*, *Sorghum halepense*, and *Xanthium italicum* in bean crops and to *Cyperus rotundus* in red pepper crops. The two red pepper growers did not have other jobs. On the contrary, farming was a side job for bean growers.

Beans were cultivated since 2011 in both of the surveyed farms. Soil tillage and sowing were carried out in early June 2019. Sprinkle or drip irrigation was performed each 5–6 days. In one farm, beans were rotated with winter wheat. In the other one, only fallowing was carried out. The control of weed vegetation was achieved by either manual eradication or hoeing.

Red peppers were cultivated since 2015 in a surveyed farm and since 2018 in the other. Soil tillage was carried out in early May in a farm and in early June in the other, and transplantation in the open field was performed in late May and early June, respectively. Red peppers were rotated with winter broad bean, maize, and *Brassica* sp. Drip irrigation was provided each 2–15 days. Organic fertilizers were applied a couple of times per growing season. Mulching sheets were used to control weed vegetation.

### Vegetation analysis

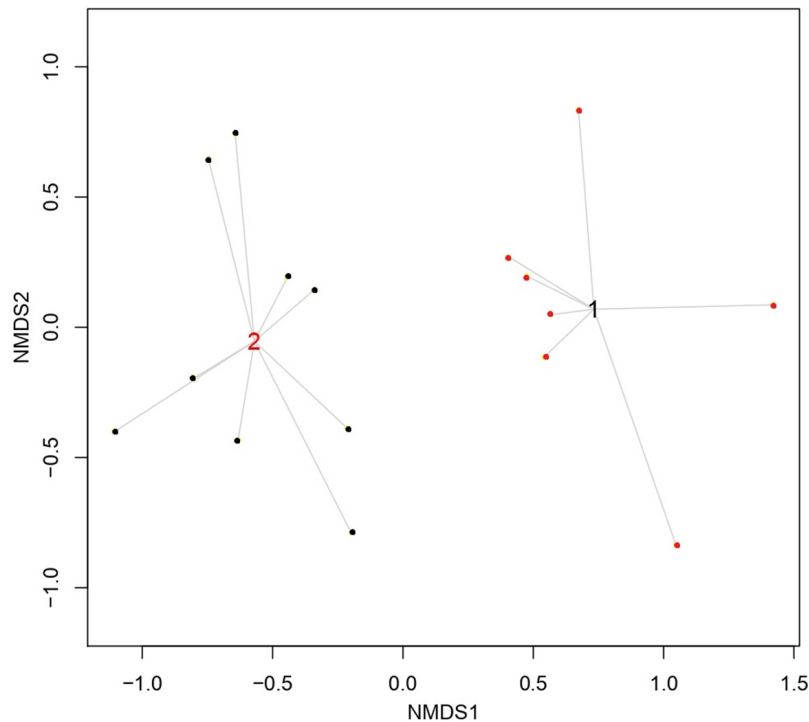
The numerical analysis of the relevés produced two interpretable clusters, exactly separating the arable weed communities of Atina from those of Pontecorvo. The results of the NMDS ordination reflect this split, with the two groups being well separated in space (Fig. 2).

The detected vegetation types were attributable to two different subassociations of the *Panico-Polygonetum persicariae*, in the alliance *Spergulo arvensis-Erodion cicutariae* (*Eragrostietalia*, *Digitario sanguinalis-Eragrostietea minoris*). The alliance includes the sub-thermophilous summer-annual weed communities that develop on sandy and sandy-loamy soils in the Atlantic to subcontinental regions of the nemoral zone of Europe (Mucina et al. 2016) (Table 1). The floristic composition of the association actually overlaps that of the alliance, hosting summer-annual taxa as *Amaranthus* spp., *Datura stramonium*, *Echinochloa crus-galli*, *Persicaria maculosa*, *Setaria* spp., and *Xanthium italicum*. Frequent class characteristics are *Digitaria sanguinalis* and *Portulaca oleracea*. Some ruderal generalist from the *Sisymbrietea* constantly occur, including *Chenopodium album*, *Convolvulus arvensis*, and

**Table 1.** Analytic table of the relevés. Crops: B = bean; P = red pepper; R = red pepper field in its first rest year.

Relevé number	16	10	13	14	11	12	15	8	3	9	7	4	2	1	5	6
Crop	P	P	P	R	R	R	P	B	B	B	B	B	B	B	B	B
Relevé area (m <sup>2</sup> )	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Elevation (m a.s.l.)	55	50	55	55	50	50	55	380	410	390	415	410	380	380	415	415
Cover of weed vegetation (%)	3	10	90	30	90	70	90	80	20	10	25	10	100	60	20	25
Number of species	6	12	11	8	8	19	11	9	7	5	11	9	6	9	14	6
<b><i>Panico-Polygonetum persicariae</i> and <i>Spergulo-Erodion</i></b>																
<i>Amaranthus retroflexus</i>	.	1	r	r	.	.	r	r	2	2	.	.	4	1	r	2
<i>Xanthium italicum</i>	.	.	.	.	.	+	.	1	.	.	1	.	2	2	2	r
<i>Setaria pumila</i>	.	.	.	.	.	.	+	2	.	.	.	.	.	.	.	.
<i>Persicaria maculosa</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.
<i>Datura stramonium</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	1	r	.
<i>Echinochloa crus-galli</i> subsp. <i>crus-galli</i>	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	r
<i>Setaria italica</i> subsp. <i>viridis</i>	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<b>Char. <i>cyperetosum rotundi</i></b>																
<i>Cyperus rotundus</i>	1	1	4	2	1	+	3	.	.	.	.	.	.	+	.	.
<b>Char. <i>sorghetosum halepensis</i></b>																
<i>Sorghum halepense</i>	.	.	.	.	.	.	.	1	1	r	2	2	1	+	1	r
<i>Abutilon theophrasti</i>	.	.	.	.	.	.	.	.	.	.	+	r	3	.	.	+
<b>Facies of fallow pepper fields</b>																
<i>Kickxia elatine</i> subsp. <i>elatine</i>	.	.	+	r	1	3	.	.	.	.	.	.	.	.	.	.
<i>Artemisia verlotiorum</i>	.	+	+	.	5	.	.	.	2	.	.	.	.	.	.	.
<i>Erigeron sumatrensis</i>	.	.	.	.	+	2	.	.	.	.	.	.	.	.	.	.
<i>Erigeron canadensis</i>	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
<b><i>Eragrostietalia</i> and <i>Digitario-Eragrostietea</i></b>																
<i>Portulaca oleracea</i>	+	1	2	1	.	.	3	r	.	r	.	.	.	+	2	.
<i>Digitaria sanguinalis</i>	.	+	+	+	.	+	1	3	+	.	.	.	.	.	.	.
<i>Cynodon dactylon</i>	.	.	.	.	.	.	.	1	+	.	.	.	.	.	r	.
<i>Heliotropium europaeum</i>	r	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Polygonum aviculare</i> subsp. <i>aviculare</i>	.	.	+	.	.	1	.	.	.	.	.	.	.	.	.	.
<i>Euphorbia prostrata</i>	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.
<i>Euphorbia maculata</i>	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
<i>Euphorbia chamaesyce</i>	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
<b><i>Sisymbrietea</i></b>																
<i>Convolvulus arvensis</i>	.	1	1	1	.	.	2	.	r	r	+	1	+	.	+	.
<i>Sonchus oleraceus</i>	r	+	r	+	r	.	.	.	r	.	r	+	.	.	.	.
<i>Chenopodium album</i> subsp. <i>album</i>	.	.	.	.	.	r	.	+	1	.	.	r	1	2	1	.
<i>Cirsium arvense</i>	+	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.
<i>Sinapis arvensis</i> subsp. <i>arvensis</i>	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.
<b><i>Papaveretea rhoeadis</i></b>																
<i>Mercurialis annua</i>	.	.	.	.	.	.	.	.	.	.	1	1	.	1	+	.
<i>Veronica persica</i>	+	+	r	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Visnaga daucooides</i>	.	.	r	.	.	1	.	.	.	.	.	.	.	.	.	.
<i>Lysimachia arvensis</i> subsp. <i>arvensis</i>	.	.	.	.	r	+	.	.	.	.	.	.	.	.	.	.
<i>Euphorbia helioscopia</i> subsp. <i>helioscopia</i>	.	.	.	.	.	.	.	.	r	.	.	.	.	.	r	.
<b>Companions</b>																
<i>Artemisia vulgaris</i>	.	.	.	.	.	.	.	.	.	.	+	.	.	.	r	+
<i>Rumex crispus</i>	.	.	.	.	+	.	+	.	.	.	.	.	.	.	r	.
<i>Centaurium pulchellum</i> subsp. <i>pulchellum</i>	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.
<b>Sporadic species</b>	0	1	0	0	0	7	2	3	0	0	1	2	0	0	0	0





**Figure 2.** Ordination diagram based on the results of the NMDS: 1 = *Panico-Polygonetum cyperetosum* (red pepper fields); 2 = *Panico-Polygonetum sorghetosum* (bean fields); dots = relevés.

*Sonchus oleraceus*. The community was described in hoed summer crops of the eastern Po Plain (Pignatti 1953). Later, many authors detected it in other parts of Italy, especially in maize crops (Lorenzoni 1963-1968; Covarelli 1968; De Dominicis et al. 1988; Zanin et al. 1991).

For the weed vegetation of bean fields, we recognized the subassociation *Panico-Polygonetum persicariae* Pignatti 1953 *sorghetosum halepensis* Baldoni 1995 (Fig. 3), which was described in Marche (central Italy). In our relevés, it is distinguished by the occurrence of *Sorghum halepense* and *Abutilon theophrasti*, which sometimes reach high cover values. It develops in summer-annual crops growing in areas with a shallow water table and with nutrient-enriched soils (Baldoni 1995). The mean number of species per relevé was 8.

The weed vegetation of red pepper crops was referred to the subassociation *Panico-Polygonetum persicariae* Pignatti 1953 *cyperetosum rotundi* Lorenzoni 1967 *nom. corr. hoc loco* (Art. 14 and 41b; Fig. 4). It was originally named “*Panico-Polygonetum persicariae* Pignatti 1953 subassociazione a *Cyperus rotundus*” in Lorenzoni (1967 – Quaderno VII di Maydica, page 4). It was described as a weed community of maize crops in Latium and Campania, and later detected in Calabria. The community is physiognomically characterized by the geophyte *Cyperus rotundus* and it develops in lowlands, on moist and sandy soils (Lorenzoni 1967, 1968). The mean number of species per relevé was 11. In fallow red pepper fields,

due to the lack of irrigation, we detected a xerophilous facies characterized by *Artemisia verlotiorum*, *Erigeron canadensis*, *E. sumatrensis*, and *Kickxia elatine*, without a specific sociological value.

Structurally, the two communities are distinctively annual, but a fair amount of geophytes is also present. A higher incidence of therophytes featured the *cyperetosum* subassociation, while a slightly higher amount of perennials was present in the *sorghetosum* subassociation. As regards perennials, the occurrence of rhizomatous geophytes as *Artemisia verlotiorum*, *Convolvulus arvensis*, *Cynodon dactylon*, *Cyperus rotundus*, and *Sorghum halepense* stood out. The chorological analysis highlighted a poor consistency of the communities with the phytogeographic context of the study areas. This is underlined by the predominance of neophyte and cosmopolitan taxa and by the reduced occurrence of Eurasian (more abundant in the *sorghetosum*) and Mediterranean (more represented in the *cyperetosum*) species (Fig. 5). Neophytes are all invasive in Latium (Galasso et al. 2018) and all of them are of American origin (e.g., *Amaranthus retroflexus*, *Datura stramonium*, *Erigeron* spp.), with exception of the eastern Asian *Artemisia verlotiorum*. Several cryptogenic taxa are present too, in both the subassociations (*Cyperus rotundus*, *Digitaria sanguinalis*, *Portulaca oleracea*, and *Setaria italica* subsp. *viridis*). Archaeophytes are *Abutilon theophrasti* and *Sorghum halepense*, exclusive to and characteristic of the *sorghetosum* subassociation.



**Figure 3.** *Panico-Polygonetum persicariae sorghetosum halepensis* community colonizing a bean field in Atina.



**Figure 4.** *Panico-Polygonetum persicariae cyperetosum rotundi* community colonizing a red pepper field in Pontecorvo.

## Discussion and conclusions

The results highlighted the presence of weed communities previously detected in different summer-annual crops in central Italy, like maize and sugarcane (Covarelli 1968; De Dominicis et al. 1988; Baldoni 1995). These stands are floristically very different from those colonizing winter-annual crops in the same area (Covarelli 1979; Baldoni and Frattaroli 1998; Fanfarillo et al. 2019b). This confirms how crop seasonality is one of the most important factors shaping arable weed communities at middle-high latitudes, as shown in many parts of Eurasia (Lososová et al. 2004; Fried et al. 2008; Abbate et al. 2013; Nowak et al. 2015).

## Syntaxonomy

Syntaxonomically, the weed vegetation of Italian summer-annual crops pertains to the class *Digitario sanguinalis-Eragrostietea minoris* (Mucina et al. 2016). Within this class, it is mainly ascribable to the alliance *Spergulo-Erodion* (syn. *Panico-Setarion*), and subordinately to the *Diplo-taxion eruroidis* and to the *Chenopodion botryos*. Within the *Spergulo-Erodion*, the *Panico-Polygonetum persicariae* is the most common association. Some authors consider it as a synonym of the central European *Echinochloo-Setarium pumilae* (Poldini et al. 1998; Tasinazzo 2011).

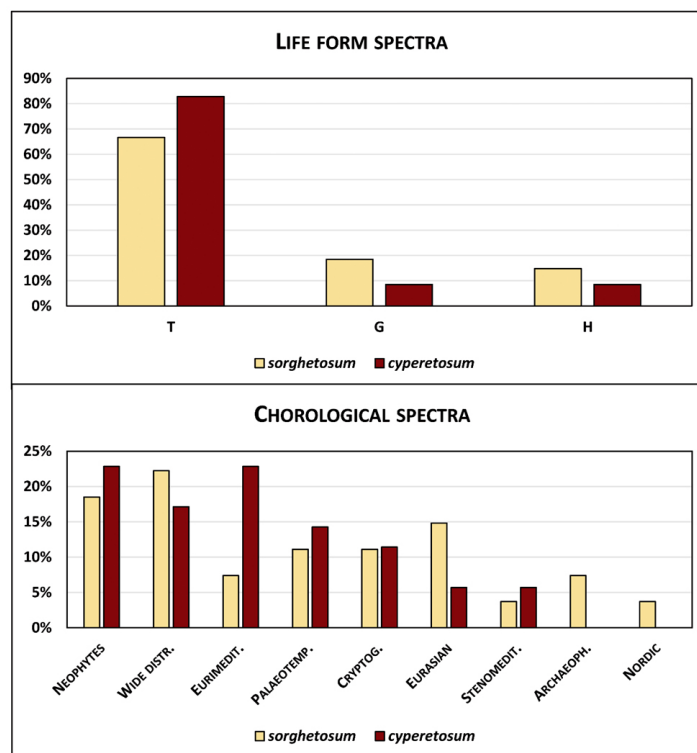
At the best of our knowledge, the weed vegetation of bean and red pepper crops is practically unknown from

a phytosociological perspective in Italy. In southern Calabria, some winter-spring communities colonizing bean fields were framed in the *Fumario agrariae-Brassicetum fruticosae* (*Fumarion wirtgenii-agrariae*, *Papaveretea rhoeadis*). Summer stands of bean fields in the same area were referred to the *Setario-Echinochloëtum colonum* (*Spergulo-Erodion*, *Digitario-Eragrostieta*) (Brullo et al. 2001). No references were found for the weed communities of red pepper crops.

According to past evidences, the *Panico-Polygonetum persicariae* is particularly common in Italian summer-annual crops, in sites where either naturally or because of irrigation an adequate amount of moisture is present (Lorenzoni 1963–1968). This plant community was described by Pignatti (1953) in the eastern Po Plain. Its affinity with the *Echinochloo-Setarietum pumilae*, previously described in central Europe by Felföldy (1942), was soon remarked by Lorenzoni (1963). Nevertheless, the latter and later authors preferred to use the *Panico-Polygonetum* as a reference for the weed vegetation of Italian summer-annual crops (Covarelli 1968; De Dominicis et al. 1988; Zanin et al. 1991; Baldoni 1995). Poldini et al. (1998) then statistically proved that there was no floristic difference between the *Echinochloo-Setarietum* and the *Panico-Polygonetum*. Thus, the authors put the latter syntaxon in synonymy with the former. Since syntaxonomic issues go beyond the aims of this work, we followed the original framing of the detected subassociations in the *Panico-Polygonetum*.

Other arable weed communities dominated by *Cyperus rotundus* and/or *Sorghum halepense* are present in Europe.

The summer-annual weed communities of the woody crops of Sicily were ascribed by Maugeri (1979) to the *Amarantho-Cyperetum rotundi*, with several subassociations. In southern Calabria, Brullo et al. (2001) described the *Setario ambiguae-Cyperetum rotundi* in irrigated citrus groves. Since it was invalidly published, the *Amarantho-Cyperetum* was later synonymized with the *Setario-Cyperetum*, and its subassociation *echinochloëtum coloni* was put in synonymy with the *Setario glaucae-Echinochloëtum colonum* (Brullo et al. 2007). The *Setario-Cyperetum* is very different from our communities, in which the diagnostic *Cyperus esculentus* and *Setaria verticillata* are missing, as well as constant species as *Galinsoga quadriradiata*, *Chenopodium vulvaria*, and *Urtica membranacea*. In Catalonia (Spain), Ninot et al. (2010–2011) described the *Convolvulo arvensis-Cyperetum rotundi* in fruit orchards and kitchen gardens under low-intensity agricultural practices, including low irrigation. This community was later detected also in irrigated summer crops of Tajikistan (Nowak and Nowak 2013). It is featured by generalist and widely distributed species and this makes possible, in the future, that it could be detected elsewhere, including Italy. Summer arable weed communities dominated by *S. halepense* are the *Setario ambiguae-Sorghetum halepensi*, present in Eastern Europe and Middle Asia (Nowak and Nowak 2013), and the *Hibisco trioni-Sorghetum halepensi*, described for Dalmatia (Mitić et al. 2009). Because of differences in floristic composition and the different geographic location, these syntaxa are not a good reference for our relevés.



**Figure 5.** Life form and chorological spectra for the subassociations *sorghetosum halepensis* and *cyperetosum rotundi* of the *Panico-Polygonetum persicariae*.

## Synecology

Given the affinity in agricultural management between beans and red peppers (late spring tillage, irrigation, no use of herbicides), the detected differences in the weed vegetation are restrained and mainly due to geographic and environmental factors. The lower elevation and the higher proximity to the sea give to the area of Pontecorvo a phytoclimate closer to a Mediterranean type, with a clear period of summer drought. The area of Atina lies more inland and in the hilly belt, so that its phytoclimate is more clearly Temperate. Furthermore, bean fields are located very close to the courses of Melfa and Mollarino rivers. At the same level of irrigation, site conditions are featured by a higher moisture availability in Atina. That is why weed vegetation hosts meso-hygrophilous differential species of the *sorghetosum* subassociation. On the contrary, the warmer and dryer conditions of Pontecorvo promote the development of the *cyperetosum*, anyway in a context of alluvial soils with a fair moisture amount. These differences are also highlighted by the higher amount of therophytes and Mediterranean species in the *cyperetosum* communities, whereas perennials, Eurasian, and palaeotemperate taxa have a higher incidence in the *sorghetosum* ones.

## Considerations on environmental and agricultural sustainability

Despite the low-input agricultural practices, the surveyed arable weed vegetation resulted rich in elements of no conservation value, such as neophyte, widely distributed, and generalist taxa. This evidence is consistent with the general patterns known in Europe and does not necessarily point towards a low environmental sustainability of the studied crops. Both bean and red pepper, as most of the summer-annual crops of Italy, were “recently” introduced from tropical America. Their spread provided a new ecological and phenological niche across Europe, whose climatic features make annual plants that complete their life cycle under hot and wet conditions poorly represented in the native flora. Neotropical and generalist taxa soon occupied this niche, which was not suitable for many native species (Brullo and Guarino 2007).

The interviewed farmers mentioned *Cyperus rotundus* and *Sorghum halepense* as the most troublesome weeds in their fields. This was not surprising, since these taxa are between the worst agricultural weeds worldwide (Holm et al. 1977). They had a big spread in summer crops of Latium in the last decades, as well as other rhizomatous grasses as *Cynodon dactylon* and *Paspalum distichum* (Fanfarillo et al. 2019a). Their success as arable weeds is due to rhizome dispersion by tillage, to herbicide resistance, to a very efficient C4 metabolism, and even to the release of allelochemicals (Bryson and Richard 2008; Heap 2014; Kashif et al. 2015). Another hard to control species was *Cirsium arvense*, which has a high ability to

spread both vegetatively, through its root buds, and sexually, through the effective anemochorous dispersion of its achenes. The fourth species mentioned by farmers as a troublesome weed was the summer-annual *Xanthium italicum*, whose success is easily linkable to an abundant fruit production and zoochory. In order to avoid the use of chemical control, farmers should establish better-planned crop rotations with a higher temporal and spatial crop diversification. This would promote the establishment of more balanced and species-rich communities, which are less competitive and cause less damage to the crop, avoiding the selection of few, highly harmful species (Storkey and Neve 2018).

## Syntaxonomic scheme

DIGITARIO SANGUINALIS-ERAGROSTIETEA MINORIS

Mucina, Lososová et Šilc in Mucina et al., 2016

ERAGROSTIETALIA J. Tx. ex Poli, 1966

**Spergulo arvensis-Erodion cicutariae** J.Tx. in Passarge, 1964

*Panico-Polygonetum persicariae* Pignatti, 1953

*cyperetosum rotundi* Lorenzoni, 1967, *nom. corr. hoc loco*

*sorghetosum halepensis* Baldoni, 1995

Other syntaxa quoted in the text (in alphabetic order)

*Amarantho-Cyperetum rotundi echinochloëtosum coloni* Maugeri et al., 1980 *nom. inval.*; *Chenopodion botryos* S. Brullo et Marcenò, 1980; *Convolvulo arvensis-Cyperetum rotundi* Carretero et Aguilera ex Ninot, X. Font, Masalles et Vigo, 2010–2011; *Daphno laureolae-Quercetum cerridis* Taffetani et Biondi, 1993; *Diplotaxion eruroidis* Br.-Bl. in Br.-Bl. et al., 1936; *Echinochloo-Setarietum pumilae* Fel-foldy, 1942 *corr. Mucina*, 1993; *Fraxino-Quercion roboris* Passarge, 1968; *Fumario agrariae-Brassicetum fruticulosae* S. Brullo et al., 2001; *Fumarion wirtgenii-agrariae* S. Brullo in S. Brullo et Marcenò, 1985; *Hibisco trioni-Sorghetum halepensi* Mitić et al., 2009; *Malo florentinae-Quercetum frainetto* Biondi, Gigante, Pignattelli et Venanzoni, 2001; *Setario ambiguae-Sorghetum halepensi* Ștefan et Oprea, 1997; *Setario-Echinochloëtum colonum* A. et O. Bolòs, 1956; *Panico-Setarion* Sissingh in Westhoff et al., 1946; *Papaveretea rhoeadis* S. Brullo et al., 2001; *Salicion albae* Soó, 1951; *Setario ambiguae-Cyperetum rotundi* Brullo et al., 2001; *Setario glaucae-Echinochloëtum colonum* A. & O. Bolòs ex O. Bolòs, 1956.

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## Appendixes

### Appendix I – Sporadic species in Table 1

- Rel. 4: *Geranium molle* (+), *Potentilla reptans* (+).  
 Rel. 7: *Sonchus asper* subsp. *asper* (r).  
 Rel. 8: *Amaranthus hybridus* subsp. *hybridus* (+), *Medicago arabica* (r), *Raphanus raphanistrum* s.l. (r).  
 Rel. 10: *Malva neglecta* (r).  
 Rel. 12: *Bunias erucago* (r), *Coleostephus myconis* (+), *Helminthotheca echioides* (r), *Lolium multiflorum* (+), *Lotus hispidus* (r), *Lysimachia foemina* (r), *Trifolium arvense* subsp. *arvense* (+).  
 Rel. 15: *Chrozophora tinctoria* (+), *Cichorium intybus* (r).

### Appendix II – Date, location, and coordinates (Decimal Degrees) of the relevés in Table 1

- Rel. 1: 2019/07/15, Supremo farm, Atina (FR), 41.616843 N, 13.8143009 E.  
 Rel. 2: 2019/07/15, Supremo farm, Atina (FR), 41.6166946 N, 13.8146228 E.  
 Rel. 3: 2019/07/15, Supremo farm, Atina (FR), 41.6241718 N, 13.832592 E.  
 Rel. 4: 2019/07/15, Supremo farm, Atina (FR), 41.6248214 N, 13.8335791 E.  
 Rel. 5: 2019/07/15, Supremo farm, Atina (FR), 41.6245088 N, 13.8340714 E.  
 Rel. 6: 2019/07/15, Di Palma Basilio farm, Atina (FR), 41.6247842 N, 13.8354823 E.  
 Rel. 7: 2019/07/15, Di Palma Basilio farm, Atina (FR), 41.6252718 N, 13.8353528 E.  
 Rel. 8: 2019/07/15, Supremo farm, Atina (FR), 41.6161071 N, 13.8147192 E.  
 Rel. 9: 2019/07/15, Supremo farm, Atina (FR), 41.6164056 N, 13.8203945 E.  
 Rel. 10: 2019/07/17, Il Ponte farm, Pontecorvo (FR), 41.439898 N, 13.6668126 E.  
 Rel. 11: 2019/07/17, Il Ponte farm, Pontecorvo (FR), 41.4400749 N, 13.6669481 E.  
 Rel. 12: 2019/07/17, Il Ponte farm, Pontecorvo (FR), 41.440061 N, 13.6669818 E.  
 Rel. 13: 2019/07/17, Peperdop farm, Pontecorvo (FR), 41.4536843 N, 13.6610711 E.  
 Rel. 14: 2019/07/17, Peperdop farm, Pontecorvo (FR), 41.4535878 N, 13.6608404 E.  
 Rel. 15: 2019/07/17, Peperdop farm, Pontecorvo (FR), 41.4530913 N, 13.6607519 E.  
 Rel. 16: 2019/07/17, Il Ponte farm, Pontecorvo (FR), 41.4406832 N, 13.66496 E.



# The potentiality of Sentinel-2 to assess the effect of fire events on Mediterranean mountain vegetation

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## Abstract

Wildfires are currently one of the most important environmental problems, as they cause disturbance in ecosystems generating environmental, economic and social costs. The Sentinel-2 from Copernicus Program (Sentinel satellites) offers a great tool for post-fire monitoring. The main objective of this study is to evaluate the potential of Sentinel-2 in a peculiar mountainous landscape by measuring and identifying the burned areas and monitor the short-term response of the vegetation in different 'burn severity' classes. A Sentinel-2 dataset was created, and pre-processing operations were performed. Relativized Burn Ratio (RBR) was calculated to identify 'burn scar' and discriminate the 'burn severity' classes. A two-year monitoring was carried out with areas identified based on different severity classes, using Normalized Difference Vegetation Index (NDVI) to investigate the short-term vegetation dynamics of the burned habitats; habitats refer to Annex I of the European Directive 92/43/EEC. The study area is located in 'Campo Imperatore' within the Gran Sasso – Monti della Laga National Park (central Italy). The first important result was the identification and quantification of the area affected by fire. The RBR allowed us to identify even the less damaged habitats with high accuracy. The survey highlighted the importance of these Open-source tools for qualitative and quantitative evaluation of fires and the short-term assessment of vegetation recovery dynamics. The information gathered by this type of monitoring can be used by decision-makers both for emergency management and for possible environmental restoration of the burned areas.

## Keywords

burn severity classes, NDVI, post-fire, satellite remote sensing, short-term vegetation monitoring

## Introduction

Wildfires are currently one of the most important environmental problems as they cause disturbances in ecosystems generating environmental, economic and social costs (Vianna-Soto et al. 2017). In recent years, Geographic Information System (GIS) techniques are more and more used for biodiversity conservation and human impact issues (Dominy and Duncan 2002; Foody 2008; Iannella et al. 2016, 2019a; D'Alessandro et al. 2018; Di Musciano et al. 2020), and revealed interesting results especially when coupled with ecological modelling (Santos et al. 2006; Iannella et al. 2018; Cerasoli et al. 2019; Iannella et al. 2019b; Lepcha et al. 2019) and remote sensing applications (Kerr and Ostrovsky 2003; Pettorelli et al. 2014, 2016; Wang and Gamon 2019).

Remote sensing has been used to monitor active fires and burned areas at the global and national scale (Giglio et al. 1999; Alonso-Canas and Chuvieco 2015; de Carvalho Júnior et al. 2015). Sensors like Advanced Very High-Resolution Radiometer (AVHRR), Moderate Resolution Imaging Spectroradiometer (MODIS), and Medium Resolution Imaging Spectrometer (MERIS) with spatial resolutions between 300 m and 1 km are generally used for these purposes (Mouillot et al. 2014).

Their daily revisit cycle is useful to capture active fire signatures or burn scars, however, the relatively coarse spatial resolution causes underestimations in case of burned area small extent. Comparisons between different burned area products generally show high variation in results (Padilla et al. 2015). A higher resolution of

open source satellite image might strongly increase the estimation accuracy of burned area and the associated severity classes.

Satellite remote sensing (SRS) is ideal for monitoring burned areas, especially for large and remote places. Among the available satellites, the Copernicus Program (Sentinel satellites) offers a great tool for post-fire monitoring, both for the great spatial and temporal resolution, and for the accessibility of the data completely open source (Malenovsky et al. 2012).

For burned areas detecting, optical satellite data from Multi Spectral Instrument (MSI) on Sentinel-2 (S2), starting from 2015, have a potential five-day temporal resolution (when the two satellites are operational) and have a spatial resolution of 10 m. S2 carries a multispectral sensor with 13 bands, from 0.443 to 2.190  $\mu\text{m}$ . The visible RGB and the NIR bands are available at a 10 m spatial resolution, highly suitable for application in vegetation canopies. Four red-edge bands at 20 m spatial resolution are also available and are particularly suited for chlorophyll content analysis and to parametrize ecophysiological largescale models (Puletti et al. 2017). These features make S2 suitable for evaluating the unique fire events on the Apennines due to the relatively small extension of the burned areas or their configuration.

In the European context, the year 2017 was a record season for fires, especially in Italy for the amounts of hectares burned (Battipaglia et al. 2017; Frate et al. 2018). In summer 2017, the Abruzzo region (Italy) was strongly affected by fires, even of considerable size.

Fire is a frequent disturbance and a dominant factor in the evolution and ecology of Mediterranean areas (Schaffhauser et al. 2012; Tessler et al. 2015). For this reason, Mediterranean-type ecosystems are generally resilient to forest fire, mainly owing to the high proportion of plant species adapted to fires (Naveh et al. 1990). Post-fire plant species composition tends to revert to pre-fire composition through auto-succession or direct regeneration (Hanes 1971).

Nevertheless, these fires affected in some cases montane and subalpine regions where the plant communities are not adapted to this phenomenon, leading to net changes in the affected natural communities (Harvey et al. 2016). Moreover, montane species and ecosystems are also threatened by climate change (Brunetti et al. 2019). These communities are extremely important for the ecosystem services they provide and are characterized by a great heterogeneity of species showing different functional traits (Di Musciano et al. 2018).

In this paper we use the S2 satellite imagery, whose data can be freely downloaded from the Open Access Hub of the European Space Agency (ESA) for burned area monitoring purposes, as well as for searching approaches to study the effects of fire on vegetation (Verhegghen et al. 2016).

The aims of this study are i) to evaluate the potential of S2 to detect and quantify the burn scars and ii) to monitor the short-term vegetation dynamics in different 'burn severity' classes.

This approach was tested in the southern sector of the Gran Sasso massif (Abruzzo, central Italy) where wildfire events recently occurred. Moreover, to assess the short-term dynamics of vegetation recovery in the different habitat types (with reference to the Annex I of the European Directive 92/43/EEC; European Commission 2013) of montane and subalpine ecosystems, vegetation monitoring through S2 satellites was carried out. Furthermore, this study also investigated the response of Annex I habitat types to fire, a topic poorly present in the literature.

## Materials and methods

### Study areas

The study area is 'Fonte della Vetica' (Centroid coordinates: 42°24'56.44"N; 13°45'30.07"E), in the 'Campo Imperatore' upland plain falling within the Gran Sasso – Monti della Laga National Park in central Italy (Figure 1). The research focused on the habitats of the Annex I of the European "Habitats" Directive (92/43/EEC and subsequent amendments; <http://vnr.unipg.it/habitat/>).

The study area was chosen for the importance of its floristic (Conti and Bartolucci 2016) and vegetational (Biondi et al. 1999) biodiversity. Furthermore, the area falls within a Special Protection Area (SPA) (Birds Directive, 79/409/EEC and further updates) and in a Site of Community Interest (SCI) (Habitat Directive, 92/43/EEC). It is one of the largest upland plains in Italy, the largest in the Italian Apennines (Gratani et al. 1999), immediately next to the 'Corno Grande' peak, the highest in the Apennines (2912 m a.s.l.).

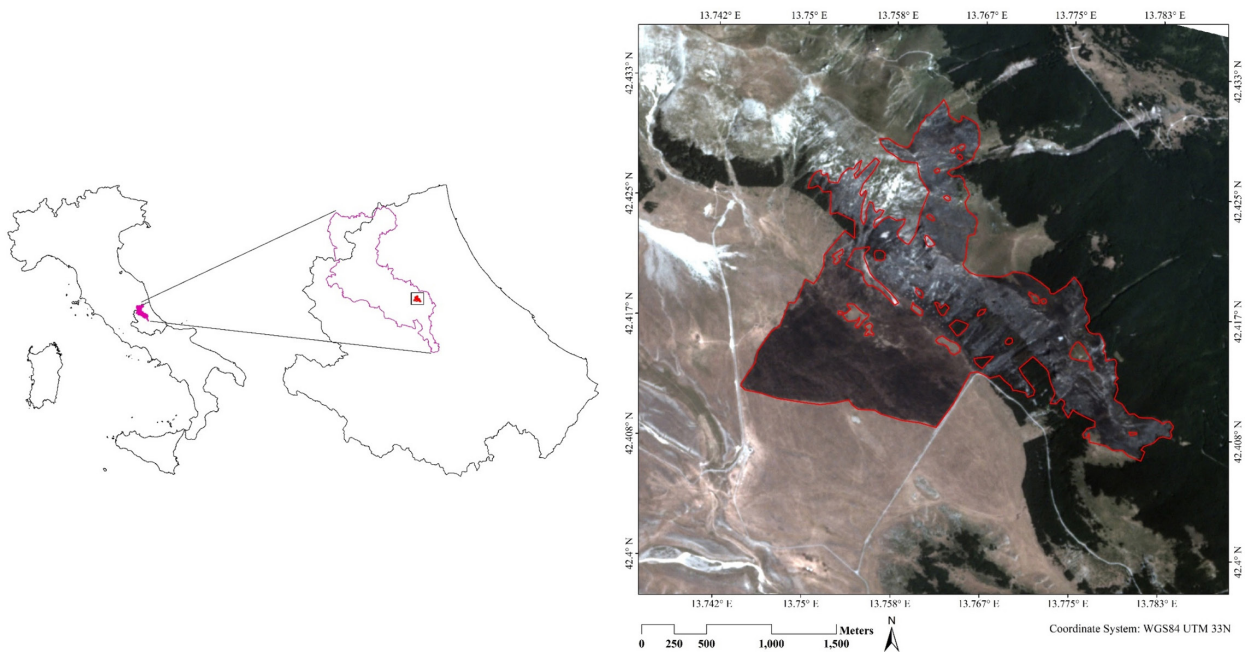
An accidental fire triggered by anthropogenic causes, which occurred between 5 and 9 August 2017, has devastated several important plant communities and left huge burned areas which represent the object of the present study.

### Dataset and pre-processing

We analysed six images from S2 satellite (Spatial resolution: 10 m, Radiometric resolution: 12 bit) acquired by ESA's Open Access (<https://scihub.copernicus.eu>), with a time interval between July ÷ October 2017 and 2018, listed in the Appendix: Table A1.

In order to build the dataset, the aforementioned Level 1C (TOA – Top of Atmosphere reflectance) images were chosen based on the low cloud cover percentage and pre-processed for atmospheric correction (Szantoi and Strobl 2019) with the Sen2Cor (Louis et al. 2016) plugin (SNAP software – Sentinel-2 Toolbox) provided by ESA. Following the atmospheric correction, we obtained the Level 2A (BOA – Bottom of Atmosphere reflectance) that is more useful than TOA reflectance when trying to detect a process on the surface such as a fire event, because the atmospheric effects caused by the event itself are reduced (Zhuravleva et al. 2017). Subsequently, a water-cloud mask was created by calculating the Normalized Difference Water Index (NDWI)





**Figure 1.** Map of the study area. Burned scar framed through Planet Scope image of 10 August 2017. Fire area perimeters are marked in red.

(McFeeters 1996) and applied to the multispectral indices (Relativized Burn Ratio – RBR and Normalized Difference Vegetation Index – NDVI) to correct possible biases caused by phenomena not directly related to fire's effects.

### Detection of burned areas

The detection of burned areas was carried out by Relativized Burn Ratio index (RBR) (Parks et al. 2014), which allows the discrimination of the burned surface by severity classes (Moderate-Low, Moderate-High and High severity) on the basis of multitemporal raster (Spatial resolution: 10 m) of the pre- and post-fire situation, through a specific discrete class threshold proposed by the United States Geological Survey (Key and Benson 2006) (Figure 2).

The RBR was chosen because of its reliability in situations where the pre-combustion biomass is low or very variable and heterogeneous (Morgan et al. 2014).

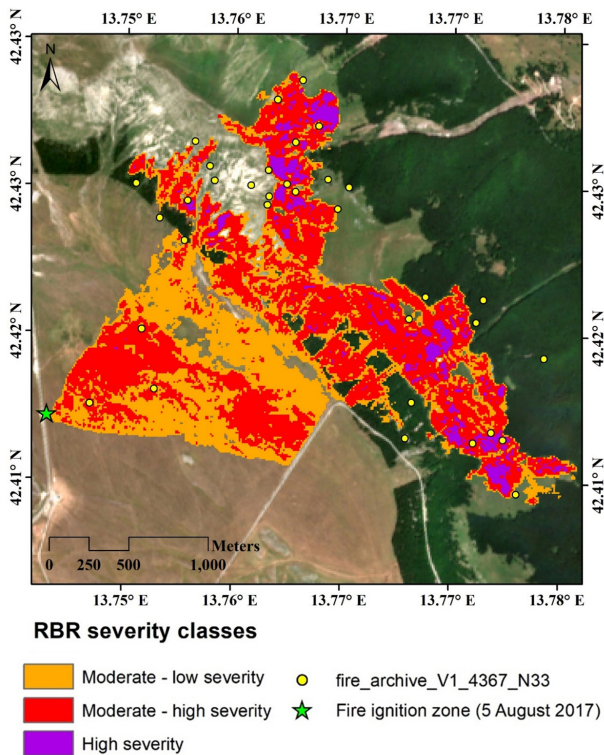
The RBR is a relativized version of the Delta Normalized Burn Ratio (dNBR:  $NBR_{prefire} - NBR_{postfire}$ ) (Key and Benson 2006). Fire-affected areas have relatively low near-infrared reflectance (NIR) and high reflectance in the short-wave infrared band (SWIR). A high NBR value generally indicates healthy vegetation; on the contrary a low value indicates bare soil and recently burned areas (Prodan and Racetin 2019). To evaluate the accuracy of the RBR, considering that the index was assessed through ground field surveys and Visible Infrared Imaging Radiometer Suite (VIIRS, spatial resolution = 375 m) provided by the Fire Information for Resource Management System (FIRMS) (Davies et al. 2008), we further verified its accuracy by performing a random forest (RF)

classification using the RStoolbox (Leutner et al. 2017) package in R environment. The 'superClass' function was used for the classification process, by keeping 80% of the data for training the model and the remaining 20% for validation; further, the Overall accuracy and Kappa statistics (Congalton and Green 2019) were obtained through the same function.

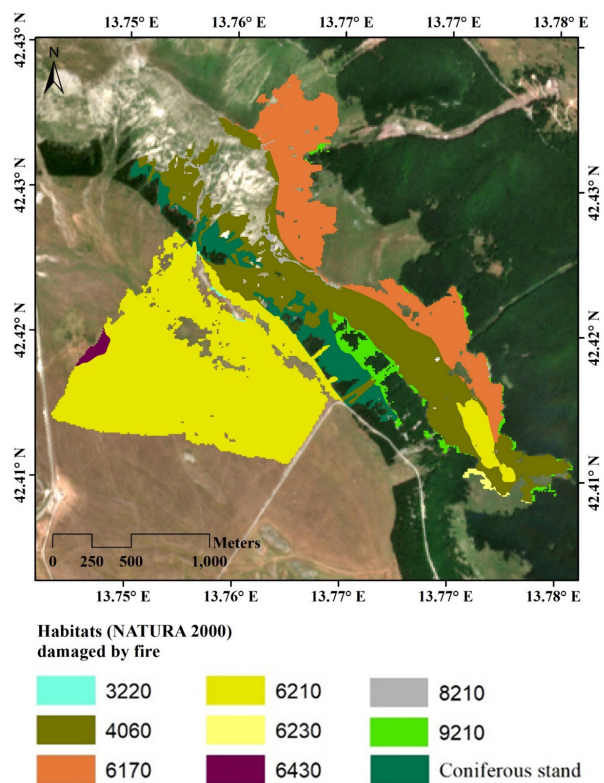
### Vegetation monitoring

After the identification of the study area, rasters were manipulated in GIS (QGIS 3.4.5, QGIS Development Team 2016) and R (RStudio) (R Core Team 2016) environments to calculate the NDVI (Rouse 1974; Cherki and Gmira 2013; Addabbo et al. 2016; Viana-Soto et al. 2017). The NDVI is estimated as the normalized difference between the near infrared (NIR) and visible red (RED) bands, which discriminate vegetation from other surfaces based on the chlorophyll absorption of the green vegetation of the red light for the photosynthesis and reflection of NIR wavelengths (Tucker 1978). The index was calculated within three-time intervals: pre-fire, immediately after the event and two months later. Furthermore, the NDVI was calculated in a period of two years (2017 and 2018) to compare the different situations into the burned areas, considering the vegetation seasonality (e.g. August 2017 vs August 2018, etc.). The resulting rasters were further clipped based on the area identified by RBR and intersected with the land cover map 'Map of Nature of Parco Nazionale Gran Sasso and Monti della Laga' (Bagnaia et al. 2015) (Figure 3).

The NDVI was discretized into 10 classes with values ranging from 0 (0.0 to 0.1) to 10 (0.9 to 1.0), with 10 rep-



**Figure 2.** Relativized Burn Ratio (RBR) for the study area. The index has been discretized in three ‘burn severity’ classes (Moderate-Low, Moderate-High and High severity). The validation points (VIIRS) are marked in yellow, while the point where the 2017 fire was triggered is indicated with green star.



**Figure 3.** Annex I Habitats burned by the fire of 2017 in the study area. The numerical codes refer to the nomenclature used to identify the Annex I habitats (<http://vnr.unipg.it/habitat/>, see also Table 1).

representing the highest photosynthetic activity (Klisch and Atzberger 2016).

Resulting NDVI raster maps were processed through zonal statistics for each type of Annex I habitats affected within each severity class of the RBR (Graser 2016). The seasonality among the years 2017 and 2018 was not considered because of the summer dry period in the study area. Indeed, even considering the wettest season, usually the grasslands became dry at the beginning of July, while for the other vegetation types we could assume that they are not strongly affected by seasonality.

To make the analysis comparable with an undisturbed situation, we built a 500 m buffer around the burned area. The control area (“Unburned control area”) was defined based on the presence of the same Annex I habitats identified in the burned area. Furthermore, the buffer was built based on the occurrence of similar topographical conditions. The approach used in this study is shown in the workflow in Figure 4.

## Result

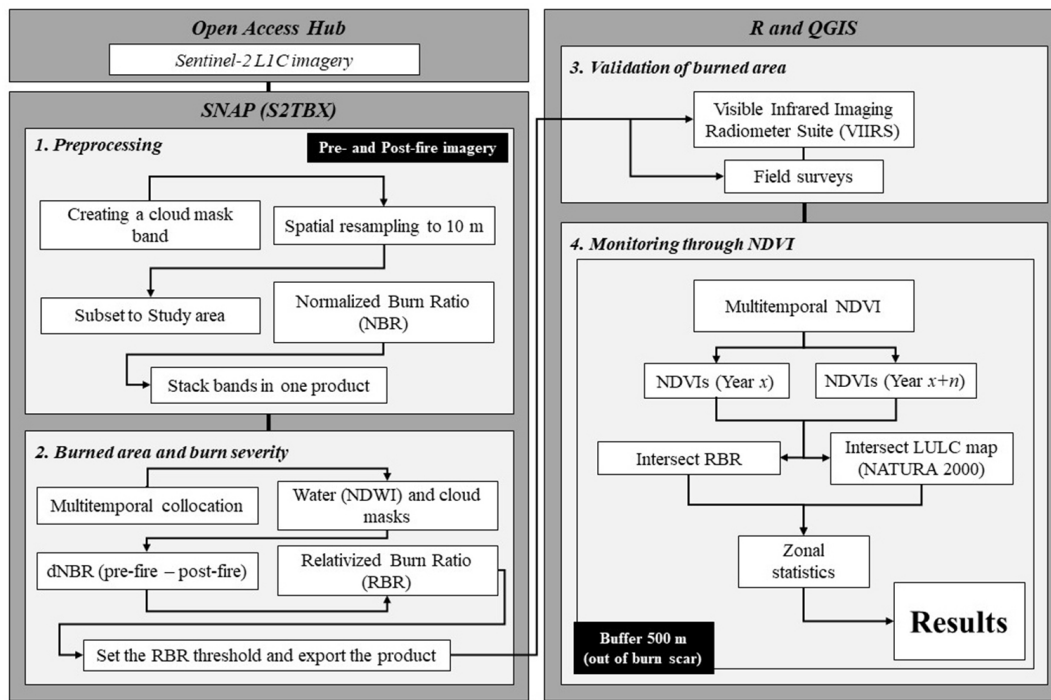
### Detection of burned area

The area affected by the fire was identified by the Relativized Burn Ratio index. The RF model used to validate the RBR index showed a high degree of classification accuracy with an Overall accuracy of 83% and a Kappa of 77% (Appendix: Table A2). The total area affected by the 2017 fire results in 311.3 hectares. The vegetation types affected by fire can be referred to the followed Annex I habitats: “Alpine rivers and the herbaceous vegetation along their banks” (3220), “Alpine and boreal heaths” (4060), “Alpine and subalpine calcareous grasslands” (6170), “Semi-natural dry grasslands and scrubland facies on calcareous substrates” (6210\*), “Species-rich *Nardus* grasslands, on siliceous substrates in mountain areas” (6230\*), “Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels” (6430), “Calcareous rocky slopes with chasmophytic vegetation” (8210), “Apennine beech forests with *Taxus* and *Ilex*” (9210\*), as well as several hectares of coniferous stands (Table 1). The pre- and post-fire imagery provided rapid, qualitative and quantitative indications of the areas affected by fire. For each habitat within each ‘burn severity’ class the NDVI zonal statistics are reported (Table 2).

The habitats more threatened by the wildfire resulted to be the grasslands at low altitude (~1,500 meters) covering 45.2% of the total area, the shrublands at medium altitude (~1,600 meters, 25.08%), the grasslands at high altitude (>1,700 meters, 18.78%), the coniferous stands (6.76%) and the beech forests (2.62%).

### Vegetation monitoring

A strong trend resulted from the multi-temporal analysis of NDVI, above all in the grasslands vegetation.



**Figure 4.** Simplified workflow. Scheme of the procedure for the identification and monitoring of the areas burned by S2 data.

**Table 1.** EU Annex I codes of the habitat types present in the study area, with relative description (with asterisk the priority habitats; European Commission 2013).

HABITAT CODE	DESCRIPTION
3220	Alpine rivers and the herbaceous vegetation along their banks
4060	Alpine and Boreal heaths
6170	Alpine and subalpine calcareous grasslands
6210*	Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (*important orchid sites)
6230*	Species-rich <i>Nardus</i> grasslands, on siliceous substrates in mountain areas and submountain areas, in Continental Europe
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
8210	Calcareous rocky slopes with chasmophytic vegetation
9210*	Apennine beech forests with <i>Taxus</i> and <i>Ilex</i>

The month of July 2017 (pre-fire) was taken as reference for a ‘no disturbed area’. The NDVI values resulted in an average of 6.65 for the grasslands (habitats 6170, 6210\* and 6230\*), 7.75 for the forests (habitat 9210\* and Coniferous stands), and 6.35 for the shrublands (habitat 4060).

In the months following the fire event, the NDVI values were in clear decline, especially immediately after the event (August 2017), showing average values of 3.50 for the grasslands, 4.23 for the forests, and 2.88 for the shrublands.

Interestingly, in October 2017, only two months after the event, an increase in NDVI values was observed. In particular, the grasslands showed high average values (NDVI = 5.10), unlike the shrubland and forest habitats.

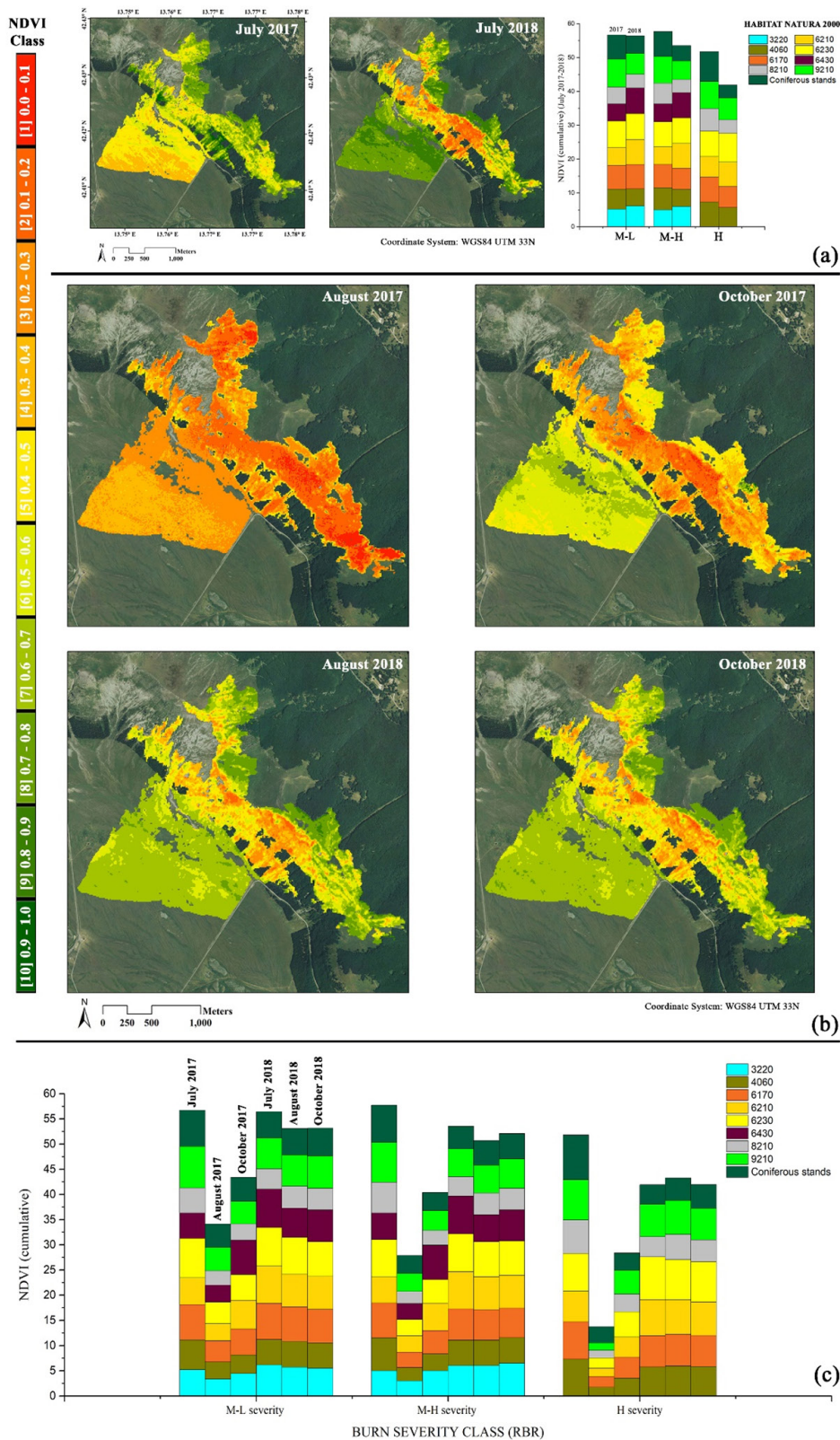
The monitoring for the year 2018 showed other interesting values. In particular, the grasslands at low and high elevation (habitats 6170\*, 6210\*, 6230\*, 6430) revealed an average value of NDVI = 7.27 for the month of July, and ~ 6.50 for the months of August and October.

In the same year, the forest habitat and the conifer stands also showed increasing values. All these trends are shown in Figure 5 and in Table 2.

The NDVI values (Table 2) within the three ‘burn severity’ classes show a very similar trend in the Moderate-Low and Moderate-High severity classes, that occupy respectively 42.24% and 51.03% of the total area. Instead, the High severity class (6.72% of the total burn scar) reveals a more resilient response to the extreme event with values that rise more rapidly towards stability. The com-

**Table 2.** Zonal statistics for each Annex I habitat affected by fire within each severity class of the RBR (Relativized Burn Ratio). The NDVI values was discretized into 10 classes with values ranging from 0 (0.0 to 0.1) to 10 (0.9 to 1), with 10 representing the highest photosynthetic activity. The numerical codes of the habitats correspond to: Alpine rivers and the herbaceous vegetation along their banks (3220), Alpine and Boreal heaths (4060), Alpine and subalpine calcareous grasslands (6170), Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (\*important orchid sites) (6210\*), Species-rich *Nardus* grasslands, on siliceous substrates in mountain areas and submountain areas, in Continental Europe (6230\*), Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels (6430), Calcareous rocky slopes with chasmophytic vegetation (8210), Apennine beech forests with *Taxus* and *Ilex* (9210\*).

NDVI AVERAGE VALUES WITHIN HABITAT NATURA 2000										
BURN SEVERITY CLASS (RBR)	3220	4060	6170	6210	6230	6430	8210	9210	Coniferous stands	Total
Moderate-low severity [1]	5.20	5.95	6.98	5.32	7.82	5.06	4.97	8.27	7.16	6.42
Moderate-high severity [2]	5.00	6.54	6.90	5.16	7.44	5.29	6.09	7.89	7.42	6.57
High severity [3]		7.32	7.39	6.06	7.50		6.67	8.00	8.86	7.40
Total Burned	5.19	6.35	7.01	5.26	7.67	5.12	5.39	8.16	7.33	6.55
Total Unburned (buffer 500m)	4.00	5.30	6.61	5.23	7.06	5.10	4.38	7.90	7.56	6.17
NDVI AVERAGE VALUES WITHIN HABITAT NATURA 2000										
BURN SEVERITY CLASS (RBR)	3220	4060	6170	6210	6230	6430	8210	9210	Coniferous stands	Total
Moderate-low severity [1]	3.38	3.38	4.16	3.42	4.27	3.40	2.85	4.66	4.62	3.87
Moderate-high severity [2]	3.00	2.64	3.07	3.24	3.23	3.18	2.40	3.56	3.56	3.05
High severity [3]		1.75	2.09	1.69	2.00		1.50	1.50	3.21	2.00
Total Burned	3.33	2.88	3.40	3.32	3.77	3.32	2.69	4.31	4.15	3.39
Total Unburned (buffer 500m)	3.17	4.97	6.09	4.34	6.52	3.20	4.36	7.63	7.02	6.16
NDVI AVERAGE VALUES WITHIN HABITAT NATURA 2000										
BURN SEVERITY CLASS (RBR)	3220	4060	6170	6210	6230	6430	8210	9210	Coniferous stands	Total
Moderate-low severity [1]	4.46	3.69	5.14	5.66	5.12	6.85	3.22	4.47	4.79	4.62
Moderate-high severity [2]	5.00	3.34	4.63	5.45	4.69	6.83	2.91	3.94	3.58	4.11
High severity [3]		3.53	4.19	4.00	5.00		3.50	4.75	3.43	3.84
Total Burned	4.48	3.52	4.77	5.55	4.98	6.85	3.12	4.33	4.26	4.34
Total Unburned (buffer 500m)	4.09	4.90	6.03	5.27	5.74	5.06	4.57	6.59	7.12	5.85
NDVI AVERAGE VALUES WITHIN HABITAT NATURA 2000										
BURN SEVERITY CLASS (RBR)	3220	4060	6170	6210	6230	6430	8210	9210	Coniferous stands	Total
Moderate-low severity [1]	6.17	5.05	7.15	7.38	7.69	7.60	4.04	6.16	5.21	5.98
Moderate-high severity [2]	6.00	5.10	6.20	7.34	7.54	7.50	3.84	5.50	4.55	5.67
High severity [3]		5.73	6.20	7.18	8.50		4.00	6.50	3.80	5.96
Total Burned	6.15	5.16	6.50	7.35	7.65	7.57	3.97	5.99	4.86	5.84
Total Unburned (buffer 500m)	5.67	5.78	7.37	6.86	7.48	6.18	5.08	8.24	6.54	6.71
NDVI AVERAGE VALUES WITHIN HABITAT NATURA 2000										
BURN SEVERITY CLASS (RBR)	3220	4060	6170	6210	6230	6430	8210	9210	Coniferous stands	Total
Moderate-low severity [1]	5.70	5.14	6.85	6.48	7.30	5.81	4.37	6.17	5.28	5.80
Moderate-high severity [2]	6.00	5.12	6.00	6.54	6.94	5.38	4.31	5.56	4.84	5.52
High severity [3]		5.94	6.26	6.86	8.00		5.00	6.75	4.47	6.05
Total Burned	5.75	5.23	6.36	6.52	7.19	5.67	4.36	6.02	5.06	5.70
Total Unburned (buffer 500m)	5.56	5.60	6.77	6.07	7.00	5.32	5.14	6.96	6.46	6.06
NDVI AVERAGE VALUES WITHIN HABITAT NATURA 2000										
BURN SEVERITY CLASS (RBR)	3220	4060	6170	6210	6230	6430	8210	9210	Coniferous stands	Total
Moderate-low severity [1]	5.48	5.06	6.67	6.54	6.86	6.33	4.28	6.45	5.49	5.80
Moderate-high severity [2]	6.50	5.08	5.85	6.52	6.82	6.17	4.28	5.85	5.03	5.48
High severity [3]		5.86	6.13	6.67	8.00		4.33	6.25	4.76	5.95
Total Burned	5.57	5.16	6.22	6.54	6.87	6.29	4.28	6.28	5.27	5.67
Total Unburned (buffer 500m)	5.22	5.53	6.71	6.15	7.13	5.75	4.94	8.61	6.85	6.55



**Figure 5.** NDVI trends in the burned area and cumulative areas shared by habitats threatened by fire. (a) Monthly comparison in two years of monitoring (July 2017 and July 2018). (b) Comparison of NDVI discrete maps for the monitored months (August 2017, October 2017, August 2018 and October 2018). (c) NDVI average trends in all the monitored months, within the ‘burn severity’ classes (M-L= Moderate-Low severity; M-H = Moderate-High severity; H = High severity). The different colors of the cumulative columns represent the Annex I habitats threatened by fire in the study area.

parison between the Unburned control area and the Total burned area resulted in a clear trend: 1) all plant communities followed their normal phenological cycle in the area not affected by the fire, showing similar NDVI values over time; 2) in the burned area, a decrease of NDVI values can be observed after the fire event; the index rises again in the following months, although it never reaches the original values again. All these trends, including those of the most damaged habitats mentioned above, are shown in Figure 6.

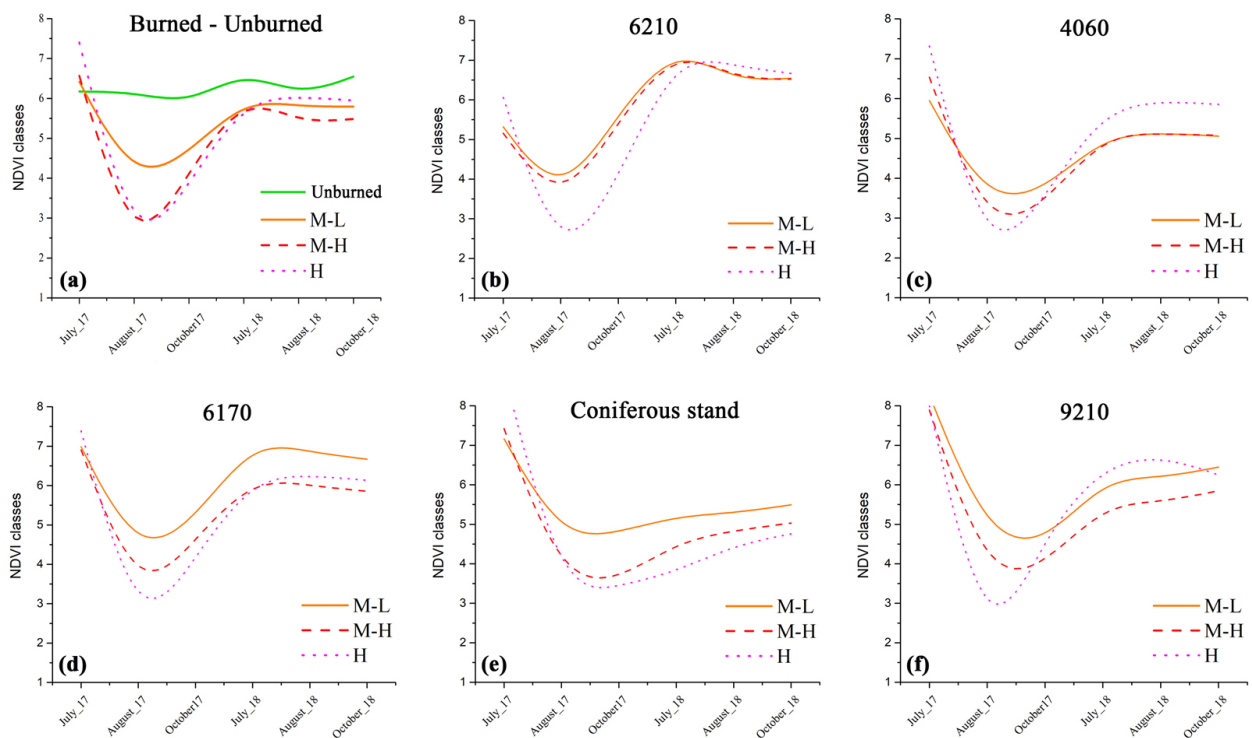
## Discussion

Fire is an important disturbance process in many ecosystems, e.g. Mediterranean ecosystems (Keeley et al. 2011), but its intensity and frequency are altered by humans in many areas as a result of land use change (Bucini and Lambin 2002) or, as in the present study, of an accidental fire. Multispectral sensors have been used to monitor active fire, map burned area, or quantify fuel availability and flammability (Herawati et al. 2015).

The study area was well suited for testing the potentiality of the S2 data to obtain the specific spectral indices used for vegetation monitoring (RBR and NDVI). Moreover, it allowed the investigation of the short-term dynamics of vegetation recovery, even verifying in the field the satellite-collected data (pers. obs.).

This study identified and characterized the burned areas at medium-high resolution, taking advantage of the spectral and temporal characteristics of the MSI S2 data. The large temporal resolution of these data (5 days) allowed a very precise use of the RBR index, as described above, based on pre- and post-fire imagery. This index, calculated at the spatial resolutions we used, allowed the identification of burn scars with great rigor. It also enabled us to discretize the burned area into severity classes and allowed to carry out both an exploratory analysis of the most affected areas and a more thorough investigation using the NDVI.

The analysis conducted within the ‘severity classes’ using the NDVI showed a clear pattern of similarity of the less severe ones, which showed relatively regular trends in values. On the other hand, a faster increase was found in



**Figure 6.** NDVI trends of the total burned and unburned area, and within ‘burn severity’ classes, in the threatened habitats. ‘Burn severity’ classes: M-L = Moderate-Low Severity (orange solid line); M-H = Moderate-High Severity (red dash line); H = High Severity (violet dotted line). (a) NDVI average trends of unburned areas in a 500 meters buffer around the burned scar (green solid line), and ‘burn severity’ classes (M-L, M-H, H) for the total threatened area. The other graphs represent the NDVI average trends within the ‘burn severity’ classes for different Annex I habitats plus coniferous stands: (b) 6210\* (Semi-natural dry grasslands and scrubland facies on calcareous substrates), (c) 4060 (Alpine and boreal heaths), (d) 6170 (Alpine and subalpine calcareous grasslands), (e) coniferous stands, (f) 9210\* (Apennine beech forests with *Taxus* and *Ilex*). The habitats 6230\* [Species-rich *Nardus* grasslands, on siliceous substrates in mountain areas (and sub-mountain areas, in Continental Europe)], 6430 (Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels) and 8210 (Calcareous rocky slopes with chasmophytic vegetation) are not included because of the limited extent of their patches.

the higher class, confirming a greater resilience at highly burned sites (Coop et al. 2016).

Results show that the most affected habitats are the grasslands (6170, 6210, 6230, 6430) and shrublands (4060). As far as the former are concerned, the analysis lead to interesting results, showing how the herbaceous vegetation, even in montane and sub-alpine environments, can rapidly recover, similarly to the Mediterranean communities. This might also (partly) be due to a rapid vegetation recovery in the first two years after the fire, becoming more gradual in the following years (Petropoulos et al. 2014).

However, extreme events, such as fires, can have very important effects on the structure and composition of grasslands (Venn et al. 2016). In the study area, a collapse of the vegetation cover just after the event was observed, followed by a recovery that favored the abundance of graminoids species with a large seed bank, as reported by Buma (2012).

Shrublands were damaged for a quarter of the total area. These communities are mainly constituted by common juniper (*Juniperus communis* L.). Our results are in line with Quevedo et al. (2007), who reported less resilient communities with poorer regeneration capacities, a result comparable to ours obtained by NDVI monitoring approach.

The coniferous forests in the study area are characterized by mixed reforestations with European silver fir (*Abies alba* Mill.), European spruce [*Picea abies* (L.) H. Karst.], European larch (*Larix decidua* Mill.) and Austrian pine (*Pinus nigra* J.E. Arnold). They represent less than 10% of the entire study area. The scarcity of active maintenance over the years made these woods very susceptible to fire, given the quantity of combustible material in the undergrowth (Moreira et al. 2009). In addition to their poor regenerative capacity (Catry et al. 2010), in the study area these plantations grow on steep slopes, which probably determines a slower recolonization.

The last habitat affected by the fire of 2017 was the beech forest (9210), representing less than 3% of the burn scar. Beech forests are not very resilient to the passage of the fire, because of the low seed vitality after such events. Interestingly, a positive trend was observed in the NDVI index values, accounting for a good regenerative capacity, due to the development of the herbaceous undergrowth species present in the seed bank. In fact, the fertile soil of beech woods can facilitate the development of herbaceous vegetation (and therefore an increase in its photosynthesis index) in the period following the fire (Ascoli et al. 2013). These species take advantage of better light and moisture conditions (Maringer et al. 2012; Gratani et al. 2018). The increase in NDVI values in burned beech patches may be partly due to the ‘edge effect’ with the nearby beech forest not affected by fire. This effect was not considered in our study, but it appears to be the least significant with respect to the surface coverage of the vegetation (competition) and the mature trees which survived the post-fire (seed sources), followed for importance by topographical factors (Fang et al. 2019). The high values of NDVI in wooded areas could also be due to errors in the index, which saturates when dealing with high density of vege-

tation; furthermore, its application is hindered in dense and structurally complex vegetation complexes (Quang et al. 2019). Despite the aforementioned disadvantages, the NDVI was here used because the affected forest area, compared to the other habitat types, covered little extent.

Satellite remotely sensed data and analyses have been widely applied in both conservation science and practice, but there are limitations to the information they can provide. In this study, the spatial resolution of S2 sensors allowed the identification of short-term trends in the photosynthetic activity of the different plant communities after the fire event, and a very accurate study of the vegetational dynamics in progress. On the other hand, in order to obtain more accurate information regarding individual populations or single species, there is a need for satellite data with a very high spatial resolution (VHR, usually commercial) that have a relatively high cost, depending on the purpose and the request (Marvin et al. 2016).

The field sampling effort for monitoring an area of this size requires considerable monetary and human resources. The use of SRS not only reduces the field work but also facilitates possible actions to restore the area interested (Dey et al. 2018). Furthermore, the use of ancillary data obtained through ‘crowdsourcing’ (Citizen science) might facilitate and/or further reduce field surveys by allowing analysis at ever larger and more accurate scales (Hufkens et al. 2019).

The use of satellite remote sensing for vegetation monitoring has allowed to observe the situation from a different perspective, compared to the classic field surveys. Through this methodology, it was possible to carry out a high resolution multitemporal analysis.

This study provided a rapid and effective monitoring of the conditions of various plant communities, including a quantification of damage and tendency to short-term recover. Furthermore, with the applied methodology it was possible to detect and quantify different burn severity classes, allowing an even more extensive study of the vegetation recovery dynamics. This approach can also make field work more efficient by focusing sampling efforts on certain areas, in order to implement specific environmental recovery measures for damaged habitats at a relatively low cost.

The proposed approach provides useful management information for fire prevention in protected areas, planning monitoring activities and implementing functional rehabilitation actions for habitats affected by these disturbing events.

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## Appendix

**Table A1.** Satellite images used for the analysis.

Satellite Instrument	Acquisition date	Product types	Pre/Post Fire
Sentinel-2 MSI	20.07.2017	Level-1C	PRE
Sentinel-2 MSI	29.08.2017	Level-1C	POST
Sentinel-2 MSI	28.10.2017	Level-1C	POST
Sentinel-2 MSI	10.07.2018	Level-1C	POST
Sentinel-2 MSI	29.08.2018	Level-1C	POST
Sentinel-2 MSI	13.10.2018	Level-1C	POST
Planet Scope MSI	10.08.2017	Level 1B	POST

**Table A2.** Accuracy statistics. Classification accuracy (%) for the index classification when applied to the validation dataset. Training data consisted of a random sample (80%) of the full dataset and validation was conducted on the remaining data.

Overall Statistics				
	Accuracy: 0.8333	Kappa: 0.7778		
	95% CI: (0.3588, 0.9958)	P-Value [Acc > NIR]: 0.01783		
	No Information Rate: 0.3333			
Statistics by Class:				
	Class: 1	Class: 2	Class: 3	Class: 4
Sensitivity	0.5000	10.000	10.000	10.000
Specificity	10.000	10.000	10.000	0.8000
Pos Pred Value	10.000	10.000	10.000	0.5000
Neg Pred Value	0.8000	10.000	10.000	10.000
Prevalence	0.3333	0.3333	0.1667	0.1667
Detection Rate	0.1667	0.3333	0.1667	0.1667
Detection Prevalence	0.1667	0.3333	0.1667	0.3333
Balanced Accuracy	0.7500	10.000	10.000	0.9000



# First report of fasciation symptom in *Artemisia eriantha* (Asteraceae), a typical orophyte of high-altitude cliffs, in Central Apennines (Italy)

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## Abstract

*Artemisia eriantha* Ten., also known as "Apennines genepi", is a valuable aromatic plant with several medicinal properties. Among the several phytoplasma symptoms to which this plant can be subjected, the fasciation is one of the less reported and studied. In natural environments this plant is a characteristic species of the association *Artemisietum erianthae* Brullo 1984. In this study, the first occurrence of fasciation in *Artemisia eriantha* is described. This phenomenon was observed during the *ex vitro* experimental cultivations, located in Assergi and Barisciano (L'Aquila, Italy), settled for the restocking of this endangered species. The fasciation occurred only in Assergi experimental field with a magnitude of 0.12%. Specific PCR analysis did not show the phytoplasma presence. This first report allows to expand knowledge about fasciation in Apennines genepi.

## Keywords

Apennines genepi, *Artemisietum erianthae*, Gran Sasso Monti della Laga National Park, *Macrosiphoniella artemisiae*, micropropagation, restocking, stem fasciation

## Introduction

*Artemisia eriantha* Ten. [syn. *A. umbelliformis* Lam. ssp. *eriantha* (Ten.) Vallès-Xirau and Brañas (Asteraceae)], known as "Apennines genepi", is a small plant of Central Italy showing 10-15 cm stems, bipinnate or tripinnate leaves, petioles and silvery-white trichomes. In natural environments its flowering period is in summer, and the flowers are yellow and organized in flower heads, arranged along the stem to form a spike (Abad et al. 2012). Regarding phytosociological aspects, *A. eriantha* is a characteristic species of the association *Artemisietum erianthae* Brullo 1984. The latter was described by Brullo (1984) in the high-altitude cliffs of Majella and Gran Sasso d'Italia, located above 2,200 m a.s.l. In view of the extremely precarious environmental conditions, this is a highly specialised cenosis. The author framed the association in the alliance *Saxifragion australis* Biondi and Ballelli ex Brullo 1984 [order *Potentilletalia caulescentis* Br.-Bl. in Br.-Bl.

and Jenny 1926, class *Asplenietea trichomanis* (Br.-Bl. in Meier and Br.-Bl. 1934) Oberdorfer 1977]. This alliance brings together casmophytic and comophytic communities of the calcareous and dolomitic rocks. These communities develop in Temperate Macrobioclimate -in the thermotypes from Supratemperate to Superior orotemperate, sometimes with descents in the Mesotemperate in humid and fresh conditions (limestone gorges)- and in the Mediterranean Macrobioclimate -in the Supramediterranean to Oromediterranean thermotypes. It is widespread in the Central and Southern Apennines and in Eastern Sicily and can be considered, in these sectors, the vicariant of *Potentillion caulescentis* Br.-Bl. in Br.-Bl. and Jenny 1926 of Central Europe, Alps and Northern Apennines (Biondi et al. 2014). Biondi et al. (2000) indicate the species as the differential taxon of the subassociation *artemisietosum erianthae* Biondi, Allegrezza, Ballelli and Taffetani 2000 of the association *Caricetum kitaibelianaerupestris* Biondi, Allegrezza, Ballelli and Taffetani 2000, described by

the Authors for the Corno Grande of Gran Sasso d'Italia and belonging to the *Seslerion apenninae* alliance Bruno and Furnari 1966 (order *Seslerietalia tenuifoliae* Horvat 1930, class *Festuco-Seslerietea* Barbero and Bonin 1969). The association corresponds to a typical edafo-xerophilous formation in catenal connection with the *Elyna myosuroides*-dominated vegetation [*Elyna myosuroides* (Vill.) Fritsch, now *Carex myosuroides* Vill.], the so-called "elineti". This type of vegetation constitutes the Apenninic vicariant of *Caricetum rupestris* Pignatti and Pignatti 1984 of the Italian Dolomites (Pignatti and Pignatti 1985). The subassociation describes the communities established on the microterraces and microdepressions of the northern rocky crests.

*A. eriantha* is also present, sporadically or with low cover values, in other vegetation types of high altitude, for example, in the associations *Saxifrago speciosae-Silenetum caenisiae* Petriccione 1993, found on Sibillini (Costanzo et al. 2009); *Potentillo apenninae-Festucetum alfrediana* Blasi, Di Pietro, Fortini and Catonica 2003 (*Saxifragion australis* Biondi and Ballelli ex Brullo 1984) found on Gran Sasso (Blasi et al. 2003); and *Saxifrago speciosae-Papavertum julici* Feoli Chiapella and Feoli 1977 found on Majella (Blasi et al. 2005).

This aromatic plant produces oils with a complex terpenoid profile, rich in sesquiterpenes and several compounds and whose content increases with the plant age (D'Andrea et al. 2003; Reale et al. 2011; Reale et al. 2014). For wild and micropropagated plants of this species the thujones have been recorded as major constituents (60–85%), with the predominance of the  $\alpha$  isomer (Pace et al. 2010). Beyond its strong scent, exploited as flavouring agent, Apennines genepi is well-known for its medicinal properties. Its namesake liqueur and infusions, in fact, are utilized in traditional medicine for their thermogenic properties and are recommended to counteract airways infections, weakness and indigestion (Appendino et al. 1982; Mucciarelli and Maffei 2002; Simonnet et al. 2006; Rubiolo et al. 2009; Maggio et al. 2012; Vouillamoz et al. 2015).

Like other medicinal and aromatic plants, Apennines genepi can be affected by several symptoms. Among them, fasciation is one of the most interesting phenomena, in fact, it is distinct from other kinds of deformity (Choob and Sinyushin 2012). It may arise because of (i) genetic mutations, with a progeny that inherits the changed phenotype (Samineni et al. 2008; Iliev and Kitin 2011; Onda et al. 2011) or (ii) in response to abiotic (e.g. cytokinins, herbicides, photoperiod, radiations - Thimann and Sachs 1966; Jambhulkar 2002; Chriqui 2008; Bondada 2011) and biotic (e.g. *Rhodococcus fascians*, *Candidatus Phytoplasma* spp. or other pathogenic bacteria - Battikhi 2002; Putnam and Miller 2007; Bertaccini and Duduk 2009; Wu et al. 2012; Akhtar et al. 2013; Pavlovic et al. 2013; Yu et al. 2016; Gahukar 2018) factors, not transmitting this altered state to their progeny.

Fasciation is very common in species belonging to several families (e.g. Asteraceae, Rosaceae, Ranunculaceae, Liliaceae, Euphorbiaceae, Crassulaceae, Fabaceae, Ona-

graceae and Cactaceae – White 1948; Binggeli 1990; Kumar et al. 2010), however, many interesting features of fasciation development still have no explanations (Iliev and Kitin 2011). In addition, information about the frequency of this phenomenon is also very limited and many reports on fasciated plants do not describe the inducing agent.

In the study area, cultivation practices of Apennines genepi have been proposed to restock this endangered species and to offer the local populations the opportunity to promote economic activities in high altitude areas, whilst preserving their local habits and traditions (Pace et al. 2010; Di Cecco et al. 2017; Chelli et al. 2019). In this study we describe a fasciation in Apennines genepi propagated *in vitro* and transplanted in experimental fields.

## Materials and methods

### Plant material and micropropagation

*In vitro* Apennines genepi plantlets and tissue cultures were obtained from seeds collected on Monte Portella 2500 m asl (*Gran Sasso Monti della Laga* National Park) in August 2013 (Fig.1a). Seed surface sterilization and *in vitro* germination were obtained according to the method previously described in Pace et al. (2004). Rooted plantlets were transferred to soil and kept in a greenhouse as previously described (Pace et al. 2020) before being transplanted to the experimental fields.

### Experimental fields

In spring 2014 about 10.000 clones were obtained by *in vitro* propagation and at the end of May they were transplanted in two experimental fields located at Barisciano (AQ) and Assergi (AQ) in the *Gran Sasso Monti della Laga* National Park. The main features of selected sites are detailed in Table 1 (soil pH, potassium, phosphorus, and nitrogen were measured according to standard methods by an external laboratory).

### Plant fasciation

At the end of May 2015, the adult plants were mapped and collected; during the samplings twelve fasciated plants were discovered at Assergi experimental field, randomly spread throughout the field. The plants were observed and photographed then were brought in laboratory. After that the width of the stems just below the fasciated heads was measured and the number of flower heads was counted. Two sample T-test was used to evaluate whether there was a significant difference between fasciated and non-fasciated plants with "Past3" software for experimental field of Assergi. Some plants were dried, others were cryopre-

**Table 1.** Features of field sites of *Artemisia eriantha*.

Parameter	Barisciano (AQ)	Assergi (AQ) San Pietro Camarda
Altitude (m)	1170	1200
Geographical coordinates	42°20'25"N, 13°34'14"E (DMS)	42°26'30"N, 13°28'19"E (DMS)
Fertilization	None	None
Previous cultivation	uncultured	<i>Solanum tuberosum</i>
Soil pH	8.35	8.35
P (g/kg)	6	9.478
N	1.65	2.16
K	6	9.47

served at  $-80^{\circ}\text{C}$  and were used for nucleic acid extraction (Prince et al. 1993) for phytoplasma detection by PCR amplification using nested system with primers amplifying the 16S ribosomal gene (Gundersen and Lee 1996).

### Aphids identification

Some specimens of nymphs and adults of aphids observed in mid May 2015 at Assergi experimental field, were collected in plastic bags and brought to the laboratory. According to the current preparation method for aphids (Blackman and Eastop 2000) they were identified by specialists to species level.

## Results

*A. eriantha* specimens did not show any abnormality during micropropagation process. Although transplanted clones exhibited a high morphological plasticity, with different sizes of rosette and various number of shoots, they were morphologically identical in the two experimental fields ( $p > 0.05$ ). In 2015 spring, the flowering was exceptionally abundant up to 16 flower-heads for rosette (Fig. 1b).

Except for mineral contents, soil analysis did not show differences between the two experimental fields. The highest mineral content was recorded for Assergi field and was due to the previous cultivation with *Solanum tuberosum* L. (Table 1).

In Table 2 the biometrical parameters (i.e. number of flower heads and width of stems) are reported, recorded for the twelve fasciated (Fig.1c) and normal plants collected from Assergi experimental field and both fields, respectively. As shown, the fasciated plants had significantly higher mean number of flower heads ( $p < 0.001$ ) than those counted on the normal plants. The width of the stems was also significantly higher in fasciated plants ( $p < 0.001$ ) than those reported for the normal ones.

The nested PCR tests carried out on nucleic acid extracted from symptomatic materials provided negative results for phytoplasma presence.

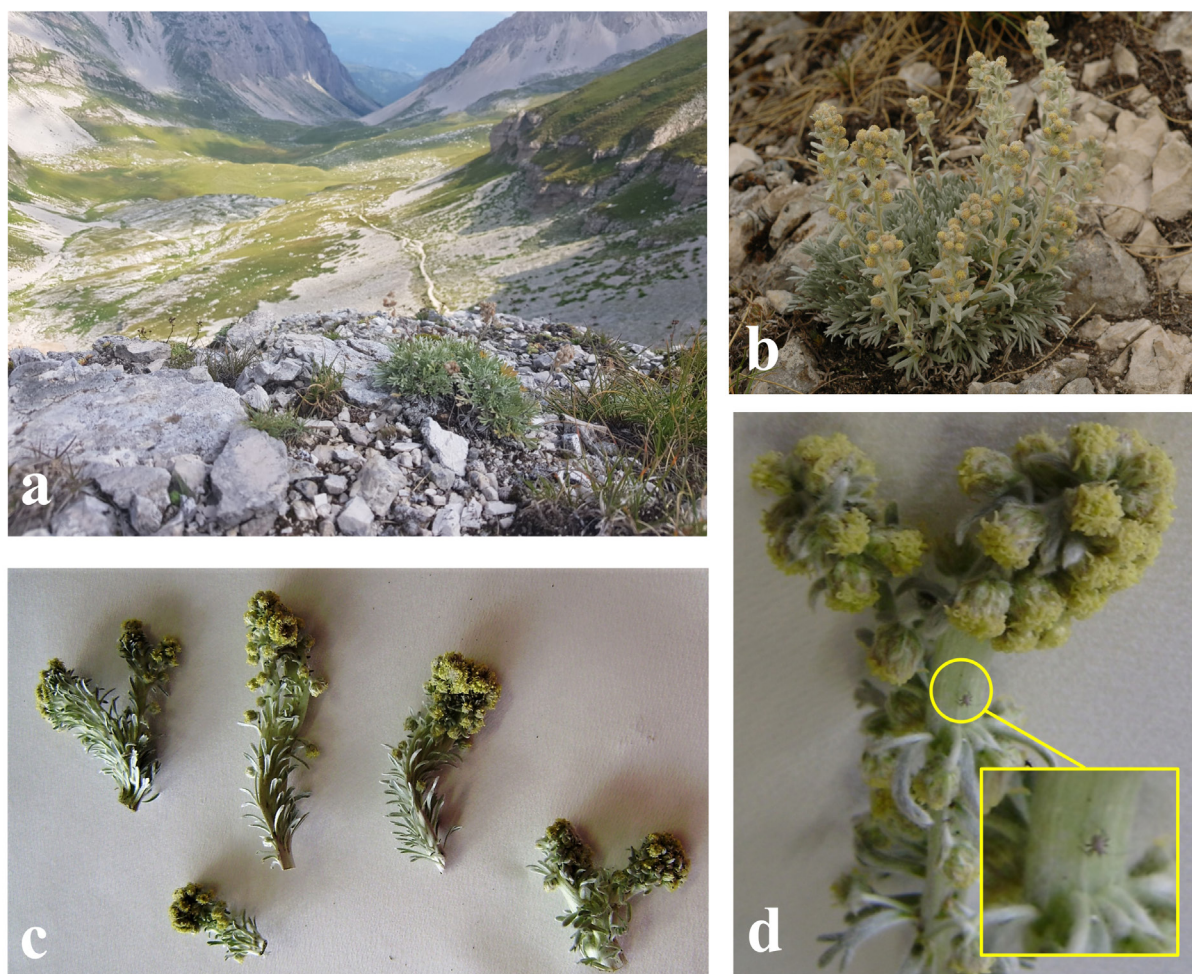
The occurrence of aphids was observed only on upper parts of Apennines genepi of Assergi experimental field. The infestation was observed especially between inflores-

cences, and both adults and nymphs were found (Fig.1d). The identification allowed to establish that aphids (Fig.1d) belong to the species *Macrosiphoniella artemisiae* (Boyer de Fonscolombe 1841). It is a Palearctic species widespread from North Africa and Europe to Siberia, Mongolia, and China, which was accidentally introduced to North America (Blackman and Eastop 2007). Very common in Italy on *Artemisia vulgaris* (typical feeding plant for this aphid), it is found among the inflorescences as large colonies (Barbagallo et al. 2011, Barbagallo and Cocuzza 2014). It can occasionally be found also on *Leucanthemum vulgare*, *Tanacetum parthenium* and other species of *Artemisia* (Mifsud et al. 2011).

## Discussion

As stated before, the biotic factors can have an inducing ability on fasciation arising (Battikhi 2002; Bertaccini and Duduk 2009; Wu et al. 2012; Akhtar et al. 2013; Pavlovic et al. 2013; Yu et al. 2016). PCR analysis did not show the presence of phytoplasma, thus, in the current study fasciation is not associated with the presence of these pleomorphic bacteria. On the contrary, the presence of *M. artemisiae* was observed only on upper parts of Apennines genepi of Assergi experimental field. The presence of *M. artemisiae* on *A. eriantha* is reported for the first time in this study; however, this phenomenon cannot be correlated to fasciation of plants. The aphids, in fact, were also found on plants without symptoms of the same field. The crop previously cultivated on Assergi experimental field was *Solanum tuberosum*, and Avila et al. (2014) reported the presence of this aphid species on potatoes cultivations. Thus, we cannot exclude that the presence of the aphid on Apennines genepi can derive from an unappropriated field management strategy, that left this infestation on the field.

Fasciation was noted only in the field of Assergi. Both the fields were transplanted with plantlets derived from clones obtained from several seeds. Thus, this phenomenon could result also from micropropagation process. Multiplication of plants by this technique, can induce phenotypic aberrations in *ex vitro* cultivations that were not observed during *in vitro* culturing (Shirani et al. 2009; Iliev and Kitin 2011; Chiruvella et al. 2014).



**Figure 1.** a) One of the natural stations on Gran Sasso massif. b) Rosette of *ex vitro* *Artemisia eriantha* photographed on experimental fields. c) *A. eriantha* fasciated stems and inflorescences. d) *Macrosiphoniella artemisiae* adults on fasciated plants.

**Table 2.** Biometrical parameters recorded for fasciated and normal plants of *Artemisia eriantha* (mean $\pm$ SD).

Sample	Flower heads	Width of stems
Fasciated plants	23.58 $\pm$ 7.29	7.74 $\pm$ 6.54
Normal plants	16.74 $\pm$ 5.26	1.15 $\pm$ 0.254
<i>T</i> -test	$t = 4.40; p < 0.001$	$t = 22; p < 0.001$

## Conclusions

Although micropropagation process can be a valid tool for the recovery of plants threatened by climatic change and undiscerning collection, this technique might induce phenotypic aberrations in *ex vitro* cultivations and should be for this reason used with great care. This process, together with the presence of other biotic and abiotic factors, could have induced plant fasciation in *Artemisia eriantha*. The presence of the aphid *Macrosiphoniella artemisiae* on Apennines genepi is here described for the first time and shows that careful control of aphids' infestation, by appropriate field management strategies, is important to protect the restocking of this aromatic plant.

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## Statements

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# A first checklist of the alien-dominated vegetation in Italy

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## Abstract

This study provides a first step toward the knowledge of the alien-dominated and co-dominated plant communities present in Italy. The first ever checklist of the alien phytocoenoses described or reported in literature for the Italian territory has been compiled, produced by data-mining in national and local thematic literature. The resulting vegetation-type draft-list has been checked in the light of the most recent syntaxonomic documentation and updated with regards to syntaxonomy and nomenclature, with special reference to the frame proposed in the Italian Vegetation Prodrome. The list includes 27 vascular and one bryophyte vegetation classes, hosting 194 low rank alien-dominated *syntaxa*. The different vegetation types detected for each syntaxonomic class and macro-vegetation group, defined by physiognomical and ecological attributes, are discussed.

## Keywords

biodiversity, conservation, habitat, Invasive Alien Species, phytosociology, plant communities, syntaxonomy, threats

## Introduction

Biological invasions are an ever-increasing global process arising from the intentional or accidental human-mediated introduction of species to areas outside their native range, overcoming natural dispersal mechanisms and biogeographic barriers (Richardson and Pyšek 2006; Blackburn et al. 2014; Seebens et al. 2018).

The consideration and debate on Invasive Alien Species (IAS) date back to long ago (Allan 1936; Egler 1942; Baker 1948; Elton 1958). In the last few decades, invasion science has emerged, becoming a relevant discipline of its own (Richardson et al. 2000; Richardson and Pyšek 2006; Richardson 2011), also as a consequence of the increasing rates of alien species' introductions at the global scale (Seebens et al. 2017, 2018) with no exception in Europe (DAISIE 2009) and in the Mediterranean (Hulme et al. 2008).

Biological invasions are nowadays widely recognized as an important component of human-induced global environmental change (Vitousek et al. 1997; Parmesan and Yohe 2003; Vilà et al. 2011; Vilà and Hulme 2017), being the second most common threat associated to species that underwent extinction in recent times (Bellard et al. 2016). Despite the accumulation of rigorous evidence of its importance to science and society, invasion biology has been the target of criticisms from scientists and academics who do not agree on the role of alien *taxa* as one of the greatest extinction threat at global scale (Da-

vis 2011; Richardson and Ricciardi 2013; Pearce 2015; Russell and Blackburn 2017; Ricciardi and Ryan 2018). However, it is renowned that the establishment and spread of IAS can drastically affect the native biodiversity by changing community composition, biotic interactions and other ecosystem processes (Vilà et al. 2011; Pyšek et al. 2012; Vilà and Hulme 2017), as well as by replacing it with common and widespread *taxa* (McKinney and Lockwood 1999; Hahs and McDonnell 2016), and can promote alternative successional trajectories that may dramatically affect the landscape (Williamson 1996; McKinney and Lockwood 1999; Weber 2003; Acosta et al. 2007; Del Vecchio et al. 2013; Gaertner et al. 2014; Stinca et al. 2015; Malavasi et al. 2018).

An alien organism needs to overcome geographical, environmental, and reproductive barriers to colonize a new region and spread over wide areas. In this process, some factors and traits can be more significant than others in explaining its success and therefore its invasiveness (Van Kleunen et al. 2015). Particularly, the concept of invasiveness of plant species has been integrated with that of propagule pressure and of "invasibility" of habitats and plant communities, i.e. the susceptibility of an environment to invasions by alien species, as different habitats and phytocoenoses may be more invulnerable than others and show different degrees of resistance/resilience (Rejmánek 1989; Lonsdale 1999; Rejmánek et al. 2005; Richardson and Pyšek 2006). All these concepts have been included in

the unifying theory of invasion syndromes (Perkins and Nowak 2013).

Patterns of distribution and abundance of IAS depend on a number of drivers including introduction history and pathways, life traits, availability of potentially invulnerable ecosystems, residence time, disturbance (Wilson et al. 2007; Carranza et al. 2010; Richardson et al. 2011; Comin et al. 2011; Dainese and Poldini 2012; Jucker et al. 2013). It is acknowledged that anthropogenic drivers play a crucial role in the establishment and spread of alien species (Pyšek and Richardson 2006; Pyšek et al. 2010a, 2010b; Bolpagni and Piotti 2015; Lazzaro et al. 2017; Stinca et al. 2017), however alien species showed to be largely constrained also by the same broad environmental factors acting on the native vegetation (Rouget et al. 2015). The same applies to IAS populations as well, as it has been demonstrated that what is good for natives is good for aliens too (Pyšek and Richardson 2006; Dalle Fratte et al. 2019).

Vascular plants are the most investigated taxonomic group in the field of invasive biology, and Europe devoted great efforts to their study, being the second continent (after North America) for investigative endeavour on plant invasions (Pyšek et al. 2009; Early et al. 2016). However, in spite of a huge scientific production about alien species numbers, ecology, impacts and distribution (for a synthesis at the European level, see DAISIE 2009 and Galasso et al. 2018 for Italy), their patterns and co-occurrence dynamics have only recently started to be in the spotlight, together with the factors driving alien plant assemblages (Hui et al. 2013; Pyšek and Chytrý 2014; Rouget et al. 2015).

A number of studies addressed the key role of cover and dominance of alien species to understand the invasion patterns (Lundholm and Larson 2004; Smith et al. 2004; Crall et al. 2006; Chytrý et al. 2008, 2009; Pyšek et al. 2010a, 2010b). This seems to some extent more important than alien species number, suggesting the hypothesis that the more an alien *taxon* becomes dominant in a vegetation type, the stronger the impact on native species diversity might be. This approach gave a pulse to research on alien plant species assemblages, and recently investigations on IAS have been addressed also at the community scale and benefitted from the currently available large databases of vegetation plots (see, e.g., Dengler et al. 2011; Landucci et al. 2012; Del Vecchio et al. 2015; Chytrý et al. 2016; Sperandii et al. 2018; Bonari et al. 2019).

A study by Chytrý et al. (2008) demonstrated that the habitat type is a reliable predictor of the level of plant invasion. This paper took into account patterns of plant invasions across habitats at the European scale, suggesting precious insights for biodiversity conservation and habitat monitoring, especially when considering the acknowledged correspondence between syntaxonomic types and habitats *sensu* Dir. 92/43/EEC (European Commission 1992, 2013; Evans 2010; Biondi et al. 2012; Viciani et al. 2016). Indeed, alien species have been listed among the causes of habitat decline and loss also in the most recent

red-list assessments, both at European (Janssen et al. 2016) and Italian scale (Gigante et al. 2018).

Some authors started to qualify and quantify the role of alien species in different vegetation and habitat types, and to point out the functional role that alien species play in plant communities (Celesti-Grapow et al. 2010; Pyšek and Chytrý 2014; Prisco et al. 2016). Moreover, habitat misclassification can be favoured by the presence of alien species (Sarmati et al. 2019). However, to date only few studies focussed on alien-dominated plant communities and the role of aliens in natural assemblages. With notable exceptions (e.g. Jurko 1964; Hadač and Sofron 1980; Ubaldi 2003; Vítková and Kolbek 2010; Sirbu and Oprea 2011; Allegrezza et al. 2019), the large majority of vegetation studies, especially outside Europe, are still mostly focused on natural and semi-natural phytocoenoses with few or no aliens (Chytrý et al. 2009; Pyšek and Chytrý 2014).

Despite a long-dated Italian tradition of phytosociological studies, a national synthesis of the alien-dominated (and co-dominated) plant communities thriving in Italy has never been produced yet. Therefore, the present research aims at taking the first step toward the filling of this knowledge gap.

The European and national projects dedicated to IAS, which involved and currently still involve research academic centres and institutions, are numerous in Italy. Some of them have helped to gather a significant amount of information on invasive plant and animal species. Among the most recent, addressing non-native plant species, their impact and their management, as well as the awareness of the general public on these topics, we can mention: LIFE ASAP (<http://www.lifeasap.eu>), LIFE GESTIRE IP2020 (<http://www.naturachevale.it/il-progetto/life-gestire-2020/>), LIFE REDUNE (<http://www.liferedune.it>), MARITTIMO ALIEM (<http://interreg-maritime.eu/web/aliem>).

The present work is the result of a research agreement between SISV (the Italian Society for Vegetation Science) and ISPRA (the Italian Institute for Environmental Protection and Research), with financial support from the Italian Ministry of Environment, aimed at supporting the implementation of Regulation EU 2014/1143 (updated by EU Reg. 2017/1263) on the prevention and management of the introduction and spread of invasive alien species. In particular, the general agreement focused on: i) the update of the Database of Italian Alien Species (DIAS) with reference to their impacts on the ecosystems and the most threatened habitats and ii) the identification of the alien-dominated or co-dominated plant communities occurring in Italy. The outcomes of the latter are here presented. The research on alien plant communities and habitats was carried out through the collaboration of a wide working group of experts led by a Coordinating Committee composed by SISV members.

## Methods

A dedicated SISV working team, formed by national and local experts, collected all the thematic literature related to terrestrial and freshwater alien-dominated and co-dominated vegetation. On the basis of this bibliographic dataset, a selection of all vegetation data was carried out, with special attention to nomenclature and syntaxonomic classification. All the existing national and regional vegetation databases (e.g. LiSy – <http://www.scienzadellavegetazione.it/sisv/lisy/index.jsp>; Poldini et al. 1985; Poldini 1991, 2002, 2009; Gallizia Vuerich et al. 1999; Brullo et al. 2001; Gigante et al. 2012; Landucci et al. 2012; Evangelista et al. 2016), together with the regional bibliographic sources (e.g. Poldini 1989; Poldini and Vidali 1989; Poldini et al. 1991, 1999), were consulted. Data concerning each phytocoenosis were selected if one or more alien species played a substantial role in the analysed vegetation unit. In particular, the SISV Coordinating Committee collected and checked the information and selected the data whenever:

1. the analysed low rank *syntaxon* (association, subassociation, phytocoenon) was dominated or co-dominated by one or more alien plant species; a cover value  $\geq 3$  according to the "Braun-Blanquet" scale (Braun-Blanquet 1979) for alien species cover in each relevé has been set as threshold; if, instead of the "Braun-Blanquet" scale, the "Pignatti" scale was used in the bibliographical reference (Pignatti and Mengarda 1962), the cover value threshold was set to  $\geq 2$ , i.e. 20-40%;
2. the alien species name was included in the name of the *syntaxon*, by that implying that it is a characteristic/differential/diagnostic or somehow important *taxon* for the definition of the *syntaxon*, or even dominating and determining its vertical structure (as stated in Art. 10b of the International Code of Phytosociological Nomenclature: Theurillat et al. 2020).

Starting from this selected dataset, a draft syntaxonomic list was produced. The names of the plant communities and their syntaxonomic attributions at higher ranks have been acknowledged (and are here reported) in the same form as published by the original Authors. In case of inconsistencies or discrepancies, a specific comment has been provided.

The syntaxonomic scheme has then been updated in accordance with the Italian Vegetation Prodrôme (Biondi et al. 2014; <http://www.prodromo-vegetazione-italia.org/>), which however does not take into considerations *syntaxa* below the alliance level. Relevant differences and discrepancies with other syntaxonomic frames, especially regarding the EuroVegChecklist (Mucina et al. 2016), have been commented.

Plant nomenclature in the text follows the Checklists of the vascular flora of Italy (Bartolucci et al. 2018; Galasso et al. 2018) and later updates reported in the "Portal to the flora of Italy" ([http://dryades.units.it/floritaly/index](http://dryades.units.it/floritaly/index.php)

[php](http://dryades.units.it/floritaly/index.php)), to which we referred also to identify the species to be considered as aliens to Italy, including archaeophytes (e.g. *Arundo donax*, *Acanthus mollis* subsp. *mollis*) as well. New hybridogenic species due to xeno-speciation events (e.g. some species of *Oenothera* or *Vitis*) were taken into account, when considered as alien *taxa* by Galasso et al. (2018). In case of species considered alien to an administrative region and native to another one, only the communities reported for the region where the species is alien have been recorded (e.g.: a community dominated by *Acanthus mollis* subsp. *mollis* was considered alien to Liguria but not to Sicily, where this species is considered as native, see Minissale et al. 2019).

This process allowed to produce a first checklist of the Italian alien-dominated plant communities. On this ground, some statistics were calculated considering the number of alien vegetation units with reference to i) each resulting syntaxonomic class and ii) homogeneous groups of the resulting syntaxonomic classes, clustered according to their physiognomic and ecological characteristics.

## Results and discussion

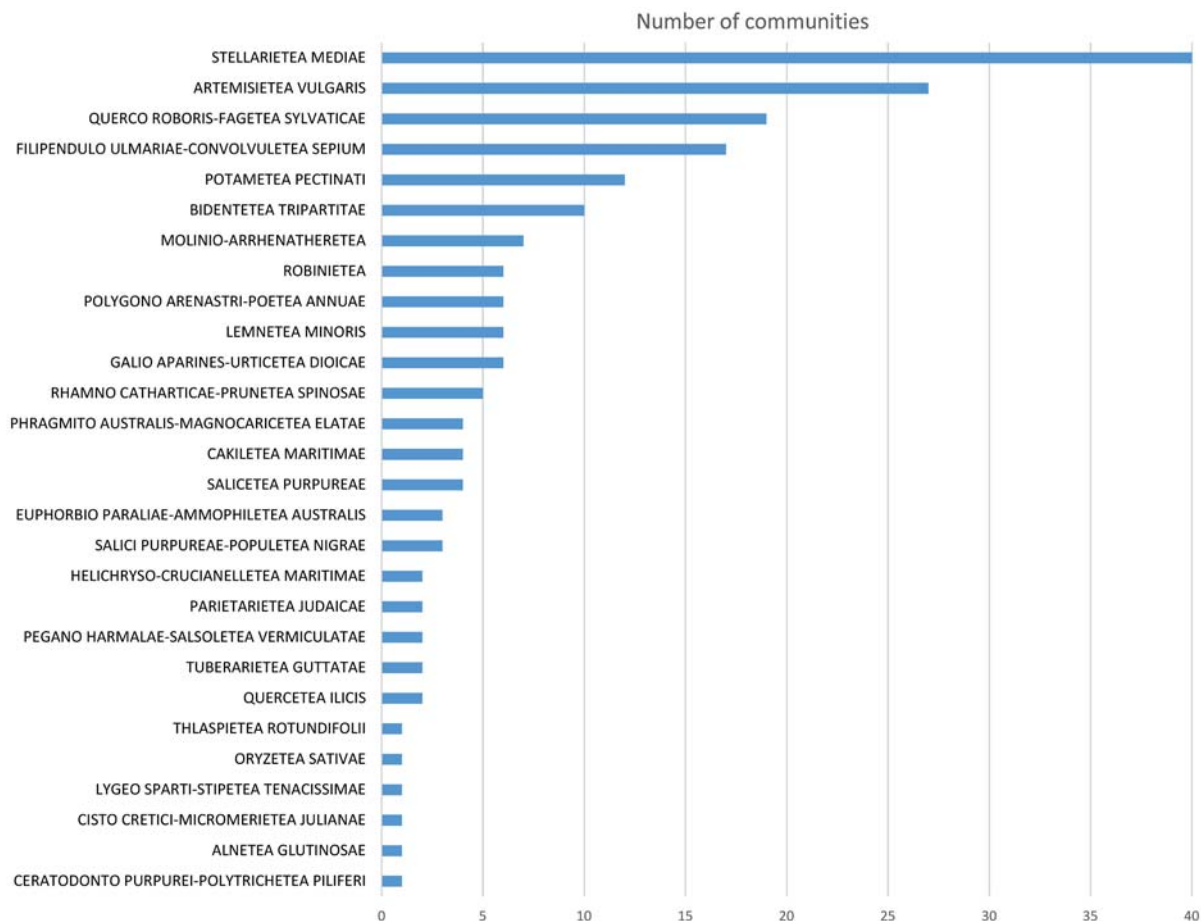
A comprehensive and annotated checklist of the alien-dominated and co-dominated plant communities occurring in Italy is provided in Appendix I. All phytocoenoses have been framed in an updated syntaxonomic scheme. A specific bibliographical list with references for all the *syntaxa* quoted in the checklist is available in Appendix II.

The checklist includes a total of 27 classes of vascular plant vegetation and one of bryophyte vegetation, including plant communities dominated or co-dominated by aliens to Italy. The total number of low rank *syntaxa* (associations/subassociations/communities) amounts to 194.

The number of communities for each class is reported in Fig. 1. As expected, the class with the highest number of alien-dominated plant communities resulted by far *Stellarietea mediae*, followed by *Artemisietea vulgaris*. The presence of some higher-rank *syntaxa* named after and mainly formed by IAS (e.g. the class *Robinietea*, the order *Nicotiano glaucae-Ricinetalia communis*) is worth to be noted, which highlights the coenological and physiognomic-structural autonomy of these communities.

The 27 identified classes and some subordinate *syntaxa* have been grouped in clusters based on their physiognomy and ecology. The considered groups are as follows:

- Forest vegetation (*Quercio-Fagetea*, *Quercetea ilicis*);
- Anthropogenic woody vegetation (*Robinietea* and part of *Rhamno-Prunetea*);
- Alluvial, marshy and riparian woody vegetation (*Alnetea*, *Salici-Populetea*, *Salicetea*, *Alnion incanae*);
- Perennial herbaceous hygrophilous and hygro-nitrophilous vegetation (*Galio-Urticetea*, *Filipendulo-Convulvuletea*, *Molinio-Arrhenatheretea*, *Phragmito-Magnocaricetea*);



**Figure 1.** Number of alien-dominated communities for each syntaxonomic class of the checklist reported in Appendix I.

- Perennial ruderal herbaceous vegetation (*Artemisietea*);
- Annual ruderal herbaceous vegetation (*Stellarietea*, *Polygono arenastri-Poetea annuae*);
- Annual herbaceous hygro-nitrophilous vegetation (*Bidentetea*);
- Hydrophitic freshwater vegetation (*Potametea*, *Lemneteae*);
- Psammophilous vegetation (*Euphorbio-Ammophiletea*, *Cakiletea*, *Helichryso-Crucianelletea*).

Results of the community rates per class groups are shown in Fig. 2. The group including the classes of annual ruderal herbaceous vegetation (*Stellarietea mediae* and *Polygono arenastri-Poetea annuae*) hosts about 25% of the total number of the detected alien-dominated communities. *Stellarietea mediae* is by definition characterized by high rates of alien plant species, especially archaeophytes (<http://www.prodromo-vegetazione-italia.org/>). However, data analysis showed that this explains only part of the story. Actually, the involved alien species and genera are mainly represented by neophytes (e.g. *Robinia pseudoacacia*, *Artemisia* sp.pl., *Amaranthus* sp.pl., *Erigeron* sp.pl., *Euphorbia* sp.pl., *Solidago* sp.pl.). Indeed, it is known that neophytes mostly occur in strongly anthropogenic areas, whose habitats appear to be not only the most invaded, but also the most invisable (Pyšek et al. 2002,

2005; Deuschewitz et al. 2003; Kühn et al. 2003; Chytrý et al. 2008). On the contrary, relatively low- or non-anthropized ecosystems, such as nutrient-poor environments or montane habitats, are least or not invaded (Chytrý et al. 2008; Angiolini et al. 2019). For these reasons, heavily human-impacted environments (i.e. arable lands and fallow fields, urban and industrial areas, aquatic and riparian habitats) show the highest levels of neophyte invasion, as already suggested by previous studies, at least in continental areas (Kowarik 1995; Walter et al. 2005; Richardson and Pyšek 2006; Chytrý et al. 2009; Myśliwy 2014) and, as a consequence, the highest number of alien-dominated plant communities (Bolpagni and Piotti 2015).

Also the coastal areas are highly impacted by IAS (Acosta et al. 2007; Carboni et al. 2010; Del Vecchio et al. 2013, 2015; Lazzaro et al. 2017). Indeed, the close connection between invasibility, propagule pressure and habitat disturbance is a widely accepted relationship (Di Castri 1990; Vitousek et al. 1997; Pino et al. 2006; Perkins and Nowak 2013). This is indirectly confirmed in this study, by the fact that many of the less represented groups of alien-dominated communities refer to scarcely invisable environments, such as screes (*Thlaspietea rotundifolii*) or Mediterranean grass-dominated vegetation (*Lygeo-Stipetea*). Unexpectedly, our data seem to suggest that psammophilous coastal vegetation experiences low rates of

alien community occurrence (Figs. 1, 2). However, to correctly interpret this outcome, it should be considered that the collected data might outline a biased picture due to a lack of syntaxonomic investigation and classification for some communities. In support of this hypothesis, it should be noted that many alien coastal communities dominated by *Yucca* sp.pl., *Agave* sp.pl., *Opuntia* sp.pl. or *Acacia* sp.pl. have been noted although not syntaxonomically described yet (Carboni et al. 2010; Santoro et al. 2012; Del Vecchio et al. 2013; Lazzaro et al. 2014, 2015, 2017; Stinca et al. 2017). Moreover, low numbers of alien-dominated communities described for a particular environment do not imply low rates of invasion, as even few IAS can spread dramatically to the detriment of native plant communities. For instance, the neo-phytocoenoses formed by just two species of *Carpobrotus* are nowadays massively distributed along the coasts of the whole Europe (Souza-Alonso et al. 2019), possibly leading to a peculiar coenological diversity which, however, has never been formalized in syntaxonomic terms yet.

Disturbance regimes are often related to fluctuation in resource availability, indicated as a key driver for invasions, in relation to the intermittent resource enrichment or release (Alpert et al. 2000; Davis et al. 2000; Richardson and Pyšek 2006). For this reason, besides strongly anthropized habitats, also aquatic and riparian ecosystems are particularly susceptible and extremely vulnerable to biological invasions and generally show high rates of alien species, due to their intrinsically medium-high levels of disturbance (Di Castri 1990; Rauchich and Reader 1999; Pyšek and Prach 1993; Alpert et al. 2000; Bolpagni 2013; Bolpagni and Piotti 2015). As it is known, alien hydrophytes often become dominant in these environments, and give rise to species-poor alien communities. This is confirmed by our results (Figs. 1, 2) where, despite the relative scarcity of ecological niches in aquatic environments, the percentage of alien hydrophytes communities is relevant (Lazzaro et al. 2019). This can have severe consequences considering that alien aquatic plants, as primary producers and often structural component of the ecosystems, can drastically transform the structure of freshwater habitats and their water quality (Valley and Bremigan 2002; Rommens et al. 2003; Perna and Burrows 2005; Ricciardi and MacIsaac 2011; Brundu et al. 2012; Brundu 2015; Ceschin et al. 2016, 2019).

Other habitats also linked to water (and to the related high levels of disturbance) show a high number of alien-dominated communities. It is the case of riparian non-woody habitats, or of annual and perennial herbaceous hygrophilous and hygro-nitrophilous vegetation types (Fig. 2), which reach high percentages (the latter more than 18%).

Also the alien communities attributed by many authors to *Quercus-Fagetum* have a prevalent mesohygrophilous character (Appendix I). The most relevant woody invasive alien species, also found in the anthropogenic neophytic woody vegetation (e.g. *Robinia pseudoacacia*, *Ailanthus altissima*, *Amorpha fruticosa*, and many others)

can be defined as “ecosystem engineers”, i.e. species that shape habitats and/or cause changes to their state and resources availability (Vitousek 1986; Schmitz et al. 1997; Jones et al. 1997; Crooks 2002; Bañnou 2009; Bañnou and Vilá 2009; Djurdjevic et al. 2011; Benesperi et al. 2012; Cierjacks et al. 2013; Vítková et al. 2017; Lazzaro et al. 2018). The replacement of native species by alien plants, even when apparently ecologically equivalent, almost always negatively affects the ecosystems, especially if those species act as “ecosystem engineers” (Brown et al. 2006; Wilson and Ricciardi 2009; Lazzaro et al. 2018; Sitzia et al. 2018; Uboni et al. 2019).

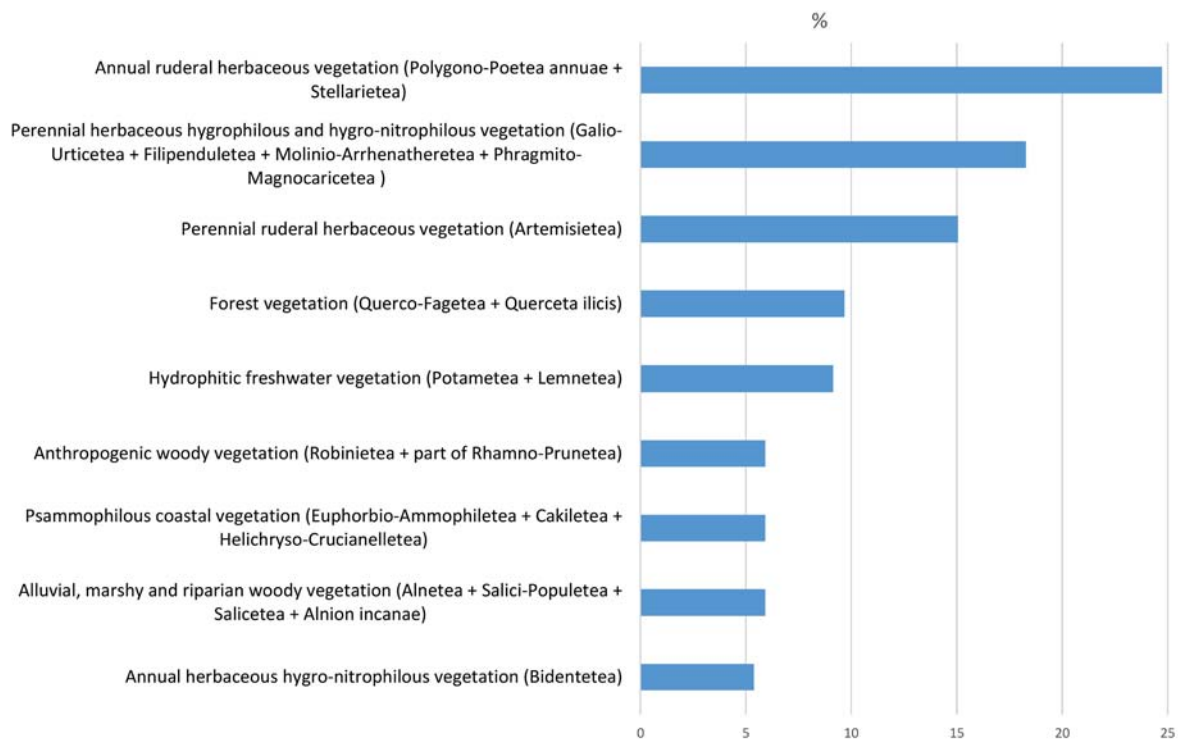
In the checklist we also recorded a bryophyte community dominated by the alien *Campylopus introflexus*, which in Europe is considered a neophytic moss, introduced from the Southern hemisphere and rapidly expanding (Hill et al. 2006). It was detected along Mediterranean ponds and neighbouring wood glades (Cogoni et al. 2002; Puglisi et al. 2016; Poponessi et al. 2016, 2018) and its distribution deserves to be monitored.

Few considerations can be made on the number of alien species involved in the communities reported in the checklist. According to Galasso et al. (2018), there are 791 non-native naturalized species in the Italian territory, 221 of which are considered invasive in at least one region. Our checklist shows that, based on the current knowledge, less than one hundred of these species (precisely 88) perform a dominant or co-dominant role in the considered plant communities. Only five of these (*Ailanthus altissima*, *Elo-dea nuttallii*, *Lagarosiphon major*, *Myriophyllum aquaticum*, *Cenchrus setaceus*) are considered IAS of Union Concern (see [https://ec.europa.eu/environment/nature/invasivealien/list/index\\_en.htm](https://ec.europa.eu/environment/nature/invasivealien/list/index_en.htm)), however this number grows considerably when downscaling at the national level, with 76 of them (i.e. more than 86% of the total) to be considered as IAS in Italy (Galasso et al. 2018). Again, this can be traced back to the fact that most of these IAS are neophytes, many have been introduced in relatively recent times, and probably there was not enough time to give rise to such a degree of invasion to be relevant at European scale yet. Additionally, also at the national scale these invasions are often very localized or at very early stages, and their study from the phytosociological point of view is still a minor topic (although emergent).

At the same time, the continuous rate of introduction-naturalisation-invasion of new alien plants is an ongoing process that should be detected just in early stages, in order to prevent serious damage to native biodiversity. The numbers here reported raise the alarm for planning conservation biodiversity studies, monitoring protocols and management activities.

## Conclusion

The here presented first checklist of the alien-dominated plant communities in Italy should not be considered exhaustive. It is the first step toward a better understanding



**Figure 2.** Percentages of alien-dominated communities in physiognomically and ecologically homogeneous groups of classes and subordinate *syn taxa*, based on the checklist reported in Appendix I.

of distribution, ecology and invasion processes of alien species at community level in this country. Our review represents a screenshot of the current knowledge and suggests that a serious lack of investigation for certain vegetation types (and probably for certain areas of the country) has to be highlighted.

The present checklist of the alien vegetation in Italy can represent a very useful tool, not only for stimulating further studies and investigations but also for prevention, management and monitoring purposes. As emphasized by Olaczek (1982), the phytosociological school, taking into account the whole floristic composition of plant communities, was one of the first approaches able to detect the effects of alien species on the diversity of natural phytocoenoses and to include these new communities in the syntaxonomical vegetation classification. In fact, the “floristic and phylogenetic homogenization” (e.g. Pino et al. 2009) and the “degeneration of phytocoenoses” by means of a progressive modification of structure and floristic composition due to the alien species invasion, concepts expressed by Olaczek (1982) and Faliński (1998a, 1998b), can transform a native plant community into an anthropogenic one, or even in a “novel ecosystem” (Lugo 2015), susceptible to be classified in a new syntaxonomic frame.

This becomes particularly important when considering the close link between plant communities syntaxonomically described and Natura 2000 habitat types, as listed in the Annex I to the Directive 92/43/EEC (European Commission 1992, 2013). It is mandatory for Member States to conserve Annex I habitats in Europe in a favourable

conservation status (Evans 2012; Gigante et al. 2016). Undoubtedly, a better understanding of the processes by which a plant community and a habitat type are firstly invaded and then dominated by alien species, together with the comprehension of the successional (and syntaxonomic) implications of those processes, can effectively support the monitoring and management of biodiversity and protected areas.

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## Appendixes

### Appendix I – Alien-dominated and co-dominated plant communities in Italy (Syntaxa authors are abbreviated according to Izco 2002)

Class	Order	Alliance	Association/Phytocoenon	Reference number in the specific bibliographical list of Supplement 1
2	LEMNETEA	MINORIS O.	Bolòs & Masclans 1955	
	2.1	LEMNETALIA	MINORIS O. Bolòs & Masclans 1955	
			<i>Lemna minuta</i> community	115
	2.1.1	Lemnion	minoris O. Bolòs & Masclans 1955	
			<i>Azollo filiculoidis</i> - <i>Lemnetum minuscolae</i> Felzines & Loiseau 1991	82, 83, 90
			<i>Ceratophyllo</i> - <i>Azolletum filiculoidis</i> Nedelcu 1967	56, 58
			<i>Lemna minuta</i> community	110
			<i>Lemnetum minuto-gibbae</i> Liberman Cruz, Pedrotti & Venanzoni 1988	56
			<i>Lemno</i> - <i>Azolletum filiculoidis</i> Br.-Bl. 1952	40, 115
3	POTAMETEA	PECTINATI	Klika in Klika & V. Novák 1941	
	3.1	POTAMETALIA	PECTINATI Koch 1926	
	3.1.1	Potamion	pectinati (Koch 1926) Libbert 1931	
			<i>Callitricho</i> - <i>Elodeetum canadensis</i> Passarge 1964 ex Passarge 1994	39
			<i>Elodea canadensis</i> and <i>Potamogeton crispus</i> community	91
			<i>Elodea nuttallii</i> community	28
			<i>Elodeo</i> - <i>Potametum crispum</i> (Pignatti 1953) Passarge 1994	40
			<i>Elodeo</i> - <i>Ranunculetum</i> Richard 1975	114
			<i>Lagarosiphon major</i> community	28
			<i>Myriophyllum aquaticum</i> community	64
			<i>Potametum crispum</i> Soó 1927 <i>Myriophyllum aquaticum</i> variant	64
			<i>Potametum lucentis</i> Hueck 1931 <i>Lagarosiphon major</i> variant	116
	3.1.2	Nymphaeion	albae Oberdorfer 1957	
			<i>Hydrocotyletum ranunculoidis</i> Corbetta & Lorenzoni 1976	42

Class	Order	Alliance	Association/Phytocoenon	Reference number in the specific bibliographical list of Supplement 1
		3.1.3	<b>Ranunculion aquatilis</b> Passarge 1964	
			<i>Callitriche stagnalis</i> and <i>Myriophyllum aquaticum</i> community	64
			<i>Lemno-Callitrichetum cophocarpae</i> (Mierwald 1988) Passarge 1992 <i>Myriophyllum aquaticum</i> variant	64
12	BIDENTETEA	TRIPARTITAE	Tüxen, Lohmeyer & Preising ex Von Rochow 1951	
	12.1	<i>BIDENTETALIA</i>	<i>TRIPARTITAE</i> Br.-Bl. & Tüxen ex Klika in Klika & Hadac 1944	
		12.1.1	<b>Bidention tripartitae</b> Nordhagen 1940	
			<i>Bidens frondosus</i> community	57
			<i>Bidenti-Polygonetum mitis</i> (Von Rochow 1951) Tüxen 1979 <i>Bidens frondosa</i> variant	126
			<i>Bidenti-Polygonetum mitis</i> (Von Rochow 1951) Tüxen 1979 <i>echinochloetosum crus-galli</i> Baldoni & Biondi 1993	15
			<i>Polygonetum hydropiperis</i> Passarge 1965 <i>Bidens frondosus</i> facies	61
			<i>Xanthio italicum-Polygonetum persicariae</i> O. Bolòs 1957	61, 60
			<i>Xanthio italicum-Persicarietum maculosae</i> O. Bolòs 1957 nom. mut. propos. <i>Abutilon theophrasti</i> variant	59
			<i>Xanthium orientale</i> subsp. <i>italicum</i> community	46
		12.1.2	<b>Chenopodion rubri</b> (Tüxen 1960) Hilbig & Jage 1972	
			<i>Cyperetum esculenti</i> Wisskirchen 1995	62
			<i>Polygono-Xanthietum italicum</i> Pirola & Rossetti 1974	1, 7, 13, 20, 29, 38, 43, 44, 46, 53, 55, 63, 68, 70, 75, 76, 81, 92, 94, 95
			<i>Polygono-Xanthietum italicum</i> Pirola & Rossetti 1974 <i>Ambrosia artemisiifolia</i> variant	4
16	PHRAGMITO	AUSTRALIS-MAGNOCARICETEA	ELATAE Klika in Klika & V. Novák 1941	
	16.1	<i>PHRAGMITETALIA</i>	<i>AUSTRALIS</i> Koch 1926	
		16.1.1	<b>Phragmition communis</b> Koch 1926	
			<i>Scirpetum maritimi</i> (Christiansen 1934) Tüxen 1937 <i>Paspalum distichum</i> variant	60
	16.3	<i>MAGNOCARICETALIA</i>	<i>ELATAE</i> Pignatti 1953	
		16.3.1	<b>Magnocaricion elatae</b> Koch 1926	
			<i>Cyperus eragrostis</i> community	16
			<i>Cyperus glomeratus</i> community	43
	16.5	<i>NASTURTIO OFFICINALIS-GLYCERIETALIA</i>	<i>FLUITANTIS</i> Pignatti 1953	
		16.5.1	<b>Glycerio fluitantis-Sparganion neglecti</b> Br.-Bl. & Sissingh in Boer 1942	
			<i>Eleocharitetum palustris</i> Schennikov 1919 <i>paspaletosum paspaloidis</i> Biondi et al. 2002	25
20	EUPHORBIO	PARALIAE-AMMOPHILETEA	AUSTRALIS Géhu & Rivas-Martínez in Rivas-Martínez, Asensi, Díaz-Garretas, Molero, Valle, Cano, Costa & T.E. Díaz 2011	
	20.1	<i>AMMOPHILETALIA</i>	<i>AUSTRALIS</i> Br.-Bl. 1933	
		20.1.1	<b>Ammophilion australis</b> Br.-Bl. 1933 em. Géhu & Géhu-Franck 1988	
			<i>Carpobrotus acinaciformis</i> community	88

Class	Order	Alliance	Association/Phytocoenon	Reference number in the specific bibliographical list of Supplement 1
			<i>Carpobrotus edulis</i> community	88
			<i>Xanthietum-Ammophiletum</i> Pignatti 1953	91
21	CAKILETEA MARITIMAE	Tüxen & Preising ex Br.-Bl. & Tüxen 1952		
	21.1	EUPHORBIETALIA PEPLIS Tüxen 1950		
		21.1.1 Euphorbion peplis Tüxen 1950		
			<i>Cakilo-Xanthietum italici</i> Pignatti 1953	1, 9, 12, 38, 91, 93
			<i>Salsolo kali-Cakiletum maritimae</i> Costa et Mansanet 1981 corr. Rivas-Martínez et al. 1992	17, 24, 48, 70, 91, 106
			<i>xanthietosum</i> (Pignatti 1953) Géhu & Scoppola 1984	
			<i>Xanthio italici-Cenchretum incerti</i> Biondi, Brugiapaglia, Allegrezza & Ballelli 1992	24, 100, 109
			<i>Xanthio italici-Cenchretum longispini</i> Poldini et al. 1999	100, 106
22	HELICHRYSO-CRUCIANELLETEA MARITIMAE	(Sissingh 1974) Géhu, Rivas-Martínez & Tüxen 1973 em. Sissingh 1974		
	22.1	HELICHRYSO-CRUCIANELLETALIA MARITIMAE Géhu, Rivas-Martínez & Tüxen 1973 em. Sissingh 1974		
		22.1.1 Crucianellion maritimae Rivas Goday & Rivas-Martínez 1958		
			<i>Crucianello-Helichrysetum microphylli</i> Bartolo, Brullo, De Marco, Dinelli, Signorello & Spampinato 1992 <i>Carpobrotus acinaciformis</i> variant	125
			<i>Ephedro-Helichrysetum microphylli</i> Valsecchi & Bagella 1991 <i>Carpobrotus acinaciformis</i> variant	125
31	PARIETARIETEA JUDAICAE	Oberdorfer 1977		
	31.1	TORTULO-CYMBALARIETALIA Segal 1969		
		31.1.1 Parietarion judaicae Segal 1969		
			<i>Cheiranthetum cheirii</i> Segal 1962	46
			<i>Erigeronetum karvinskiani</i> Oberdorfer 1969	46, 54, 70
33	THLASPIETEA ROTUNDIFOLII	Br.-Bl. 1948		
	33.6	EPILOBIETALIA FLEISCHERI Moor 1958		
			<i>Oenothera biennis</i> and <i>Scrophularia canina</i> community	114
34	ARTEMISIETEA VULGARIS	Lohmeyer, Preising & Tüxen ex Von Rochow 1951		
			<i>Sporobolus vaginiflorus</i> community	104
			<i>Senecio mikanioides</i> community	101
			<i>Helianthus tuberosus</i> community	99, 104
			<i>Solidago gigantea</i> community	70, 120
			<i>Senecio inaequidens</i> community	99
	34.1	ARCTIO LAPPAE-ARTEMISIETALIA VULGARIS Dengler 2002		
		34.1.1 Arction lappae Tüxen 1937		
			<i>Artemisietum verlotorii</i> Lang 1973	41, 99, 101
			<i>Arundo donax</i> community	43
			<i>Saponario-Artemisietum verlotorum</i> Biondi & Baldoni 1993	15, 63, 72
			<i>Sileno albae-Acanthetum mollis</i> Biondi, Allegrezza & Filigheddu 1990	21

Class	Order	Alliance	Association/Phytocoenon	Reference number in the specific bibliographical list of Supplement 1
34.2	AGROPYRETALIA	INTERMEDII-REPENTIS	Oberdorfer, Müller & Görs in Müller & Görs 1969	
	34.2.1	<b>Convolvulo arvensis-Agropyrion repentis</b>	Görs 1966	
		<i>Artemisia verlotiorum</i> community		13, 127
		<i>Sorghum halepense</i> community		46
34.4	BRACHYPODIO	RAMOSI-DACTYLETALIA	HISPANICAE Biondi, Filigheddu & Farris 2001	
	34.4.4	<b>Bromo-Oryzopsion miliaceae</b>	O. Bolòs 1970	
		<i>Boerhaavio-Oryzopsietum miliaceae</i> Brullo 1984		33
34.5	ONOPORDETALIA	ACANTHII	Br.-Bl. & Tüxen ex Klika in Klika & Hadač 1944	
		<i>Reynoutria japonica</i> community		118
		<i>Artemisia verlotiorum</i> community		104
		<i>Helianthus tuberosus</i> community		29
		<i>Senecio inaequidens</i> community		29
		<i>Solidago gigantea</i> community		29
	34.5.1	<b>Onopordion acanthii</b>	Br.-Bl. in Br.-Bl., Gajewski, Wraber & Walas 1936	
		<i>Erigeron canadense</i> and <i>Broussonetia papyrifera</i> community		91
	34.5.2	<b>Dauco carotae-Melilotion albi</b>	Görs 1966	
		<i>Artemisia verlotiorum</i> community		47, 118
		<i>Artemisia absinthii-Senecionetum inaequidentis</i> Pirone 2001		45, 96
		<i>Echio-Melilotetum</i> Tüxen 1947		30
		<i>Senecio inaequidens</i> and <i>Erigeron annuus</i> variant		30
		<i>Echio-Melilotetum</i> Tüxen 1947 <i>Oenothera biennis</i> (aggr.) variant		31
		<i>Erigeron annuus</i> community		78
		<i>Helianthus tuberosus</i> community		29
		<i>Oenothera biennis</i> community		123
		<i>Senecio inaequidens</i> community		29, 31, 129
		<i>Solidago gigantea</i> community		29
34.6	CARTHAMETALIA	LANATI	Brullo in Brullo & Marcenò 1985	
	34.6.2	<b>Onopordion illyrici</b>	Oberdorfer 1954	
		<i>Carduo pycnocephali-Nicotianetum glaucae</i> Biondi, Blasi, Brugiapaglia, Fogu & Mossa 1994		23
36	ORYZETEA	SATIVAE	Miyawaki 1960	
	36.1	CYPERO DIFFORMIS-ECHINOCHLOETALIA	ORYZOIDIS O. Bolòs & Masclans 1955	
		36.1.1 <b>Oryzo sativae-Echinochloion oryzoidis</b>	O. Bolòs & Masclans 1955	
		<i>Heteranthera</i> sp.pl. community		39
37	PEGANO	HARMALAE-SALSOLETEA	VERMICULATAE Br.-Bl. & O. Bolòs 1958	
	37.2	NICOTIANO GLAUCAE-RICINETALIA	COMMUNIS Rivas-Martínez, Fernández-González & Loidi 1999	
		37.2.1 <b>Nicotiano glaucae-Ricinion communis</b>	Rivas-Martínez, Fernández-González & Loidi 1999	
		<i>Nicotiano glaucae-Ricinetum communis</i> (Br.-Bl. & Maire 1924) de Foucault 1993		37, 87
		<i>Polycarpo-Nicotianetum glaucae</i> Sunding 1972		37

Class	Order	Alliance	Association/Phytocoenon	Reference number in the specific bibliographical list of Supplement 1
38	POLYGONO ARENASTRI-POETEA ANNUAE	Rivas-Martínez 1975 corr. Rivas-Martínez, Báscones, T.E. Díaz, Fernández-González & Loidi 1991		
			<i>Eleusinetum indicae</i> (Slavnic 1951) Pignatti 1953	30
			<i>Euphorbio-Oxalidetum corniculatae</i> Lorenzoni 1964	30
38.2	SAGINO APETALAE-POLYCARPETALIA TETRAPHYLLI	de Foucault 2010		
38.2.1	<b>Polycarpion tetraphylli</b>	Rivas-Martínez 1975		
			<i>Eleusine indica</i> community	91
			<i>Eleusinetum indicae</i> (Slavnic 1951) Pignatti 1953	46, 70, 99, 104
			<i>Euphorbietum maculatae</i> Poldini 1989	70, 99, 101, 104
			<i>Euphorbio-Oxalidetum corniculatae</i> Lorenzoni 1964	38, 99, 101
39	STELLARIETEA MEDIAE	Tüxen, Lohmeyer & Preising ex Von Rochow 1951		
39a.3	SOLANO NIGRI-POLYGONETALIA CONVULVULI	(Sissingh in Westhoff, Dijk, Passchier & Sissingh 1946) O. Bolòs 1962		
39a.3.1	<b>Digitario ischaemi-Setarion viridis</b>	Sissingh in Westhoff, Dijk, Passchier & Sissingh 1946		
			<i>Amarantho-Chenopodietum albi</i> (Morariu 1943) Soó 1957	101
			<i>Amarantho-Digitarietum sanguinalis</i> Pignatti 1953	67, 71, 91, 101
			<i>Chenopodium album</i> and <i>Amaranthus retroflexus</i> community	99
			<i>Cynodonto-Sorghetum halepensis</i> (Laban 1974) Kojic 1979	38
			<i>Echinochloo-Setarietum pumilae</i> Felföldy 1942 corr. Mucina 1993 <i>xanthetosum italicum</i> Poldini et al. 1998	105
			<i>Oxalido-Chenopodietum polyspermi</i> (Br.-Bl. 1921) Sissingh (1942) 1946 (*)	66, 67, 91
			<i>Oxalido-Chenopodietum polyspermi</i> (Br.-Bl. 1921) Sissingh (1942) 1946 <i>Galinsoga parviflora</i> (*) subassociation	66
			<i>Panico sanguinalis-Polygonetum persicariae</i> Pignatti 1953 <i>sorghetosum halepensis</i> Baldoni 1995 (*)	14
			<i>Panico sanguinalis-Polygonetum persicariae</i> Pignatti 1953 <i>Acalypha virginica</i> (*) facies	67
			<i>Panico sanguinalis-Polygonetum persicariae</i> Pignatti 1953 <i>Echinochloa oryzoides</i> (*) facies	66
			<i>Panico sanguinalis-Polygonetum persicariae</i> Pignatti 1953 <i>Panicum capillare</i> (*) subassociation	66
			<i>Panico sanguinalis-Polygonetum persicariae</i> Pignatti 1953 <i>Datura stramonium</i> and <i>Portulaca oleracea</i> (*) variant	51
			<i>Panico sanguinalis-Polygonetum persicariae</i> Pignatti 1953 <i>Bolboschoenus maritimus</i> and <i>Paspalum distichum</i> (*) variant	51
			<i>Euphorbio-Galinsogetum ciliatae</i> Passarge 1981	79
			<i>Galeopsido tetrahit-Galinsogetum parviflorae</i> Poldini et al. 1998	105
			<i>Galinsogo-Portulacetum</i> Br.-Bl. 1949 ex Pedrotti 1959	78, 91
			<i>Setario-Echinochloetum colonum</i> A. & O. Bolòs ex O. Bolòs 1956	34, 38
			<i>Setario-Galinsogetum parviflorae</i> (Beck 1941) Tüxen 1950 em. Müller & Oberdorfer	70
			<i>Setario ambiguae-Cyperetum rotundi</i> Brullo, Scelsi & Spampinato 2001	38
39a.3.3	<b>Diplotaxion eruroidis</b>	Br.-Bl. in Br.-Bl., Gajewski, Wraber & Walas 1936 em. Brullo & Marcenò 1980		
			<i>Amaranthus retroflexus</i> community	86
39a.3.5	<b>Fumarion wirtgenii-agrariae</b>	Brullo in Brullo & Marcenò 1985		
			<i>Oxalis pes-caprae</i> community	85, 87



Class	Order	Alliance	Association/Phytocoenon	Reference number in the specific bibliographical list of Supplement 1	
39b.1	CHENOPODIETALIA	MURALIS	Br.-Bl. in Br.-Bl., Gajewski, Wraber & Walas 1936		
39b.1.1	<b>Chenopodion muralis</b>	Br.-Bl. in Br.-Bl., Gajewski, Wraber & Walas 1936			
		<i>Amarantho blitoidis-Chenopodietum ambrosoidis</i>	O. Bolòs 1967	46	
		<i>Amarantho muricati-Chenopodietum ambrosioidis</i>	O. Bolòs 1967	34	
		<i>Amarantho-Chenopodietum ambrosioidis</i>	O. Bolòs 1967	34, 38, 99	
		<i>Conyzetum albidiae-canadensis</i>	Baldoni & Biondi 1993	8	
		<i>Lolium multiflorum</i>	variant		
		<i>Conyzetum albido-canadensis</i>	Baldoni & Biondi 1993	46, 101	
		<i>Conyzo canadensis-Oenotheretum biennis</i>	Biondi, Brugiapaglia, Allegrezza & Ballelli 1992	24	
		<i>Xanthio italici-Daturetum stramoni</i>	Fanelli 2002	46	
		<i>Amaranthus deflexus</i> and <i>Polycarpon tetraphyllum</i>	community	91	
		<i>Datura stramonium</i>	community	21	
39b.2	THERO-BROMETALIA	(Rivas Goday & Rivas-Martínez ex Esteve 1973)	O. Bolòs 1975		
39b.2.1	<b>Echio plantaginei-Galactition tomentosae</b>	O. Bolòs & Molinier 1969			
		<i>Erigeron canadensis</i>	community	121	
		<i>Galactito-Isatidetum canescentis</i>	Brullo 1983	32	
39b.3	SISYMBRIETALIA	OFFICINALIS	J. Tüxen ex W. Matuszkiewicz 1962		
39b.3.1	<b>Sisymbrium officinalis</b>	Tüxen, Lohmeyer & Preising ex Von Rochow 1951			
		<i>Artemisietum annuae</i>	Fijalcowski 1967	30	
		<i>Artemisietum annuae</i>	Fijalcowski 1967 <i>ambrosietosum</i>	Siniscalco & Montacchini 1989	118, 119
		<i>Conyzo-Lactucetum serriolae</i>	Lohmeyer in Oberdorfer 1957	3, 31, 104	
		<i>Datura stramonium</i> and <i>Malva neglecta</i>	community	67, 91	
		<i>Erigeron canadensis</i>	community	70, 86	
39b.3.2	<b>Hordeion leporini</b>	Br.-Bl. in Br.-Bl., Gajewski, Wraber & Walas 1936 corr. O. Bolòs 1962			
		<i>Bassia scoparia</i> and <i>Chenopodium ambrosioides</i>	community (**)	91	
39b.4	URTICO-SCROPHULARIETALIA	PEREGRINAE	Brullo ex Biondi, Blasi, Casavecchia & Gasparri in Biondi, Allegrezza, Casavecchia, Galdenzi, Gasparri, Pesaresi, Vagge & Blasi 2014		
		<i>Oxalis pes-caprae</i>	community	70	
39b.4.1	<b>Veronico-Urticion urentis</b>	Brullo in Brullo & Marcenò 1985			
		<i>Bromo-Brassicetum sylvestris</i>	Brullo & Marcenò 1985	34	
40	GALIO APARINES-URTICETEA	DIOICAE	Passarge ex Kopecký 1969		
		<i>Artemisia verlotiorum</i>	community	30	
40.1	GALIO APARINES-ALLIARIETALIA	PETIOLATAE	Oberdorfer ex Görs & Müller 1969		
		<i>Robinia pseudoacacia</i>	community	39	
40.1.1	<b>Petasion officinalis</b>	Sill. 1933 em. Kopecký 1969			
		<i>Robinia pseudoacacia</i>	community	5	
40.1.2	<b>Geo-Alliarion</b>	Lohmeyer & Oberdorfer ex Görs & Müller 1969			
		<i>Solidago canadensis</i>	community	5, 89	
40.1.5	<b>Allion triquetri</b>	O. Bolòs 1967			
		<i>Acantho-Smyrnetum olusatri</i>	Brullo & Marcenò 1985	34, 70	
		<i>Acanthus mollis</i>	community	70, 117	

Class	Order	Alliance	Association/Phytocoenon	Reference number in the specific bibliographical list of Supplement 1
41	FILIPENDULO ULMARIAE-CONVOLVULETEA SEPIUM	Géhu & Géhu-Franck 1987		
	41.1	CALYSTEGIETALIA SEPIUM	Tüxen ex Mucina 1993 nom. mut. propos. Rivas-Martínez, T.E. Díaz, Fernandez-Gonzales, Izco, Loidi, Lousã & Penas 2002	
			<i>Reynoutria japonica</i> community	31
			<i>Helianthus tuberosus</i> community	31
			<i>Solidago canadensis</i> and <i>Erigeron annuus</i> community	31
			<i>Erigeron annuus</i> community	31
	41.1.1	Calystegion sepium	Tüxen ex Oberdorfer 1957 nom. mut. propos. Rivas-Martínez, T.E. Díaz, Fernandez-Gonzales, Izco, Loidi, Lousã & Penas 2002	
			<i>Amorpha fruticosa</i> community	81
			<i>Artemisia verlotiorum</i> community	127
			<i>Arundini-Convolvuletum sepium</i> (Tüxen & Oberdorfer) O. Bolòs 1962 <i>Artemisia verlotiorum</i> variant	72
			<i>Arundini-Convolvuletum sepium</i> (Tüxen & Oberdorfer 1958) O. Bolòs 1962	11, 15, 34, 40, 46, 80, 99, 101
			<i>Arundo donax</i> community	43
			<i>Calystegio sylvaticae-Arundinetum donacis</i> Brullo, Scelsi & Spampinato 2001	35, 38, 73, 84, 85, 87
			<i>Calystegio-Asteretum lanceolati</i> (Holzner et al. 1978) Passarge 1993	63
			<i>Helianthus tuberosus</i> community	15, 63, 71, 127
			<i>Humulus scandens</i> community	39
			<i>Rubus caesius</i> and <i>Amorpha fruticosa</i> community	89
			<i>Solidago canadensis</i> community	81, 83
			<i>Solidago gigantea</i> community	39, 63, 127
50	TUBERARIETEA GUTTATAE (Br.-Bl. in Br.-Bl., Roussine & Nègre 1952)	Rivas Goday & Rivas-Martínez 1963 nom. mut. propos. Rivas-Martínez, T.E. Díaz, Fernández-González, Izco, Loidi, Lousa & Penas 2002		
	50.2	MALCOLMIETALIA	Rivas Goday 1958	
		50.3.2	Laguro ovati-Vulpion fasciculatae Géhu & Biondi 1994	
			<i>Ambrosio coronopifoliae-Lophochloetum pubescentis</i> Biondi, Brugiapaglia, Allegrezza & Ballelli 1992	95, 99, 102
			<i>Sileno coloratae-Vulpietum membranaceae</i> (Pignatti 1953) Géhu & Scoppola 1984 <i>ambrosietosum coronopifoliae</i> Pirone 2005	97
55	LYGEO SPARTI-STIPETEA TENACISSIMAE	Rivas-Martínez 1978 nom. conserv. propos. Rivas-Martínez, T.E. Díaz, Fernández-González, Izco, Loidi, Lousa & Penas 2002		
	55.2	HYPARRHENIETALIA HIRTAE	Rivas-Martínez 1978	
		55.2.1	Hyparrhenion hirtae Br.-Bl., P. Silva & Rozeira 1956	
			<i>Penniseto setacei-Hyparrhenietum hirtae</i> Gianguzzi, Ilardi & Raimondo 1996	36, 52
56	MOLINIO-ARRHENATHERETEA	Tüxen 1937		
	56.4	HOLOSCHOENETALIA VULGARIS	Br.-Bl. ex Tchou 1948	
		56.4.4	Paspalo distichi-Agrostion semiverticillatae Br.-Bl. in Br.-Bl., Roussine & Nègre 1952	
			<i>Aster squamatus</i> and <i>Inula viscosa</i> community	94
			<i>Loto tenuis-Paspaletum paspaloidis</i> Biondi, Casavecchia & Radetic 2002	25, 68
			<i>Paspalo distichi-Polypogonetum viridis</i> Br.-Bl. in Br.-Bl., Gajewski, Wraber & Walas 1936 nom. mut. propos. Rivas-Martínez et al. 2002 (= <i>Paspalo distichi-Agrostidetum verticillati</i> Br.-Bl. in Br.-Bl., Roussine & Nègre 1952)	15, 41, 46, 60, 61, 63, 68, 70, 76, 93, 94, 95, 99, 101, 115

Class	Order	Alliance	Association/Phytocoenon	Reference number in the specific bibliographical list of Supplement 1
			<i>Paspalo distichi-Polypogonetum viridis</i> Br.-Bl. in Br.-Bl., Gajewski, Wraber & Walas 1936 nom. mut. propos. Rivas-Martínez et al. 2002 facies with <i>Cyperus eragrostis</i>	63
			<i>Paspalum distichum</i> (= <i>paspaloides</i> ) community	19, 81, 103
	56.5	PLANTAGINETALIA MAJORIS	Tüxen ex Von Rochow 1951	
		56.5.1	<b>Lolio perennis-Plantaginion majoris</b> Sissingh 1969	
			<i>Juncetum macri</i> (Diemont et al. 1940) Tüxen 1950	78
			<i>Eleusine indica</i> community	91
61		CISTO CRETICI-MICROMERIETEA JULIANAE	Oberdorfer ex Horvatić 1958	
	61.1	CISTO CRETICI-ERICETALIA MANIPULIFLORAE	Horvatić 1958	
		61.1.1	<b>Cisto cretici-Ericion manipuliflorae</b> Horvatić 1958	
			<i>Opuntia ficus-indica</i> community	69, 85
64		RHAMNO CATHARTICAE-PRUNETEA SPINOSAE	Rivas Goday & Borja ex Tüxen 1962	
	64.1	PRUNETALIA SPINOSAE	Tüxen 1952	
			<i>Robinia pseudoacacia</i> and <i>Rubus ulmifolius</i> community	6
			<i>Robinia pseudoacacia</i> and <i>Sambucus nigra</i> community	70
		64.1.1	<b>Berberidion vulgaris</b> Br.-Bl. 1950	
			" <i>Corno sanguineae-Ligustretum vulgaris</i> " sensu Biondi et al. 1999 non Horvat 1956 <i>amorphetosum fruticosae</i> Biondi, Vagge, Baldoni & Taffetani 1999	27
		64.1.2	<b>Cytision sessilifolii</b> Biondi in Biondi, Allegranza & Guitian 1988	
			<i>Cercido siliquastri-Rhoetum coriariae</i> Biondi, Allegranza & Guitian 1988	22
		64.3.1	<b>Pruno-Rubion ulmifolii</b> O. Bolòs 1954	
			<i>Clematido vitalbae-Arundinetum donacis</i> Biondi & Allegranza 2004	18
65		ALNETEA GLUTINOSAE	Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946	
	65.1	SALICETALIA AURITAE	Doing ex Westhoff in Westhoff & Den Held 1969	
		65.1.1	<b>Salicion cinereae</b> Müller & Görs 1958	
			<i>Salicetum cinereae</i> Zolyomi 1931 <i>Amorpha fruticosa</i> variant	65
68		SALICI PURPUREAE-POPULETEA NIGRAE	Rivas-Martínez & Cantó ex Rivas-Martínez, Báscones, T.E. Díaz, Fernández-González & Loidi 2001	
	68.1	POPULETALIA ALBAE	Br.-Bl. ex Tchou 1948	
			<i>Robinia pseudoacacia</i> community	122
		68.1.1	<b>Populion albae</b> Br.-Bl. ex Tchou 1948	
			<i>Acer negundo</i> community	46
			<i>Ailanthus altissima</i> and <i>Robinia pseudoacacia</i> community	6
69		SALICETEA PURPUREAE	Moor 1958	
	69.1	SALICETALIA PURPUREAE	Moor 1958	
		69.1.1	<b>Salicion albae</b> Soó 1930	
			<i>Amorpha fruticosae-Salicetum albae</i> Poldini, Vidali, Bracco, Assini & Villani in Poldini, Vidali & Ganis 2011	13, 27, 48, 71, 107
			<i>Sicyos angulatus</i> community	40, 112
		69.1.2	<b>Salicion triandrae</b> Müller & Görs 1958	
			<i>Salicetum triandrae</i> (Malcuit 1929) Noirfalise 1955 <i>Amorpha fruticosa</i> variant	27

Class	Order	Alliance	Association/Phytocoenon	Reference number in the specific bibliographical list of Supplement 1
		69.1.4	<b>Salicion incanae</b> Aichinger 1933	
			<i>Salicetum incano-purpureae</i> Sillinger 1933 <i>Amorpha fruticosa</i> variant	27, 62
70	QUERCETEA	ILICIS	Br.-Bl. in Br.-Bl., Roussine & Nègre 1952	
			<i>Sequoia sempervirens</i> community	49
	70.1	QUERCETALIA	ILICIS Br.-Bl. ex Molinier 1934	
		70.2.2	<b>Oleo sylvestris-Ceratonion siliquae</b> Br.-Bl. ex Guinochet & Drouineau 1944	
			<i>Asparago acutifolii-Oleetum sylvestris</i> Bacchetta et al. 2003	117
			<i>Opuntia ficus-indica</i> variant	
71	QUERCO	ROBORIS-FAGETEA	SYLVATICAE Br.-Bl. & Vlieger in Vlieger 1937	
			<i>Acacia melanoxylon</i> community	49
			<i>Euonymus europaeus</i> and <i>Robinia pseudoacacia</i> community	77
			<i>Festuca heterophylla</i> and <i>Robinia pseudoacacia</i> community	77
			<i>Arrhenatherum elatius</i> variant	
			<i>Festuca heterophylla</i> and <i>Robinia pseudoacacia</i> community	77
			<i>Rubus macrophyllus</i> variant	
			<i>Pinus canariensis</i> community	49
			<i>Pinus radiata</i> community	49
			<i>Robinia pseudoacacia</i> community	50
			<i>Robinia pseudoacacia</i> and <i>Prunus serotina</i> community	113
			<i>Sambucus nigra</i> and <i>Robinia pseudoacacia</i> community	77
			<i>Chelidonium majus</i> variant	
			<i>Sambucus nigra</i> and <i>Robinia pseudoacacia</i> community	77
			<i>Poa trivialis</i> variant	
			<i>Sambucus nigra</i> and <i>Robinia pseudoacacia</i> community	77
			<i>Rubus</i> gr. <i>discolores</i> variant	
	71.1	FAGETALIA	SYLVATICAE Pawłowski in Pawłowski, Sokołowski & Wallisch 1928	
		71.1.4	<b>Tilio platyphylli-Acerion pseudoplatani</b> Klika 1955	
			<i>Robinia pseudoacacia</i> community	50
		71.1.6	<b>Carpinion betuli</b> Issler 1931	
			<i>Prunus serotina</i> community	113
		71.1.10	<b>Alnion incanae</b> Pawłowski in Pawłowski, Sokolowski & Wallisch 1928	
			<i>Amorpha fruticosa</i> community	40
			<i>Populus nigra</i> and <i>Robinia pseudoacacia</i> community	26
			<i>Robinia pseudoacacia</i> and <i>Rubus ulmifolius</i> community	55
	71.2	QUERCETALIA	ROBORIS Tüxen 1931	
			<i>Buddleja davidii</i> community	74
		71.2.1	<b>Quercion roboris</b> Malcuit 1929	
			<i>Robinia pseudoacacia</i> community	50
	71.3	QUERCETALIA	PUBESCENTI-PETRAEAE Klika 1933	
		71.3.3	<b>Crataego laevigatae-Quercion cerridis</b> Arrigoni 1997	
			<i>Sambuco nigrae-Robinetum pseudacaciae</i> Arrigoni 1997	10
75	ROBINIETEA	Jurko ex Hadac & Sofron 1980		
	75.1	CHELIDONIO-ROBINIETALIA	Jurko ex Hadac & Sofron 1980	

Class	Order	Alliance	Association/Phytocoenon	Reference number in the specific bibliographical list of Supplement 1
	75.1.1	<b>Balloto nigrae-Robinion</b>	Jurko ex Hadac & Sofron 1980 <i>Ailanthus altissima</i> community	88
	75.1.2	<b>Bryonio-Robinion</b>	Ubaldi, Melloni & Cappelletti in Ubaldi 2003 <i>Ailanthus altissima</i> community <i>Bryonio-Robinetum</i> Ubaldi, Melloni & Cappelletti in Ubaldi 2003 <i>Robinia pseudoacacia</i> community	46 124 46, 98, 128, 130
	75.1.3	<b>Lauro nobilis-Robinion pseudoacaciae</b>	Allegrezza, Montecchiari, Ottaviani, Pelliccia & Tesei 2019 <i>Melisso altissimae-Robinetum pseudoacaciae</i> Allegrezza, Montecchiari, Ottaviani, Pelliccia & Tesei 2019 <i>Rubio peregrinae-Robinetum pseudoacaciae</i> Allegrezza, Montecchiari, Ottaviani, Pelliccia & Tesei 2019	2 2

## BRYOPHYTE COMMUNITIES

CERATODONTO PURPUREI-POLYTRICHETEA PILIFERI Mohan 1978

*POLYTRICHETALIA PILIFERI* von Hübschmann 1975

**Campylopodion polytrichoidis** Giacomini 1951

*Campylopus introflexus* community

108, 111

(\*) In Poldini et al. (1998) the associations *Panico-Polygonetum persicariae* Pignatti 1953 and *Oxalido-Chenopodietum polyspermi* (Br.-Bl. 1921) Sissingh (1942) 1946 are considered syntaxonomic synonyms of *Echinochloo-Setarietum pumilae* Felföldy 1942 corr. Mucina 1993. The authors reached this result by elaborating the synthetic tables of only a part of the works published at national level with the name *Panico-Polygonetum* and *Oxalido-Chenopodietum*. Beside this, in Poldini et al. (1988) the numbers of tables and relevés taken into account for the analysis were not indicated. These authors did not also consider any subassociations and variants described. For these reasons, we prefer to report the names of the associations as they were indicated in the original works, without including them as synonyms in the name *Echinochloo-Setarietum*.

(\*\*) This association was described for the north-Adriatic Italian coasts, published by Pignatti (1952-53) as "nom. prov.", therefore not validly, according to ICPN (Art. 3b, Weber et al., 2000). It cannot be attributed to *Atriplicion littoralis* sensu Nordhagen 1940, as already highlighted by Mucina et al. (2016, p. 137), according to whom it must be referred to ruderal communities of *Atriplicion Passarge* 1978 (*Sisymbrietalia*). After examining the original table in Pignatti (1952-53), we agree with the comments of Mucina et al. (2016). Anyway, in the Italian Vegetation Prodrome, the alliance *Atriplicion* Passarge 1978 is not reported, so we provisionally prefer to attribute this association to *Hordeion leporini*, the most similar alliance from the eco-coenological point of view present in the Italian Vegetation Prodrome.

Soon after the development and data analysis of this article, Pellizzari (2020) hypothesized a reinterpretation of *Cyperus glomeratus*, currently considered alien species

in Italy, as a probable native. We are currently sticking to the consolidated position of Galasso et al. (2018), pending a reassessment of the chorology of this species.

## Appendix II – Specific bibliographical list with reference numbers for all the syntaxa quoted in the checklist of Appendix I

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# Conservation status of Italian coastal dune habitats in the light of the 4<sup>th</sup> Monitoring Report (92/43/EEC Habitats Directive)

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## Abstract

Coastal dunes are among habitats with the worst conservation status on a global, European and national scale. Monitoring and reporting are of strategic importance to determine the effectiveness of the implementation of Habitats Directive and to preserve the unique biodiversity heritage of the Italian dunes. In this study we show main results of the 4<sup>th</sup> National Report with specific reference to the macro-habitat “Coastal Sand Dunes and Inland Dunes”, highlighting its updated current conservation status at the national and Biogeographical level. A comprehensive Working Group of territorial experts collected, updated, validated and integrated the data available for 11 Annex I Habitats, distributed in the Alpine, Continental and Mediterranean Biogeographical Regions. The conservation status was evaluated through the following criteria: geographic range, surface area, structure, functions, pressures, threats, conservation measures and prospects. Results highlighted the dramatically bad conservation status of Italian dune Habitats: the overall assessment reported 88% of habitats in bad conservation status and the remaining 12% is in inadequate conditions. Results showed a generalised threat and a worrying conservation status both on herbaceous and wooded communities, in particular in some relevant habitats, such as the shifting dunes. Main pressures and threats were linked to residential, commercial and industrial activities, as well as alien species. Although some of the changes in distribution and trends are probably deriving from more accurate and updated data, the alarming conservation status of Italian sand dunes requires a better knowledge of pressures and threats for further management actions and monitoring plans, inside and outside protected areas.

## Keywords

Continental Biogeographical Region, European guidelines, Mediterranean Biogeographical Region, national report, psammophilous vegetation, threats

## Introduction

Sandy coastlines and dune ecosystems are fragile environments currently exposed to several pressures and partic-

ularly threatened at a global, European and national scale (Acosta et al. 2009; Feola et al. 2011; Prisco et al. 2013; Genovesi et al. 2014; Janssen et al. 2016; Gigante et al. 2018). Although the degradation and loss of dune systems

affect many countries all over the world, it is particularly intense along the Mediterranean coasts.

The Mediterranean basin is one of the world biodiversity hotspots (Myers et al. 2000), but, at the same time, it is one of the regions of the world subjected to the highest level of historical anthropic pressure (Newton et al. 2012; Anthony 2014). Indeed, more than 450 million inhabitants currently live in the Mediterranean countries, and especially near the coasts (UNEP/MAP 2012). The high population density along the Mediterranean shorelines represents a major threat to coastal sand dunes, which suffer from unregulated urbanization, intensive farming, infrastructures, massive bathing tourism, pollution, biological invasions and over-exploitation of the natural resources (Buffa et al. 2007, 2012; Malavasi et al. 2013, 2016; Basnou et al. 2015; Del Vecchio et al. 2015; Sciandrello et al. 2015; Poeta et al. 2017; Nordhaus et al. 2018; Sperandii et al. 2018; Giulio et al. 2020). In Italy, previous studies reported that coastal sand dunes are among the habitats with the worst conservation status, therefore, the unique biodiversity heritage along the Italian coasts needs to be preserved for the future generations and its protection should represent a priority both at national and European level.

In the last years, we have witnessed a growing global awareness concerning habitat monitoring and conservation; habitats as a whole are probably more useful indicators of ecosystem functioning compared to individual species (Balmford et al. 2002; Cowling et al. 2004; Bunce et al. 2013; Gigante et al. 2016a). The protection of biodiversity requires a constant and rigorous technical-scientific commitment at national level, which should also be extended to the obligations deriving from community rules. In particular, the Habitats Directive (92/43/EEC) requires the Member States to implement surveillance on the conservation status of habitats and species of Community Interest, taking into account also the most important threat factors that influence their future prospects (Angelini et al. 2016; Gigante et al. 2016b).

In 2016, the first European Red List of Habitats had been published. Traditionally, the Red Lists, based on criteria developed by the International Union for Conservation of Nature (IUCN), have always focused on single species with extinction risk and trends evaluated at the *taxa* level. The European Red List of Habitats represents a step further since plant communities and habitats have been taken into account as assessment units. This Red List confirms not only the key role of habitats concerning the implementation of conservation strategies and priorities, but also the necessity of monitoring at the ecosystem level (Rodwell et al. 2013; Keith et al. 2013, 2017; Janssen et al. 2016; IUCN 2016; Gigante et al. 2018).

Monitoring and reporting are of strategic importance to determine the effectiveness of the implementation of the Community Directives on biodiversity. Moreover, they serve as a reference framework to identify priorities and critical issues for the next monitoring period (Genovesi et al. 2014).

In this frame, based on the European guidelines (Evans and Arvela 2011), a technical manual for habitat monitoring has been produced at the national level in Italy. This manual provides practical standardised monitoring tools particularly tuned to the Italian ecological and biogeographical characteristics and peculiarities, standing as an official reference for fulfilling the monitoring obligations imposed by the Habitats Directive (Angelini et al. 2016; Gigante et al. 2016b). Major goals of the Habitats Directive are achieved through the technical reports on the conservation status of Habitats listed in Annex I (Dir. 92/43/EEC) and on conservation measures implemented in accordance with article 17. Reporting is requested every six years to each Member States and in 2019 Italy, just like the other EU27 countries, has delivered its 4<sup>th</sup> National Report referred to the period 2013–2018. The here collected and processed information represents the most updated picture of the conservation status of habitats and species of Community Interest in the whole Italian territory. The complete set of rough data is available on the Eionet Central Data Repository (2018).

The activities for the preparation of the 4<sup>th</sup> National Report have been coordinated by the Italian Institute for Environmental Protection and Research (ISPRA) on behalf of the Ministry for Environment, Land and Sea Protection (MATTM), with the scientific support of the Italian Botanical Society (SBI) and the Italian Society of Vegetation Science (SISV). Between October 2018 and May 2019, a comprehensive Working Group of territorial experts distributed by administrative regions and macro-habitat categories, worked in synergy with ISPRA itself and, where possible, with regional administrations, in order to collect, analyse and validate all the available data concerning the 124 types of terrestrial and inland water Habitats present in Italy (Gigante et al. 2019). Through a complex and multi-level teamwork and by comparing the results of the previous reporting period (2007–2012), it was possible to assess the current conservation status of each habitat at biogeographical scale and therefore to fill out the standard European assessment sheets.

As part of the results achieved by the Working Group, this paper aims at presenting the major results of the 4<sup>th</sup> National Habitat reporting for the macro-habitat type “Coastal Sand Dunes and Inland Dunes”. Specifically, we reported the updated conservation status of each coastal dune habitat at national level with reference to Biogeographical Regions.

## Materials and Methods

The macro-habitat type “Coastal Sand Dunes and Inland Dunes” encompasses 21 Annex I Habitats in Europe, 11 of which have been reported in Italy. Out of these 11 habitats, 10 are coastal habitats occurring in the Continental and Mediterranean Biogeographical Regions, while only the inland dunes (Habitat 2330) is a non-coastal habitat

occurring in the Continental and (marginally) Alpine Biogeographical Region (Table 1). The reporting activities led to the compilation of 19 assessment sheets, with the new inclusion of two marginal types which had not been evaluated in the 3<sup>rd</sup> Report due to a lack of robust data at that time (Genovesi et al. 2014). Among the 19 assessment sheets, one pertained to the Alpine Region, 10 to the Continental Region and 8 to the Mediterranean Region (Table 1).

## Data collection and analysis

The first step was the collection and integration of data available for reporting: information provided by administrative regions and autonomous provinces (centralised by ISPRA; hereafter: “collected data”) and further data deriving from the latest available updates of the Natura 2000 sites Standard Data Forms. These data were organised at two different levels: I) National scale, through the implementation of distribution maps; II) Biogeographic Regions, which is the scale of the final assessment (Gigante et al. 2019). In addition to the material provided by local administrations, we included the official data available on the MATTM and EEA (European Environmental Agency) websites.

A critical review and analysis of the collected data were necessary, mainly due to their heterogeneity and incompleteness. In some cases, the administrative regions provided incomplete data (e.g. surface area of the habitat missing, incomplete indication regarding the conservation measures applied) or they provided data in a different format than allowed (e.g. surface area in hectares instead of km<sup>2</sup>, cartographic files with no spatial reference, etc.). Therefore, a comprehensive scientific exchange within and between the macro-habitats Working Group and Subgroups was carried out, which finally led to shared and methodologically sound solutions to fill gaps and discrepancies emerged. The missing data were initially requested to the involved administrative regions and then integrated through the official information hold in the Natura 2000 sites Standard Data Forms, data gathered

in published material, “gray” literature, unpublished data of specialists and all sources deemed useful to provide an updated picture on the current conservation status of the Habitats. The data received in different formats were also homogenised.

At the same time, an all-embracing analysis of the information was carried out with the scope to update the geographic distribution of Habitats at the national level. We used the maps of the 3<sup>rd</sup> Report as starting background information, based on the European 10 km x10 km cells grid, Reference System ETRS89-LAEA5210. In each grid cell, the collected data on Habitats occurrence were validated, integrated or modified taking into account different sources such as official maps, scientific papers, published books, phytosociological tables or direct field surveys, combined with the expert knowledge of the Working Group. In particular, the major contribution to the data implementation derived from the most recent scientific publications on dune systems and related topics with reference, at least in part, to the Italian territory (Buffa et al. 2007, 2012; Viciani et al. 2007; Gamper et al. 2008; Sburlino et al. 2008, 2013; Prisco et al. 2012; Minisale and Sciandrello 2013, 2015, 2017; Pisanu et al. 2014; Sciandrello et al. 2015, 2017; Gheza et al. 2016; Silan et al. 2017; Tomaselli and Sciandrello 2017; Angiolini et al. 2018; Bonari et al. 2018; Del Vecchio et al. 2018; Marcenò et al. 2018).

Finally, extensive cross-check work allowed the development of a comprehensive biogeographic database. This database includes for each cell the information originally derived from the 3<sup>rd</sup> Report, updated and verified by regions, autonomous provinces or territorial experts, using explicit data or confirmed by direct verification. In this way, new occurrences were added only when supported by authoritative sources. We should point out that we proceeded to delete presences in cases they were not justified or clearly incorrect, always including a valid motivation. In the absence of any updated information, we confirmed data from the 3<sup>rd</sup> Report as provided by the administrative regions.

All data supporting the Habitats’ distribution and characteristics (georeferenced phytosociological relevés, both

**Table 1.** List of the evaluated coastal sand dunes and inland dunes Habitats and their presence in the Italian Biogeographical Regions: Alpine (ALP), Continental (CON) and Mediterranean (MED).

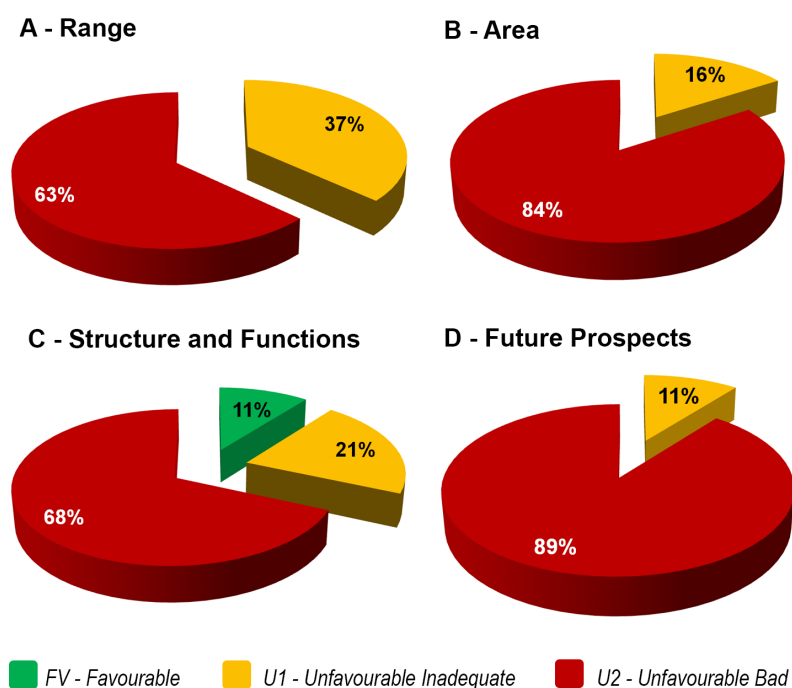
HABITATS (Group 2xxx)	Biogeographic Regions		
	ALP	CON	MED
2110 Embryonic shifting dunes		X	X
2120 Shifting dunes along the shoreline with <i>Ammophila arenaria</i>		X	X
2130 Fixed coastal dunes with herbaceous vegetation		X	
2160 Dunes with <i>Hippophae rhamnoides</i>		X	
2210 <i>Crucianellion maritimae</i> fixed beach dunes			X
2230 <i>Malcolmietalia</i> dune grasslands		X	X
2240 <i>Brachypodietalia</i> dune grasslands with annuals		MARGINAL	X
2250 Coastal dunes with <i>Juniperus</i> spp.		X	X
2260 <i>Cisto-Lavanduletalia</i> dune sclerophyllous scrubs		X	X
2270 Wooded dunes with <i>Pinus pinea</i> and/or <i>Pinus pinaster</i>		X	X
2330 Inland dunes with open <i>Corynephorus</i> and <i>Agrostis</i> grasslands	MARGINAL	X	

published and unpublished) are currently being archived in the National Database of phytosociological surveys VegItaly (Gigante et al. 2012; Landucci et al. 2012), freely accessible online and managed by the Italian Society of Vegetation Science (Gigante et al. 2019).

### Assessment criteria for Annex I Habitat reporting

The standard European assessment sheets for Habitats reporting foresee several criteria that must be considered in order to assess the final conservation status. Criteria were derived from the European guidelines (Evans and Arvela 2011) and encompass the seven points listed below.

- Range: provides the range surface area (expressed as the area of 10 km × 10 km cells) of the outer limits of the habitat distribution and can be considered as an envelope including the areas of actual occurrence; it was calculated by applying a standardised algorithm to the distribution map of the habitat, by using the Range tool (Eionet Central Data Repository 2019).
- Area covered by the habitat type: provides the total area (in km<sup>2</sup>) currently occupied by the habitat at biogeographical level.
- Structure and functions: provides the area (in km<sup>2</sup>) of the habitat with good, not-good and unknown condition, considering both abiotic and biotic factors; when missing, we deduced this information from the data reported in the Standard Data Forms of Natura 2000 sites. An updated list of habitat-specific typical species was also delivered, based on the indications provided by Angelini et al. (2016).
- Main pressures and threats: provides a list of pressures (impact on the long-term) and threats (future/foreseeable effects) with a ranking of their impacts on the conservation status of each habitat; pressures and threats were weighted according to their frequency and importance on the biogeographical scale. We referred to the official list of pressures and threats adopted by Eionet and IUCN, based on Salafsky et al. (2008).
- Conservation measures: in this case, we implemented the data provided by the administrative regions with information deriving from the existing Natura 2000 management plans.
- Future prospects indicate the direction of expected changes in conservation status in the near future; we combined current status, reported pressures and threats, and existing conservation measures with reference to range, area, structure and functions.
- Overall assessment: indicates the conservation status at the end of the reporting period. It represents the combination of the assessments for each single parameter (range, area, structure and functions, future prospects, overall trend), with reference to the four different categories: Favourable (FV), Unfavourable-Inadequate (U1), Unfavourable-Bad (U2) and Unknown (XX).



**Figure 1.** Percentage of the Italian coastal sand dunes and inland dunes Habitats in each assessment category (FV, U1, U2) based on the criteria: A Range, B Area, C Structure and functions, D Future prospects.

## Results

### Range, area, structure and functions and future prospects criteria

For the range criterion, 63% of the assessed Habitats is in Unfavourable-Bad conservation status (U2, Fig. 1A) while about 37% is in Unfavourable-Inadequate (U1) conservation status. Habitats in the worst conditions are mainly located in the Continental Biogeographical Region.

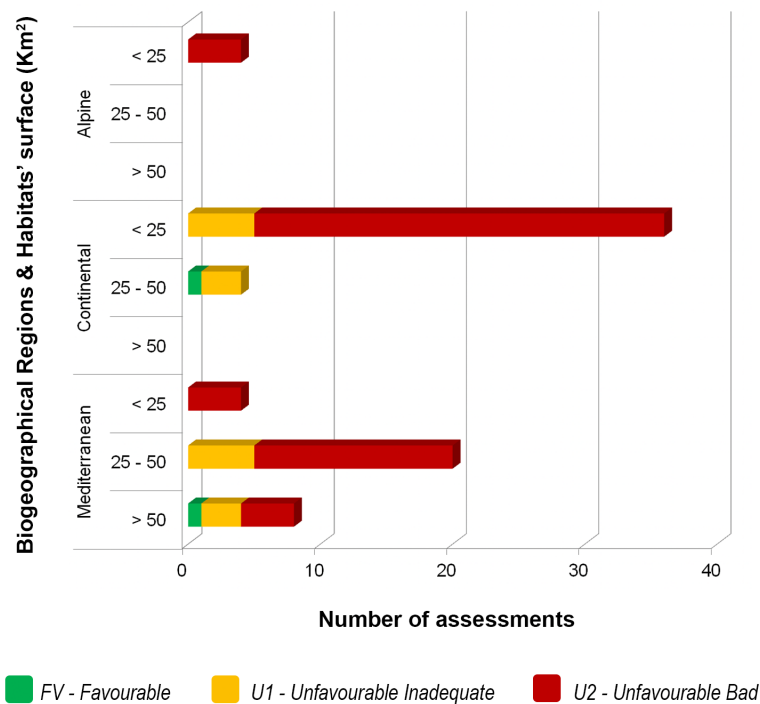
Regarding the total area currently occupied, almost all Habitats (84%) are in an Unfavourable-Bad conservation status (U2, Fig. 1B); the only habitat in the U1 category is the wooded dunes with *Pinus* species (2270).

Considering structure and functions, about 68% of the Habitats is in Unfavourable-Bad (U2) conservation status and includes embryo and shifting dunes (Habitats 2110 and 2120), fixed dunes (Habitat 2130, Continental Region), dune grasslands (Habitats 2210, 2230 and 2240 in both Biogeographical Regions) and dunes with *Juniperus* species (Habitat 2250, Continental Region), while 21% of Habitats are in Unfavourable-Inadequate (U1) conservation status; however, the wooded dunes with *Pinus* species (Habitat 2270) show a Favourable habitat quality (FV, Fig. 1C).

The future prospects of the major part of the habitats are definitely Unfavourable-Bad (U2, 89%). Only the wooded dunes with *Pinus* species are considered with Unfavourable-Inadequate (U1) conservation status (Fig. 1D).

In order to highlight the variation of the conservation status in relation with the area of the Habitats, for each Biogeographic Region we gathered those with similar surface area and then analysed how the previous assessments were distributed in each surface class (< 25 km<sup>2</sup>, between 25 and 50 km<sup>2</sup>, > 50 km<sup>2</sup>). The highest occurrence of Unfavourable-Bad conservation conditions (U2) affects especially Habitats with less than 25 km<sup>2</sup> of extent in the Continental Region (Fig. 2). Similar trends could be observed for Mediterranean Habitats with a surface between 25 and 50 km<sup>2</sup>. On the other hand, Habitats with Favourable (FV) or Unfavourable-Inadequate (U1) conservation status are mainly the woody ones on stabilised dunes (Habitat 2270 and 2260).

We should highlight that the key dune habitat 2120 (Shifting dunes with *Ammophila arenaria*) has an Unfavourable-Bad conservation status (U2) for all the criteria in both Biogeographical Regions. In the Continental Region, Habitats with all U2 assessments are the fixed dunes with herbaceous vegetation (Habitat 2130), the dune grasslands (Habitat 2230) and the inland dunes (Habitat 2330); the latter has an Unfavourable-Bad conservation status for all the criteria also in the Alpine Region. In the Mediterranean Region, Habitats with all U2 assessments are the dune with *Juniperus* species (Habitat 2250) and the maquis with sclerophyllous scrubs (Habitat 2260).



**Figure 2.** Total number of assessment in each category (FV, U1, U2) disaggregated by Biogeographical Region and surface area (km<sup>2</sup>) of the Italian coastal sand dunes and inland dunes Habitats. We summed up the results of all criteria considered for the assessment: range, area, structure and functions, future prospects.

## Main pressures, threats and conservation measures

Among the main pressures (P) and threats (T) observed in the assessments, most of them are directly or indirectly related to human activities:

- Development, construction and use of residential, commercial, industrial and infrastructure areas (P 34% – T 36%), in all habitats, in at least one administrative region;
- Alien and problematic species (P 17% - T 17%), in all habitats, in at least one administrative region.

However, others could also be associated with natural process, particularly coastal erosion:

- Natural processes (P 11% - T 10%), in almost all habitats except dune grasslands and fixed dunes.

Concerning the conservation measures adopted by the administrative regions to limit the negative impact of pressures and threats, we could highlight:

- Measures related to residential, commercial, industrial and recreational infrastructures, operations and activities (39%), in almost all habitats in at least one administrative region;
- Measures related to alien and problematic native species (22%), in almost all habitats except fixed and wooded dunes;
- Measures related to natural processes, geological events and natural catastrophes (10%), in about half of the habitats, mainly in the Mediterranean Region.

## Overall conservation status and trend

As it could be envisaged from previous results, the overall assessment of Dune Habitats at the end of the 4<sup>th</sup> reporting period is clearly Unfavourable-Bad (U2) for about 90% of the assessed Habitats (Fig. 3A), and the trend with reference to the last reporting cycle is deteriorating for almost 70% of Habitats (Fig. 3B). Only 21% of Habitats could be considered in a stable trend, mostly represented by woody habitats on fixed dunes.

The reported unknown trend is referred to the two marginal Habitats that have been evaluated for the first time in this report (see Table 1).

Although more than half of Habitats showed a considerable change in the overall conservation status compared to the previous Report, it is worth pointing out that probably a consistent part of this degradation process is related to a better knowledge of the distribution and quality of Habitats. However, we could not exclude an actual deterioration of the conservation status for some habitats, such as the Mediterranean dune grasslands (Habitat 2230).

The complete set of data relating to all the criteria used for assessing the conservation status of the Habitats are available on the Article 17 Web Tool (European Topic Centre on Biological Diversity 2019).

## Trends in the last reporting cycles

If we consider the trend across the last three reporting cycles (Table 2), we note a gradual improvement in knowledge concerning the Habitats conservation status, which led to a better definition of all the assessments, from unknown (or data deficient) to more clear categories. At the same time, Habitats in Favourable (FV) and Unfavourable-Inadequate conservation status (U1) have progressively reduced and in the last Report the large majority of the Italian dune Habitats show an Unfavourable-Bad conservation status (U2) (Table 2).

## Discussion

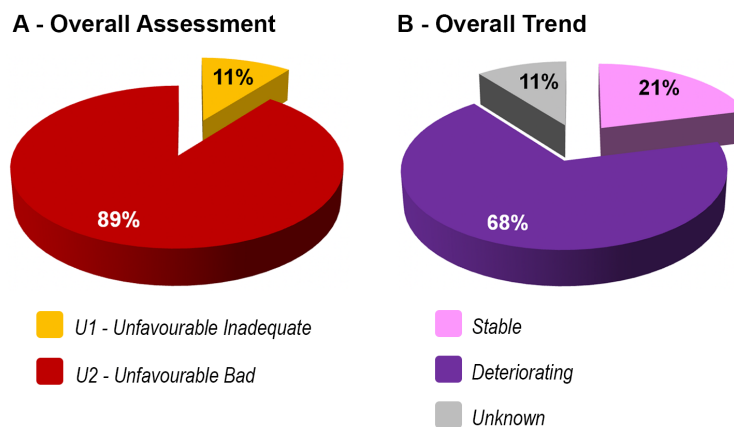
The valuable ecological diversity and the multiple ecosystem services associated to dune habitats have been progressively threatened by the expansion of anthropic activities and also by natural factors, making coastal dunes among the most threatened ecosystems at the global and local scale (Schlacher et al. 2007; Defeo et al. 2009; Prisco et al. 2015, 2016a; Acosta and Ercole 2015; Sciandrello et al. 2015; Janssen et al. 2016; Malavasi et al. 2016; Marcenò et al. 2018; Sarmati et al. 2019; Carranza et al. 2020). Although the Italian shoreline still hosts several of well-preserved stretches of sandy dunes, the 4<sup>th</sup> monitoring Report just completed has clearly highlighted the alarming bad or inadequate conservation status of most dune habitats in Italy.

One of the greatest threats is related to their limited geographical extent which, with a continuously decreasing trend over the years, will lead to an increasingly worse future scenario. The most affected Habitats are those with the minimum extension, which are mainly concentrated in the Continental Region, but also in the Mediterranean one (shifting dunes, fixed dunes, dunes with *Hippophae rhamnoides*, dune grasslands, dunes with *Juniperus* species, maquis with sclerophyllous scrubs, inland dunes). Moreover, our results showed that both herbaceous and wooded Habitats are highly threatened. In particular, we should highlight the worrying conservation state of some relevant dune Habitats (e.g. Shifting dunes with *Ammophila arenaria*, Habitat 2120) considered with a key role in some ecosystem services, such as dune stability enhancement, coastal erosion protection, resistance of the coastal dune pollination networks, as well as in providing habitat for coastal fauna and in supporting fungal diversity (Prisco et al. 2016b; Filesi et al. 2017; Fantinato et al. 2018; Konlechner et al. 2019; De Battisti and Griffin 2020). The Habitat 2270 (Wooded dunes with *Pinus* species) is the only one to show at least a favourable criterion (structure



**Table 2.** Final assessments of the Italian coastal sand dunes and inland dunes Habitats as resulting in the last three reporting cycles, from 2001 to 2018 (FV: Favourable; U1: Unfavourable-Inadequate; U2: Unfavourable-Bad; XX: Unknown; DD: Data Deficient).

HABITAT	2 <sup>nd</sup> Report (2001-2006)			3 <sup>rd</sup> Report (2007-2012)			4 <sup>th</sup> Report (2013-2018)		
	ALP	CON	MED	ALP	CON	MED	ALP	CON	MED
2110 Embryonic shifting dunes		U2	U2		U2	U2		U2	U2
2120 Shifting dunes along the shoreline with <i>Ammophila arenaria</i>		U2	U2		U2	U2		U2	U2
2130 Fixed coastal dunes with herbaceous vegetation		U1			U2			U2	
2160 Dunes with <i>Hippophae rhamnoides</i>		U1			U2			U2	
2210 <i>Crucianellion maritima</i> fixed beach dunes			U1			U2			U2
2230 <i>Malcolmietalia</i> dune grasslands		U1	XX		U2	U1		U2	U2
2240 <i>Brachypodietalia</i> dune grasslands with annuals		U1	XX		DD	U1		U2	U2
2250 Coastal dunes with <i>Juniperus</i> spp.		U2	U1		U2	U2		U2	U2
2260 <i>Cisto-Lavanduletalia</i> dune sclerophyllous scrubs		U2	U1		U2	U2		U2	U2
2270 Wooded dunes with <i>Pinus pinea</i> and/or <i>Pinus pinaster</i>		FV	FV		FV	U1		U1	U1
2330 Inland dunes with open <i>Corynephorus</i> and <i>Agrostis</i> grasslands	DD	XX		DD	U2		U2	U2	

**Figure 3.** A Final overall assessment and B overall trend in the conservation status of the Italian coastal sand dunes and inland dunes Habitats.

and functions); however, the overall conservation status of this habitat is still inadequate (Bonari et al. 2018). Although wooded dunes are usually found in the inner part of the coastal vegetation zonation, they are often subjected to intense silvicultural treatments and tourists trampling (Sarmati et al. 2019).

The overall worrying state of conservation of the dune systems claims for a better knowledge of pressures and threats acting on these habitats and for further monitoring plans. Without such a systematic approach, coastal dune habitats are going to face further degradation trends in both structure and functions, including also the disruption of spatial zonation of plant communities (Sarmati et al. 2019). This degradation process could finally lead to a dramatic alteration of the ecosystem services they provide (Everard et al. 2010; Barbier et al. 2011; Drius et al. 2019). Additionally, degraded dune habitats are more susceptible to biological invasions (Del Vecchio et al. 2015; Gheza et al. 2018; Giulio et al. 2020).

In dynamic and vulnerable ecosystems such as coastal dunes, successful conservation outcomes in the long-

term depend on sound evaluations of the effectiveness of current management measures, supported by regular and highly frequent on-ground monitoring, both inside and outside protected sites. We believe that our results provide bases and useful insights for dune habitats protection and management, in the context of the monitoring and reporting obligations set up by the Habitats Directive.

Overall, the results of the 4<sup>th</sup> Report testify for better knowledge on the geographical distribution, quality, typical species and conservation status of the whole Italian Habitats at biogeographical scale. Therefore, we should clarify that for dune Habitats, some of the changes in distribution and trends might probably be related to the application of more accurate and updated data. However, even though the geographical distribution maps of these Habitats have been validated by a large group of experts with detailed territorial knowledge, yet the lack of information on the actual location of the Habitats outside the Natura 2000 sites has negatively influenced the quantification of the Range parameter, as well as the structure and functions parameter. Finally, it's worth noting that

the information collected has been structured to ensure the archiving and traceability of both published and unpublished literature, placing a solid base of reliable and verified data at the local scale for the next reporting cycles (Gigante et al. 2019).

## Conclusions

According to the 4<sup>th</sup> Monitoring Report (92/43/EEC Habitats Directive) the conservation status of Italian coastal sand dunes and inland dunes Habitats is dramatically bad: the overall assessment reports 88% of Habitats in a bad conservation status and the remaining 12% in an inadequate condition. Key dune habitats, such as “Shifting dunes with *Ammophila arenaria*”, show a bad conservation status for all the considered criteria in both Biogeographical Regions. Main pressures and threats are the development of residential, commercial and industrial areas and the expansion of alien and ruderal species. Results show an overall worse conservation status with respect to previous national reports. Although part of these changes is probably due (but not only) to the provision of more accurate and updated data, the undoubtedly bad conservation status of these unstable but resilient Habitats should draw attention to more effective conservation measures, supported by monitoring activities, both inside and outside protected areas.

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# New national and regional Annex I Habitat records: from #13 to #15

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## Abstract

New data on the distribution of the Annex I Habitats 3160, 7210\* and 9320 are reported in this contribution. In detail, 24 new occurrences in Natura 2000 Sites are presented and 42 new cells in the EEA 10 km x 10 km Reference grid are added. The new data refer to Italy and in particular to the Administrative Regions Lombardy, Sardinia, and Sicily.

## Keywords

3160, 7210\*, 9320, biodiversity, conservation, 92/43/EEC Directive, Italy, vegetation

## Introduction

This is the third standardized contribution reporting records of new occurrences of Annex I Habitats in Europe. The data here presented have been compared to the results of the 4<sup>th</sup> Report ex-Art. 17 on Annex I Habitat Monitoring in Europe, delivered in 2019 and available on the Eionet Central Data Repository (Eionet, 2019). As usual, the related phytosociological relevés here reported will be archived in the Italian database "VegItaly" (Gigante et al. 2014; Landucci et al. 2012).

## Habitats Records

The single records including details and descriptions of the newly recorded habitats are hereafter listed. As standard reference for official sources and formats, the indications in Gigante et al. (2019) have been followed. A

synthetic overview of the newly recorded occurrences is provided in Table 1. The maps have been created by using the open source QGIS Geographic Information System (QGIS.org 2020).

**#13. Annex I Habitat: 3160 Natural dystrophic lakes and ponds (Bolpagni R, Dalla Vecchia A, Cerabolini BEL)**

**EUNIS Classification system:** C1.45 Peatmoss and Utricularia communities of dystrophic waterbodies

**Biogeographical Region:** Continental

**National Habitat Checklist of reference:** Manuale Italiano di interpretazione degli habitat della Direttiva 92/43/CEE (Biondi et al. 2009).

**Phytosociological reference:** *Scorpidio-Utricularion minoris* Pietsch 1965, *Utricularietalia intermedio-minoris*

**Table 1.** Syntetic overview of the newly reported data.

Hab ID	Hab name	Cell ID	Country	BR	N2000 Site	Authors
3160	Natural dystrophic lakes and ponds	10kmE437N245	Italy	CON	IT20B0017	Bolpagni R, Dalla Vecchia A, Cerabolini BEL
7210*	Calcareous fens with <i>Cladium mariscus</i> and species of the <i>Caricion davallianae</i>	10kmE423N199	Italy	MED	ITB012211	Rivieccio G, Caria MC, Bagella S
9320	<i>Olea</i> and <i>Ceratonia</i> forests	10kmE450N152, 10kmE452N165, 10kmE452N166, 10kmE454N166, 10kmE455N167, 10kmE456N162, 10kmE456N166, 10kmE456N167, 10kmE457N162, 10kmE457N165, 10kmE458N142, 10kmE458N166, 10kmE459N166, 10kmE460N166, 10kmE461N162, 10kmE461N167, 10kmE461N168, 10kmE462N166, 10kmE463N161, 10kmE463N164, 10kmE463N166, 10kmE464N166, 10kmE467N166, 10kmE468N166, 10kmE469N166, 10kmE470N166, 10kmE471N156, 10kmE471N166, 10kmE471N167, 10kmE472N156, 10kmE474N163, 10kmE474N164, 10kmE475N154, 10kmE476N162, 10kmE476N168, 10kmE477N157, 10kmE477N162, 10kmE477N163, 10kmE477N168, 10kmE478N168	Italy	MED	ITA010003, ITA010004, ITA010005, ITA010008, ITA010010, ITA010016, ITA010019, ITA020003, ITA020006, ITA020012, ITA020014, ITA020024, ITA020025, ITA020043, ITA030007, ITA030012, ITA030017, ITA040001, ITA040007, ITA070011, ITA080009, ITA090009	Gianguzzi L, Bazan G

Pietsch 1965, *Utricularietea intermedio-minoris* Pietsch 1965 (Biondi and Blasi 2015).

**Geographic information:** Italy, Lombardy, Mantua, La Piuda, 20 m a.s.l., Coordinates: 45.16735 N, 10.70986 E (Table 2, Relève 1); 45.16682 N, 10.70964 E (Table 2, Relève 2).

**Cell ID in the EEA reference grid:** 10kmE437N245 (Figure 1).

**Natura 2000 Site Code:** SAC IT20B0017 "Ansa e Valli del Mincio"

**Phytosociological table:** Table 2; taxonomic nomenclature according to Bartolucci et al. (2018) and Aleffi et al. (2015).

**Notes:** Relict *Utricularia minor* L. populations have been recently recorded for the "La Piuda", an extensive alkaline fen habitat (~115 ha) located few kilometres north-west the city of Mantua, in the central sector of the Po plain. Here, a series of small dystrophic pools (<5 m<sup>2</sup>) are scattered within a series of peat meadows dominated by *Molinia caerulea* (L.) Moench and *Cladium mariscus* (L.) Pohl (Biondi et al. 2009; Brusa et al. 2017). These species create a complex vegetation mosaic interspersed by dense pioneer stands of *Rhynchospora alba* (L.) Vahl. The system results largely fed by groundwater seepage and apparently it is hydrologically disconnected by the nearby Mincio River. Indeed, the water quality of the ponds is not compliant with the physical and chemical status of surface water bodies of the Po plain (Bolpagni et al. 2016). The re-

active soluble phosphorous, for example, turned out to be always lower than the analytical detection limit (5 µg L<sup>-1</sup>, Bolpagni R., unpublished data). These peculiar chemical features offer the basal conditions for the maintenance of the *U. minor* communities and peatland mosses, mainly represented by *Sphagnum contortum* Schultz and *Campylium stellatum* (Hedw.) Lange & C.E.O. Jensen. Further, the local water oligotrophy guarantees the presence of species and vegetation of exceptional biogeographical value in the context of the Po plain, at an altitude of only 20 m a.s.l. The present report expands and reinforces the presence of the habitat 3160 in the Continental region in Italy, that was considered, so far, only marginal.

**#14. Annex I Habitat: 7210\*** Calcareous fens with *Cladium mariscus* and species of the (Rivieccio G, Caria MC, Bagella S)

**EUNIS Classification system:** D5.2 Beds of large sedges normally without free-standing water (narrower), D5.24 Fen *Cladium mariscus* beds (wider).

**Biogeographical Region:** Mediterranean

**National Habitat Checklist of reference:** Manuale Italiano di interpretazione degli habitat della Direttiva 92/43/CEE (Biondi et al. 2009).



**Figure 1.** Distribution in Italy of the Habitat 3160: in black the new cell, in grey the cells officially reported in the 4<sup>th</sup> Habitat report ex-Art. 17 (period 2013–2018).

**Table 2.** Habitat 3160.

Relevé number	1	2	
Cell ID	10kmE437N245	10kmE437N245	
Latitude	4.516.735	4.516.682	
Longitude	1.070.986	1.070.964	
Date	10/07/2019	10/07/2019	
Area (m <sup>2</sup> )	4	4	
Altitude (m a.s.l.)	20	20	
Aspect	-	-	
Slope (°)	0	0	
Emergent herb layer Cover (%)	60	35	
Submerged herb layer Cover (%)	10	25	
Moss layer Cover (%)	5	0	
Water surface (%)	35	50	Presences
<b><i>Utricularietea intermedio-minoris</i></b>			
^ <i>Utricularia minor</i> L.	1	2	2
Other species			
<i>Cladium mariscus</i> (L.) Pohl	3	1	2
<i>Juncus subnodulosus</i> Schrank	1	2	2
<i>Lythrum salicaria</i> L.	1	+	2
^ <i>Rhynchospora alba</i> (L.) Vahl	1	1	2
<i>Hydrocotyle vulgaris</i> L.	+	+	2
<i>Juncus articulatus</i> L. subsp. <i>articulatus</i>	+	+	2
<i>Campylium stellatum</i> (Hedw.) Lange & C.E.O. Jensen	+	.	1
<i>Mentha aquatica</i> L. subsp. <i>aquatica</i>	.	+	1

^ Reference plant species of the Habitat 3160, from Biondi et al. (2009).

**Phytosociological reference:** *Magnocaricion elatae* Koch 1926, *Magnocaricetalia elatae* Pignatti 1953, *Phragmito australis-Magnocaricetea elatae* Klika in Klika & Novák 1941 (Biondi & Blasi, 2015; Venanzoni et al. 2018).

**Geographic information:** Italy, Sardinia, Sassari, Trinità d'Agultu e Vignola, Costa Paradiso, Spiaggia di Li Cossi, 3 m a.s.l., Coordinates: 41.046760 N, 8.936343 E (Table 3, Relevé 1); Coordinates: 41.046661 N, 8.936558 E (Table 3, Relevé 2); Coordinates: 41.046535 N, 8.936687 E (Table 3, Relevé 3).

**Cell ID in the EEA reference grid:** 10kmE423N199 (Figure 2).

**Natura 2000 Site Code:** SAC ITB012211 "Isola Rossa - Costa Paradiso"

**Phytosociological table:** Table 3; taxonomic nomenclature according to Portale della Flora d'Italia (2019).

**Notes:** This new station was detected basing on the data concerning *Cladium mariscus* (L.) Pohl distribution reported in the online floristic database "Wikiplantbase" (Peruzzi et al. 2017). This is the second reported site of

occurrence of this priority habitat for Sardinia Region, being the first one at Platamona lagoon (Gigante et al. 2019). The station is very close to the sea and in contact with psammophilous vegetation.

### #15. Annex I Habitat: 9320 Olea and Ceratonia forests (Gianguzzi L, Bazan G)

**EUNIS Classification system:** G2.41 Wild *Olea europaea* woodland

**Biogeographical Region:** Mediterranean

**National Habitat Checklist of reference:** Manuale Italiano di interpretazione degli habitat della Direttiva 92/43/CEE (Biondi et al. 2009).

**Phytosociological reference:** *Ruto chalepensis-Oleetum sylvestris* Gianguzzi et Bazan 2019, *Ruto oleetosum sylvestris* Gianguzzi et Bazan 2019, *Ruto chalepensis-Oleetum sylvestris* Gianguzzi et Bazan 2019, *Ruto cercidetosum siliquastris* Gianguzzi et Bazan 2019, *Ruto*

**Table 3.** Habitat 7120\*.

Relevé number	1	2	3	
Cell ID	10kmE423N199	10kmE423N199	10kmE423N199	
Latitude	41.046.760	41.046.661	41.046.535	
Longitude	8.936.343	8.936.558	893.668	
Date	10/6/2019	10/6/2019	10/6/2019	
Area (m <sup>2</sup> )	4	6	6	
Altitude (m a.s.l.)	3	3	3	
Cover (%)	100	100	100	
Average vegetation height (m)	1.4	1.4	1.4	
Water presence	no	yes	no	Presences

#### *Magnocaricion elatae, Magnocaricetalia elatae, Phragmito australis-Magnocaricetea elatae*

<sup>^</sup> <i>Cladium mariscus</i> (L.) Pohl	5	5	5	3
<i>Phragmites australis</i> (Cav.) Trin. ex Steud.	1	1	1	3
<i>Carex hispida</i> Willd. ex Schkuhr	.	1	+	2
<i>Lythrum salicaria</i> L.	1	+	.	2

#### Other species

<i>Convolvulus sepium</i> L.	+	1	2	3
<i>Dittrichia viscosa</i> (L.) Greuter subsp. <i>viscosa</i>	+	+	+	3
<i>Rubia peregrina</i> L.	+	+	+	3
<i>Hydrocotyle vulgaris</i> L.	.	+	+	2
<i>Alnus glutinosa</i> (L.) Gaertn.	.	.	r	1
<i>Armeria pungens</i> (Link) Hoffmanns. & Link	.	.	+	1
<i>Clematis flammula</i> L.	.	+	.	1
<i>Ficus carica</i> L.	.	r	.	1
<i>Juncus maritimus</i> Lam.	.	.	+	1
<i>Limniris pseudacorus</i> (L.) Fuss	.	1	.	1
<i>Mentha aquatica</i> L. subsp. <i>aquatica</i>	.	+	.	1
<i>Myrtus communis</i> L.	.	.	+	1
<i>Oenanthe lachenalii</i> C.C.Gmel.	.	.	+	1
<i>Potentilla reptans</i> L.	.	.	+	1
<i>Schoenus nigricans</i> L.	.	.	+	1
<i>Salix</i> sp.	.	.	+	1

<sup>^</sup> Reference plant species of the Habitat 7210\*, from Biondi et al. (2009).





**Figure 2.** Distribution in Italy of the Habitat 7120\*: in black the new cell, in grey the cells officially reported in the 4<sup>th</sup> Habitat report ex-Art. 17 (period 2013–2018), in white (black outline) the cell recorded after the 4<sup>th</sup> Habitat report (Gigante et al. 2019).

*chalepensis-Oleetum sylvestris* Gianguzzi et Bazan 2019  
*celtidetosum australis* Gianguzzi et Bazan 2019, *Ruto chalepensis-Oleetum sylvestris* Gianguzzi et Bazan 2019  
*euphorbietosum bivonae* Gianguzzi et Bazan 2019, *Ruto chalepensis-Oleetum sylvestris* Gianguzzi et Bazan 2019  
*rhamnietosum oleoidis* Gianguzzi et Bazan 2019, *Ruto chalepensis-Oleetum sylvestris* Gianguzzi et Bazan 2019  
*periplocetosum angustifoliae* Gianguzzi et Bazan 2019, *Chamaeropo humilis-Oleetum sylvestris* Gianguzzi et Bazan 2019  
*acanthetosum mollis* Gianguzzi et Bazan 2019, *Chamaeropo humilis-Oleetum sylvestris* Gianguzzi et Bazan 2019  
*ephedretosum fragilis* Gianguzzi et Bazan 2019, *Oleo sylvestris-Ceratonion siliquae* Br.-Bl. ex Guinochet et Drouineau 1944, *Pistacio lentis-ci-Rhamnietalia alaterni* Rivas-Martínez 1975, *Calicotomo infestae-Oleetum sylvestris* Gianguzzi et Bazan 2019  
*typicum*, *Calicotomo infestae-Oleetum sylvestris* Gianguzzi et Bazan 2019  
*asplenietosum obovatae* Gianguzzi et Bazan 2019, *Erico arboreae-Quercion ilicis* Brullo, Di Martino et Marcenò 1977, *Quercetalia ilicis* Br.-Bl. ex Molinier 1934; *Quercetalia ilicis* Br.-Bl. in Br.-Bl., Roussine et Nègre 1952 (Gianguzzi and Bazan 2019a, 2019b; Biondi and Blasi 2015). For a detailed correspondence with the EEA reference grid cells, see Table 4.

**Geographic information:** Relevés and tables mentioned in this paragraph refer to Gianguzzi and Bazan (2019a): Italy, Sicily, Patti, Promontorio Tindari, 118 m a.s.l., Coor-

dinates: 15.050378 E, 38.135782 N (Relevé 1, Table S1); Isnello, Aquileia, 389 m a.s.l., Coordinates: 14.047021 E, 37.944303 N (Relevé 2, Table S1); Modica, Cava d'Ispica, 360 m a.s.l., Coordinates: 14.843852 E, 36.848259 N (Relevé 3, Table S1); Rosolini, Cava d'Ispica, 110 m a.s.l., Coordinates: 14.862874 E, 36.816794 N (Relevé 4, Table S1); Termini Imerese, Fiume San Leonardo, 110 m a.s.l., Coordinates: 13.668602 E, 37.978917 N (Relevé 5, Table S1); Altavilla Milicia, Torre Normanna, 20 m a.s.l., Coordinates: 13.599493 E, 38.026267 N (Relevé 6, Table S1); Santo Stefano Quisquina, C.da Liste Inferno, 680 m a.s.l., Coordinates: 13.542324 E, 37.578661 N (Relevé 7, Table S1); Patti, Promontorio Tindari, 200 m a.s.l., Coordinates: 15,036618 E 38,147196 N (Relevé 8, Table S1); Patti, Promontorio Tindari, 15 m a.s.l., Coordinates: 15,037066 E 38,145108 N (Relevé 9, Table S1); Patti, Promontorio Tindari, 50 m a.s.l., Coordinates: 15,036824 E 38,146639 N (Relevé 10, Table S1); Castelbuono, Gole di Tiberio, 95 m a.s.l., Coordinates: 14,148705 E 37,954782 N (Relevé 11, Table S1); Sortino, Valle dell'Anapo, 230 m a.s.l., Coordinates: 15,037351 E 37,138930 N (Relevé 12, Table S1); Palermo, Monte Pellegrino, 140 m a.s.l., Coordinates: 13,345964 E 38,162923 N (Relevé 13, Table S1); Palermo, Monte Pellegrino, 140 m a.s.l., Coordinates: 13,344326 E 38,165197 N (Relevé 14, Table S1); Palermo, Monte Pellegrino, 140 m a.s.l., Coordinates: 13,342264 E 38,168068 N (Relevé 15, Table S1); Palermo, Monte Pellegrino, 130 m a.s.l., Coordinates: 13,344986 E 38,165258 N (Relevé

**Table 4.** Habitat 9320: cells of the EEA reference grid and Natura 2000 Sites where the new records are located; table and relevés numbers refer to Gianguzzi and Bazan (2019a).

Cell ID	N2000 site	Table number	Relevés number
10kmE450N152	SAC ITA010019 "Isola di Pantelleria: Montagna Grande e Monte Gibele"	S3	55-57
10kmE452N165	SAC ITA010004 "Isola di Favignana"	S3	49
10kmE452N165	SAC ITA010004 "Isola di Favignana"	S3	51-53
10kmE452N166	SAC ITA010003 "Isola di Levanzo"	S3	44-48
10kmE454N166	SAC ITA010010 "Monte San Giuliano"	S2	39
10kmE455N167	SAC ITA010016 "Monte Cofano e Litorale"	S2	27-31
10kmE455N167	SAC ITA010016 "Monte Cofano e Litorale"	S2	33-35
10kmE456N162	SAC ITA010005 "Laghetti di Preola e Gorghetti Tondi e Sciare di Mazara"	S4	69
10kmE456N166	SAC ITA010008 "Complesso Monte Bosco e Scorce"	S6	106-107
10kmE456N167	-	S2	36
10kmE457N162	-	S4	65-68
10kmE457N162	-	S4	74-87
10kmE457N165	-	S4	72
10kmE457N165	-	S6	104-105
10kmE458N142	SAC ITA040001 "Isole dello Stagnone di Marsala"	S3	58-59
10kmE458N166	-	S2	32
10kmE458N166	-	S5	94-103
10kmE459N166	-	S4	70-71
10kmE459N166	-	S4	73
10kmE459N166	-	S5	88-89
10kmE460N166	-	S2	43
10kmE461N162	SAC ITA020025 "Isola di Linosa"	S2	41-42
10kmE461N167	SAC ITA020012 "Valle del Fiume Oreto"	S4	60-64
10kmE461N168	SAC ITA020006 "Capo Gallo"	S2	37-38
10kmE461N168	SAC ITA020014 "Monte Pellegrino"	S1	13-16
10kmE461N168	SAC ITA020014 "Monte Pellegrino"	S2	21-26
10kmE461N168	SAC ITA020014 "Monte Pellegrino"	S2	40
10kmE462N166	-	S6	108
10kmE463N161	SAC ITA040007 "Pizzo della Rondine, Bosco di S. Stefano Quisquina"	S1	7
10kmE463N164	SAC ITA020024 "Rocche di Ciminna"	S3	54
10kmE463N166	-	S1	6
10kmE464N166	SAC ITA020043 "Monte Rosamarina e Cozzo Famò"	S1	5
10kmE467N166	-	S1	2
10kmE468N166	SAC ITA020003 "Boschi di San Mauro Castelverde"	S1	11
10kmE469N166	-	S6	112-113
10kmE470N166	-	S3	50
10kmE471N156	-	S5	90-91
10kmE471N166	SAC ITA030017 "Vallone Laccaretta e Urio Quattrocchi"	S6	109-110

**Table 4.** Continuation.

Cell ID	N2000 site	Table number	Relevés number
10kmE471N167	-	S6	111
10kmE472N156	-	S5	92-93
10kmE474N163	SAC ITA070011 "Poggio S. Maria"	S6	114
10kmE474N164	-	S6	115
10kmE475N154	SAC ITA080009 "Cava d'Ispica"	S1	3-Apr
10kmE476N162	-	S1	18
10kmE476N168	SAC ITA030012 "Laguna di Oliveri - Tindari"	S1	1
10kmE476N168	SAC ITA030012 "Laguna di Oliveri - Tindari"	S1	8-Oct
10kmE477N157	SAC ITA090009 "Valle del Fiume Anapo, Cavagrande del Calcinara, Cugni di Sortino"	S1	12
10kmE477N162	-	S1	17
10kmE477N162	-	S1	19
10kmE477N163	-	S1	20
10kmE477N168	-	S6	116
10kmE478N168	-	S6	117
10kmE478N168	-	S6	119-120
10kmE478N168	SAC ITA030007 "Affluenti del Torrente Mela"	S6	118

16, Table S1); Aci Sant'Antonio, Piano San Giovanni, 260 m a.s.l., Coordinates: 15,132394 E 37,607401 N (Relevè 17, Table S1); Belpasso, C.da Giovencheria, 328 m a.s.l., Coordinates: 14,960469 E 37,564890 N (Relevè 18, Table S1); Aci Sant'Antonio, Piano San Giovanni, 250 m a.s.l., Coordinates: 15,130932 E 37,603752 N (Relevè 19, Table S1); Acireale, C.da Pizzone, 180 m a.s.l., Coordinates: 15,158616 E 37,611611 N (Relevè 20, Table S1); Palermo, Monte Pellegrino, 560 m a.s.l., Coordinates: 13,353614 E 38,165324 N (Relevè 21, Table S2); Palermo, Monte Pellegrino, 570 m a.s.l., Coordinates: 13,358136 E 38,162278 N (Relevè 22, Table S2); Palermo, Monte Pellegrino, 550 m a.s.l., Coordinates: 13,352480 E 38,165630 N (Relevè 23, Table S2); Palermo, Monte Pellegrino, 540 m a.s.l., Coordinates: 13,356010 E 38,162879 N (Relevè 24, Table S2); Palermo, Monte Pellegrino, 580 m a.s.l., Coordinates: 13,353118 E 38,165582 N (Relevè 25, Table S2); Palermo, Monte Pellegrino, 310 m a.s.l., Coordinates: 13,363137 E 38,157461 N (Relevè 26, Table S2); Custonaci, Riserva Monte Cofano, 90 m a.s.l., Coordinates: 12,687013 E 38,103337 N (Relevè 27, Table S2); Custonaci, Riserva Monte Cofano, 130 m a.s.l., Coordinates: 12,686441 E 38,103813 N (Relevè 28, Table S2); Custonaci, Monte Palatimone, 223 m a.s.l., Coordinates: 12,695398 E 38,096905 N (Relevè 29, Table S2); Custonaci, Monte Palatimone, 221 m a.s.l., Coordinates: 12,694294 E 38,097898 N (Relevè 30, Table S2); Custonaci, Monte Palatimone, 225 m a.s.l., Coordinates: 12,696293 E 38,095822 N (Relevè 31, Table S2); Partinico, Santuario Madonna del Ponte, 580 m a.s.l., Coordinates: 13,033546

E 38,039098 N (Relevè 32, Table S2); Custonaci, Mt. Cofano, 130 m a.s.l., Coordinates: 12,686595 E 38,103635 N (Relevè 33, Table S2); Custonaci, Mt. Cofano, 100 m a.s.l., Coordinates: 12,686737 E 38,103432 N (Relevè 34, Table S2); Custonaci, Monte Cofano, 50 m a.s.l., Coordinates: 12,675570 E 38,113053 N (Relevè 35, Table S2); Custonaci, Monte Palatimone, 250 m a.s.l., Coordinates: 12,706626 E 38,088938 N (Relevè 36, Table S2); Palermo, Monte Gallo, 460 m a.s.l., Coordinates: 13,310307 E 38,216177 N (Relevè 37, Table S2); Palermo, Monte Gallo, 430 m a.s.l., Coordinates: 13,309178 E 38,217142 N (Relevè 38, Table S2); Erice, C.da Pizzolungo, 240 m a.s.l., Coordinates: 12,578676 E 38,059250 N (Relevè 39, Table S2); Palermo, Monte Pellegrino presso l'Addaura, 47 m a.s.l., Coordinates: 13,338136 E 38,194702 N (Relevè 40, Table S2); Burgio, Castello Gristia, 375 m a.s.l., Coordinates: 13,268518 E 37,638385 N (Relevè 41, Table S2); Burgio, Castello Gristia, 380 m a.s.l., Coordinates: 13,268334 E 37,638033 N (Relevè 42, Table S3); San Giuseppe Jato, Pizzo Mirabella, 720 m a.s.l., Coordinates: 13,217704 E 38,001451 N (Relevè 43, Table S2); Levanzo, Capo Grosso, 85 m a.s.l., Coordinates: 12,332344 E 38,013284 N (Relevè 44, Table S3); Levanzo, Punta Genovese, 150 m a.s.l., Coordinates: 12,331608 E 38,010906 N (Relevè 45, Table S3); Levanzo, Capo Grosso, 65 m a.s.l., Coordinates: 12,331930 E 38,012122 N (Relevè 46, Table S3); Levanzo, La Fossa, 190 m a.s.l., Coordinates: 12,342342 E 37,999787 N (Relevè 47, Table S3); Levanzo, La Fossa, 170 m a.s.l., Coordinates: 12,342443 E 37,999643 N (Relevè 48, Table S3); Favignana, Montagna Grossa, 160 m a.s.l., Coordinates:

12,309161 E 37,938484 N (Relevè 49, Table S3); Mistretta, Montagna Grossa, 110 m a.s.l., Coordinates: 14,384398 E 37,942904 N (Relevè 50, Table S3); Favignana, Montagna Grossa, 95 m a.s.l., Coordinates: 12,308115 E 37,938558 N (Relevè 51, Table S3); Favignana, Montagna Grossa, 90 m a.s.l., Coordinates: 12,307137 E 37,938754 N (Relevè 52, Table S3); Favignana, Montagna Grossa, 80 m a.s.l., Coordinates: 12,305797 E 37,938689 N (Relevè 53, Table S3); Ciminna, Montagna Grossa, 70 m a.s.l., Coordinates: 13,584770 E 37,850821 N (Relevè 54, Table S3); Pantelleria, C.da Favare, 465 m a.s.l., Coordinates: 12,000675 E 36,770708 N (Relevè 55, Table S3); Pantelleria, C.da Favare, 460 m a.s.l., Coordinates: 12,000350 E 36,770569 N (Relevè 56, Table S3); Pantelleria, C.da Favare, 450 m a.s.l., Coordinates: 12,002469 E 36,770179 N (Relevè 57, Table S3); Linosa, C.da Grotta, 0 m a.s.l., Coordinates: 12,865183 E 35,866445 N (Relevè 58, Table S3); Linosa, C.da Grotta, 0 m a.s.l., Coordinates: 12,867218 E 35,866030 N (Relevè 59, Table S3); Palermo, Fuime Oreto, 66 m a.s.l., Coordinates: 13,342731 E 38,089208 N (Relevè 60, Table S4); Palermo, Fuime Oreto, 63 m a.s.l., Coordinates: 13,343899 E 38,088774 N (Relevè 61, Table S4); Palermo, Fuime Oreto, 60 m a.s.l., Coordinates: 13,342409 E 38,088735 N (Relevè 62, Table S4); Palermo, Fuime Oreto, 67 m a.s.l., Coordinates: 13,337801 E 38,087655 N (Relevè 63, Table S4); Palermo, Fuime Oreto, 65 m a.s.l., Coordinates: 13,338085 E 38,087875 N (Relevè 64, Table S4); Castelvetrano, Castello della Pietra, 160 m a.s.l., Coordinates: 12,890245 E 37,662671 N (Relevè 65, Table S4); Castelvetrano, Castello della Pietra, 250 m a.s.l., Coordinates: 12,891669 E 37,666048 N (Relevè 66, Table S4); Castelvetrano, Castello della Pietra, 200 m a.s.l., Coordinates: 12,891641 E 37,665574 N (Relevè 67, Table S4); Campobello di Mazara, Cave di Cusa, 70 m a.s.l., Coordinates: 12,719638 E 37,619277 N (Relevè 68, Table S4); Campobello di Mazara, Cave di Cusa, 70 m a.s.l., Coordinates: 12,714475 E 37,619458 N (Relevè 69, Table S4); Partinico, Fiume Iato, 150 m a.s.l., Coordinates: 13,073628 E 38,021498 N (Relevè 70, Table S4); Partinico, Fiume Iato, 160 m a.s.l., Coordinates: 13,075261 E 38,021952 N (Relevè 71, Table S4); Calatafimi, C.da Scorigiagatto, 250 m a.s.l., Coordinates: 12,872111 E 37,933454 N (Relevè 72, Table S4); Partinico, Fiume Iato, 135 m a.s.l., Coordinates: 13,073967 E 38,021332 N (Relevè 73, Table S4); Castelvetrano, Strada del Filo, 80 m a.s.l., Coordinates: 12,809836 E 37,628560 N (Relevè 74, Table S4); Castelvetrano, Strada del Filo, 78 m a.s.l., Coordinates: 12,787859 E 37,629975 N (Relevè 75, Table S4); Castelvetrano, Strada del Filo, 79 m a.s.l., Coordinates: 12,781526 E 37,628579 N (Relevè 76, Table S4); Castelvetrano, Strada del Filo, 70 m a.s.l., Coordinates: 12,797897 E 37,630373 N (Relevè 77, Table S4); Castelvetrano, Strada del Filo, 76 m a.s.l., Coordinates: 12,797626 E 37,630343 N (Relevè 78, Table S4); Castelvetrano, Strada del Filo, 81 m a.s.l., Coordinates: 12,784324 E 37,628846 N (Relevè 79, Table S4); Castelvetrano, Strada del Filo, 81 m a.s.l., Coordinates: 12,783345 E 37,629091 N (Relevè 80, Table S4); Castelvetrano, Strada del Filo, 74 m a.s.l., Coordinates: 12,785612 E 37,629500 N (Relevè 81, Table S4); Castelvetrano, Strada del Filo, 86 m a.s.l., Coordinates: 12,815327 E 37,628691 N (Relevè 82, Table S4); Castelvetrano, Strada del Filo, 84 m a.s.l., Coordinates: 12,811872 E 37,628789 N (Relevè 83, Table S4); Castelvetrano, Strada del Filo, 80 m a.s.l., Coordinates: 12,818864 E 37,628506 N (Relevè 84, Table S4); Castelvetrano, Strada del Filo, 80 m a.s.l., Coordinates: 12,815974 E 37,628746 N (Relevè 85, Table S4); Castelvetrano, Strada del Filo, 65 m a.s.l., Coordinates: 12,797759 E 37,630078 N (Relevè 86, Table S4); Castelvetrano, Strada del Filo, 67 m a.s.l., Coordinates: 12,797919 E 37,630609 N (Relevè 87, Table S4); Partinico, Fiume Jato, 155 m a.s.l., Coordinates: 13,062089 E 38,024018 N (Relevè 88, Table S5); Partinico, Fiume Jato, 160 m a.s.l., Coordinates: 13,061635 E 38,021488 N (Relevè 89, Table S5); Gela, C.da Piano Stella, 90 m a.s.l., Coordinates: 14,378464 E 37,050093 N (Relevè 90, Table S5); Gela, C.da Piano Stella, 110 m a.s.l., Coordinates: 14,379472 E 37,050006 N (Relevè 91, Table S5); Acate, C.da Litteri, 150 m a.s.l., Coordinates: 14,486855 E 37,026701 N (Relevè 92, Table S5); Acate, C.da Litteri, 110 m a.s.l., Coordinates: 14,486369 E 37,026492 N (Relevè 93, Table S5); Partinico, Cozzo Ciluffo, 40 m a.s.l., Coordinates: 13,028215 E 38,052982 N (Relevè 94, Table S5); Partinico, Cozzo Ciluffo, 70 m a.s.l., Coordinates: 13,029255 E 38,053315 N (Relevè 95, Table S5); Partinico, Cozzo Ciluffo, 70 m a.s.l., Coordinates: 13,029249 E 38,053055 N (Relevè 96, Table S5); Partinico, Torrente Forgitella, 130 m a.s.l., Coordinates: 13,019845 E 38,044132 N (Relevè 97, Table S5); Partinico, Scarpate Piano Fico, 40 m a.s.l., Coordinates: 13,026285 E 38,048979 N (Relevè 98, Table S5); Partinico, Scarpate Piano Fico, 80 m a.s.l., Coordinates: 13,025797 E 38,047035 N (Relevè 99, Table S5); Partinico, Scarpate Piano Fico, 30 m a.s.l., Coordinates: 13,025846 E 38,049345 N (Relevè 100, Table S5); Partinico, Scarpate Piano Fico, 40 m a.s.l., Coordinates: 13,025341 E 38,049667 N (Relevè 101, Table S5); Partinico, Scarpate Piano Fico, 60 m a.s.l., Coordinates: 13,025496 E 38,049493 N (Relevè 102, Table S5); Partinico, Scarpate Piano Fico, 50 m a.s.l., Coordinates: 13,025566 E 38,048844 N (Relevè 103, Table S5); Calatafimi, C.da Vignazzi, 300 m a.s.l., Coordinates: 12,870861 E 37,932696 N (Relevè 104, Table S6); Calatafimi, C.da Vignazzi, 320 m a.s.l., Coordinates: 12,875185 E 37,939364 N (Relevè 105, Table S6); Buseto Palizzolo, Monte Scorace, 465 m a.s.l., Coordinates: 12,771394 E 37,986300 N (Relevè 106, Table S6); Buseto Palizzolo, Monte Scorace, 467 m a.s.l., Coordinates: 12,771227 E 37,985920 N (Relevè 107, Table S6); Bolognetta, Pzo Mangiatoriello, 540 m a.s.l., Coordinates: 13,489366 E 37,965510 N (Relevè 108, Table S6); Mistretta, C.da di Zupardo, 400 m a.s.l., Coordinates: 14,405601 E 37,939854 N (Relevè 109, Table S6); Mistretta, C.da Zupardo, 420 m a.s.l., Coordinates: 14,405761 E 37,939382 N (Relevè 110, Table S6); Caronia, C.da Onofrio, 300 m a.s.l., Coordinates: 14,431832 E 38,014651 N (Relevè 111, Table S6); Tusa, Milianni, 250 m a.s.l., Coordinates: 14,198336 E 38,013350 N (Relevè 112, Table S6); Tusa, C.da Marro, 180 m a.s.l., Coordinates: 14,239668 E

38,003724 N (Relevè 113, Table S6); Centuripe, Strada Cesarò-Adrano, 300 m a.s.l., Coordinates: 14,793680 E 37,656520 N (Relevè 114, Table S6); Bronte, Strada Cesarò-Adrano, 500 m a.s.l., Coordinates: 14,786433 E 37,731222 N (Relevè 115, Table S6); Mazzarrà Sant'Andrea, C.da Musclonita, 160 m a.s.l., Coordinates: 15,133028 E 38,082438 N (Relevè 116, Table S6); Santa Lucia del Mela, Castello, 335 m a.s.l., Coordinates: 15,281521 E 38,139027 N (Relevè 117, Table S6); Santa Lucia del Mela, Torrente Mela, 320 m a.s.l., Coordinates: 15,293759 E 38,091113 N (Relevè 118, Table S6); Santa Lucia del Mela, Torrente Mela, 250 m a.s.l., Coordinates: 15,280420 E 38,138956 N (Relevè 119, Table S6); Santa Lucia del Mela, Torrente Mela, 250 m a.s.l., Coordinates: 15,279890 E 38,139038 N (Relevè 120, Table S6).

**Cells ID in the EEA reference grid:** See Table 4 and Figure 3.

**Natura 2000 Site Codes:** See table 4.

**Phytosociological table:** Tab. S1, S2, S3, S4, S5, S6 in Gianguzzi and Bazan (2019a). The online database “The Plant List” (2013) and the Euro+Med Plantbase (Euro+Med, 2006-2019) were used for taxa nomenclature.

**Notes:** Recent studies have paid attention to the forest communities dominated by *Olea europaea* L. var. *sylvestris* (Mill.) Lehr. in Sicily (Gianguzzi & Bazan, 2019a) and the Mediterranean area (Gianguzzi & Bazan, 2019b), highlighting some inconsistencies in the correct interpretation and distribution of habitat 9320. In fact,

as shown by the map in Fig. 3, the data collected for the IV Report (Eionet, 2019) still showed clear gaps in the distribution of this habitat in Sicily and in the southern part of the Italian Peninsula. These gaps were partly attributable to the significant destruction of oleaster forest formations – especially in the coastal belt – largely replaced by agricultural systems and urbanized areas, and only surviving in limited and fragmentary forest patches. *Olea europaea* var. *sylvestris* is a typical element of maquis dominated by *Pistacia lentiscus* as well as by *Euphorbia dendroides* (see, e.g., Molinier 1954; Trinajstić 1973, 1984)]. The abandonment of agricultural use and the reduction of human disturbances (on scrublands) lead over time to the gradual development of oleaster-dominated forest formations (Gianguzzi et al. 2016). Recent phytosociological surveys carried out on a large scale in Sicily (Gianguzzi & Bazan, 2019a, 2019b), have highlighted a more widespread presence of habitat 9320 than expected, although in punctual and small areas. These forest formations – and therefore the habitat 9320 – show a large-scale distributive potential, in line with what has been highlighted in other areas of the Mediterranean (Fig. 3). Considering their peculiarity, a more precise location of the representative sites and mature consortia would be necessary to promote their conservation and to limit their further floristic and phytocenotic biodiversity loss and structural deterioration.



**Figure 3.** Distribution in Italy of the Habitat 9320: in black the new cells, in grey the cells officially reported in the 4<sup>th</sup> Habitat report ex-Art. 17 (period 2013-2018).

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# A new pioneer association of detrital substrata of the hilly and low-mountain belts in Central Apennines (Italy)

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## Abstract

Plant communities dominated by *Petrosedum* ser. *Rupestria* in Italy have always been referred to the *Sedo albi-Scleranthetea biennis* Br.-Bl. 1955 class. This group of species was also often found more or less abundant in the garrigue and pasture vegetation. Some unusual plant communities dominated by *Petrosedum rupestre* (L.) P.V.Heath with a conspicuous presence of typical species of scree vegetation were found and sampled in the Abruzzo region, on more or less mobile debris. In order to classify such communities, syntaxonomic, structural, chorological and ecological analyses have been performed. All the *Petrosedum* ser. *Rupestria* dominated communities reported in Italy have been compared with the sampled vegetation. A new perennial pioneer association, linked to more or less mobile detrital substrata of the hilly and lower-mountain belts of the calcareous Central Apennines has been here described with the name *Linario purpureae-Petrosedetum rupestris*. Based on the syntaxonomic analysis, this association has been included in the *Linarion purpureae* alliance (*Scrophulario bicoloris-Helichrysetalia italici* order). The *Linario-Petrosedetum* has been divided into two subassociations: a typical one named *petrosedetosum rupestris* and a thermophilous one of the lower altitudes named *teucrietosum flavi*. The study revealed the originality of such communities and their appropriate classification in the *Thlaspietea rotundifolii* class. This is the first record in Italy of a *Petrosedum* ser. *Rupestria*-rich community framed in the scree vegetation class.

## Keywords

debris, limestone, *Linarion purpureae*, plant community, phytosociology, *Petrosedum*, vegetation

## Introduction

The vegetation dominated by *Petrosedum rupestre* (L.) P.V.Heath has been very little reported in the phytosociological literature (de Bolòs 1983), with particular reference to Italy (Poldini 1989; Mariotti 1995; Di Pietro et al. 2006; Pignatti and Pignatti 2016). It was always referred to the *Sedo albi-Scleranthetea biennis* Br.-Bl. 1955 class, even if this species was also found sometimes abundant in the garrigue communities of the *Cisto cretici-Micromerietea juliana* Oberdorfer ex Horvatić 1958 class (e.g. Pirone and Tammaro 1997), the chasmophytic vegetation of the *Asplenieta trichomanis* (Br.-Bl. in Meier & Br.-Bl. 1934) Oberdorfer 1977 class (e.g. Brullo and Spampinato 2003),

and the perennial pastures of the *Festuco valesiaca-Brometea erecti* Br.-Bl. & Tüxen ex Br.-Bl. 1949 class (e.g. Biondi and Galdenzi 2012).

During phytosociological investigations on the vegetation that colonizes debris substrates in the Abruzzo region, some unusual communities dominated by *Petrosedum rupestre* and *Cephalaria leucantha* were found and sampled. Although *Petrosedum rupestre* is considered a diagnostic species of the *Sedo-Scleranthetea* class (Mucina et al. 2016; Biondi et al. 2014), a certain debris mobility together with the presence of several species considered as diagnostic of the scree vegetation of the *Thlaspietea rotundifolii* class, casted doubt upon an easy classification of the observed plant community. In order to properly un-

derstand and describe it, several kinds of analyses were performed together with a comparison with all other *Setum* ser. *Rupestris*-dominated communities described in Italy.

## Materials and methods

The vegetation survey has been carried out in several places of the Abruzzo region inside or just outside the "Gran Sasso and Laga Mountains" National Park, "Abruzzo, Lazio and Molise" National Park and "Sirente-Velino" Regional Park (Fig. 1). A complete list of the localities of sampling is provided in the Appendix I. The climate of the study areas was identified using published data of temperatures and rainfalls (Ufficio Idrografico e Mareografico di Pescara, 1971-2000) spatialized for the whole Abruzzo region (unpublished). According to Rivas-Martínez et al. (2011), the thermotypes were found to be ranging between Upper Mesotemperate and Lower Supratemperate while ombrotypes were found to be ranging between Upper Subhumid and Lower Humid.

Fourteen relevés were performed in the hilly-low mountain belt, from 400 to 1,170 m a.s.l., using the classic phytosociological method proposed by Braun-Blanquet (1964). Life forms and Chorotypes were drawn from Pignatti (1982). In order to make the chorological spectra easier to understand, some chorotypes were merged into categories with a widest phytogeographical meaning: Eurasian; S-European; C-European; Palearctic; Endemic; Illyrian; Orophyte (Orophyte-W-Mediterranean, Orophyte-S-European-W-Asiatic); Euri-Mediterranean,

(Euri-Mediterranean, N-Euri-Mediterranean, Mediterranean-W-Asiatic); Steno-Mediterranean (Steno-Mediterranean, E-Steno-Mediterranean, C-Mediterranean, N-Mediterranean). The life form spectra and the chorological spectra were both performed normal, frequency-based and weighted.

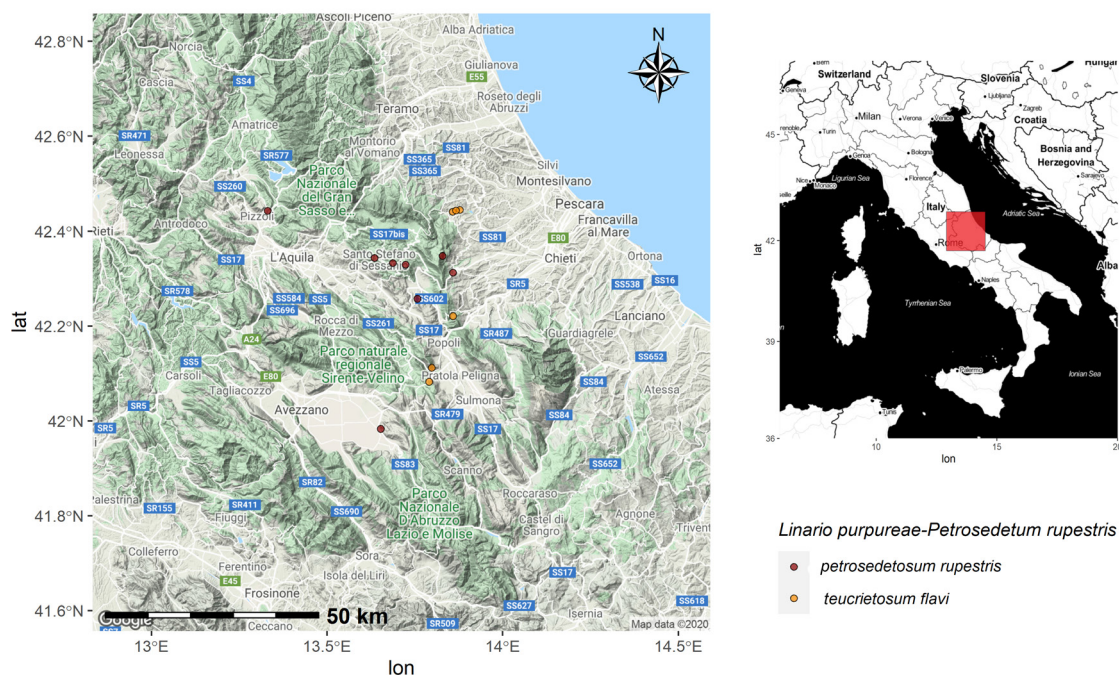
To better understand the ecology of the surveyed vegetation for each group of relevés, the Ellenberg indicator values (Pignatti, 2005) were calculated in three different ways: normal (based on the presence/absence of species in the relevés group), frequency-based (based on the occurrences of the species within the group) and weighted by cover of each species.

We used the species indicated by Mucina et al. (2016) as diagnostic of the vegetation classes to develop syntaxonomical spectra of the surveyed vegetation, that were also calculated normal, frequency-based and weighted.

A synoptic table including all the relevés available in the Italian phytosociological literature, having taxa belonging to *Petrosedum* ser. *Rupestris* as dominant species, was built in order to highlight possible floristic differences among different geographical areas.

Finally, we compared the results of all these analyses with the diagnoses of the alliances, orders and classes in Biondi et al. (2014) and Mucina et al. (2016), in order to identify the most suitable syntaxonomic frame for the surveyed vegetation, in terms of structural, bioclimatic, phytogeographical, ecological and floristic features.

For the syntaxonomic references at the ranks of alliance, order and class, we referred to Biondi et al. (2014). Plant species nomenclature follows Bartolucci et al. (2018).



**Figure 1.** Sampling sites; the background maps were extrapolated from Google using the function `get_map` from `ggmap` package (Kahle and Wickham 2013).



## Results

The performed vegetation relevés are reported in Table 1. The floristic composition of the investigated communities shows the presence of several species typical of loose and mobile debris substrates, belonging to *Thlaspietea rotundifolii* Br.-Bl. 1948. Several species of the garrigues of *Cisto-Micromerietea* Oberdorfer ex Horvatić 1958 (e.g.

*Satureja montana* subsp. *montana*, *Euphorbia spinosa*, *Fumana thymifolia*, *Helianthemum apenninum* subsp. *apenninum*, *Artemisia alba*, *Stachys italica*, etc.) occur only in the second group of relevés (rel. 9-13), representing a good set of differential taxa compared to the first group (rel. 1-8). The more abundant presence of chamaephytes, that are typical of garrigue vegetation, in the second group is to be correlated with the lower altitude at which they spread.

**Table 1.** Phytosociological table.

N°		1*	2	3	4	5	6	7	8	9	10	11	12	13	14*	
Elevation (m s.l.m.)		1170	970	895	745	550	950	1150	750	400	460	450	420	525	430	
Aspect		SE	E	ESE	OSO	E	E	O	E	ESE	SSE	SO	E	S	ESE	
Slope (°)		35	40	35	45	40	35	30	35	45	40	40	45	45	35	
Bio.	Vegetation cover (%)	60	45	50	40	35	30	50	40	40	40	40	30	30	70	
Form	Chorotype	Area (m <sup>2</sup> )	15	12	15	20	15	6	20	15	30	40	10	30	45	
<b><i>Linarion purpureae-Petrosedetum rupestris</i> ass. nova <i>petrosedetosum rupestris</i> subass. nova</b>																
Ch	W-Centroeuro-p	<i>Petrosedum rupestre</i> (L.) P.V.Heath	3.4	2.3	3.3	3.3	2.2	2.2	3.3	2.2	2.2	1.2	3.3	1.2	2.2	3.3
H	S-Europ	<i>Cephalaria leucantha</i> (L.) Roem. & Schult.	2.2	1.2	2.2	3.3	2.2	2.2	.	3.2	2.3	2.3	2.3	2.3	2.3	2.3
<b><i>teucrietosum flavi</i> subass. nova</b>																
Ch	Steno-Medit	<i>Teucrium flavum</i> L. ssp. <i>flavum</i>	.	.	.	.	.	.	.	.	+	+2	+2	+2	1.2	2.3
Ch	N-Medit	<i>Euphorbia spinosa</i> L.	.	.	.	.	.	.	.	.	.	.	+2	+2	+2	1.2
T	Euri-Medit	<i>Geranium purpureum</i> Vill.	.	.	.	.	.	.	.	.	.	+2	.	.	.	.
Ch	Steno-Medit	<i>Fumana thymifolia</i> (L.) Spach ex Webb	.	.	.	.	.	.	.	.	.	.	.	.	.	1.2
Ch	Center-Medit	<i>Cistus creticus</i> L. ssp. <i>creticus</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	+
<b><i>Linarion purpureae, Scrophulario-Helichrysetalia</i></b>																
H	Endem	<i>Linaria purpurea</i> (L.) Mill.	1.1	1.2	+	+	1.2	+2	+2	1.1	+	.	+	2.2	+2	+
H	Euri-Medit	<i>Scrophularia canina</i> L.	1.2	2.2	+2	1.2	1.2	.	+2	+	1.1	1.2	.	+	+	+2
H	Orof. S-Europ-W-Asiat	<i>Rumex scutatus</i> L. ssp. <i>scutatus</i>	2.3	1.2	+	+	.	1.2	2.2	.	1.2	.	2.3	+2	1.2	1.2
Ch	S-Europ	<i>Helichrysum italicum</i> (Roth) G.Don ssp. <i>italicum</i>	.	.	+2	.	.	.	.	.	.	+2	.	.	.	.
<b><i>Thlaspietea rotundifolii</i></b>																
T	N-Medit	<i>Galeopsis angustifolia</i> Ehrh. ex Hoffm. ssp. <i>angustifolia</i>	1.2	+	.	.	.	1.1	2.2	2.1	.	.	1.2	.	1.2	.
H	Medit-W-Asiat	<i>Lactuca viminea</i> (L.) J.Presl & C.Presl ssp. <i>chondrilliflora</i> (Boreau) St.-Lag.	1.1	.	+	.	+	.	.	+	.	+	.	+	.	.
H	Eurasiat	<i>Vincetoxicum hirundinaria</i> Medik. ssp. <i>hirundinaria</i>	.	+	.	.	.	.	.	.	.	.	.	.	.	+2
<b>Other species</b>																
T	Euri-Medit	<i>Odontites luteus</i> (L.) Clairv. ssp. <i>luteus</i>	.	+	.	.	.	+	.	.	+	+	.	+	+2	1.1
Ch	Orof-W-Medit	<i>Satureja montana</i> L. ssp. <i>montana</i>	.	.	.	1.2	+2	+2	+2	+2	.	.	1.2	.	.	1.2
H	Euri-Medit	<i>Asperula cynanchica</i> L. ssp. <i>cynanchica</i>	1.2	+	+2	+2	.	.	.	.	.	.	.	+2	.	+2
H	Italo-Illir (Anfiadriat)	<i>Dianthus ciliatus</i> Guss. ssp. <i>ciliatus</i>	+	.	+	.	.	.	.	+	.	+2	+2	.	.	1.1
H	Steno-Medit	<i>Galium corrudifolium</i> Vill.	.	.	+2	+2	+2	.	.	+	.	+2	1.2	.	.	.
H	Endem	<i>Phleum hirsutum</i> Honck. subsp. <i>ambiguum</i> (Ten.) Cif. & Giacom.	+2	1.2	.	+2	.	.	.	.	.	.	+2	.	.	.
H	Endem	<i>Festuca inops</i> De Not.	+2	.	+2	.	.	.	.	.	.	+2	.	.	.	+2
H	Paleotemp	<i>Poterium sanguisorba</i> L. s.l.	.	+	+	.	+	.	.	+	.	.	.	.	.	.
H	Steno-Medit-Or.	<i>Convolvulus elegantissimus</i> Mill.	.	.	.	.	+	.	.	+	+	.	+	.	.	.
Ch	Euri-Medit	<i>Sedum album</i> L. ssp. <i>album</i>	.	+2	.	.	.	.	.	.	1.2	.	+2	.	.	.
Ch	Endem	<i>Stachys italica</i> Mill.	+2	.	.	+2	.	.	.	.	.	.	.	.	.	.
H	Paleotemp	<i>Bromopsis erecta</i> (Huds.) Fourr. subsp. <i>erecta</i>	.	.	+2	.	.	.	.	.	.	.	+2	.	.	.
Ch	Endem	<i>Micromeria graeca</i> (L.) Benth. ex Rchb. ssp. <i>tenuifolia</i> (Ten.) Nyman	.	.	.	.	+	.	.	.	.	.	.	.	.	1.2
P	Euri-Medit	<i>Clematis flammula</i> L.	.	.	.	.	.	.	.	.	+	.	.	.	.	+
G	Paleotemp	<i>Allium sphaerocephalon</i> L. ssp. <i>sphaerocephalon</i>	.	.	.	.	.	.	.	.	.	.	+	.	.	+

The synoptic table reported in Table 2 was built including all the *Petrosedum* ser. *Rupestris*-dominated vegetation types described in Italy (Poldini 1989; Di Pietro et al. 2006; Pignatti and Pignatti 2016). It shows the autonomy and the peculiar floristic composition of the studied vegetation, that results clearly characterized by a significant presence of diagnostic species of the class *Thlaspietea rotundifolii*. These species are almost completely absent in the communities surveyed on Prenestini Mts (Di Pietro et al. 2006), on Dolomites (Pignatti and Pignatti 2016) and in Friuli (Poldini 1989). On the contrary, the diagnostic species of the *Sedo-Scleranthetea* class are well represented in the *Sedetum sexangulare-rupestris* Di Pietro, Burrascano & Blasi 2006 of the Prenestini Mts. and in the *Sedetum montani* Br.-Bl. 1955 of the Dolomites, but extremely scarce in both the surveyed vegetation and in the *Sedum montanum/orientale* phytocoenon found in Friuli region. The species of the *Cisto-Micromerietea* are represented in our relevés more than in the other communities, while the species of the *Festuco-Brometea* are mostly represented in the *Sedetum montani* and, secondly, in the studied vegetation where, however, they show low frequency values.

The syntaxonomical spectra of the Abruzzo communities, calculated in order to establish the relative weight of the various groups of species (see Appendix II), show the prevalence of the species of the *Festuco-Brometea* class in the normal spectrum, while the species of the *Thlaspietea rotundifolii* class are prevalent in the frequency-based spectrum. Those of the *Sedo-Scleranthetea* and *Cisto-Micromerietea* classes prevail in the spectrum weighted on cover values.

The life form spectra show the prevalence of hemicryptophytes both in the normal and in the frequency-based spectra, while chamaephytes prevail in the weighted spectrum (Figure 2).

The chorological spectra reveal the prevalence of the Mediterranean species in all the cases, with a significant presence of the S-European species mostly in the spectrum weighted on cover values (Figure 3).

The application of the Ellenberg indicator values (Pignatti 2005) to the two groups of relevés of Table 1 (see Appendix III) shows a high light intensity (L) and moderately high values of temperature (T), both of them with maximum values in the second group of relevés; moderately high values of continentality (C), very low values of humidity (U), high values of soil pH (R), and very poor nutrient conditions (N).

## Discussion

As shown in the synoptic table (Table 2), the coenological autonomy and floristic identity of the surveyed vegetation are evident. A high number of *Thlaspietea rotundifolii* diagnostic species allow the Abruzzo communities to be distinguished from similar communities described for other Italian areas.

**Table 2.** Synoptic table of the Italian *Sedum* ser. *Rupestris* dominated communities.

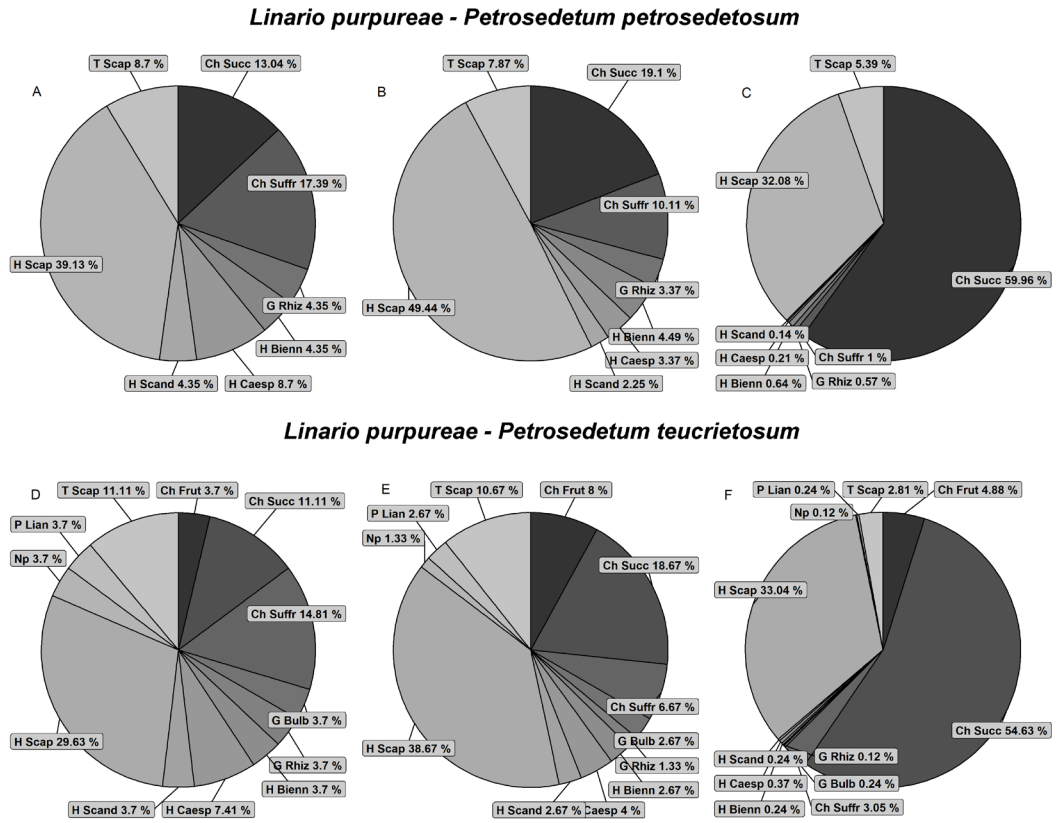
Community	<i>Linario purpureae-Petrosedatum rupestris petrosedetosum</i>	<i>Linario purpureae-Petrosedatum rupestris teucrietosum</i>	<i>Sedetum sexangulare-rupestris</i>	<i>Sedetum montani</i>	<i>Sedum orientale/montanum</i> phytocoenon
No. of relevés	8	4	8	14	5
<i>Petrosedum rupestre</i> s.l.	V	V	V	IV	.
<i>Petrosedum thartii</i>	.	.	.	.	V
<b><i>Linarion purpureae/Scrophulario-Helichrysetalia/Thlaspietea rotundifolii</i></b>					
<i>Linaria purpurea</i>	V	V	.	.	.
<i>Scrophularia canina</i>	V	V	II	.	.
<i>Rumex scutatus</i> ssp. <i>scutatus</i>	IV	V	.	.	.
<i>Galeopsis angustifolia</i> ssp. <i>angustifolia</i>	IV	II	.	.	.
<i>Lactuca viminea</i> ssp. <i>chondrilliflora</i>	III	II	.	.	.
<i>Vincetoxicum hirundinaria</i> ssp. <i>hirundinaria</i>	I	I	.	.	.
<i>Euphorbia spinosa</i>	.	IV	.	.	.
<i>Geranium purpureum</i>	.	I	.	.	.
<i>Trisetaria argentea</i>	.	.	.	II	.
<b><i>Sedo-Scleranthetea</i></b>					
<i>Sedum album</i> ssp. <i>album</i>	I	II	.	III	.
<i>Sedum sexangulare</i>	.	.	V	III	I
<i>Clinopodium acinos</i> s.l.	.	.	IV	II	.
<i>Sedum acre</i>	.	.	I	III	.
<i>Aethionema saxatile</i>	.	.	IV	.	.
<i>Sempervivum arachnoideum</i>	.	.	.	IV	.
<i>Hylotelephium maximum</i> ssp. <i>maximum</i>	.	.	.	IV	.
<i>Sedum dasyphyllum</i> ssp. <i>dasyphyllum</i>	.	.	.	III	.
<i>Arenaria serpyllifolia</i> ssp. <i>serpyllifolia</i>	.	.	.	III	.
<i>Petrorhagia saxifraga</i> ssp. <i>saxifraga</i>	.	.	.	II	.
<i>Potentilla argentea</i>	.	.	.	II	.
<i>Scleranthus polycarpus</i>	.	.	.	I	.
<i>Herniaria glabra</i> ssp. <i>glabra</i>	.	.	.	I	.
<i>Sempervivum tectorum</i>	.	.	.	I	.
<i>Scleranthus annuus</i>	.	.	.	I	.
<i>Sedum annuum</i>	.	.	.	I	.
<b><i>Cisto-Micromerietea</i></b>					
<i>Satureja montana</i> ssp. <i>montana</i>	IV	II	.	.	IV
<i>Helichrysum italicum</i> ssp. <i>italicum</i>	I	I	II	.	.
<i>Cephalaria leucantha</i>	V	V	.	.	.
<i>Micromeria graeca</i> ssp. <i>tenuifolia</i>	I	I	.	.	.
<i>Teucrium flavum</i> ssp. <i>flavum</i>	.	V	.	.	III
<i>Fumana thymifolia</i>	.	I	.	.	.

**Table 2.** Continuation.

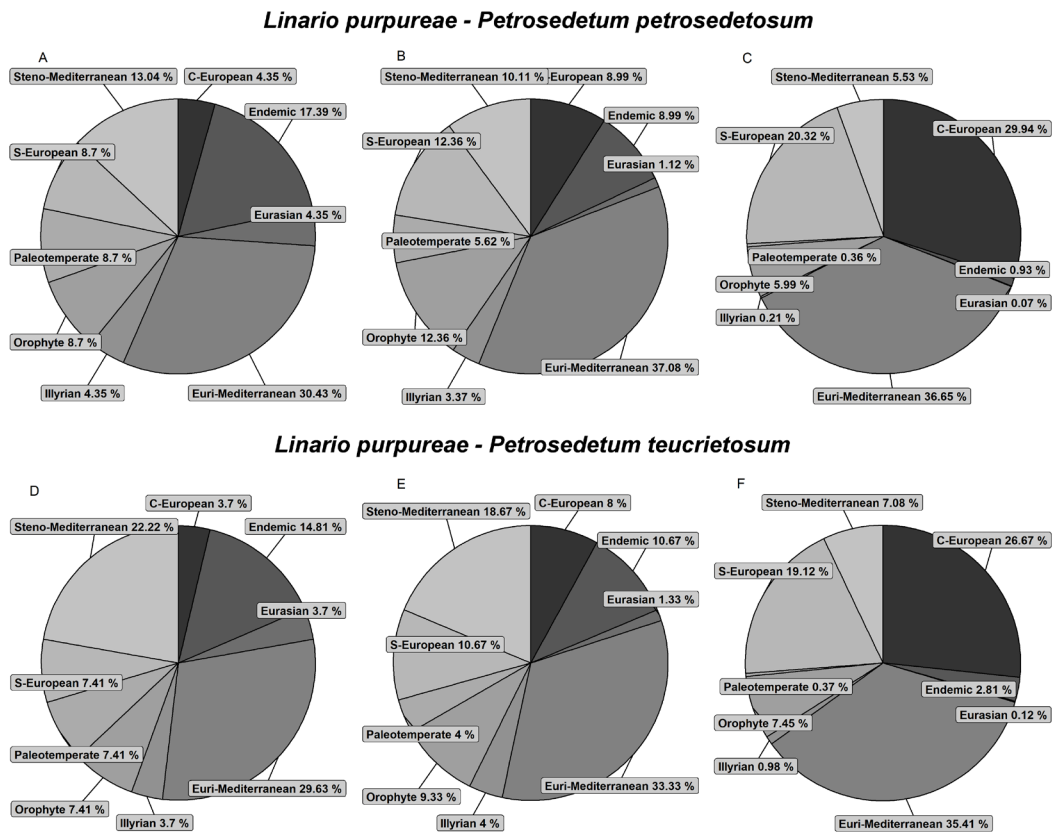
Community	<i>Linario purpureae-Petrosetetum rupestris petrosedetosum</i>	<i>Linario purpureae-Petrosetetum rupestris teucritetosum</i>	<i>Sedetum sexangulare-rupestris</i>	<i>Sedetum montani</i>	<i>Sedetum orientale/montanum phytocoenon</i>
No. of relevès	8	4	8	14	5
<i>Cistus creticus</i> ssp. <i>creticus</i>	.	I	.	.	.
<i>Ononis pusilla</i> ssp. <i>pusilla</i>	.	.	IV	.	.
<i>Micromeria graeca</i> ssp. <i>graeca</i>	.	.	II	.	.
<i>Fumana procumbens</i>	.	.	.	I	.
<i>Teucrium montanum</i>	.	.	.	I	.
<i>Salvia officinalis</i> ssp. <i>officinalis</i>	.	.	.	.	II
<b>Festuco-Brometea</b>					
<i>Galium corradifolium</i>	III	II	V	.	.
<i>Bromopsis erecta</i> s.l.	I	I	II	.	.
<i>Phleum hirsutum</i> subsp. <i>ambiguum</i>	II	I	II	.	.
<i>Poterium sanguisorba</i> s.l.	III	.	II	I	.
<i>Allium sphaerocephalon</i> ssp. <i>sphaerocephalon</i>	.	II	I	I	.
<i>Odontites luteus</i> ssp. <i>luteus</i>	II	V	.	.	.
<i>Asperula cynanchica</i> ssp. <i>cynanchica</i>	III	II	.	.	.
<i>Dianthus ciliatus</i> ssp. <i>ciliatus</i>	II	III	.	.	.
<i>Festuca inops</i>	II	II	.	.	.
<i>Convolvulus elegantissimus</i>	II	II	.	.	.
<i>Teucrium chamaedrys</i>	.	.	IV	I	.
<i>Dianthus</i> gr. <i>sylvestris</i>	.	.	III	I	.
<i>Brachypodium rupestre</i>	.	.	I	I	.
<i>Stachys italica</i>	II	.	.	.	.
<i>Seseli montanum</i> ssp. <i>montanum</i>	.	.	IV	.	.
<i>Tragopogon samaritani</i>	.	.	III	.	.
<i>Thymus longicaulis</i>	.	.	II	.	.
<i>Catapodium rigidum</i> s.l.	.	.	II	.	III
<i>Koeleria splendens</i>	.	.	II	.	.
<i>Arabis collina</i> ssp. <i>collina</i>	.	.	II	.	.
<i>Hippocrepis comosa</i> ssp. <i>comosa</i>	.	.	II	.	.
<i>Anthyllis vulneraria</i> s.l.	.	.	II	.	.
<i>Helictochloa praetutiana</i> ssp. <i>praetutiana</i>	.	.	II	.	.
<i>Crupina vulgaris</i>	.	.	II	.	.
<i>Thymus oenipontanus</i>	.	.	.	III	.
<i>Potentilla verna</i>	.	.	.	III	.
<i>Festuca stricta</i> ssp. <i>sulcata</i>	.	.	.	II	.
<i>Festuca valesiaca</i> ssp. <i>valesiaca</i>	.	.	.	II	.
<i>Koeleria macrantha</i> ssp. <i>macrantha</i>	.	.	.	II	.

**Table 2.** Continuation.

Community	<i>Linario purpureae-Petrosetetum rupestris petrosedetosum</i>	<i>Linario purpureae-Petrosetetum rupestris teucritetosum</i>	<i>Sedetum sexangulare-rupestris</i>	<i>Sedetum montani</i>	<i>Sedetum orientale/montanum phytocoenon</i>
No. of relevès	8	4	8	14	5
<i>Centaurea stoebe</i>	.	.	.	II	.
<i>Poa angustifolia</i>	.	.	.	II	.
<i>Seseli kochii</i>	.	.	.	.	III
<i>Galium lucidum</i> ssp. <i>lucidum</i>	.	.	.	.	III
<i>Euphorbia fragifera</i>	.	.	.	.	II
<b>Tuberarietea guttatae</b>					
<i>Trifolium campestre</i>	.	.	II	I	.
<i>Coronilla scorpioides</i>	.	.	V	.	.
<i>Linum strictum</i> s.l.	.	.	III	.	.
<i>Polygala monspeliaca</i>	.	.	III	.	.
<i>Crepis neglecta</i> s.l.	.	.	II	.	.
<i>Bupleurum baldense</i>	.	.	II	.	.
<i>Trifolium stellatum</i> s.l.	.	.	II	.	.
<i>Trifolium arvense</i> ssp. <i>arvense</i>	.	.	.	II	.
<b>Other species</b>					
<i>Dactylis glomerata</i> s.l.	.	.	II	I	.
<i>Cerastium arvense</i> ssp. <i>arvense</i>	.	.	II	I	.
<i>Plantago lanceolata</i>	.	.	II	I	.
<i>Silene vulgaris</i> s.l.	.	.	II	I	.
<i>Asplenium ceterach</i> s.l.	.	.	I	I	.
<i>Clematis flammula</i>	.	II	.	.	.
<i>Cota tinctoria</i> s.l.	.	.	V	.	.
<i>Reichardia picroides</i>	.	.	III	.	.
<i>Poa bulbosa</i> s.l.	.	.	II	.	.
<i>Picris hieracioides</i> s.l.	.	.	II	.	.
<i>Sonchus tenerrimus</i>	.	.	II	.	.
<i>Clematis vitalba</i>	.	.	II	.	.
<i>Orlaya grandiflora</i>	.	.	II	.	.
<i>Veronica fruticans</i>	.	.	.	II	.
<i>Saxifraga paniculata</i>	.	.	.	II	.
<i>Geranium columbinum</i>	.	.	.	II	.
<i>Galium album</i> s.l.	.	.	.	II	.
<i>Asplenium trichomanes</i> s.l.	.	.	.	II	.
<i>Asplenium septentrionale</i> ssp. <i>septentrionale</i>	.	.	.	II	.
<i>Campanula pyramidalis</i>	.	.	.	.	IV
<i>Allium horvatii</i>	.	.	.	.	II



**Figure 2.** Life form spectra of the two detected subassociations (A, D = normal; B, E = frequency-based; C, F = weighted).



**Figure 3.** Chorological spectra of the two detected subassociations (A, D = normal; B, E = frequency-based; C, F = weighted).

The syntaxonomical spectra were analyzed in order to weigh the different role of taxa with reference to the various vegetation classes (see Appendix II). They show that the *Festuco-Brometea* is represented by a high number of species, showing low frequency values and even lower coverage values. The species of the *Thlaspietea rotundifolii* class are clearly prevalent in the frequency-based spectrum, while those of the *Sedo-Scleranthetea* and *Cisto-Micromerietea* classes prevail in the spectrum weighted on cover values. Obviously, the dominance of *Petrosedum rupestre* drives the role of *Sedo-Scleranthetea* prevailing in the weighted life form spectrum (Fig. 2C and 2F), while the high values of *Cisto-Micromerietea* of the second group of relevés (9–13 of Tab. 1) is due to the greater contribution of the chamaephytes in this group. The high values of the diagnostic species of *Thlaspietea rotundifolii* are linked to the mobility of the debris on which the surveyed vegetation preferentially grows. For these reasons, we include the surveyed vegetation in this last class. Subordinate syntaxa may be represented by *Linario-Festucion dimorphae* Avena & Bruno 1975 and *Thlaspietalia stylosi* Avena & Bruno 1975 which are widely spread in Central Apennines (cf. Feoli Chiapella and Feoli 1977; Feoli Chiapella 1983; Biondi et al. 2000; Di Pietro et al. 2001, 2008; etc.). Other alliances and/or orders reported for the Apennines such as *Petasition paradoxo* Zollitsch ex Lippert 1966 (*Polystichetalia lonchitis* Rivas-Martínez, T.E. Diaz, F. Prieto, Loidi & Penas 1984), *Violo magellensis-Cerastion thomasi* Biondi, Blasi and Allegranza in Biondi, Allegranza, Casavecchia, Galdenzi, Gasparri, Pesaresi, Vagge and Blasi 2014 (*Thlaspietalia stylosi*), and *Epilobion fleischeri* G. Braun-Blanquet ex Br.-Bl. 1949 (*Epilobietalia fleischeri* Moor 1958) are to be disregarded due to the altitudinal location and ecological features of the studied vegetation (see Appendix III). We also do not include the alliance *Stipion calamagrostis* Jenny-Lips ex Quantin 1932 (*Stipetalia calamagrostis* Oberdorfer & Seibert in Oberdorfer 1977) since it is associated with the *Stipa calamagrostis*-dominated communities (Biondi et al. 2014). The communities of *Linario-Festucion dimorphae* which are normally found in the montane and subalpine belts of Central Apennines are characterized by the prevalence of Apennine Endemic, South-European Orophyte and Eurasian elements (e.g. Conti and Manzi 1992; Petriccione 1993; Biondi et al. 1999; Di Pietro et al. 2004). On the contrary, the analysis of the chorological spectra of the studied vegetation, as noticed, reveals a clear prevalence of the Mediterranean element, with relevant percentages of Steno-Mediterranean species, mostly in the normal and frequency-based spectra and in the second group of relevés (Figure 3). Such occurrence makes this collocation difficult.

A more consistent option is the order *Scrophulario bicoloris-Helichrysetalia italici* described by Brullo et al. (1998) for Sicily, recently used to classify some communities found in Central Italy. In fact, Di Pietro et al. (2017) provisionally referred to this order the association *Helichryso italici-Dittrichietum viscosae* Trinajstić ex Di Pietro,

Germani and Fortini 2017, found on Cornicolani Mts. in southern Lazio, in the alliance *Linaron purpureae* Brullo 1984. Moreover, the vegetation of *Artemisio variabilis-Helichrysetum italici* Brullo and Spampinato 1990, reported for the terraces of the Trigno river (central Italy), was also referred to *Scrophulario-Helichrysetalia*, in the alliance *Artemisio variabilis* Biondi, Ballelli, Allegranza, Taffetani & Francalancia 1994 (Pirone et al. 2009). The *Linaron purpureae* alliance includes the pioneer communities of carbonatic or pyroclastic volcanic screes which mainly develop in mountain areas of Southern Italy and Sicily (Brullo 1984), while *Artemisio variabilis* includes the chamaephytic nitrophilous communities growing on river terraces and other gravelly incoherent substrata, in the Thermo-mediterranean and Mesomediterranean thermotypes of Southern Italy (Biondi et al. 2014).

The studied vegetation shows similar ecological features to *Linaron purpureae*, together with the presence of the diagnostic species *Linaria purpurea* and *Rumex scutatus* subsp. *scutatus*, and others similarly linked to mobile debris with a Mediterranean distribution (*Scrophularia canina*, *Galeopsis angustifolia* subsp. *angustifolia*, *Lactuca viminea* subsp. *chondrilliflora*).

On the basis of these considerations, we describe here a new association, with two subassociations, classified in the *Linaron purpureae* alliance and *Scrophulario bicoloris-Helichrysetalia italici* order. They are hereafter characterized.

Mucina et al. (2016), include this order in the Balkanic *Drypidetea spinosae*, whereas Biondi et al. (2014) include it in *Thlaspietea rotundifolii*. In this paper we have preferred to follow the syntaxonomical interpretation provided by Biondi et al. (2014), since the species that are indicated as diagnostic of the *Drypidetea spinosae* class by Mucina et al. (2016) are almost absent in Central and Southern Italy, while the species of the *Thlaspietea rotundifolii* class are well represented both in our relevés and in those from Southern Italy.

*Linaron purpureae-Petrosedetum rupestris*  
ass. nova, *petrosedetosum rupestris*  
subass. nova, *typicum* (Table 1, rels. n. 1–8;  
*holotypus*: rel. n. 2).

**Physiognomy and structure.** Discontinuous vegetation with hemicryptophytes and chamaephytes, with dominance of *Petrosedum rupestre*, *Cephalaria leucantha*, *Linaria purpurea* and *Scrophularia canina*.

**Diagnostic species.** *Petrosedum rupestre* and *Cephalaria leucantha*. The first is a succulent chamaephyte with a Central-W-European distribution, linked to stony, rocky and debris habitats; the second is a semi-rosette hemicryptophyte with a S-European distribution, which lives mostly in garrigues, stony pastures and other debris environments (Pirone and Tammaro 1997; Allegranza et al. 1997; Biondi et al. 2005). The choice of these species has been made on the basis of their dominance and frequency, and because

they (more than others) reveal a peculiar vegetation in the frame of the *Thlaspietea rotundifolii* class.

**Syntaxonomy.** For the reasons explained in the discussion, the new association *Linarion purpureae-Petrosedetum rupestris* ass. nova is framed in the *Linarion purpureae* alliance (order *Scrophulario bicoloris-Helichrysetalia italici*, class *Thlaspietea rotundifolii*).

**Syndynamics.** The association is framed in the vegetation series of both mixed thermophilous and semi-mesophilous oak forests of the order *Quercetalia pubescenti-petraeae* Klika 1933 and mesophilous forests of the order *Fagetalia sylvaticae* Pawłowski in Pawłowski, Sokołowski and Wallisch 1928 (Pirone et al. 2010). The subassociation *petrosedetosum rupestris* is mainly linked to the series of semi-mesophilous and mesophilous woods.

**Synecology.** The association develops on carbonatic incoherent sediments (gravel, debris, etc.), at altitudes between 400 and 1300 m a.s.l. The bioclimatic context ranges from Upper Mesotemperate to Lower Supratemperate, with ombrotypes from Upper Subhumid to Lower Humid. The typical subassociation is linked to an altitudinal range between 700 and 1,300 m a.s.l. with a Supratemperate thermotype.

**Synchorology.** The association is known at the moment only for the hilly and lower mountain belts of the Gran Sasso, Sirente-Velino and Marsica Mts. groups and their surroundings; its potential distribution might include also other areas of the Carbonatic Apennines.

*Linarion purpureae-Petrosedetum rupestris* ass. nova, *teucrietosum flavi* subass. nova (Table 1, rels. n. 9-14; *holotypus*: rel. n. 15)

**Physiognomy and structure.** Comparable to the typical subassociation, with a more abundant presence of chamaephytes.

**Differential species.** *Teucrium flavum* subsp. *flavum* and *Euphorbia spinosa*. These species have been chosen since they well highlight the more thermophilous character of this subassociation.

**Syndynamics.** The subassociation is framed in the vegetation series of mixed thermophilous and semi-mesophilous oak woods of the order *Quercetalia pubescenti-petraeae* Klika 1933 (Pirone et al. 2010).

**Synecology.** The subassociation settles on carbonatic incoherent sediments (gravel, escarpments with clastic debris, etc.), at an altitudinal range between 400 and 700 m a.s.l. The bioclimatic context can be referred to Upper Mesotemperate thermotype and Upper Subhumid ombrotype. It describes the most thermophilous aspects of the association, characterized by a greater presence of species of the *Cisto-Micromerietea* class.

**Synchorology.** The subassociation is known at the moment only for the Gran Sasso and Sirente-Velino mountain groups and their surroundings; its potential distribution might include also other areas of the Carbonatic Apennines.

## Conclusions

The performed syntaxonomic, structural, chorological and ecological analyses clearly showed the autonomy and the peculiarity of the studied vegetation that is formalized in the new association *Linarion purpureae-Petrosedetum rupestris* ass. nova. The two subassociations *petrosedetosum rupestris*, *typicum*, and *teucrietosum flavi*, have been identified inside the association, the latter with reference to the most thermophilous aspects linked to the lower altitudes and differentiated by chamaephytes that are typical of the garrigue vegetation.

On the basis of the floristic, ecological and chorological features of the new association, we think that its best classification is in the *Linarion purpureae* alliance (order *Scrophulario bicoloris-Helichrysetalia italici*). At the moment we agree with the interpretation by Biondi et al. (2014) who put the order in the *Thlaspietea rotundifolii* class even if Mucina et al. (2016) includes it in the *Drypidetea spinosae*. A complete revision of the scree plant communities spread in the whole Center and Southern Italy and the Balkans should be performed in order to better understand the relationships between the two classes, but this goes beyond the aim of this work.

This is the third report from Central Italy of communities referable to the *Scrophulario-Helichrysetalia italici* order after the ones by Pirone et al. (2009) and Di Pietro et al. (2017). However, Di Pietro et al. (2017) cast doubt on the possibility that typical classes of high-altitude scree and talus slopes such as *Drypidetea* and *Thlaspietea* may could represent strictly Mediterranean vegetation units like the ones surveyed on Cornicolani Mts. As to the *Linarion purpureae* alliance, this may be considered its first record from Central Italy, since the inclusion of the *Helichryso italici-Dittrichietum viscosae* in this alliance was provisional (Di Pietro et al. 2017).

Our results confirm the presence of the *Linarion purpureae* alliance and the *Scrophulario bicoloris-Helichrysetalia italici* order in Central Italy.

## Syntaxonomic scheme

THLASPIETEA ROTUNDIFOLII Br.-Bl. 1948  
SCROPHULARIO BICOLORIS-HELICHRYSOTALIA ITALICI  
Brullo 1984

**Linarion purpureae** Brullo 1984  
*Linarion purpureae-Petrosedetum rupestris* ass. nova  
*petrosedetosum rupestris* subass. nova  
*teucrietosum flavi* subass. nova

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## Appendixes

### Appendix I - Localities, dates and sporadic species of the relevè in Table 1

- Rel. 1: Between Passo delle Capannelle and Acqua di Pizzoli (AQ), 06/07/2017, *Digitalis micrantha* (1.1), *Asperula purpurea* (+.2), *Pimpinella tragium* (1.1), *Hypericum perforatum* s.l. (+), *Melica ciliata* ssp. *ciliata* (+.2), *Silene vulgaris* s.l. (+.2), *Aethionema saxatile* (+).
- Rel. 2: S. Stefano di Sessanio (AQ), 5/07/2012.
- Rel. 3: Brittole (PE), 30/07/2012.
- Rel. 4: Carpineto della Nora (PE), 30/07/2012, *Crepis lacera* ssp. *lacera* (+).
- Rel. 5: Venere di Pescina (AQ), 15/07/2011, *Nigella damascena* (+).
- Rel. 6: Between Capestrano and Navelli (AQ), 10/08/2012, *Reichardia picroides* (+), *Stachys recta* s.l. (+), *Crupina vulgaris* (+), *Ruta graveolens* (+.2).
- Rel. 7: Between Ofena and Calascio (AQ), 25/09/2012, *Artemisia alba* (+.2).

- Rel. 8: Calascio (AQ), 25/09/2012, *Sabulina* sp. (1.2), *Matthiola fruticulosa* ssp. *fruticulosa* (+).  
 Rel. 9: Goriano Sicoli (AQ), 02/08/2013, *Plantago semper-virens* (+).  
 Rel. 10: Colle S. Angelo (PE), 16/07/2011, *Fraxinus ornus* ssp. *ornus* (+).

- Rel. 11: Colle S. Angelo (PE), 16/07/2011, *Spartium junceum* (+).  
 Rel. 12: Gole di S. Venanzio (AQ), 26/07/2012, *Linum tenuifolium* (+), *Silene italica* ssp. *italica* (+.2), *Petrorhagia saxifraga* ssp. *saxifraga* (+.2).  
 Rel. 13: Colle S. Angelo (PE), 16/07/2011, *Silene otites* (+).  
 Rel. 14: Monte di Roccatagliata (PE), 15/07/2011.

## Appendix II - Syntaxonomical spectra

NORMAL				
	Thl	S-S	C-M	F-B
<i>Linario-Petrosedetum petrosedetosum</i>	27.3	9.1	18.2	45.5
<i>Linario-Petrosedetum teucrietosum</i>	29.6	7.4	25.9	37.0
FREQUENCY				
	Thl	S-S	C-M	F-B
<i>Linario-Petrosedetum petrosedetosum</i>	38.3	11.1	17.3	33.3
<i>Linario-Petrosedetum teucrietosum</i>	34.2	11.0	24.7	30.1
COVERAGE				
	Thl	S-S	C-M	F-B
<i>Linario-Petrosedetum petrosedetosum</i>	24.0	42.9	29.3	3.8
<i>Linario-Petrosedetum teucrietosum</i>	19.4	36.1	38.7	5.8

Syntaxonomical spectra (Thl = *Thlaspietea rotundifolii*, S-S = *Sedo-Scleranthetea*, C-M = *Cisto-Micromerietea*, F-B = *Festuco-Brometea*).

## Appendix III - Ellenberg's indicator values (Pignatti 2005) for the two groups of relevès

	<i>Linario purpureae-Petrosedetum rupestris petrosedetosum</i>						<i>Linario purpureae-Petrosedetum rupestris teucrietosum</i>					
	L	T	C	U	R	N	L	T	C	U	R	N
NORMAL	7.9	6.6	4.9	3.0	6.4	2.5	8.2	7.1	4.9	2.9	6.1	2.5
FREQUENCY	8.4	7.3	5.4	3.3	7.0	2.9	9.5	8.1	5.7	3.2	7.4	2.8
COVER	10.0	8.1	7.2	3.7	7.8	2.5	10.8	8.7	7.3	3.7	8.2	2.7

Ellenberg's indicator values for the two groups of relevès (L = light, T = temperature, C = continentality, U = humidity, N = nutrients).





# Does an open access journal about vegetation still make sense in 2020?

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## Abstract

The current issue is the first one of the new version of *Plant Sociology*, the international peer-reviewed journal of the "Società Italiana di Scienza della Vegetazione" (SISV). The technical management of the journal has been entrusted to the editorial platform Pensoft, the Editorial Board has been largely reshaped, now including also a dedicated Social media team. *Plant Sociology* is focused on all aspects of vegetation from phytocoenosis to landscape level, through time and space, at different geographic and ecological scales; the journal contributes to spread around the issues related to management and conservation of plant communities and plant diversity. All the articles are freely available in Open Access (OA) with affordable article processing charge (APC). In the present Editorial, we briefly discuss the importance of opening the access to knowledge and data about vegetation. We believe that disseminating plant science might be a precious tool for understanding ecological processes, modelling future trends and supporting decision makers. The introduced technological improvement will hopefully allow a larger visibility and circulation for the papers published on *Plant Sociology*.

## Keywords

open science, phytosociology, plant diversity, plant science

## Introduction

June 2020: the first issue of *Plant Sociology*, the international journal of the "Società Italiana di Scienza della Vegetazione" (SISV), sees the light in its new version. It is an important step for our journal, implying many changes and some challenges.

The first, prominent aspect is that the technical management of the journal has been entrusted to Pensoft, an independent and innovative editorial platform, that will take charge of all aspects regarding production, submission system and online publishing. SISV and the Editorial Board of the journal maintain respectively the ownership and the scientific management, including the entire peer-review process. This big improvement will hopefully

allow a larger visibility and circulation for the papers published on *Plant Sociology*.

The second, equally important point is that, following the journal's policy of the last years, all the articles of *Plant Sociology* are freely available in Open Access (OA) mode. The Editorial Board deeply believes in the importance of open, free and huge dissemination of scientific results. To maintain this possibility, authors are now asked to contribute a very reasonable article processing charge (APC), further reduced for SISV members. It is perhaps worth to say that, being owned by a scientific society, *Plant Sociology* is a non-profit journal and all the requested charges serve to the technical support provided by the publisher.

The whole Editorial Board has been reorganized, now including also a dedicated Social media team, and keeping

some important continuity elements, such as the presence of Edoardo Biondi, now Consultant Editor, who for more than 25 years has worked with incomparable dedication to the management and improvement of the journal.

Besides these crucial points, *Plant Sociology* maintains its long-lasting vocation to focus on all aspects of vegetation from phytocoenosis to landscape level, through time and space, at different geographic and ecological scales, hosting the results of studies centred on plant communities and habitats modelization, interpretation, assessment, mapping, management, conservation and monitoring.

## Open Access evolution and perspectives

Since Swartz (2008) stated that "sharing is a moral imperative", the "open science" topic became more and more central in the scientific community. Reality is that the popularity of sharing tools such as the controversial Sci-Hub, containing more than 47 million pirated research papers (Androcec 2017), or the moderate Research Gate ([www.researchgate.net/](http://www.researchgate.net/)), is evidently increasing all over the world (Bohannon 2016; Himmelstein et al. 2017; Nicholas et al. 2018), representing a serious threat to editorial companies and posing challenging questions to the whole scientific world (Anderson 2018).

Alexandra Elbakyan's Sci-Hub, in the words of Bohannon (2016) "an awe-inspiring act of altruism or a massive criminal enterprise, depending on whom you ask", certainly inspired many authors and editors to take the road of OA.

In Europe, the trend is evident by the large number of scientific journals going open. Initiatives such as the *Declaration of the Budapest Open Access Initiative* (2002, [www.budapestopenaccessinitiative.org](http://www.budapestopenaccessinitiative.org)), the *ECHO Charter* (2002, [https://echo.mpiwg-berlin.mpg.de/policy/oa\\_basics/charter](https://echo.mpiwg-berlin.mpg.de/policy/oa_basics/charter)), the *Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities* (2003, <https://openaccess.mpg.de/Berlin-Declaration>) and many others, provided definitions, addresses and paradigms for promoting and disseminating knowledge at the global scale. A significant push came from the European Research Council (ERC) and its ERC Scientific Council Statement on OA (2006) strongly promoting the availability of research results in open access repositories.

Additionally, international research funding sources are more and more pushing towards open access as the best or even mandatory way to publish results of research and scientific data. For instance, under Horizon 2020, each beneficiary must ensure open access to all peer-reviewed scientific publications relating to its results (Article 29.2 of the Model Grant Agreement; European Commission 2017).

OA is not always a synonym of easy and equal access to publishing, since behind this praiseworthy policy, unaffordable costs sometimes lay behind, as indicated by Van

Noorden (2013), who also demonstrated that OA costs are weakly related to the actual influence of journal and articles.

In a world where scientific publishing developed into an industry, it has been showed that in both Natural and Medical Sciences (NMS) there is still a moderate level of concentration of scientific papers in the hands of a few big publishers, highlighting a relative independence that has been attributed to the strength of scientific societies (Larivière et al. 2015).

As a matter of fact, SISV decided to support (also economically) the OA mode for its official journal, choosing for "gold open access" i.e. making the journal's content freely available for readers on the publisher's website (at the same time, *Plant Sociology* still retains a printed version, only for libraries and official repositories). Similar decisions have been taken, e.g., by the Italian Botanical Society (SBI) with the journal *Italian Botanist*, formerly *Informatore Botanico Italiano* (Peruzzi and Siniscalco 2016), by the Italian Society of Agronomy (SIA) with the *Italian Journal of Agronomy* (Perniola et al. 2020), by the European Association of Science Editors (EASE) with the journal *European Science Editing* (Baždarić 2020), by the International Association for Vegetation Science (IAVS) with the journal *Vegetation Classification and Survey* (Jansen et al. 2020), by the Swiss Entomological Society (SES) with the journal *Alpine Entomology* (Lachat and Baur 2017), by the International Society of Hymenopterists (ISH) with the *Journal of Hymenoptera Research* (Schmidt et al. 2013), by the Societas Europaea Lepidopterologica (SEL) with the *Journal Nota Lepidopterologica* (Rota 2014), and many others.

*Plant Sociology* is included in the Directory of OA Journals (DOAJ, <https://doaj.org>), the independent online archive of high quality, open access, peer-reviewed journals. *Plant Sociology* also supports the open Italian Vegetation Data Base VegItaly (Gigante et al. 2012; Landucci et al. 2012) - a member of the Global Index of Vegetation-Plot Databases (Dengler et al. 2011) - and urges the contributing Authors to store their vegetation data in it. Additionally, the journal is integrated with the Dryad Digital Repository (<https://datadryad.org/stash>) to make data publication simple and easy for authors, sharing the view that biodiversity data should be published, disseminated, shared and re-used (Vision 2010; Chavan and Penev 2011; Smith et al. 2013).

## About the journal

*Plant Sociology* has succeeded *Notiziario della Società Italiana di Fitosociologia* (1964-1989, ISSN 1120-4605) and, later, *Fitosociologia* (1990-2011, ISSN 1125-9078), the historical journals of the SISV. In this large timespan, started 56 years ago, the journal published a total of 819 scientific papers organized in 58 volumes and 102 issues. The name *Plant Sociology* is a tribute to the founder of Phytosociology, Josias Braun-Blanquet (1884-

1980), who used it as title of his major monographic work "Pflanzensoziologie: Grundzüge der Vegetationskunde" (Braun-Blanquet 1928).

*Plant Sociology* is an international, peer-reviewed OA journal. It publishes original research articles dealing with all aspects of vegetation, from plant community to landscape level, including dynamic processes and community ecology. It favours papers focusing on *Plant Sociology* and vegetation survey for developing ecological models, vegetation interpretation, classification and mapping, environmental quality assessment, plant biodiversity management and conservation, EU Annex I habitats interpretation and monitoring, on the ground of rigorous and quantitative measures of physical and biological components.

The journal is open to territorial studies at different geographic scale and accepts contributes dealing with applied research, provided they offer new methodological perspectives and a robust, updated vegetation analysis. The main subject are represented by:

- Phanerogamic and cryptogamic vegetation survey and classification
- Vegetation mapping
- Plant ecology and synecology
- Plant community traits
- Plant community conservation and management
- Syntaxonomy and nomenclature
- Biostatistic analysis and data banks
- Habitat directive
- Alien plant invasions

The types of article hosted by the journal include Research articles, Review articles, Short communications, Editorials, Corrigendum and/or addendum.

Each issue contains contributes for the column "Habitat Records", a specific section of the journal dedicated to providing data and supporting the implementation of the 92/43/EEC "Habitat" Directive in Europe (Gigante et al. 2019). The journal gives space to papers presenting the results of collaborative projects (e.g. Viciani et al. 2020).

Since 2012 *Plant Sociology* is indexed in the international databases Scopus (Source id: 21100211323) and Web of Science (Biological Abstracts, BIOSIS Preview).

*Plant Sociology* represents one of the few editorial spaces open to the publication of original research articles on all aspects of Vegetation Science, contributing to spread around the issues related to management and conservation of plant diversity. Its history has been built over the decades through many challenges successfully faced, thanks to the scrupulous work of the various collaborators who have contributed selflessly to its management.

The current European and global editorial scenario sees the role of large publishers expanding more and more at the expense of small editors and scientific communities. This is certainly one of the reasons that caused a certain drop in the number of articles published in the two annual issues of *Plant Sociology*, together perhaps with a general sense of disillusionment that pushes more and

more young people to move towards publishing giants, that have literally transformed the realm of knowledge in a market. Not that we decided to abandon the field.

The renewal of *Plant Sociology* is a challenge that we have undertaken with conviction, aware of the difficulties and pitfalls that characterize the life of a scientific journal today. Entrusting the technical management of the journal to a professional company aims to improve its dissemination and attractiveness, but also to focus our efforts only on scientific content. The management of the journal has since weighed on a small editorial staff that has taken on all the necessary procedures for the creation of a modern scientific periodical; today this "home made" method is no longer sufficient to guarantee an adequate circulation of our authors' articles in an editorial scene that has deeply changed.

As a result of the recently started partnership with Pensoft and thanks to the high-tech services provided by the scholarly publishing platform ARPHA, the first 2020 papers of are now available on the new website of *Plant Sociology*. All pre-2020 issues and articles remain available on the former website [http://www.scienzadellavegetazione.it/sisv/rivista/rivista\\_elenco.jsp](http://www.scienzadellavegetazione.it/sisv/rivista/rivista_elenco.jsp).

We believe and hope that more authors will want to help support the improvement and growth of *Plant Sociology*, actively collaborating in the relaunch of the journal, choosing it again and again for the publication of the results of their research.

## Conclusive remarks

Going to the question in the title: Does an OA journal about vegetation science still make sense in 2020? Our answer is: Definitely yes. Openly and freely disseminating research and knowledge about plant diversity and living systems should be one of the major targets (if not the most prominent) of human societies. In the present time, a frightening epidemic (Coronavirus disease 2019 or COVID-19) is spreading around in our planet, still reaping victims and undermining from the foundations a development system that for decades has neglected the signals coming from the other components of the living world. The harmful consequences of habitat fragmentation and ecosystems disruption have been too long predicted and proved, demonstrating the negative impacts of humans on natural systems (Corlett et al. 2020). Scientists are already suggesting how much humans can learn from COVID-19, in order to effectively drive new conservation strategy (Ervin 2020; Pearson et al. 2020).

We are not so naïve to believe that humankind will emerge improved from this catastrophe. However, we can rely on knowledge to hope removing/mitigating the impacts of our species on ecosystems. A journal focusing on all aspects of natural, semi-natural and anthropic plant systems, from basic investigation to their modelization, assessment, mapping, management, conservation and monitoring, is certainly a precious tool to detect environmental unbalances, understand processes and out-

line predictive scenarios that support decision makers. In this sense, we believe that more and more OA journals focused on biodiversity should find space in the academic editorial world, because only through deep knowledge of processes and functions of a complex planet, humankind can find a way to survive healthy.

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