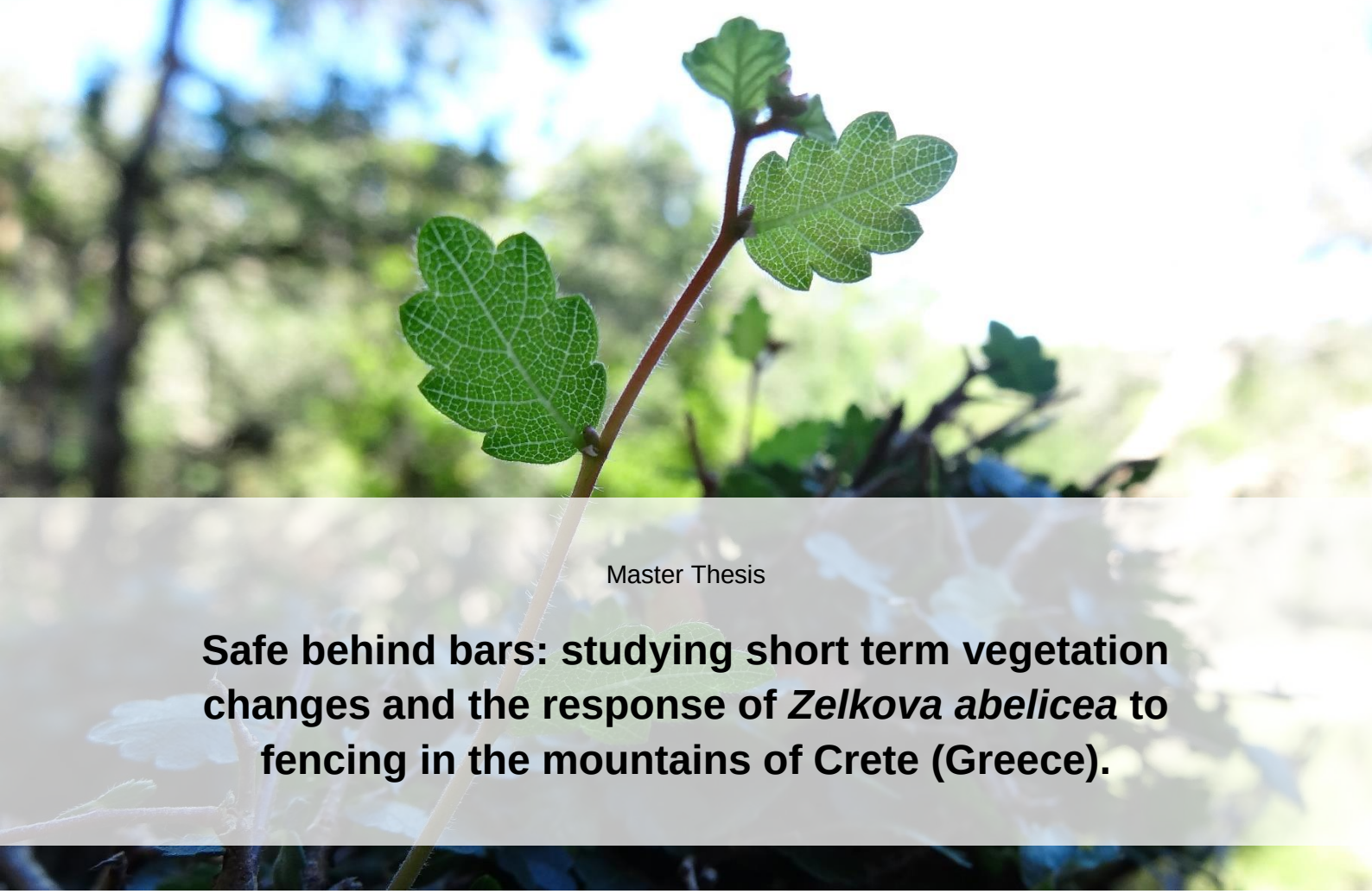


Master Thesis

Safe behind bars: studying short term vegetation changes and the response of *Zelkova abelicea* to fencing in the mountains of Crete (Greece).

Presented by:

Marie Carron

Jasminweg 4
3930 Visp
marie.carron2@unifr.ch

Under the supervision of

Dr. Nadine Salzmann (University of Fribourg, Department of Geography)

Prof. Dr. Gregor Kozlowski (University of Fribourg, Department of Biology)

Laurence Fazan (University of Fribourg, Department of Biology)

UNI FR
UNIVERSITÉ DE FRIBOURG
UNIVERSITÄT FREIBURG

Department of Geosciences

Fribourg, October 2016

Table of contents

Acknowledgments 2

Abstract 3

1. Introduction 4

2. Material and Methods 8

2.1. Study species 8

2.2. Study area 9

2.3. Study sites 9

2.4. Data collection 12

2.5. Data analysis 14

3. Results 15

3.1. Plant taxa growing in association with *Z. abelicea* 15

3.2. Changes in vegetation cover and plant taxonomic richness after fencing 17

3.3. Response of juvenile *Z. abelicea* shoots after browsing removal 20

3.4. Influence of physical parameters 21

4. Discussion 24

4.1. Plant species occurring with *Z. abelicea* 24

4.2. Shift in vegetation patterns and higher species richness after fencing 25

4.3. Growth of juvenile *Z. abelicea* shoots in fenced plots 28

4.4. Impact of the abiotic parameters on the study plots 29

5. Conclusions 31

6. Bibliography 32

Annex 38

Acknowledgments

Depuis le début et tout au long de cette thèse, de nombreuses personnes m'ont soutenue, soit en partie, soit durant tout le processus. Je tiens à les remercier toutes du fond du cœur.

En premier lieu j'aimerais remercier ma superviseuse Laurence Fazan, qui est devenue mon amie au cours des camps de terrain en Crète. Merci pour toute ta patience, ta gentillesse, tes encouragements et pour tout le temps que tu m'as consacré pour ce travail. Je n'oublierai jamais ces *merveilleux* moments passés avec toi en Crète! ΛΩΛ

De plus, je remercie le Prof. Gregor Kozlowski, fondateur du projet de conservation *Zelkova*, de m'avoir acceptée en tant que géographe. Merci de m'avoir donné l'opportunité de vous aider dans le cadre du projet *Zelkova*.

Merci à la Dr. Nadine Salzmann, ma superviseuse du département de Géographie, qui m'a également suivie lors du travail.

Un grand Merci à Salvatore Pasta du Projet *Zelkova*. Je te remercie vivement pour tes idées, ton soutien, ton humour (qui me fait toujours bien rire) et pour tous les moments que tu m'as consacrés.

Merci à Giuseppe Garfì pour tes suggestions et tes idées, ainsi que les données sur *Zelkova sicula.*

Je tiens également à remercier les personnes du MAICh, principalement Christini Fournaraki et Panagiota Gotsiou, de m'avoir donné la possibilité de travailler en collaboration avec elles.

J'aimerais remercier infiniment tout le *Zelkova Team* de m'avoir financé les voyages en Crète et d'avoir rendu possible la réalisation de ce travail ! La Crète est magnifique et les *Zelkova abelicea* le sont encore plus! Merci!

Merci à toutes les personnes que j'ai rencontrées en Crète pour leur gentillesse: Dimos Dimitriou et sa famille, Nikos et Fotis Samaritakis, Giorgos Drakoulakis et les personnes de l'hôtel Neos Omalós, ainsi que toutes les autres personnes dont j'ai fait la connaissance.

Pour finir j'aimerais remercier mon grand-papa Firmin Bruchez et ma grand-maman Anne-Marie Beffa, ainsi que ma belle-famille Carron pour tout leur soutien !

Ce travail est dédié à mon fiancé et à présent mari, Bernard Carron qui me soutient dans tout ce que je fais! Merci pour tout ton amour, de m'avoir encouragée et supportée tout au long de ce travail. Merci pour toutes les fois que tu as cuisiné quand je travaillais. Merci du fond de mon cœur! Je t'aime!

Abstract

This study investigates the consequences of browsing exclusion in terms of plant diversity, vegetation patterns and growth of the relict species *Zelkova abelicea* (Ulmaceae), in the mountains of Crete (Greece). During various stages of the Cenozoic, Paleogene relict species, such as *Z. abelicea*, had a large-scale dispersion over western Eurasia, before being constrained by changing environmental conditions. *Z. abelicea* eventually survived in suitable habitats during those unfavourable periods, known as refugial regions, which nowadays correspond to the highest mountain ranges of Crete (Kozlowski and Gratzfeld, 2013).

Browsing was experimentally excluded by fencing 15 permanent plots in different areas (Xeropotamos, Machi, Fokies, Therisso and Niato Plateau) of the Lefka Ori in western Crete, which were (over)browsed until fall 2014. Identification and abundance of plant taxa, estimation of their cover, and growth of juvenile *Z. abelicea* shoots as well as physical parameters were monitored within the fenced and the six additional unfenced plots in 2015. Browsing cessation led to a significant higher taxonomic richness, over a period of 6 months. Interestingly, fenced plots showed overall a lower therophyte-cover, as well as a higher hemicryptophyte-cover. However, geophytes showed almost no change in cover between fenced and non-fenced sites. Additionally, the juvenile *Z. abelicea* shoots significantly increased in length over the scope of one year, with growth rates reaching 0.135 cm / day during the summer months (May to October 2015). Throughout PCAs, we finally analysed the physical parameters which might have influenced the vegetation associated with *Z. abelicea*. This analysis revealed that altitude positively affected the number of endemic taxa, as well as therophytes and geophytes. The study evidently shows that browsing represents the main factor limiting the growth of *Z. abelicea* and influencing its surrounding vegetation.

Keywords

Browsing impact, Crete, fencing, vegetation patterns, physical parameters, shoot growth, *Zelkova abelicea*

1. Introduction

Paleogene relict species, such as *Zelkova abelicea*, had a rather extensive distribution during different periods of the Cenozoic (Kozlowski and Gratzfeld, 2013). For millions of years afterwards, *Z. abelicea* had to withstand changing environmental conditions (Fazan et al. 2012) and finally survived in disconnected patches, so called refugia (Christe et al. 2014). In Crete, *Z. abelicea* is now restricted to the four main mountain ranges (Lefka Ori, Psiloritis, Dikti and Thripti) (Egli, 1997; Bauer and Bergmeier, 2011; Kozlowski et al. 2014) and is one of the few tree species endemic to the eastern Mediterranean. This relict species is therefore of considerable scientific and conservation interest (Kozlowski et al. 2014).

Islands such as Crete represent hotspots for species with restricted distribution, like endemic species. However, the adjacent continental areas have usually higher species diversity, in comparison to the islands (Whittaker et al. 2007; Iliadou et al. 2014). Bergmeier (2002) mentions that the low number of vascular plant species together with the high concentration of endemics in the mountains of Crete, reflect the long geographical isolation of the island. In fact, the convenient climatic conditions and the complex relief of Crete, might explain why *Z. abelicea* eluded extinction (Kozlowski and Gratzfeld, 2013).

Even though agriculture and livestock breeding have been present on Crete for the past 10’000 years, browsing by wild herbivores existed already since the Pleistocene (Fazan et al. 2012). Nowadays, pastoralism with sheep and goats is still practiced and flocks graze in the mountains throughout the summer. In fact, during the last decades the total number of livestock has significantly increased in the mountains of Crete, by more than 250% between 1971 and 2005 (Bergmeier, 2002; Hostert et al. 2003; Bauer and Bergmeier, 2011).
Overbrowsing, together with uncontrolled fires, water stress and soil erosion, are the main cause of land degradation in the Mediterranean areas (Hill et al. 1998; Hostert et al. 2003; Kozlowski and Gratzfeld, 2013). Moreover, Le Lannou (1941) noticed that animal husbandry in Sardinia has disturbed the land in several ways and has significantly modified and shaped the Mediterranean vegetation (Papanastasis et al. 2002; Camarda et al. 2015). Indeed, the vegetation is nowadays dominated by maquis or garigue, with dwarfed and bushy tree individuals, as a result of browsing and wildfires (Papanastasis et al. 2002; Fazan et al. 2012). Also, plants have long developed defensive traits by functional adaptations (e.g. thorny branches and leaves, reduces leaf system, poisonous metabolites, etc.) against herbivores (Camarda et al. 2015).

This study is innovative because no research has been carried out to this day focusing on *Z. abelicea*, the surrounding vegetation and their reaction after browsing removal. Recent studies on *Z. abelicea* have concentrated on diverse topics. Christe et al. (2014) analysed

the phylogeographic patterns of *Z. abelicea*, revealing a very ancient history of diversification and structuring of the populations. Furthermore, Fazan et al. (2012) performed dendrochronological analyses on *Z. abelicea* individuals and showed that dwarfed individuals may attain ages of > 500 years. The distribution, threats and population structure of our study species have been investigated by Kozlowski et al. (2014). Showing an extremely fragmented distribution and asymmetric population structure, they confirmed that *Z. abelicea* is a threatened species, so that present conservation strategies should be strengthened.
Fencing activities have already been carried out in Crete and other Mediterranean areas (Floret, 1981; Noy-Meir et al. 1989; Fernández Alés et al. 1993; Bergmeier, 1998a; Bergmeier, 1998b; Lavorel et al. 1999; Noy-Meir and Oron, 2001; Bergmeier, 2002; Papanastasis et al. 2002; Osem et al. 2004; Casasús et al. 2007; Kazakis et al. 2007; Farris et al. 2010; Gabay et al. 2011; Fernández-Lugo et al. 2013a; Fernández-Lugo et al. 2013b), but never concentrating specifically on *Z. abelicea*. Egli (1997) is the only one who established fences in the Lefka Ori (in spring 1992) to protect *Z. abelicea* seedlings from browsing impact, but without success, as in autumn of the same year seedlings were destroyed by browsing and summer drought. Finally, enclosures were installed in Sicily to protect the only two known stands of the endemic, very rare and threatened *Zelkova sicula* and observe the regrowth of browsed individuals (Garfì and Pasta 2015).

This study is part of the interdisciplinary project *Zelkova*, which has been launched in 2010 by the Botanic Garden of the University of Fribourg (Switzerland), together with the Natural History Museum of Fribourg and Botanic Gardens Conservation International (United Kingdom). The aim of the project was to establish a global conservation action plan on relict, rare and threatened woody species, focusing especially on the relict tree genus *Zelkova*, including *Z. abelicea* (Kozlowski and Gratzfeld, 2013; www.zelkova.ch).
Nowadays the rarity of *Z. abelicea* populations, makes rapid conservation actions indispensable. Conservationists estimate that livestock browsing is inconsistent with the preservation of high biodiversity (Papanastasis et al. 2002), so that durable fencing activities represent the most efficient measure for an immediate, albeit not long-term protection against overbrowsing (Kozlowski and Gratzfeld, 2013).

In this study, the following questions are addressed:

I. Which are the plant taxa co-occurring with *Z. abelicea* on the mountains of Crete (Greece)?
II. How does the vegetation associated with *Z. abelicea* respond to browsing removal?
III. How does the length of juvenile *Z. abelicea* shoots change after browsing removal?
IV. What are the main physical parameters (altitude, slope, rock cover and browsing) influencing the number of species and the vegetation patterns associated with *Z. abelicea*?

After identifying the plants associated with *Z. abelicea*, as well as the changes in vegetation patterns after browsing removal, we tested three main hypotheses: (1) The positive influence of browsing removal on species richness. This has already been shown by Bergmeier (1998a), who compared grazed and non-grazed plots in southern Lefka Ori (Crete). He has demonstrated that the species number increased slightly during the study period of 3 years after fencing. Furthermore, Papanastasis et al. (2002) revealed that overgrazed areas of the Psiloritis mountains (Crete) had significant lower values of species richness, which has also been found in Britain by Stewart and Pullin (2008). (2) We presume that browsing exclusion will lead to a rapid elongation of juvenile *Z. abelicea* shoots. In fact, Garfì and Pasta (2013 and 2015) have pursued observations on the endemic Sicilian *Zelkova sicula*, revealing considerable shoot-growth only one year after fencing. (3) Finally, we predict a shift in relative cover of plant life forms (Table 1), which is mediated by the browsing removal. This has been previously shown in different studies. Pettit et al. (1995) observed in western Australia (Mediterranean climate) a decline of therophytes in ungrazed situations, while hemicryptophytes were found more abundant in protected sites. Interestingly, the same shift was found in the Psiloritis mountains in Crete by Papanastasis et al. (2002). Moreover, Fernández-Lugo et al. (2013a) indicated that the frequency of therophytes was higher in heavily browsed areas of the Canary Islands, whereas in Israel hemicryptophytes were observed to be more frequent in protected sites (Noy-Meir et al. 1989).

Table 1: *Description of the Raunkiær plant life forms (Smith, 1913; Cain, 1950; Louhaichi et al. 2009).*

	Description	Morphology	Examples
Phanerophyte	Plant bearing its perennating* buds well above the surface of the ground, on aerial shoots.	Trees, woody perennials	- *Quercus coccifera* - *Acer sempervirens*
Chamaephyte	The hibernating buds of the plant are borne very close to the ground. During the critical period, they are sheltered by dead leaves and snow.	Shrubs, woody perennials	- *Verbascum spinosum* - *Prunus porstrata*
Hemicryptophyte	The dominant buds appear in the upper layer of the soil, right underneath the surface. The aerial shoots of the plant are herbaceous and die away in the unfavorable season.	Many woodland and hedgerow non-woody species, rosette or half-rosette species	- *Poa bulbosa* - *Trifolium physodes*
Therophyte	Plant completing the life cycle rapidly during the propitious season and surviving throughout the critical period as seeds.	annual grasses and forbs	- *Cardamine graeca* - *Geranium purpureum*
Geophyte	The dominant buds of the plant are subterrestrial and filled with stored food, which facilitates the plant to make quick vegetative development with the occurrence of the favorable period.	Roots and shoots (bulbs, rhizomes, tubers, tuberous shoots and roots) that are modified as storage organs.	- *Muscari neglectum* - *Crocus sieberi*

* Perennating buds are vegetative means for biennial and perennial plants to survive rigorous seasons (e.g. drought or cold). The classification of the Raunkiær plant life forms are made according to the position and the protection of the vegetative form of the plant body (Smith, 1913; Cain, 1950).

2. Material and Methods

2.1. Study species

Zelkova abelicea (Lam.) Boiss. is a relict tree of the elm family (Ulmaceae). Until recently it was considered as the only endemic tree species of Crete. However recent studies suggest that another tree, i.e. *Tamarix minoa* may also be endemic to the island, but further confirmation is needed (Villar et al. 2015). The species is listed in the Red Data Book of Rare and Threatened Plants of Greece as vulnerable (Egli 1995) and considered as endangered on the IUCN Red List of Threatened Species (Kozlowski et al. 2014). *Z. abelicea* is present in all four mountain ranges of Crete (Lefka Ori, Psiloritis, Dikti and Thripti) at an altitudinal range of 900 – 1800 m a.s.l. The species shows therefore a discontinuous distribution over the island of Crete, and its current distribution is strongly influenced by favourable microclimatic conditions, so that it often occurs where moisture is available also during the dry and hot summer months (e.g. north-facing slopes, rocky river beds, gullies and dolines) (Egli, 1997; Fazan et al. 2012; Christe et al. 2014). *Acer sempervirens*, *Quercus coccifera* and *Cupressus sempervirens* are the most common woody species which co-occur with *Z. abelicea* (Egli, 1997; Fazan et al. 2012). Moreover, the species is also accompanied by several shrub species, e.g. *Berberis cretica*, *Phlomis cretica*, *Rhamnus oleoides*, *Verbascum spinosum*, etc. (Kozlowski and Gratzfeld, 2013).

Z. abelicea can be found in two growth habits; as an arborescent individual (Fig. 1), capable of producing fruits and as dwarfed shrubby individuals (Fig. 2). The shrubby growth form is mainly influenced by the strong browsing pressure and is much more frequent (Fazan, 2014; Kozlowski et al. 2014). Most juvenile shoots are totally grazed off, so that only the inward-directed shoots remain. The circumference of the plant is therefore built of a «harness of old, thick twigs» (Egli, 1997, p. 507). Moreover, the dwarfed individuals have no chance to produce and disperse seeds (Fazan et al. 2012; Kozlowski et al. 2014).

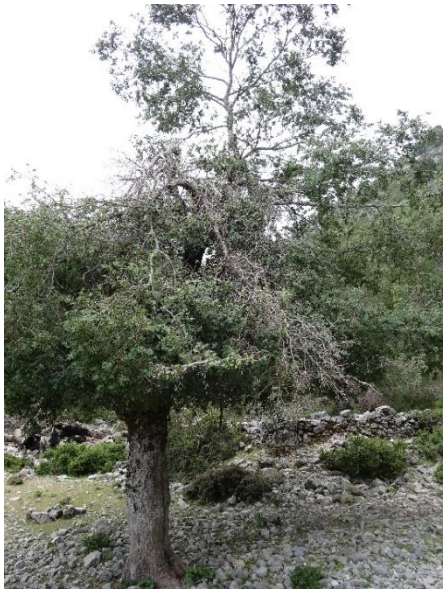


Figure 1: Z. abelicea *as tree individuals at Xeropotamos*



Figure 2: Z. abelicea *as shrub individuals at Xeropotamos*

2.2. Study area

Crete is the fifth largest Mediterranean island, with a surface of 8729 km^2, and its mountain ranges are dominated by calcareous rocks (limestone and dolomite) (Bergmeier, and Matthäs, 1996; Bosque et al. 2014). Crete is subject to a typical Mediterranean climate (Bosque et al. 2014) with hot, dry summers and mild-to-cold, wet winters. The mean annual temperatures are heavily influenced by the strong altitudinal range (from sea level up to 2400 m a.s.l.). Due to the influence of westerlies and the mountainous relief, mean annual precipitation amount is higher in the western mountain ranges (Lefka Ori) with ca. 2120 mm in Askyfou (740 m a.s.l.) compared to the eastern lowlands with ca. 440 mm in Lerapetra (10 m a.s.l) (Bosque et al. 2014). Elevation has a strong influence on precipitation, showing a positive spatial correlation (Bosque et al. 2014).

The flora of Crete counts over 1700 species, from which more than 10% are endemic (Sfikas, 1992; Jahn and Schönfelder 1995; Papanastasis et al. 2002; Papiomitoglou, 2006). One of the main causes of this relatively high endemic rate is the long-time geological isolation of the island of Crete (Jahn and Schönfelder 1995; Kozlowski et al. 2014). In addition to having connections to the European flora, a certain amount of species show close relationships to both Asian (e.g. *Z. abelicea, Ebenus cretica*) and North-African flora (e.g. *Androcymbium rechingeri*), (Jahn and Schönfelder 1995, Fielding and Turland 2005, Iliadou et al. 2014).

2.3. Study sites

A total of 21 study plots (15 fenced and 6 non-fenced) were investigated in this research. The plots are located in the Lefka Ori mountain range in western Crete (Fig. 3). Fifteen plots were fenced in summer 2014 in the framework of the *Z. abelicea* conservation project and 6 additional non-fenced plots were identified for the purpose of this study in May 2015 during fieldwork. The latter were chosen in sites close to the fenced plots, with similar abiotic conditions and vegetation patterns. The altitudinal dispersion of the plots ranges from 935 to 1261 m a.s.l., with different aspects and slopes (Table 2). Each plot contained dwarfed shrubby *Z. abelicea* individuals. The sizes of the fenced plots varied between 7.1 m^2 and 25 m^2. All external plots had a standard area of 16 m^2.

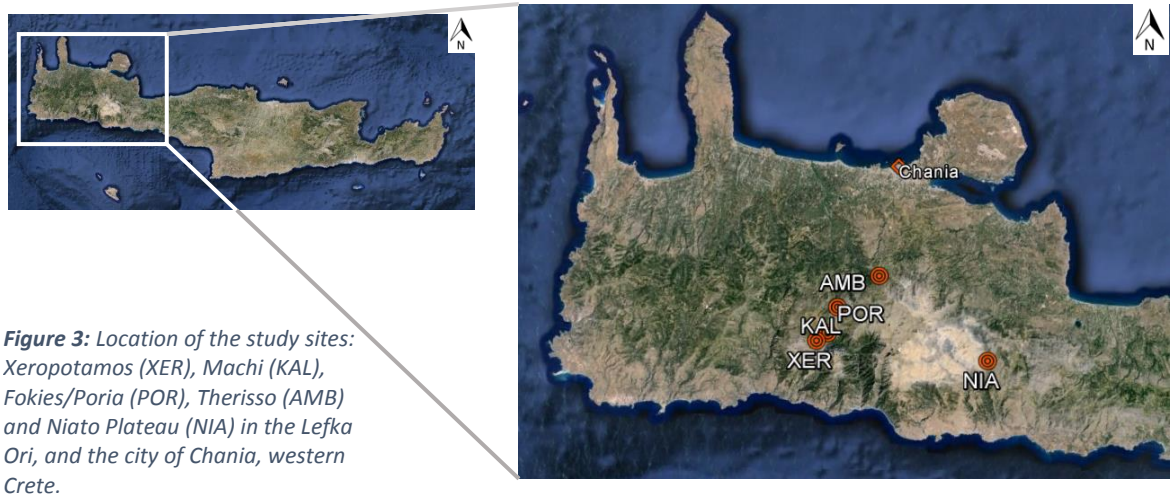


Figure 3: *Location of the study sites: Xeropotamos (XER), Machi (KAL), Fokies/Poria (POR), Therisso (AMB) and Niato Plateau (NIA) in the Lefka Ori, and the city of Chania, western Crete.*

Table 2: *Information on each study plot: plot name (-EXT corresponds to non-fenced plots), plot location (latitude and longitude), altitude, aspect, slope, study region and area.*

Plot name	Latitude [°N]	Longitude [°E]	Altitude [m a.s.l.]	Aspect [°N]	Slope [°]	Region	Area [m^2]
XER1	35.18366	23.54109	1258	25	9	Xeropotamos	16
XER2	35.18380	23.54119	1250	35	17	Xeropotamos	21,3
XER3-1	35.18376	23.54107	1254	35	10	Xeropotamos	16
XER3-2	35.18376	23.54107	1254	35	7	Xeropotamos	16
XER3-3	35.18376	23.54107	1254	35	10	Xeropotamos	16
XER3-4	35.18376	23.54107	1254	35	14	Xeropotamos	16
XER-EXT1	35.18370	23.54111	1256	30	9	Xeropotamos	16
XER-EXT2	35.18367	23.54101	1261	29	8	Xeropotamos	16
KAL1	35.19081	23.55074	1192	306	15	Machi	22,1
KAL2	35.19106	23.55066	1191	235	22	Machi	18,1
KAL-EXT	35.19085	23.55079	1193	274	10	Machi	16
AMB2	35.23081	23.59283	935	313	18	Therisso	7,1
AMB-EXT	35.23081	23.59283	935	315	18	Therisso	16
NIA1	35.17150	24.08439	1229	0	0	Niato Plateau	25,6
NIA2	35.17138	24.08476	1224	0	0	Niato Plateau	25,6
NIA3	35.17169	24.08470	1225	0	0	Niato Plateau	19,2
NIA4	35.17182	24.08459	1226	0	0	Niato Plateau	14,3
NIA-EXT	35.17180	24.08461	1225	0	0	Niato Plateau	16
POR1	35.20566	23.55558	1107	40	27	Poria / Fokies	21,3
POR2	35.20392	23.56028	1152	50	23	Poria / Fokies	25,6
POR-EXT	35.20392	23.56028	1152	50	23	Poria / Fokies	16

Plots in the Xeropotamos area (XER1, XER2, XER3-1, XER3-2, XER3-3, XER3-4, XER-EXT1 and XER-EXT2) are situated on the sides of a summer-dry river to the south of the Omalos plateau. Numerous deposits of coarse rocky material are present, due to the input of sediment coming down from ravines mainly during extreme precipitation events during autumn and winter months. The tree cover is discontinuous, with some *Z. abelicea, Acer sempervirens* and *Quercus coccifera* trees, but as browsing is intensive, most of the

individuals show a shrubby habit (Fig. 4a). The area is used intensively by shepherds from spring to autumn.



Figure 4: *Views of each study region:* ***a)*** *Xeropotamos with XER1,* ***b)*** *Fokies/Poria with POR2,* ***c)*** *Machi with KAL1,* ***d)*** *Therisso with AMB2 and AMB-EXT (yellow tape) and* ***e)*** *Niato Plateau with NIA1.*

In Machi, (plots KAL1, KAL2 and KAL-EXT), also located in the direct vicinity of the Omalos plateau, the tree cover is denser, with the formation of a mixed open forest of *Z. abelicea, A. sempervirens* and *Q. coccifera* (Fig. 4c). Flocks are also present here from spring to autumn.

Vegetation in the Fokies/Poria area (Fig. 4b) is different as it is dominated by chamaephytes and therophytes. The study plots (POR1, POR2 and POR-EXT) are situated on a quite steep (23 – 27°) east orientated slope in a north-south narrow valley at the bottom of which a seasonally dry stream can be found. Trees are mostly restricted to the upper slopes and cliffs and along the thalweg, with mainly young *C. sempervirens* trees re-colonizing the lower slopes. The majority of *Z. abelicea* individuals appear only in a shrub form. Extensive pastoralism is practised here.

In Therisso (Fig. 4d), the study plots (AMB2 and AMB-EXT) are situated in the proximity of a small doline, around which *Z. abelicea* shrubs are growing. These two plots are the lowest (933 m a.s.l.) among all the plots considered in this study and frequent herds are found in the vicinity.

The last group of considered plots (NIA1, NIA2, NIA3, NIA4 and NIA-EXT) are located on a mountain doline (between 1224 and 1229 m a.s.l.), the so-called Niato Plateau (Fig.

4e). All plots have a slope of 0° and are exposed to all directions. Of all our study regions, the Niato Plateau has the eastern most position in the Lefka Ori and is also used as browsing grounds throughout the summer.

2.4. Data collection

The data collection consisted mainly in four different tasks: measuring the species richness, estimating the plant cover, measuring the growth of young *Z. abelicea* shoots after fencing, as well as taking physical and environmental parameters for each plot.

Species richness was measured by identifying and listing all the plant taxa occurring in each plot. Species classification was carried out with the help of the book «Exkursionsflora für Kreta» (Jahn and Schönfelder, 1995). Unknown species were collected for further identification and some specimens are now stored in the herbarium of the Mediterranean Agronomic Institute of Chania (MAICh). A permit for plant collection was granted by the Greek Ministry of Environment in the scope of the *Z. abelicea* conservation project (permit n°124068/1323). Salvatore Pasta (freelance researcher collaborating with the *Zelkova*-team at the University of Fribourg) and Ralf Jahn (author of the «Exkursionsflora für Kreta», Jahn and Schönfelder, 1995) kindly provided additional help for the determination of difficult specimens. Since plot sizes varied greatly, a standard 16 m^2 sub-plot was defined in all fenced plots of greater size, in order to be able to compare species numbers between plots of various sizes (Mueller-Dombois and Ellenberg, 1974; Gorenflot and de Foucault, 2005; Meddour, 2011). As the species frequency is highly influenced by the size of the quadrat, it is essential to compare equal plot areas (Mueller-Dombois and Ellenberg 1974; Helm, 2010). As the XER3-plot had a surface of ca. 453 m^2, four sub-plots (XER3-1, XER3-2, XER3-3 and XER3-4) were established to represent the different vegetation patterns (mixed open forest and shrub vegetation). Furthermore, the two study plots in Therisso (AMB2 and AMB-EXT) were excluded from all further analyses because of the very small surface of AMB2 (ca. 7 m^2).

A modified Braun-Blanquet method (Braun-Blanquet, 1964) was adopted to estimate the cover of each plant species within the entire plot surfaces. Instead of using Braun-Blanquet cover categories (r, +, 1, 2m, 2a, 2b, 3, 4, 5), we attributed directly a cover percentage to each species in order to be more precise. Only species with very low cover such as 0.02% (one or two individuals) and 0.1% (few individuals) were assigned to the classes of « r » and « + », respectively. For the vegetation cover, which is independent of plot size (Cain, 1950), the whole plot size was considered.

A further step of the data collection consisted in the measurement of juvenile *Z. abelicea* shoots (those having sprouted in spring 2015) (Fig. 5). Between three and 16 shoots were

measured per shrub individual, using a measuring stick. In most plots, all individuals were sampled (min. 3 and max. 23 individuals). Only shoots growing out of the surface of the shrub were selected for the study, as on browsed individuals, shoots are also able to grow (without being browsed) inside the bush (Egli, 1997), due to the dense growing branches, so that sheep and goats cannot reach them.

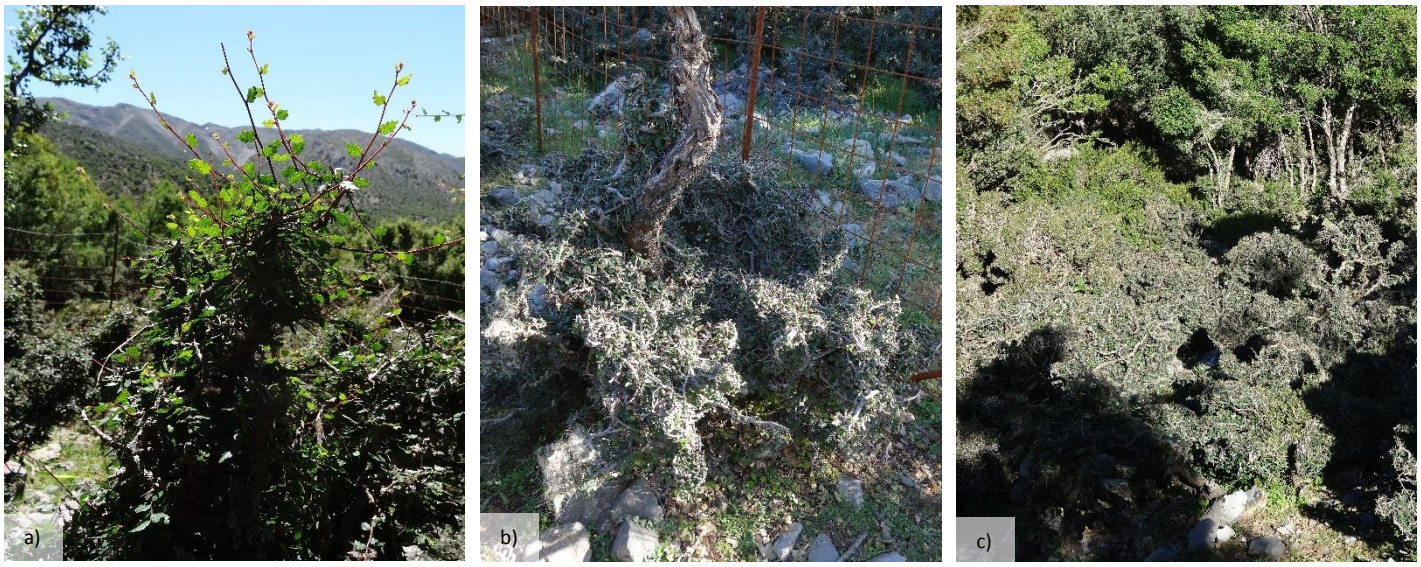


Figure 5: *Morphology of* Z. abelicea *shrubs* ***a)*** *juvenile* Z. abelicea *shoots growing out of the surface of the shrubs (KAL1),* ***b)*** *and* ***c)*** *showing strongly browsed and dense shrubs in Machi (outside KAL1).*

Lastly, physical parameters of each study plot were also recorded. Using a GPS, the location (latitude and longitude) and the altitude of each plot were assessed. The mean slope was calculated in degrees using an inclinometer and the aspect, expressed in degrees with respect to the north, with the help of a compass. In addition, each plot perimeter was measured with a measuring tape, and the plot surface calculated. Moreover, local disturbance factors (browsing and trampling by livestock) were recorded and their intensity evaluated through a semi-quantitative scale. Finally, we estimated tree (woody sp. > 2 m), shrub (woody sp. between 0.5 and 2 m) and herb cover (woody and non woody sp. < 0.5 m), the cover and the average height of *Z. abelicea* within the tree, shrub and herb layers, as well as stone, bare rock, bare soil and litter cover (Annex 2).

All the above listed measurements were done on the 15 fenced study plots and in addition were replicated on the 6 non-fenced plots, subjected to browsing. Data were collected in late May 2015, except for the young *Z. abelicea* shoots, which were additionally measured a second time in late October of the same year.

2.5. Data analysis

A Raunkiær plant life form (chamaephytes, geophytes, hemicryptophytes, phanerophytes and therophytes, Cain 1950 and Smith 1913; Table 1) was attributed to each species according to Jahn and Schönfelder (1995). Since cover values per species were known, we were able to derive the cover value of each plant life form type in every plot. In addition, stacked bar-charts were done with R Studio (Borcard et al. 2011), representing the mean value of each plant life form in percentage of the total cover of all four regions (KAL, NIA, POR and XER), of fenced and non-fenced plots. The total cover of the vegetation in a plot was reported to 100% so as to be able to compare plots with different cover values. Finally, the mean cover of each vegetation layer (tree, shrub and herb) of the fenced and non-fenced plots were also plotted for comparison.

In order to compare the plant taxonomic richness between fenced and non-fenced plots, the species abundance was estimated by counting the number of species in each $16m^2$ subplot. Only study plots having a surface greater than $16m^2$ were used for the analysis (NIA3 and NIA4 were excluded).

Significance tests were done using the Mann-Whitney U test in R Studio (Bauer 1972, Hollander et al. 2014) and the significance level was set with a p-value below 0.05.

Principal component analysis was performed in R Studio, in order to plot the physical parameters in combination with the biological ones of each 16 m^2 study plot (Annex 3 and 4). The abiotic factors taken into account were: altitude [m a.s.l.] (corrected with Google Earth), slope [°], aspect [°N], browsing [1 / 0], fencing [1 / 0], as well as soil cover [%] for every study plot. Biotic factors included total species number, endemic species number, total vegetation cover [%] of each plot and cover expressed by each plant life form [%].

With specific combinations of the above mentioned parameters, three PCAs were carried out in R studio: (1) Each study plot (Fig. 12 in subchapter «3.4. Influence of physical parameters») was plotted according to its basic physical parameters (altitude, slop, aspect, browsing and fencing) in combination with the **total number of plant taxa** and the **number of endemic taxa**. (2) The second PCA focuses on the plot distribution according to their **plant life form cover** in comparison to vegetation cover, total number of species and altitude. (3) Finally, the point of the third PCA was to combine **vegetation - and soil cover** with altitude, browsing and total number of taxa. (The factors of main interest in each PCA is shown here in bold character).

Only the scaling 1 of all PCA has been used for the analysis. «The scaling refers to the way ordination results are projected in the reduced space for graphical display» (Borcard et al. 2011, p. 120). In fact, in a scaling 1 biplot, angles among descriptor vectors are meaningless,

but the distances between objects (here: study plots) are approximations of their Euclidean distance in multidimensional space (Borcard et al. 2011).

3. Results

3.1. Plant taxa growing in association with Z. abelicea

A table of all plant species appearing in each study plot can be found in Annex 1. Below, Table 3 compares the most frequent (≥ 50 %) plant taxa co-occurring with *Z. abelicea* in the considered plots. These species have a frequency of at least 50% in either fenced or non-fenced plots.

Galium murale is the only species present in all plots, apart from *Z. abelicea*. Occurring in all fenced plots, *Poa bulbosa* appears only in a third of all the external plots. After *Asparagus aphyllus*, with a frequency of ca. 87% in fenced and 33% in non-fenced plots, *Geranium molle*, *Crepis neglecta*, *Leontodon tuberosus* and *Galium aparine* all appear to 80% in fenced plots, but to a lower frequency in browsed plots (< 67%). *Legousia hybrida* is the only species with the same amount of appearance (66.7%) in both fenced and non-fenced plots. Furthermore, *Acer sempervirens* is the only phanerophyte occurring with *Z. abelicea*, with a frequency of more than 50%. Interestingly, all plant taxa with a frequency of ≥ 50% in external plots, also appear within more than 50% of the fenced plots. The other way around is different: not all species appearing in more than 50% of the fenced plots show a frequency of ≥ 50% in non-fenced plots.

Table 3: *Comparison of species frequencies between fenced and non-fenced plots. The listed plant species have at least in one of the situations (fenced or non-fenced plots) a frequency of ≥ 50%. Bold shows the higher species frequency, with* Z. abelicea *occurring in all study plots.*

	Frequency [%]	
Species	**fenced plots (15)**	**non-fenced plots (6)**
***Zelkova abeliceae* (Lam.) Boiss.**	**100.0**	**100.0**
Galium murale (L.) All.	100.0	100.0
Poa bulbosa L.	**100.0**	33.3
Asparagus aphyllus L. subsp. *orientalis* (Baker) P. H. Davis	**86.7**	33.3
Geranium molle L.	**80.0**	66.7
Crepis neglecta L. subsp. *cretica* (Boiss.) Vierh.	**80.0**	66.7
Leontodon tuberosus L.	**80.0**	33.3
Galium aparine L.	**80.0**	50.0
Lamium amplexicaule L.	**73.3**	50.0
Dactylis glomerata L. subsp. *hispanica* (Roth) Nyman	73.3	**83.3**
Carlina corymbosa L.	**73.3**	66.7
Legousia hybrida (L.) Delarbre	66.7	66.7
Vicia lathyroides L.	**66.7**	50.0
Acer sempervirens L.	60.0	**66.7**
Sherardia arvensis L.	53.3	**66.7**

Catapodium rigidum (L.) C. E. Hubb.	60.0	**66.7**
Microthlaspi perfoliatum (L.) F.K. Mey.	**66.7**	33.3
Cynosurus echinatus L.	**66.7**	33.3
Sedum litoreum subsp. *litoreum* Guss.	**66.7**	50.0
Anthemis rigida subsp. *rigida* Boiss. ex Heldr.	**66.7**	50.0
Ranunculus paludosus Poir.	**66.7**	33.3
Lagoecia cuminoides L.	**60.0**	50.0
Geranium lucidum L.	**60.0**	50.0
Veronica arvensis L.	**60.0**	50.0
Rhagadiolus stellatus (L.) Gaertn. var. *edulis* Rouy	**60.0**	9.5
Trifolium physodes M. Bieb.	**60.0**	9.5
Arum cylindraceum Gasparr.	**60.0**	50.0
Taraxacum aleppicum Dahlst.	**60.0**	50.0
Centaurea idaea Boiss and Heldr.	**53.3**	9.5
Scaligeria napiformis (Spreng.) Grande	**53.3**	9.5

Furthermore, an analysis of the Raunkiær's life forms was done on all plant species in fenced (Fig. 6 a) and non-fenced plots (Fig. 6 b). The most frequent life form in both fenced and non-fenced plots are therophytes, representing 48% and 53% respectively. Hemicryptophyte is the second most common plant life form showing a proportion of 23% in fenced and 22% in non-fenced plots. Moreover, chamaephytes and geophytes are both more frequent in unbrowsed plots, with 10% and 15% respectively, compared to non-fenced plots (8% and 12% correspondingly). Finally, with 4% of presence in fenced plots, and 5% in non-fenced plots, phanerophyte is the life form with the smallest proportions. Interestingly, the differences for all plant life forms between fenced and non-fenced plots are not significant, with p-values ranging from 0.4 and 0.9.

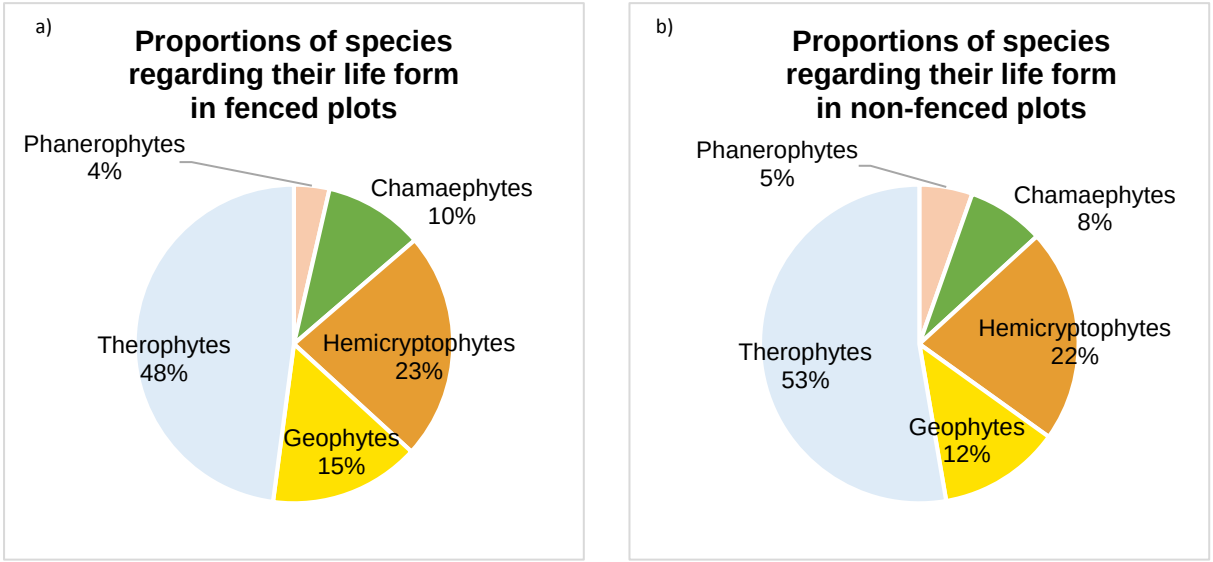


Figure 6: *Pie-charts presenting the proportions [%] of species regarding their Raunkiær's life form in fenced (a) and non-fenced plots (b). In all cases, the differences in plant life forms between fenced and non-fenced plots are not significant, with p-values superior to 0.05 (for phanerophytes p = 0.9, chamaephytes p = 0.85, geophytes p = 0.4, hemicryptophytes p = 0.4 and therophytes p = 0.75) .*

Table 4: *Proportions [%] of species regarding their plant families in fenced and non-fenced plots. The bold number represents the higher value for each family between fenced and non-fenced plots. For each plant family, the differences between fenced and non-fenced plots are not significant, with p-values superior to 0.05.* [a] *Euphorbiaceae is the only exception with p = 0.03.*
[b] *The frequency of rare families (each having values below 1%) are summed up in one row. It concerns Aliaceae, Aristolochiaceae, Asparagaceae, Berberidaceae, Campanulaceae, Colchicaceae, Convolvulaceae, Cyperaceae, Dennstaedtiaceae, Fagaceae, Fumariaceae, Hypericaceae, Iridaceae, Liliaceae, Oleraceae, Orobanchaceae, Paeoniaceae, Plantaginaceae, Pterydophyte, Rhamnaceae, Rosaceae, Sapindaceae, Saxifragaceae, Scrophyllaceae, Thymelaeaceae and Ulmaceae.*

	Proportions [%] in :	
	fenced plots	**non-fenced plots**
Poaceae	13	**14**
Asteraceae	10.7	**13.2**
Caryophyllaceae	**8.3**	7.8
Lamiaceae	**7.1**	5.4
Rubiaceae	5.3	**6.9**
Brassicaceae	**6.5**	2.3
Fabaceae	5.9	**6.2**
Apiaceae	5.3	**6.2**
Crassulaceae	1.8	**3.9**
Geraniaceae	2.9	**3.1**
Ranunculaceae	2.4	**3.1**
Veronicaceae	1.8	**3.1**
Hyacinthaceae	**2.9**	1.5
Orchidaceae	**2.4**	0.8
Euphorbiaceae[a]	**1.8**	1.6
Boraginaceae	1.2	**1.6**
Polygonaceae	1.2	**1.6**
Asphodelaceae	1.2	**1.6**
Araceae	**1.2**	0.8
Primulaceae	**1.2**	0.8
Valerianaceae	**1.2**	0
rare families[b]	15	15.2
sum	**100**	**100**

Finally, the same analysis was done with plant families (Table 4). Poaceae and Asteraceae are clearly the most represented families with 13% and 11% in fenced plots and 14% and 13% in external plots, correspondingly. Moreover, fenced study plots have a higher proportion in Caryophyllaceae and Lamiaceae (with 8% and 7% respectively) than fenced plots. The opposite can be observed, inter alia with Rubiaceae and Fabaceae which are more common in non-fenced plots with 7% and 6%, correspondingly. Curiously, none of the plant families differs statistically between fenced and non-fenced plots (p-values between 0.2 and 0.9), except of the Euphorbiaceae with p = 0.03.

3.2. Changes in vegetation cover and plant taxonomic richness after fencing

The first and most visible change in vegetation after the establishment of the fences in 2014 is the significant ($p < 0.05$) difference of plant taxonomic richness within the fenced plots (only subplots of 16 m^2) compared to the external plots (Fig. 7). With a median of 50.5

taxa in the fenced plots and of 41.5 in external plots, most fenced plots showed a much higher number of species, in comparison to their browsed surroundings (non-fenced plots). Furthermore, a higher median number of endemic taxa inside the fences (Annex 5) were found, with a significant difference ($p < 0.05$) and a median of 4.5 and 3 endemics in fenced and non-fenced plots correspondingly.

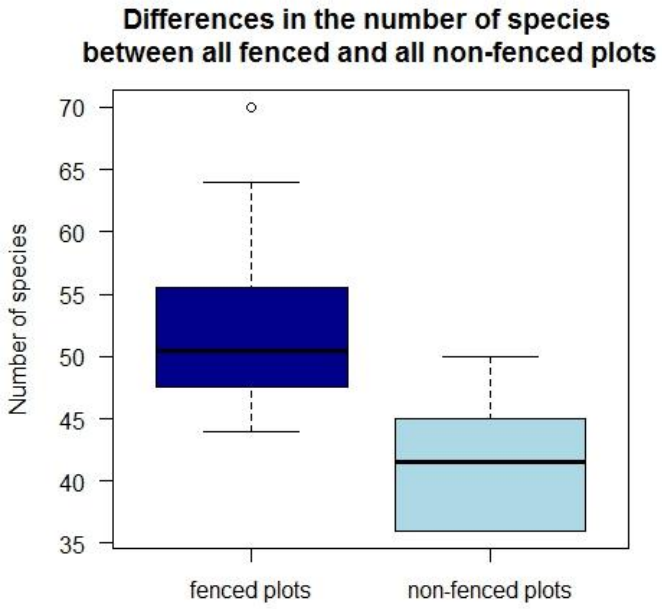


Figure 7: *Boxplots showing the distribution of the number of species in fenced and in non-fenced plots in May 2015, with a significant difference ($p < 0.05$).*

Another change in the vegetation pattern consists in the shift in cover of the plant life forms per plot after fencing (Fig. 8). The mean of each study region (details of each study region can be found in subchapter 2.3.) has been used to summarize the mean trend.

At first sight it is clear that each region has its own vegetation pattern, but in general the trend changes similarly in each of the observed region. Moreover, each plant life form is statistically similar between fenced and non-fenced plots, with p-values spanning from 0.1 to 0.6.

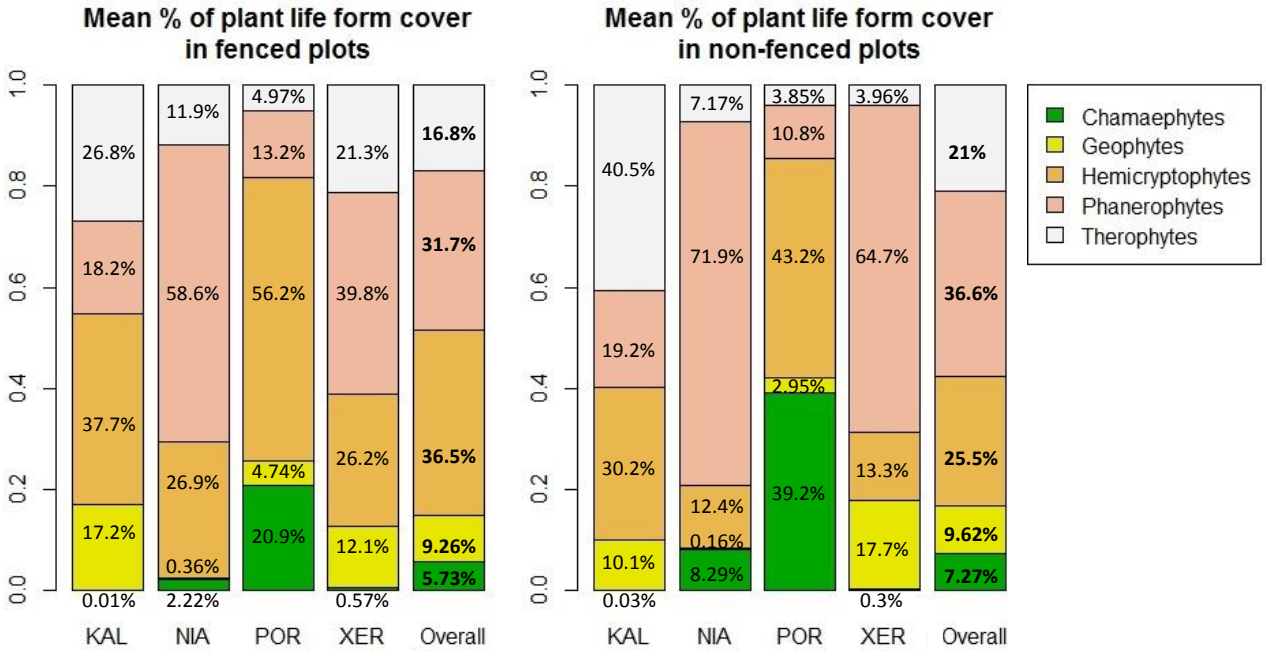


Figure 8: *Stacked bar chart with the mean % of plant life form cover in all study regions (KAL, NIA, POR and XER) of fenced and non-fenced plots, as well as the overall mean trend in fenced and non-fenced plots (May 2015). The differences are not significant for all life forms, with p-values between 0.1 and 0.6.*

Here, a globally higher hemicryptophyte-cover (36% overall) can be found inside the fenced plots. In contrast, chamaephytes and geophytes do not vary much between fenced and external plots (with an overall chamaephyte-cover of 6% and 7% respectively and an overall geophyte-cover of 9% in fenced and non-fenced plots). Therophytes show globally a smaller cover, of 5% less, in enclosed plots. Finally, phanerophytes cover clearly less surface in the fenced plots, representing 18% in Machi (KAL), 59% in Niato Plateau (NIA), 13% in Fokies (POR) and 40% in Xeropotamos (XER), and 19%, 72%, 11% and 65% in browsed plots, respectively.

As is shown in more detail, fenced as well as non-fenced plots in Machi and in Xeropotamos, are nearly without chamaephytes (only 0.012% in fenced and 0.036% in non-fenced plots (KAL) and 0.58% and 0.3% (XER), respectively). Furthermore, Niato shows hardly any geophytes in both cases, with 0.36% in fenced and 0.16% in external plots. As browsing is supposedly less intense in Fokies, differences in vegetation between fenced and non-fenced plots are not so obvious at first sight. However, this area seems quite different in terms of vegetation cover: chamaephytes cover a big part of the plots, with 21% and 39% in fenced and non-fenced plots, correspondingly. On the other hand, geophytes and phanerophytes have a much lower cover (4.7% and 3% of geophytes and 13% and 11% of phanerophytes, in fenced and non-fenced plots respectively), which is balanced out by the high hemicryptophyte-cover (56% in fenced and 43% in external study plots).

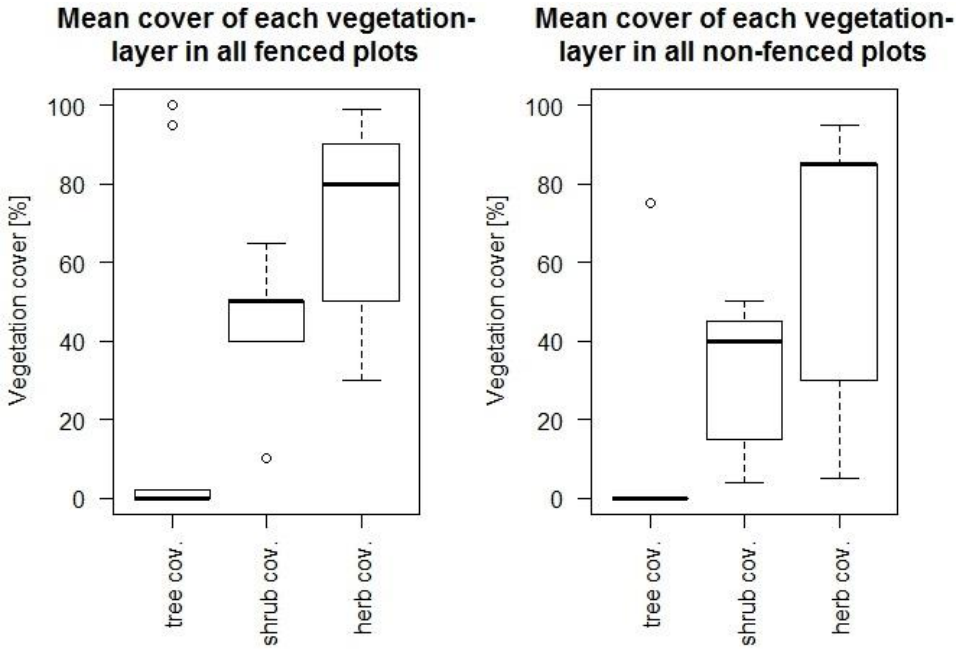


Figure 9: *Mean cover [%] of each vegetation layer (tree, shrub and herb) in all fenced and non-fenced plots. The differences between fenced and non-fenced plots are not significant, with 0.58 for herb, 0.16 for shrub and 0.7 for tree cover. The tree layer consists of woody species > 2 m, the shrub layer of woody species between 0.5 and 2 m and the herb layer of woody species < 0.5 m and of non-woody species.*

Finally the cover of each vegetation (tree, shrub and herb) layer of all fenced and non-fenced plots was investigated and represented in Figure 9. Their difference is in all cases not significant with p-values higher than 0.05 (0.58 for herb, 0.16 for shrub and 0.7 for tree cover). Mean values of all three layers are higher in the fenced plots, reaching 20% for the tree cover, 45% for shrubs and 71% for herbs, compared to cover in external plots, with 15%, 31% and 60% respectively.

3.3. Response of juvenile Z. abelicea *shoots after browsing removal*

Figure 10 demonstrates the significant growth ($p < 0.001$) of juvenile *Z. abelicea* shoots in May and October 2015 in all fenced plots (with a median of ca. 11 cm in May and 31.5 cm in October). Already in May there was a visible and significant difference ($p < 0.001$) in terms of shoot length between fenced and non-fenced plots (Fig. 10). The shoots measured in the external plots did not show a significant increase ($p = 0.4$) in length during the summer time (median around 4.5 cm). The time gap between the two measurement campaigns corresponds to a time laps of 143 to 155 days (ca. five months), during which *Z. abelicea* shoots grew at an average rate of 0.00705 cm/day (0.35 cm/month) in the non-fenced plots and at 0.135 cm/day (6.72 cm/month) inside the fenced plots. Figure 11 shows *Z. abelicea* shrubs with their juvenile shoots in May 2015 in fenced (a) and in non-fenced plots (b), as well as in October 2015 in enclosed study plots (c) and (d).

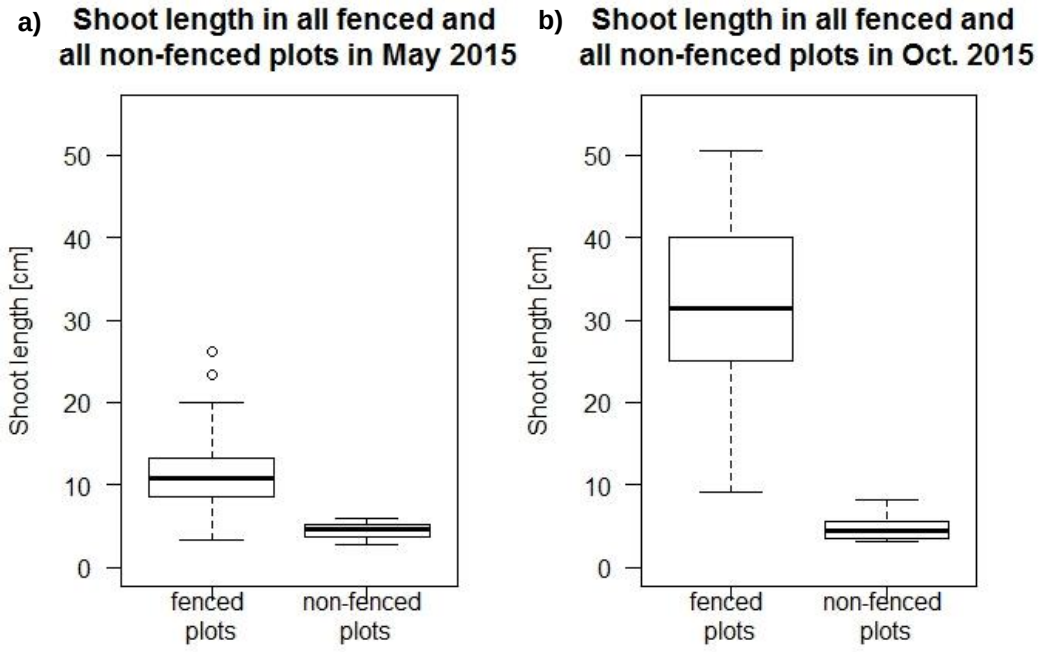


Figure 10: *Mean juvenile shoot length of each measured* Zelkova *tree in all fenced and non-fenced plots, in* ***a)*** *May 2015 (significant difference between fenced and non-fenced plots, with $p < 0.05$), and in* ***b)*** *October 2015 (significant difference between fenced and non-fenced plots, with $p < 0.05$).*



Figure 11: Z. abelicea *shrub individuals with their shoots.* ***a)*** *Juvenile shoots in May 2015 in a fenced plot (KAL2),* ***b)*** *browsed* Z. abelicea *shrub in May 2015 in POR-EXT,* ***c)*** Z. abelicea *shrub individual in October 2015 in XER1 (fenced plot) showing a strong growth since May 2015, and* ***c)*** *shrubby non-browsed* Z. abelicea *individuals in October 2015 in POR2.*



3.4. Influence of physical parameters

Figure 12 shows the opposition between fencing and browsing, which is obvious as all external plots (XER-EXT1, XER-EXT2, KAL-EXT, AMB-EXT, NIA-EXT and POR-EXT) are concentrated around the browsing-vector.

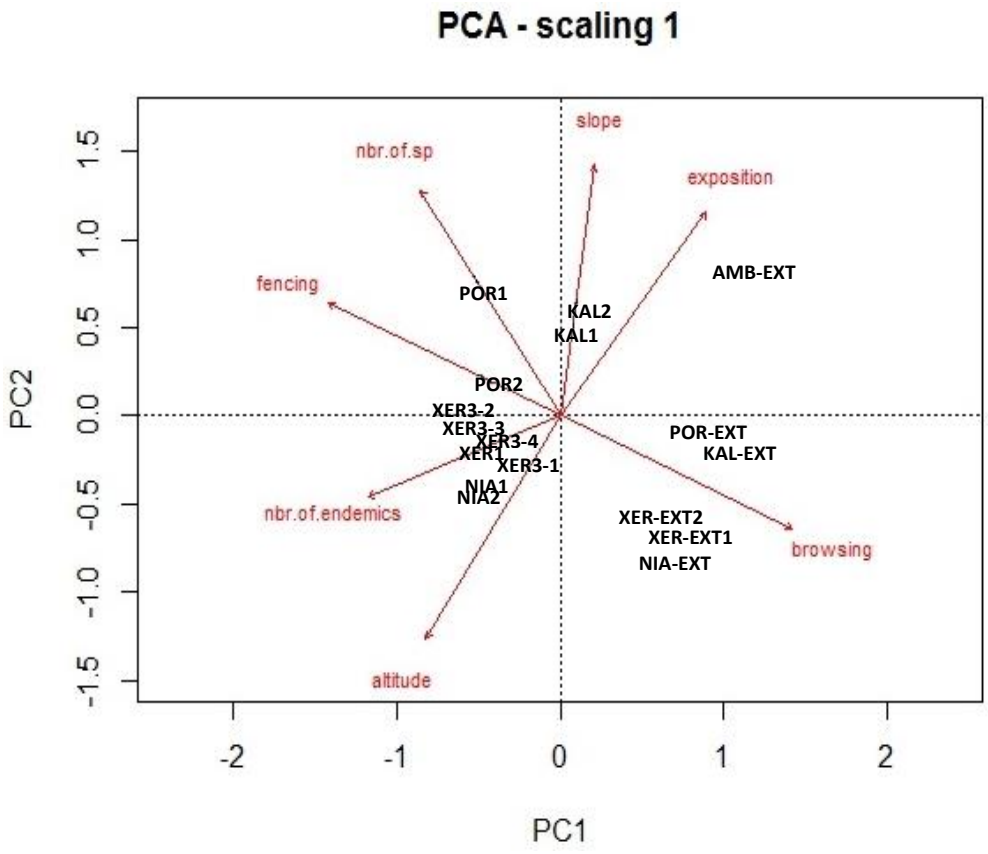


Figure 12: *PCA biplot 1 (scaling 1) of study plots and biotic and abiotic data (axes 1 and 2), Eigenvalues of axis 1 = 3.19 and of axis 2 = 2.06.*

Interestingly, plots situated higher in altitude (XER1, XER3-1, XER3-2, XER3-3, XER3-4, XER-EXT1, XER-EXT2, NIA1, NIA2 and NIA-EXT, but are close to the centre of the graphic) are more likely to have a higher rate of endemics, than plots at lower areas (KAL1, KAL2, KAL-EXT, POR1, POR2 and POR-EXT), and are located on relatively flat surface (especially influenced by the plots situated on the Niato Plateau). The majority of the study plots are north exposed, except of KAL1, KAL2 and AMB-EXT which are west-oriented. Finally, as shown in the subchapter 3.2., study plots free of browsing tend to have a higher number in plant taxa.

The second PCA biplot (Fig. 13) indicates how geophytes and therophytes tend to have higher cover values in plots located higher in altitude, whereas chamaephytes are more present at lower elevations (AMB-EXT, POR2, POR-EXT and POR1 with 12%, 31%, 40% and 9% respectively, although the other plots have a very small chamaephyte-cover). Moreover, browsed plots contain a higher cover of chamaephytes and phanerophytes, which has also been showed in the subchapter 3.2. with the bar-charts (Fig. 8).

Finally, PCA biplot 3 (Fig. 14) reveals the relatively small vegetation cover of XER3-1, KAL-EXT, NIA1, NIA-EXT as well as their high soil cover values, compared to all other study plots, (with 20%, 20%, 20% and 15% respectively). This is explained by the fact that both

vectors lie in an opposed direction. All vectors are quite dispersed, but in general plots found at higher elevations incline towards a considerable soil cover.

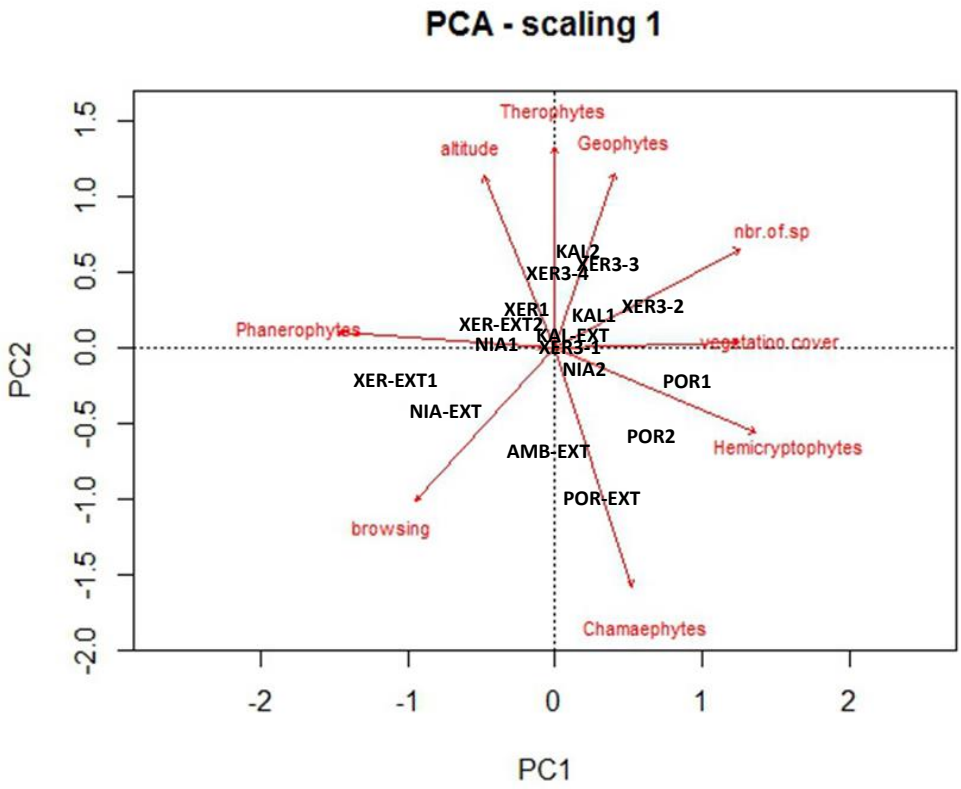


Figure 13: *PCA biplot 2 (scaling 1) of study plots and biotic and abiotic data (axes 1 and 2), Eigenvalues of axis 1 = 2.83 and of axis 2 = 2.39.*

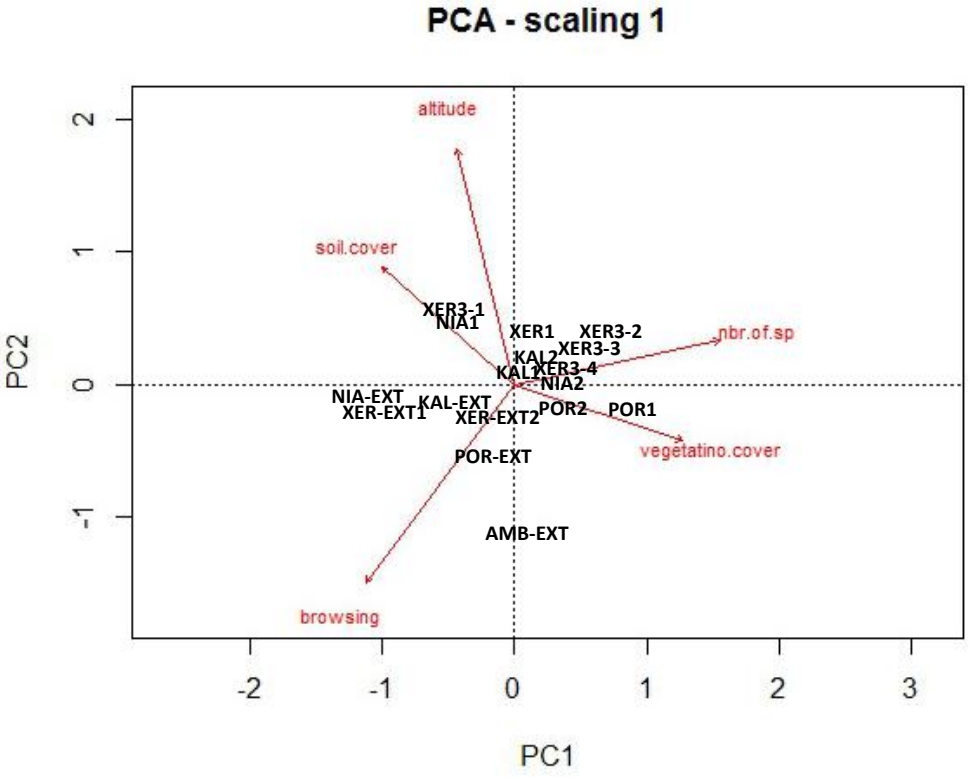


Figure 14: *PCA biplot 3 (scaling 1) of study plots and biotic and abiotic data (axes 1 and 2), Eigenvalues of axis 1 = 2.43 and of axis 2 = 1.47.*

4. Discussion

4.1. Plant species occurring with Z. abelicea

This study investigated short term vegetation changes and the response of *Z. abelicea* to fencing in the Lefka Ori. Browsing removal produced notable changes in species composition growing in association with *Z. abelicea*. This composition can also be analysed indirectly by considering plant families or life forms.

Concerning plant taxa, some species appear more frequently in fenced than in non-fenced plots. Surprisingly, all plant taxa with a frequency of ≥ 50% in external plots, also appear to more than 50% in fenced plots, which is not the case the other way around. In other words, species which occur frequently in external plots seem not to be strongly affected by browsing, and are as frequent or even more frequent in protected sites. However, plant species which are frequent in fenced plots, do not stay as frequent in presence of browsing impact. These results obviously demonstrate how overbrowsing negatively affects the vegetation, especially the species composition. The establishment of the fences in our study region was therefore functional in terms of vegetation regeneration. These results can be connected to those of subchapter 3.2., which show a significant higher species richness inside fenced plots. Indeed, according to Stewart and Pullin (2008), high browsing intensities in Britain, lead to a reduction in floristic species richness, which means that by limiting the browsing impact, species richness will eventually increase. Moreover, in the Mediterranean region, Noy-Meir et al. (1989) found three different species responses after fencing activity in Israel. The first category of plant species, was significantly more abundant in fenced sites, with a consistency of the pattern over all study sites. Anyhow, they did not mention the presence of a relationship between this category and unfenced plots. The second group was consistently more frequent in browsed areas, and the remaining category was inconsistent, belonging to neither of the two others. Similar categories have been observed by Lavorel et al. (1999) in Portugal, but focusing more specifically on species morphology. In fact, large species with leafy stems and large rosettes are strongly affected by browsing (e.g. *Leontodon tuberosus, Microthlaspi perfoliatum, Cynosurus echinatus, Trifolium physodes*). It may be concluded, together with the observations of Louhaichi et al. (2009) on the Syrian semiarid rangeland, that areas subjected to overbrowsing obviously reflect a loss in species diversity. Chaideftou et al. (2009) explain this by the fact that the soil seed bank decreases due to browsing, finally leading to a reduced vegetation diversity.

Focusing on the proportions of species regarding their Raunkiær's life form in fenced and non-fenced plots, links can be made by observing Figure 8 in subsection 3.2. (similar

results have been found in both subsections), which focuses on the mean **cover** of all plant species. Further details and explanations can be found below, in subchapter 4.2.
In fact, the differences are not significant for all plant life forms between fenced and external study plots (Fig. 6). This might partly be explained by the random sampling activity. Moreover, we would need to consider a longer time period in order to see obvious differences in life forms between browsed and protected areas.

Finally, the proportions of species in regard to plant families varies greatly, starting with Poaceae as the most common one in both, fenced and non-fenced plots, followed by Asteraceae. This pattern is typical of the Greek flora with a domination of Asteraceae and Poaceae (Strid and Tan, 1997). In fact, Papanastasis et al. (2002) and Louhaichi et al. (2009) observed a similar trend. Curiously, the proportion of Poaceae is nearly the same between fenced and non-fenced plots, which has also been revealed by Lavorel et al. (1999) and Papanastasis et al. (2002) in their study. Indeed, the small plant and seed sizes of Poaceaes favour their surviving, so that they are not disadvantaged by the livestock browsing (Noy-Meir et al. 1989; Lavorel et al. 1999). Brassicaceae is the most conspicuous plant family, showing a difference of 4.2% between fenced and non-fenced plots, as well as the Hyacinthaceae-family, with 1.4% of difference. Indeed, they both dominate in unbrowsed sites. Having high nutritive values, most Brassicaceae are quite palatable for sheep and goats (Gintzburger et al. 2003). Moreover, Orchidaceae are negatively affected by browsing, as they show a much higher frequency in fenced plots, with 1.6% of difference between fenced and unfenced sites. In fact, in browsed plots they were found only underneath thorny shrubs (e.g. *Berberis cretica*), protected from livestock. Furthermore, some plant families comprise species with poisonous components (e.g. Iridaceae, Euphorbiaceae, Araceae and Caryophyllaceae), and are therefore not so much affected by browsing (Gintzburger et al. 2003). In fact, those families show relatively small differences in frequency, between fenced and non-fenced plots (< 0.5%). Finally, other factors, such as woolly and hairy leaves and stems (some species of the Lamiaceae-family, e.g. *Phlomis cretica*) negatively affect the intake by sheep and goats (Gintzburger et al. 2003). Actually, Lamiaceae appear to a higher frequency, with 1.7% more in fenced plots.

Statistical tests revealed no significant differences for all plant families, between fenced and non-fenced plots. Strangely, only Euphorbiaceae showed a significant difference ($p = 0.03$).

4.2. Shift in vegetation patterns and higher species richness after fencing

Our results clearly suggest that overbrowsing was effective in changing species richness, which has also been proved by Papanastasis et al. (2002) in the Psiloritis

mountains (Crete). The first sign of change in vegetation after the removal of the browsing impact was the significantly higher number of species, which confirms our first hypothesis. Differences were already significant in May 2015, i.e. 6 months after the fencing took place, and during the first spring after fencing. The significantly higher number of species measured within the fenced plots is proof of how much sheep and goats negatively impact the floristic patterns of local vegetation.

Comparable results were observed by Bergmeier (1998a) with similar fencing experiments carried out on the southern slopes of the Lefka Ori (Sfakiá). Species number increased slightly during the study period (3 years), even though plot sizes comprised only 2 m^2. Moreover, Pettit et al. (1995) also observed in their study on western Australia (the climate is of Mediterranean type), a change in vegetation after browsing removal (10 x 10 m study plots). Indeed they detected a reduction in species richness and species diversity with increasing browsing disturbance. Finally, Louhaichi et al. (2009), who focused on the effects of grazing removal in the semiarid Mediterranean rangeland of Syria, observed a 200% greater species composition in protected plots relatively to browsed plots.

The biomass, which is an essential factor of floristic composition, is strongly influenced by the browsing intensity (Armstrong and Milne, 1995; Stewart and Pullin, 2008). In fact, due to the strong browsing impact, competitive species will eventually prevail over stress tolerant species, finally leading to a diminution of the total species richness (Grime et al. 1992; Stewart and Pullin, 2008). Furthermore, Hostert et al. (2003) observed in central Crete an increment in browsing pressure, which was reflected by intensified degradation of the local vegetation.

Finally, regarding endemic species between fenced and non-fenced plots, a higher number could be observed in enclosed study plots, proportionally to the greater total species number. In other words, the proportion of endemic taxa is not significantly different between fenced and unfenced plots. Therefore, browsing and its removal do not seem to influence the proportion of endemic species. Interestingly, as observed in their study on the Canary Islands (Mediterranean climate), Fernández-Lugo et al. (2013a) also demonstrate that frequencies of endemic species were not affected by the browsing regime. Indeed, this might be due to the fact that most endemic species have adaptive traits against browsing (e.g. spiny bracts (*Centaurea idaea*), spiny stems (*Verbascum spinosum*), hairs (*Sideritis syriaca* subsp. *syriaca*), and toxicity (*Colchicum cretense*)) (Papiomitoglou, 2006).

As mentioned by Camarda et al. (2015, p. 265), «the biological form of plant species expresses the conditions of adaptation to the environmental conditions as an effective response during the adverse season to its survival and development of the aerial parts of each species, which is also an efficient defence to browsing». In fact, using plant life form cover will provide us further information concerning the change of vegetation after browsing

removal, by relating also to Figure 6 (proportions of species regarding their plant life form) of subchapter 3.1.

In our study, the phanerophyte-cover is mainly linked by the sampling of each study plot and not to the change and adaptation after fencing activity. Furthermore, chamaephytes often have thorny branches (e.g. *Berberis cretica, Verbascum spinosum* and *Ononis spinosa*) or spiny cladodes (*Asparagus aphyllus* subsp. *orientalis*) acting as a defensive barrier protecting the full life cycle (Camarda et al. 2015), as their buds are at browsing height. The insignificant difference in the overall chamaephyte-cover between fenced and non-fenced plots, might be explained by the fact that chamaephytes are long-living plants with defensive protections, and therefore need more time in order to reflect any growth change.

Nevertheless, other plant life form cover show a strong change in one year between fenced and non-fenced plots, especially therophytes and hemicryptophytes. However, these differences are not significant. In fact, as described by Papanastasis et al. (2002) and Pettit et al. (1995), therophytes are more adapted to overbrowsing because they can overcome disturbance much better than hemicryptophytes, due to their briefer life cycle and their abundant seed production. Hemicryptophytes though are relatively slow-growing and typically demand multiple years to reach reproductive maturity (Pettit et al. 1995). They are quite vulnerable to browsing, as most of them are green and palatable to sheep and goats (Noy-Meir et al. 1989). Indeed, as hypothesized, the hemicryptophyte-cover was found to be significantly lower in our browsed study plots. Belgacem et al. (2011) consider the lower hemicryptophyte-cover in browsed sites in Tunisia as a sign of long-term impact of overbrowsing. Additionally, Noy-Meir et al. (1989) suggest that with increasing browsing intensity, the principal selection factor becomes the ability to colonize open space. Therophytes are effective colonizers of the open areas created by the intensive selective browsing (Panitsa et al. 1993), because they are poor competitors for space and light (Noy-Meir et al. 1989, Fernández-Lugo et al. 2013a).

Other groups such as some geophytes, can bypass the strong browsing pressure by having above-ground growth during winter and spring when grazing pressure is usually poor (Pettit et al. 1995, Camarda et al. 2015). However, sheep and goat flocks in Crete are bought to the mountains very early in the season. At this point, some geophytes might not have been able to complete their life cycle yet. Over the summer when overbrowsing is at its culmination, the above ground meristem of the remaining geophytes will die back to an underground storage organ (Pettit et al. 1995), which is called «the dormant period» (Dafni et al. 1981). However, some plant families (e.g. Orchids) do not adopt this strategy and are clearly more frequent in fenced areas, or under the protection of spiny shrubs (e.g. *Berberis cretica*), which are not accessible to livestock. Nevertheless, no significant change in the geophyte-cover has been recorded in our study between fenced and non-fenced plots, as there was not enough time

for geophytes to reproduce themselves in fenced plots. Pettit et al. (1995) mentioned in his research that geophytes were not significantly influenced by browsing. On the other hand, some authors such as Naveh and Whittaker (1979), as well as Noy-Meir and Oron (2001) have found that geophytes in Mediterranean grassland of Israel, show a higher diversity under modest browsing than in protected plots. However, geophytism is a life form that shows a natural adaptation and defence against browsing, as geophytes can outlive for some time in the underground, even without seed production (Camarda et al. 2015).
Focusing specifically on each study region, while taking into account the above explanations, the most different region concerning vegetation composition are the study plots in Fokies (POR). In general, plant cover is considered to be in deterioration when the hemicryptophyte-cover decreases, which is usually the case in overbrowsed areas (Le Houérou, 1977; Belgacem et al. 2011). In fact, vegetation in Fokies consists of a very high chamaephyte and hemicryptophyte-cover and a small therophyte-cover, which are therefore signs of reduced browsing pressure (Pettit et al. 1995). Indeed, during fieldwork this extensive browsing was remarkable as fenced and non-fenced plots did not visually differ much, except for the heads of *Phlomis cretica* being more or not bitten off (Fig. A6.2 in Annex 6), as well as *Z. abelicea* shrubs. In contrast to Fokies, plots in Machi (KAL) show a much smaller hemicryptophyte-cover in fenced plots, as well as a higher therophyte-cover, which obviously signalizes particular strong overbrowsing in this region. In fact, sheep and goats where much more abundant in Machi and in Xeropotamos (XER) than in the Fokies area. Finally, study plots in Niato (NIA) are quasi devoid of geophytes and the hemicryptophyte-cover is much lower in non-fenced plots, reflecting a heavy browsing impact in this area, as well.

Lastly, concerning the mean cover of each vegetation layer, an insignificant difference in all layers has been observed between fenced and non-fenced plots. In other words, the vegetation structure in protected plots shows similarities to overgrazed ones. This resemblance is probably due to the fact that not enough time has been considered to show any significant deviation in vegetation cover, which may appear in a few years. In fact, Bergmeier and Matthäs (1996) studied the early effects of browsing abandonment on phrygana vegetation in Crete, over a period of 17 months. They suggest that monitoring should be pursued over longer time period, in order to observe evident changes in vegetation structure, as well as future development of non-browsed study areas.

4.3. Growth of juvenile Z. abelicea *shoots in fenced plots*

As predicted in our second hypothesis, juvenile *Z. abelicea* shoots of spring 2015 showed an intense and rapid elongation in the fenced plots, already during the first field campaign in May 2015, and they continued to strongly increase throughout the summer

period. This significant growth demonstrates well how intense browsing impacts *Z. abelicea* in the Lefka Ori. Even less than one year after fencing, *Z. abelicea* shrubs explode with shoots in all directions (Figs. 11 c and d). It would be worthwhile to pursue observations and measurements during the following years on juvenile *Zelkova* shoots, in order to see if this growth rate continues or if it will slow down, and if they would eventually create an apical dominance to grow into tree individuals. Moreover, according to Floret (1981) and Noy-Meir et al. (1989), annual climatic conditions, like precipitation, might change the vegetation response to browsing. In fact, 2015 showed a much more humid spring and early summer than usual (www.meteoblue.ch), which promoted the vegetation growth and plants did not dry out very quickly in summer.

Similar studies have been done by Garfì and Pasta (2015) on the endemic Sicilian *Zelkova sicula.* Shrubby individuals (with a height of < 2 m) increased up to 10.4% of their height, one year after fencing. In the following two years though, the growth was attenuated and did not exceed 5.1%.

4.4. Impact of the abiotic parameters on the study plots

The negative correlation between slope and elevation on PCA biplot 1 (Fig. 12) is strongly influenced by study plots situated on the Niato Plateau and some in Xeropotamos. Both study regions are located at higher altitudes, between 1224 and 1261 m a.s.l. and have low declination. Having more sampling plots would certainly reduce the correlation between these two vectors. Another interesting aspect to point out, is the increasing number of endemic species with altitude. However, as the altitudinal range of the investigated study plot consists of only 300 m, results need to be interpreted carefully. In fact, this pattern might be driven by other factors or even by chance, as for example POR1 is one of the lowest considered plot, but has a rather high number of endemic taxa. However, Panitsa et al. (2006), Kazakis et al. (2007), as well as Iliadou et al. (2014) observed a strong correlation between endemic species richness and elevation in the Aegean Islands. This has been explained by the long geological isolation of the island, during which speciation took place (Kozlowski et al. 2014; Iliadou et al. 2014). Similar results have been shown previously by Bergmeier (2002) in study plots of the different mountain ranges of Crete, especially in dolines. In addition, he points out, that species diversity decreases with altitude, which is also apparent in our study.

Analogous to the observations made by Bergmeier (2002), our study demonstrates how therophytes and geophytes tend to be more numerous at higher altitudes. However, as mentioned above, the altitude-vector needs to be considered cautiously, as it takes into account only a small altitudinal range. Moreover, Bergmeier (2002) suggests that geophytes

are associated with late snow-melt and shorter vegetation period, which indicates higher elevations. In fact, geophytes have their buds filled with stored food, lying beneath the substratum. This enables them to perform a fast vegetative development as soon as favourable conditions arise (Cain, 1950). Occurring in altitude where the favourable season is shorter, they can grow and adapt quite well with those harsher conditions.
On the other hand, hemicryptophytes as well as chamaephytes were found to be correlated to lower altitudes, where the vegetation cover tends to be more developed. The former especially occurs where overbrowsing has a modest influence, and where vegetation seems to be denser. Indeed, Pettit et al. (1995) remarked how hemicryptophytes were substantially reduced in grazed study plots, as they are rather slow-growing and need multiple years to be able to reproduce. This higher occurrence of hemicryptophytes in fenced plots is also clearly apparent on Figure 8.
Finally, phanerophytes tend to cover larger surfaces in external plots, as represented on Fig. 8. This is probably an artefact due to random plot sampling and the small amount of considered unfenced plots.

As expected on PCA biplot 3 (Fig. 14), the soil cover is opposed to the vegetation cover. In fact, lots of bare soil emerges in KAL-EXT and in NIA-EXT, especially caused by the sheep flocks as they wander around and browse (creating “sheep path”, Fig. A6.3 in Annex 6). In fact, Louhaichi et al. (2009) and Belgacem et al. (2011) concluded that protected areas show a higher vegetation cover in comparison to browsed plots, while the latter reflects an expansion of bare soil. However, XER-EXT2 is located in a sparse forest with a quite high vegetation cover. In fact this plot is principally dominated by *Berberis cretica,* which is unpalatable for livestock and creates protection for smaller plant species. Furthermore, XER-EXT1-plot is situated on the rock deposits of the summer-dry Xeropotamos river with a quite small vegetation cover. Indeed, Bergmeier (2002) noticed, that scree vegetation is poorly developed. Moreover, some fenced plots (XER3-1 and NIA1) still show these sheep path with poor vegetation cover, which seem to require more time to develop. Interestingly PCA biplot 3 reveals also here how study plots in Fokies are quite different, especially by observing POR1 and POR2 with their important vegetation cover.
Finally, it could be more relevant to divide the browsing intensity into diverse classes (low, medium and strong browsing, for instance), which could reveal more detailed results about the dispersion of the study plots around those vectors.

5. Conclusions

Our study has demonstrated how browsing removal provokes short term vegetation changes and influences the response of *Z. abelicea* in the mountains of Crete (Lefka Ori). (1) First of all, we observed the plant taxa co-occurring with *Z. abelicea* in the Lefka Ori. In fact, *G. murale, P. bulbosa, A. aphyllus, G. molle, C. neglecta, L. tuberosus* and *G. aparine* are the most frequent plant species, which appear in more than 80% of fenced study plots. Regarding the plant families, Poaceae and Asteraceae have obviously the highest species proportions in both, fenced and non-fenced plots, even though the differences are not significant. (2) Furthermore, this study reveals the significant higher species richness inside unbrowsed study plots. Vegetation responses to browsing removal were also visible by observing the cover of the Raunkiær's plant life forms. In fact, therophytes cover a smaller surface in fenced plots, compared to hemicryptophyte-cover which represent the main life form. (3) Moreover, a rapid and significant elongation of juvenile *Z. abelicea* shoots could be observed in protected plots, between May and October 2015, with an average growth rate of 0.135 cm/day. (4) Finally, physical parameters were tested on all study plots, revealing the positive effect of altitude on the overall species and endemic species richness, as well as on the therophyte and geophyte-cover. However, as the investigated altitudinal range consists of only 300 m, future analyses should consider a larger range, which might demonstrate a stronger positive effect or even highlight a different pattern.

Our results show obvious signs of livestock overbrowsing, which has a negative impact on the floristic patterns and disturbing the local vegetation.

Even if durable fencing of small plots is the most efficient tool to obtain immediate protection against overbrowsing, more complex long-term *in situ* conservation strategy needs to be implemented (Kozlowski and Gratzfeld, 2013). In fact, our first results are very promising and interesting in terms of conservation of *Z. abelicea.* Monitoring should therefore be pursued on the same study plots during the following years, in order to see how the growth of *Z. abelicea* will evolve in future. Additionally, further observations would help us understand in which way vegetation patterns, surrounding *Z. abelicea*, will change and adapt to browsing removal.

6. Bibliography

Armstrong, H. M. and Milne, J. A. (1995). «The effects of grazing on vegetation species composition». In: Thompson, D. B. A., Hester, A. J. and Usher, M. B. (eds). *Heaths and Moorlands: Cultural Landscapes.* SNH/HMSO, Edinburgh. 162-173.

Bauer, D. F. (1972). «Constructing Confidence Sets using Rank Statistics». *Journal of the American Statistical Association*. 67: 687-690.

Bauer, E. and Bergmeier, E. (2011). «The mountain woodlands of western Crete – plant communities, forest goods, grazing impact and conservation». *Phytocoenologia.* 41: 73-115.

Belgacem, A. O., Tarhouni, M. and Louhaichi, M. (2011). «Effect of Protection on Plant Community Dynamics in the Mediterranean arid zone of southern Tunisia: A case study from Bou Hedma National Park». *Land Degradation Development.* 24: 57-62.

Bergmeier, E. (1998a). «Flowering intensity of phrygana plants after fencing». *Israel Journal of Plant Sciences*. 46: 41-46.

Bergmeier, E. (1998b). «Phenological Patterns of Oro-Mediterranean Vegetation in the White Mountains (Western Crete)». In: Tsekos, I. and Moustakas, M. (eds). *Progress in Botanical Research*. Springer, Dordrecht. 29-32.

Bergmeier, E. (2002). «The vegetation of the high mountains of Crete – a revision and multivariate analysis». *Phytocoenologia*. 32: 205-249.

Bergmeier, E. and Matthäs, U. (1996). «Quantitative studies of phenology and early effect of non-grazing in Cretan phrygana vegetation». *Journal of Vegetation Science.* 7: 229-236.

Borcard D., Gillet, F. and Legendre, P. (2011). *Numerical Ecology with R*. New York, Springer.

Bosque, M., Adamogianni, M., Bariotakis, M., Fazan, L., Stoffel, M., Garfì, G., Gratzfeld, J., Kozlowski, G. and Pirintsos, S. (2014). «Fine-scale spatial patterns of the Tertiary relict *Zelkova abelicea* (Ulmaceae) indicate possible processes contributing to its persistence to climate changes». *Regional Environmental Change*. 14: 835-849.

Braun-Blanquet, J. (1964). *Pflanzensoziologie: Grundzüge der Vegetationskunde (3rd Edition)*. Wien, Springer Verlag.

Camarda, I., Brundu, G., Carta, L., Vacca, G. and Brunu, A. (2015). «Plants and grazing: an evaluation of the effects on Sardinian endemic plants conservation». *Flora Mediterranea.* 25: 263-275.

Cain, S. A. (1950). «Life-forms and Phytoclimate». *The Botanical Review*. 16: 1-32.

Casasús, I., Bernués, A., Sanz, A., Villalba, D., Riedel, J. L. and Revilla, R. (2007). «Vegetation dynamics in Mediterranean forest pastures as affected by beef cattle grazing». *Agriculture, Ecosystems and Environment.* 121: 365-370.

Chaideftou, E., Thanos, C. A., Bergmeier, E., Kallimanis, A. and Dimopoulos, P. (2009). «Seed bank composition and above-ground vegetation in response to grazing in sub-Mediterranean oak forests (NW Greece)». *Plant Ecology.* 201: 255-265.

Christe, C., Kozlowski, G., Frey, D., Bétrisey, S., Maharramova, E., Garfì, G., Pirintsos, S. and Naciri, Y. (2014). «Footprints of past intensive diversification and structuring in the genus *Zelkova* (Ulmaceae) in south-western Eurasia». *Journal of Biogeography*. 41: 1081-1093.

Dafni, A., Cohen, D. and Noy-Meir, I. (1981). «Life-cycle variation in Geophytes». *Annals of the Missouri Botanical Garden.* 68: 652-660.

Egli, B. (1995). «*Zelkova abelicea* (Lam.) Boiss.». In: Phitos, D., Strid, A., Snogerup, S., Greuter, W. (eds). *The Red Data Book of rare and threatened plants of Greece*. WWF Greece, Athens. 526-527.

Egli, B. (1997). «A project for the preservation of *Zelkova abelicea* (Lam.) Boiss., a threatened endemic tree species from the mountains of Crete». *Bocconea*. 5: 506-510.

Farris, E., Filigheddu, R., Deiana, P., Farris, G. A. and Garau, G. (2010). «Short-term effects on sheep pastureland due to grazing abandonment in a Western Mediterranean island ecosystem: A multidisciplinary approach». *Journal for Nature Conservation.* 18: 258-267.

Fazan, L., Stoffel, M., Frey, D. J., Pirintsos, S. and Kozlowski, G. (2012). «Small does not mean young: Age estimation of severely browsed trees in anthropogenic Mediterranean landscapes». *Biological Conservation*. 153: 97-100.

Fazan, L. (2014). *Investigating the response to climate in two Mediterranean tree species growing in the mountains of Crete (Greece):* Zelkova abelicea *and* Cupressus sempervirens. Maitrise Universitaire en Sciences de l'Environnement, Genève, Affiliation Biodiversité, Université de Genève.

Fernández Alés, R., Laffarga, J. M. and Ortega, F. (1993). «Strategies in Mediterranean grassland annuals in relation to stress and disturbance». *Journal of Vegetation Science.* 4: 313-322.

Fernández-Lugo, S., Arévalo, J. R., de Nascimento, L., Mata, J. and Bermejo, L. A. (2013a). «Long-term vegetation responses to different goat grazing regimes in semi-natural ecosystems: a case study in Tenerife (Canary Islands)». *Applied Vegetation Science.* 16: 74-83.

Fernández-Lugo, S., Bermejo, L. A., de Nascimento, L., Méndez, J., Naranjo-Cigala, A. and Arévalo, J. R. (2013b). «Productivity: key factor affecting grazing exclusion effects on vegetation and soil». *Plant Ecology.* 214: 641-656.

Fielding, J. and Turland, N. (2005). *Flowers of Crete*. Kew, Royal Botanic Gardens.

Floret, C. (1981). «The effects of protection on steppic vegetation in the Mediterranean arid zone of Southern Tunisia». *Vegetatio.* 46: 117-129.

Gabay, O., Perevolotsky, A., Bar Massada, A., Carmel, Y. and Shackak, M. (2011). «Differential effects of goat browsing on herbaceous plant community in a two-phase mosaic». *Plant Ecology.* 212: 1643-1653.

Garfì, G. and Pasta, S. (2013). *I° Report Monitoraggio dell'impatto delle azioni concrete sulla conservazione della species target*. Palermo, Azioni urgenti per salvare *Zelkova sicula* dell'estinzione (LIFE Zelkov@zione).

Garfì, G. and Pasta, S. (2015). *II° Report Monitoraggio dell'impatto delle azioni concrete sulla conservazione della species target*. Palermo, Azioni urgenti per salvare *Zelkova sicula* dell'estinzione (LIFE Zelkov@zione).

Gintzburger, G., Toderich, K. N., Mardonov, B. K. and Mahmudov, M. M. (2003). *Rangelands of the arid and semi-arid zones in Uzbekistan.* Montpellier, CIRAD – ICARDA.

Gorenflot, R. and de Foucault, B. (2005). *Biologie végétale: les cormophytes (7th edition)*. Paris, Dunod.

Grime, J. P., Hodgson, J. G. and Hunt, R. (1992). *Comparative plant ecology.* London, Chapman and Hall.

Helm, S. R. (2010). «A Calculation of Expected Plant Frequency». *Castanea.* 75: 226-231.

Hill, J., Hostert, P., Tsiourlis, G., Kasapidis, P., Udelhoven, T. And Diemer, C. (1998). «Monitoring 20 years of increasing grazing impact on the Greek island of Crete with earth observation satellites». *Journal of Arid Environments.* 39: 165-178.

Hill, M. O., Roy, D. B., Mountford, J. O. and Bunce, R. G. H. (2000). «Extending Ellenberg's indicator values to a new area: an algorithmic approach». *Journal of Applied Ecology*. 37: 3-15.

Hollander, M., Wolfe, D. A. and Chicken, E. (2014). *Nonparametric Statistical Methods (3rd edition)*. New York, Wiley-Interscience.

Hostert, P., Röder, A., Hill, J., Udelhoven, T. and Tsiourlis, G. (2003). «Retrospective studies of grazing-induced land degradation: A case study in central Crete, Greece». *International Journal of Remote Sensing*. 24: 4019-4034.

Iliadou, E., Kallimanis, A. S., Dimopoulos, P. and Panitsa, M. (2014). «Comparing the two Greek archipelagos plant species diversity and endemism patterns highlight the importance of isolation and precipitation as biodiversity drivers». *Journal of Biological Research*. 21: 16.

Jahn, R. and Schönfelder, P. (1995). *Exkursionsflora für Kreta*. Stuttgart, Verlag Eugen Ulmer.

Kagiampaki, A., Triantis, K., Vardinoyannis, K. and Mylonas, M. (2011). «Factors affecting plant species richness and endemism in South Aegean (Greece)». *Journal of Biological Research.* 16: 282-295.

Kazakis, G., Ghosn, D., Vogiatzakis, I. N. and Papanastasis, V. P. (2007). «Vascular plant diversity and climate change in the alpine zone of the Lefka Ori, Crete». *Biodiversity and Conservation*. 16: 1603-1615.

Kozlowski, G., Frey, D., Fazan, L., Egli, B. and Pirintsos, S. (2012). *Zelkova abelicea*. The IUCN Red List of Threatened Species. Version 2014.2. http://www.iucnredlist.org/details/30319/0 [13.7.2016]

Kozlowski, G., Frey, D., Fazan, L., Egli, B., Bétrisey, S., Gratzfeld, J., Garfì, G. and Pirintsos, S. (2014). «The Tertiary relict tree *Zelkova abelicea* (Ulmaceae): distribution, population structure and conservation status on Crete». *Flaura and Fauna International, Or*yx. 48: 80-87.

Kozlowski, G. and Gratzfeld, J. (2013). «*Zelkova* – an ancient tree». Global status and conservation action. Natural History Museum Fribourg, Switzerland.

Lavorel, S., McIntyre, S. and Grigulis, K. (1999). «Plant response to disturbance in a Mediterranean grassland: How many functional groups?». *Journal of Vegetation Science.* 10: 661-672.

Le Houérou, H. N. (1977). «Biological recovery versus desertification». *Economic Geography.* 53 : 413-420.

Le Lannou, M. (1941). *Pâtres et paysans de la Sardaigne*. Tours, Arrault and Cie.

Louhaichi, Ml, Salkini, A. K. and Petersen, S. L. (2009). «Effect of Small Ruminant Grazing on the Plant Community Characteristics of Semiarid Mediterranean Ecosystems». *International Journal of Agriculture and Biology.* 11: 681-689.

Meddour, R. (2011). *La méthode phytosociologique sigmatiste ou Braun-Blanqueto-Tüxenienne*. Tizi Ouzou, Département des Sciences Agronomiques, Université Mouloud Mammeri de Tizi Ouzou.

Meteoblue AG (2006). www.meteoblue.ch [22.9.2016]

Mueller-Dombois, D. and Ellenberg, H. (1974). *Aims and Methods of Vegetation Ecology*. Michigan, John Wiley and Sons.

Naveh, Z. and Whittaker, R. H. (1979). «Structural and floristic diversity of shrublands and woodlands in Northern Israel and other Mediterranean areas». *Vegetatio.* 41: 171-190.

Noy-Meir, I., Gutman, M. and Kaplan, Y. (1989). «Responses of Mediterranean grassland plants to grazing and protection». *Journal of Ecology.* 77: 290-310.

Noy-Meir, I. and Oron, T. (2001). «Effects of grazing on geophytes in Mediterranean vegetation». *Journal of Vegetation Science.* 12: 749-760.

Osem, Y., Perevolotsky, A. and Kigel, J. (2004). «Site productivity and plant size explain the response of annual species to grazing exclusion in a Mediterranean semi-arid rangeland». *Journal of Ecology.* 92: 297-309.

Panitsa, M., Dimopoulos, P., Iatrou, G. and Tzanoudakis, D. (1993). «Contribution to the study of the Greek flora: Flora and vegetation of the Enousses (Oinousses) islands (E. Aegean area)». *Flora.* 189: 69-78.

Panitsa, M., Tzanoudakis, D., Triantis, K. A. and Sfenthourakis, S. (2006). «Patterns of species richness on very small islands: the plants of the Aegean archipelago». *Journal of Biogeography*. 33: 1223-1234.

Papanastasis, V. P., Kyriakakis, S. and Kazakis, G. (2002). «Plant diversity in relation to overgrazing and burning in mountain mediterranean ecosystems». *Journal of Mediterranean Ecology*. 3: 53-63.

Papiomitoglou, V. (2006). *Wild flowers of Crete.* Rethymno, Mediterraneo Editions.

Pettit, N. E., Froend, R.H. and Ladd, P.G. (1995). «Grazing in remnant woodland vegetation: changes in species composition and life form groups». *Journal of Vegetation Science.* 6: 121-130.

PROJECT ZELKOVA (2016). www.zelkova.ch [10.8.2016]

Sfikas, G. (1992). *Wild flowers of Crete (Nature of Crete).* Athens, Efstathiadis Group S.A.

Smith, W. G. (1913). «Raunkiær's "Life-forms" and statistical methods». *Journal of Ecology*. 1: 16-26.

Stewart, G. B. and Pullin, A. S. (2008). «The relative importance of grazing stock type and grazing intensity for conservation of mesotrophic 'old meadow' pasture». *Journal for Nature Conservation*. 16: 175-185.

Strid, A. and Tan, K. (eds) (1997). *Flora Hellenica*. Koenigstein, Koeltz Scientific Books.

Villar, J. L., Turland, N. J., Juan, A., Gaskin, J. F., Alonso, M. A. and Crespo, M. B. (2015). «*Tamarix minoa* (Tamaricaceae), a new species from the island of Crete (Greece) based on morphological and plastid molecular sequence data». *Willdenowia*. 45: 161-172.

Vogiatzakis, I. N., Griffiths, G. H., Mannion, A. M. (2003). «Environmental factors and vegetation composition, Lefka Ori massif, Crete, S. Aegean». *Global Ecology and Biogeography.* 12: 131-146.

Whittaker, R. J. and Fernández-Palacios, J. M. (2007). *Island Biogeography: Ecology, Evolution, and Conservation.* Oxford, Oxford University Press.

Annex 1

Alphabetic list of all plant species found in each study plot (the description of the plots can be found in table 2) during fieldwork in May 2015. (1 = the plant species is occurring in the 16m^2-subplot, (1) = the plant species is not occurring in the 16m^2-subplot, and 0 = the plant species is not occurring at all in the specific plot).

	Plant taxa		XER1	XER2	XER3-1	XER3-2	XER3-3	XER3-4	XER3-tot	XER-EXT1	XER-EXT2	KAL1	KAL2	KAL-EXT	AMB2	AMB-EXT	NIA1	NIA2	NIA3	NIA4	NIA-EXT	POR1	POR2	POR-EXT
1	*Acer*	*sempervirens* L.	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	0	1	0
2	*Achnatherum*	*bromoides* (L.) P. Beauv,.	0	0	0	1	1	0	1	0	1	(1)	1	0	0	1	1	1	1	1	1	1	1	1
3	*Acinos*	*alpinus* (L.) Moench	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	1	1
4	*Aegilops*	*biuncialis* Vis.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(1)	0	1	0	1	0	0	0
5	*Aetheorhiza*	*bulbosa* subsp. *microcephala* Rech. F.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
6	*Aira*	*elegantissima* Schur	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
7	*Allium*	cf. *tardans* Greuter and Zahar.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
8	*Alyssum*	*minutum* Schltdl. ex DC.	1	1	1	1	0	0	1	0	0	1	0	1	0	0	0	1	1	0	1	0	0	0
9	*Anchusa*	*undulata* subsp. *hybrida* (Ten.) Bég.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
10	*Anemone*	*coronaria* L.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	*Anthemis*	*chia* L.	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
12	*Anthemis*	*rigida* subsp. *rigida* (SM.) Boiss. ex Heldr.	1	1	1	1	0	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0
13	*Anthoxanthum*	*odoratum* L.	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0
14	*Aphanes*	*arvensis* L.	0	0	0	0	0	1	1	0	0	0	1	0	1	1	(1)	1	0	1	0	1	1	1
15	*Arabis*	*verna* (L.) R. Br.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0	0
16	*Arenaria*	*leptoclados* (Rchb.) Guss.	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	*Aristolochia*	*sempervirens* L.	0	1	1	1	1	1	1	1	0	0	1	0	0	0	1	0	1	0	0	0	0	0
18	*Arum*	*cylindraceum* Gasp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
19	*Arum*	sp.	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	1	0	1	0	0	0	0
20	*Asparagus*	*aphyllus* subsp. *orientalis* (Baker) P. H. Davis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
21	*Asperula*	*idaea* Halácsy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
22	*Asperula*	*pubescens* (Willd.) Ehrend. and Schönb.-Tem.	1	1	1	1	1	0	1	0	0	1	1	0	1	0	1	1	1	1	1	1	(1)	1
23	*Asphodeline*	*liburnica* (Scop.) Rchb.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0
24	*Asphodelus*	*ramosus* L. subsp. *ramosus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
25	*Asplenium*	*ceterach* L.	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0
26	*Ballota*	*pseudodictamnus* (L.) Benth. Subsp. *pseudodictamnus*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

27	*Bellis*	*longifolia* Boiss. and Heldr.	0	0	1	1	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1
28	*Bellis*	*perennis* L.	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
29	*Berberis*	*cretica* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
30	*Biscutella*	*didyma* L.	1	0	0	0	1	1	1	0	1	(1)	0	1	0	0	1	1	1	0	1	1	0	0
31	*Brachypodium*	*retusum* (Pers.) P. Beauv.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	(1)	0
32	*Briza*	*maxima* L.	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1
33	*Bromus*	*intermedius* Guss.	1	1	0	0	0	0	1	1	1	0	0	0	1	1	1	1	1	1	0	0	1	1
34	*Bromus*	*squarrosus* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	1	0	1
35	*Bromus*	*sterilis* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(1)	0	0	0	0	1	0	1
36	*Bufonia*	*stricta* (Sm.) Gurke subsp. *stricta*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
37	*Buglossoides*	*incrassata* (Guss.) I. M. Johnst. subsp. *incrassata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
38	*Capsella*	*bursa-pastoris* (L.) Medik.	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	*Cardamine*	*graeca* L.	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	(1)	0	0	0	0	0	0
40	*Carduus*	*pycnocephalus* L.	1	1	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
41	*Carex*	*distachya* Desf.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
42	*Carlina*	*corymbosa* L.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	(1)	0	1	1	0	0	1	1
43	*Catapodium*	*rigidum* (L.) C. E. Hubb.	1	0	0	1	1	0	1	1	0	1	1	0	0	1	1	1	1	1	1	1	1	1
44	*Centaurea*	*idaea* Boiss. and Heldr.	1	1	1	1	0	1	1	1	1	0	0	1	0	1	1	1	1	1	0	0	0	0
45	*Centaurea*	*raphanina* Sm. Subsp. *raphanina*	0	0	1	1	0	0	1	0	0	1	0	0	0	0	1	1	1	1	1	0	1	1
46	*Centranthus*	*calcitrapa* (L.) Dufr.	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0
47	*Cerastium*	*brachypetalum* Pers.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
48	*Cerastium*	*comatum* Desv.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
49	*Cerastium*	*glomeratum* Thuill.	1	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
50	*Cerastium*	*scaposum* Boiss. and Heldr.	0	1	1	0	1	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0
51	cf. *Anacamptis*	*pyramidalis* (L.) Rich.	1	1	0	1	1	1	1	1	1	1	0	1	0	0	0	0	0	1	0	0	0	0
52	cf. *Muscari*	*comosum* (L.) Mill.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
53	cf. *Ornithogalum*	*creticum* Zahar.	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	*Chaerophyllum*	*creticum* Boiss. and Heldr.	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
55	*Cichorium*	*spinosum* L.	0	0	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
56	*Clypeola*	*jonthlapsi* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0
57	*Colchicum*	cf. *cretense* Greuter	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	*Colchicum*	*pusillum* Sieber	1	1	1	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0

59	*Corydalis*	*uniflora* (Sieber) Nyman	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
60	*Crataegus*	*monogyna* Jacq.	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	*Crepis*	*neglecta* L. subsp. *cretica*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
62	*Crocus*	*sieberi* Gay subsp. *sieberi*	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	0	0
63	*Crucianella*	*angustifolia* L.	1	1	1	1	1	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
64	*Cuscuta*	sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1
65	*Cyclamen*	*creticum* Hildebr.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
66	*Cynosurus*	*echinatus* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1
67	*Cynosurus*	*effusus* Link	1	1	1	1	1	1	1	0	1	(1)	0	0	0	0	1	1	1	0	1	0	1	0
68	*Cystopteris*	*fragilis* (L.) Bernh.	1	1	1	1	1	0	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0
69	*Dactylis*	*glomerata* subsp. *hispanica* (Roth) Nyman	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	*Daphne*	*sericea* Vahl	0	0	0	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1
71	*Daucus*	*involucratus* Sm.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
72	*Draba*	*verna* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1	1	1
73	*Erodium*	*cicutarium* L.	0	1	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
74	*Eryngium*	*campestre* L.	1	0	0	0	0	0	1	0	0	0	0	0	0	0	(1)	1	0	0	0	1	0	0
75	*Euphorbia*	*acanthothamnos* Heldr. and Sart. ex Boiss.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
76	*Euphorbia*	*characias* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	1	1
77	*Euphorbia*	*peplus* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(1)	1	1	1	0	0	0
78	*Festuca*	*jeanpertii* (St.-Yves) Markgr.	1	0	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
79	*Ficaria*	*verna* Huds.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
80	*Fritillaria*	*messanensis* subsp. *sphaciotica* (Grand.) Kamiri and Phitos	0	1	0	1	1	1	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0
81	*Galium*	*aparine* L.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
82	*Galium*	cf. *monachinii* Boiss. and Heldr.	1	1	1	1	1	1	1	0	1	(1)	1	0	1	1	1	1	1	1	1	0	0	0
83	*Galium*	*murale* (L.) All.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(1)	1
84	*Galium*	*samothracicum* Rech. f.	0	1	0	0	0	1	1	1	1	0	0	0	0	0	1	0	1	1	1	1	0	1
85	*Gastridium*	*phleoides* (Nees and Meyen) C. E. Hubb.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	(1)	1	0	1	0	1	1	1
86	*Gastridium*	*ventricosum* (Gouan) Schinz and Thell.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
87	*Geranium*	*columbinum* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
88	*Geranium*	*lucidum* L.	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
89	*Geranium*	*molle* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
90	*Geranium*	*purpureum* Vill.	1	0	0	0	0	0	1	0	0	1	1	0	1	1	0	0	1	1	1	0	0	0

91	*Herniaria*	*parnassica* subsp. *cretica* Chaudhri	0	0	0	0	1	0	1	0	0	(1)	0	0	0	0	1	1	1	1	0	0	0	0
92	*Hordeum*	*bulbosum* L.	0	1	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0
93	*Hordeum*	*murinum* subsop. *leporinum* (Link) Arcang.	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
94	*Hypericum*	*trichocaulon* Boiss.and Heldr.	0	0	0	0	0	0	1	0	0	0	1	0	0	0	(1)	1	1	1	1	1	1	1
95	*Hypochaeris*	*achyrophorus* L.	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
96	*Lactuca*	*saligna* L.	1	0	1	0	0	0	1	1	0	1	1	0	0	0	1	0	0	0	0	1	0	0
97	*Lagoecia*	*cuminoides* L.	0	0	0	1	1	0	1	0	0	0	1	0	1	1	1	1	1	1	1	1	(1)	1
98	*Lamium*	*amplexicaule* L.	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	0	0	0	0
99	*Lamium*	*purpureum* L.	0	1	0	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0
100	*Lamyropsis*	*cynaroides* (Lam.) Dittrich	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0
101	*Lathyrus*	*sphaericus* Retz.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	(1)	0
102	*Legousia*	*hybrida* (L.) Delarbre	1	1	1	1	1	0	1	1	1	1	1	1	0	0	1	1	1	0	1	0	0	0
103	*Leontodon*	*tuberosus* L.	1	1	0	1	1	1	1	0	1	1	1	0	1	1	(1)	1	1	1	0	1	1	1
104	Lepidium	*hirtum* subsp. *oxyotum* (DC.) Thell.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
105	*Lolium*	*perenne* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
106	*Lolium*	*rigidum* Gaud.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	(1)	1
107	*Lysimachia*	*serpyllifolia* Schreb.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	(1)	0
108	*Medicago*	*disciformis* DC.	0	0	0	0	0	0	0	0	0	(1)	0	0	0	0	0	0	0	0	0	0	0	0
109	*Melica*	*minuta* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(1)	1	1	0	0	0	0	0
110	*Melica*	*rectiflora* Boiss. and Heldr.	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
111	*Micromeria*	*juliana* (L.) Benth. ex Rchb.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
112	*Microthlaspi*	*perfoliatum* (L.) F. K. Mey.	0	1	0	1	0	1	1	0	0	1	1	1	1	1	0	1	1	1	0	1	0	0
113	*Minuartia*	*hybrida* (Vill.) Schischkin subsp. *hybrida*	1	1	1	1	0	0	1	1	1	1	0	0	0	0	(1)	0	0	0	0	0	0	0
114	*Muscari*	*neglectum* Guss. ex Tan.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0
115	*Myosotis*	*congesta* Shuttlew. ex A. Albert and Reyn.	1	1	0	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0
116	*Myosotis*	*ramosissima* Rochel	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
117	*Neotinea*	*tridentata* (Scop.) R. M. Bateman, Pridgeon and M. W. Chase	0	0	0	1	0	0	1	0	0	(1)	0	0	0	0	0	0	0	0	0	0	0	0
118	*Ononis*	*spinosa* L. subsp. *diacantha* (Rchb.) Greuter	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1
119	*Ophrys*	*lutea* Cav. subsp. *lutea*	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	(1)	0
120	*Ophrys*	*lutea* Cav. subsp. *galilaea* (Fleischm. and Bornm.) Soó	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
121	*Origanum*	*vulgare* subsp. *hirtum* (Link.) letsw.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
122	*Orlaya*	*daucoides* (L.) Greuter	1	0	0	0	0	1	1	0	1	0	1	0	0	0	0	0	0	0	0	1	(1)	0

123	*Ornithogalum*	*pumilum* Zahar.	0	0	0	0	0	0	1	0	0	(1)	x	0	0	0	1	1	1	1	1	1	1	0
124	*Paeonia*	clusii Stern subsp. clusii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
125	*Petrorhagia*	*candica* P. W. Ball and Heywood	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0
126	*Petrorhagia*	*dubia* (Raf.) G. López and Romo	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
127	*Phelipanche*	cf. *mutelii* (Reut.) Pomel	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	1	0	0	0	0	0
128	*Phelipanche*	*nana* (Reut.) Soják	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
129	*Phillyrea*	*latifolia* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
130	*Phlomis*	*cretica* C. Presl.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
131	*Phlomis*	*fruticosa* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
132	*Picnomon*	*acarna* (L.) Cass.	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	1	0
133	*Plantago*	*lanceolata* L.	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	0	1	0	1	1	0
134	*Poa*	*annua* L.	0	0	0	1	1	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
135	*Poa*	*bulbosa* L.	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1
136	*Poa*	*trivialis* subsp. *sylvicola* (Guss.) H. Lindb.	1	1	1	1	1	1	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0
137	*Prunella*	*cretensis* Grand.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1
138	*Prunus*	*prostrata* Labill.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
139	*Pteridium*	*aquilinum* (L.) Kuhn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
140	*Quercus*	*coccifera* L.	0	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1	0	1	0	0	0	0
141	*Ranunculus*	*paludosus* Poir.	0	0	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
142	*Ranunculus*	*sprunerianus* Boiss.	1	1	1	1	1	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
143	*Rhagadiolus*	*stellatus* (L.) Gaertn.	1	0	0	1	1	1	1	0	1	(1)	1	0	1	1	1	(1)	1	0	0	1	0	0
144	*Rhamnus*	*lycioides* L.	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	1	1	1	1	0	0
145	*Rostraria*	*cristata* (L.) Tzvelev	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(1)	0	0	0	0	0	0	0
146	*Rumex*	*pulcher* L.	1	1	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0
147	*Rumex*	*tuberosus* subsp. *creticus* Rech. f.	0	0	0	0	0	0	0	0	0	(1)	0	0	1	1	0	0	0	0	0	0	0	0
148	*Saxifraga*	*rotundifolia* subsp. *chrysospleniifolia* (Boiss.)	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
149	*Scaligeria*	*napiformis* Grande	0	0	0	0	1	1	1	0	0	1	0	0	1	1	1	0	1	0	0	1	1	1
150	*Scandix*	*australis* L.	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	0	1	1	0	0	1	1
151	*Scandix*	*brachycarpa* Boiss.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
152	*Scilla*	*nana* (Schult. and Schult. F.) Speta	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
153	*Sedum*	*amplexicaule* subsp. *tenuifolium* (sm.) Greuter	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
154	*Sedum*	*cepaea* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

155	*Sedum*	*litoreum* Guss. subsp. *litoreum*	1	1	1	1	1	1	1	0	1	0	0	0	1	1	1	(1)	1	1	1	0	0	0
156	*Sedum*	*rubens* L. subsp. *rubens*	1	0	0	0	0	0	1	1	0	1	1	1	1	0	(1)	0	0	0	1	1	0	0
157	*Sherardia*	*arvensis* L.	0	0	0	0	1	0	1	0	1	1	1	1	0	0	1	1	0	1	1	1	1	1
158	*Sideritis*	sp.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
159	*Sideritis*	*syriaca* L. subsp. *syriaca*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
160	*Silene*	*cretica* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	(1)	0
161	*Silene*	*vulgaris* subsp. *macrocarpa* Turrill	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
162	*Sisymbrium*	*officinale* (L.) Scop.	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
163	*Stachys*	*cretica* L. subsp. *cretica*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
164	*Stellaria*	*cupaniana* (Jord. and Fourr.) Bég.	0	0	0	1	0	0	1	1	1	1	0	1	0	0	0	0	1	0	0	0	0	0
165	*Stellaria*	*pallida* (Dumort.) Crép.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
166	*Stellaria*	sp.	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	0	0	0	0
167	*Taraxacum*	*aleppicum* Dahlst.	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	1	1	1	1	0	0	0
168	*Taraxacum*	sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
169	*Teucrium*	*massiliense* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
170	*Theligonum*	*cynocrambe* L.	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0
171	*Tolpis*	*virgata* Bertol.	1	0	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1
172	*Tordylium*	*apulum* L.	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
173	*Trifolium*	*arvense* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
174	*Trifolium*	*campestre* Schreb.	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	0	1	1	1
175	*Trifolium*	*glomeratum* L.	0	0	0	0	0	0	0	0	0	(1)	1	0	0	0	0	0	0	0	0	0	0	0
176	*Trifolium*	*physodes* M. Bieb.	0	1	0	0	0	0	1	0	0	1	1	1	1	1	0	1	1	1	0	1	1	0
177	*Trifolium*	*rechingeri* Rothm.	0	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
178	*Trifolium*	*stellatum* L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
179	*Trifolium*	sp.	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
180	*Trifolium*	*uniflorum* L.	0	0	1	0	1	0	1	1	0	0	0	0	0	0	1	1	1	1	1	0	0	0
181	*Umbilicus*	*horizontalis* (Guss.) DD.	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0
182	*Umbilicus*	*parviflorus* Boiss.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
183	*Valerianella*	*muricata* (Steven) Baxter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
184	*Verbascum*	*macrurum* Ten.	0	0	0	0	0	0	0	0	0	(1)	0	0	0	0	0	0	0	0	0	0	0	0
185	*Verbascum*	*spinosum* L.	1	1	0	1	0	0	1	1	0	0	0	1	0	0	1	0	1	0	0	0	1	0
186	*Veronica*	*arvensis* L.	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	(1)	1	0	0	0	0	0

187	*Veronica*	*cymbalaria* Bodard	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
188	*Veronica*	*hederifolia* L.	1	1	0	1	1	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
189	*Veronica*	*trichadena* Jord. and Fourr.	0	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
190	*Vicia*	*lathyroides* L.	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	1	0	0
191	*Vulpia*	*myuros* (L.) C. C. Gmel.	0	0	0	0	0	0	0	0	0	(1)	0	0	0	0	0	0	0	0	0	0	0	0
192	*Zelkova*	*abelicea* (Lam.) Boiss.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Annex 2

Detailed information of each study plot (bare soil cover, bare rock cover, mobile stone cover, litter thickness, vegetation cover, herbaceous cover and height, tree cover and height, *Zelkova* herbaceous cover and height, *Zelkova* shrub cover and height, *Zelkova* tree cover and height, *Zelkova* fruiting / flowering, fencing, browsing, trampling).

	XER1	XER2	XER3	XER3-1	XER3-2	XER3-3	XER3-4	XER-EXT1	XER-EXT2	KAL1	KAL2	KAL-EXT	AMB-EXT	AMB2	NIA1	NIA2	NIA3	NIA4	NIA-EXT	POR1	POR2	POR-EXT
% bare soil	1	1	3	20	5	5	1	0	2	1	7	20	1	0	20	1	2	0	15	0	0	3
% bare rock (i.e. in situ)	0	0	-	0	2	2	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
% mobile rocks	30	40	12	20	3	7	15	70	3	35	10	10	15	40	20	5	5	5	35	2	1	7
% litter cover	0	0	5	0	0	0	+	0	0	5	15	25	15	15	0	0	0	0	1	0	0	0
litter thickness [mm]	-	-	1	-	-	-	1	-	-	1	1	1	1	1	-	-	-	-	1	-	-	-
% vegetation cover	70	60	85	70	90	100	100	45	95	65	75	85	85	60	65	95	93	95	60	98	99	90
% herbaceous cover	30	50	85	40	90	90	85	5	95	60	75	85	70	60	50	95	80	40	30	95	99	85
avg. H [cm]	5	5	20	5	10	15	20	NA	30	10	5	2.5	20	23	20	8	8	5	5	30	30	30
% shrub cover	65	50	70	50	40	40	10	45	4	50	50	15	80	50	40	55	70	80	40	60	50	50
avg. H [cm]	100	90	85	80	80	100	60	NA	90	120	100	110	80	100	80	110	120	110	50	60	65	60
% tree cover	0	0	60	0	0	95	100	0	75	2	0	0	20	0	0	0	5	0	0	0	0	0
avg. H [cm]	-	-	4-5 m	-	-	628	671	-	580	240	-	-	500	-	-	-	350	-	-	-	-	-
% Zelkova herb. cover	10	10	7.5	0	0	2	0	0	0	5	7.5	0	0	0.5	0	0.5	0	0	+	0	0.2	0
avg. H [cm]	20	10	30	-	-	NA	-	-	-	20	10	-	-	30	-	19	-	-	13	-	35	-
% Zelkova shrub cover	60	50	40	50	40	0	0	45	0	50	45	15	50	50	20	50	60	40	25	30	4	1
avg. H [cm]	100	90	90	80	80	-	-	?	-	120	100	110	90	100	86	110	90	110	50	60	67	74
% Zelkova tree cover	0	0	50	0	0	25	100	0	75	2	0	0	0	0	0	0	5	0	0	0	0	0
avg. H [cm]	-	-	4-5 m	-	-	628	671	-	580	240	-	-	-	-	-	-	350	-	-	-	-	-
fenced or non-fenced	f	f	f	f	f	f	f	non-f.	non-f.	f	f	non-f.	non-f.	f	f	f	f	f	non-f.	f	f	non-f.
Zelkova fruiting / flowering	no	no	no	no	no	no	no	no	yes?	no	no	no	yes	no	no	no	no	no	yes	no	no	no
browsing evidence	no	no	no	no	no	no	no	yes	yes	no	no	yes, droppings	yes	no	no	no	no	no	yes	no	no	little, some goats but no flocks of sheep and goats -> top of phlomis are missing
trampling evidence	no	no	no	no	no	no	no	yes	yes	no	no	yes	yes	no	no	no	no	no	yes	no	no	not very evident

Annex 3

Abiotic factors of each study plot, which were used for the PCA analyses (altitude, slope, aspect, soil cover, browsing and fencing).

site	Plot name	altitude [m.a.s.l.]	slope [°]	aspect [°N]	soil cover [%]	browsing [0 / 1]	fencing [0 / 1]
1	**XER1**	1258	9	25	1	0	1
2	**XER3-1**	1254	10	35	20	0	1
3	**XER3-2**	1254	7	35	5	0	1
4	**XER3-3**	1254	10	35	5	0	1
5	**XER3-4**	1254	14	35	1	0	1
6	**XER-EXT1**	1256	9	30	0	1	0
7	**XER-EXT2**	1261	8	29	2	1	0
8	**KAL1**	1192	15	306	1	0	1
9	**KAL2**	1191	22	235	7	0	1
10	**KAL-EXT**	1193	10	274	20	1	0
11	**AMB-EXT**	935	18	315	1	1	0
12	**NIA1**	1229	0	0	20	0	1
13	**NIA2**	1224	0	0	1	0	1
14	**NIA-EXT**	1225	0	0	15	1	0
15	**POR2**	1152	23	50	0	0	1
16	**POR-EXT**	1152	23	50	3	1	0
17	**POR1**	1107	27	40	0	0	1

Annex 4

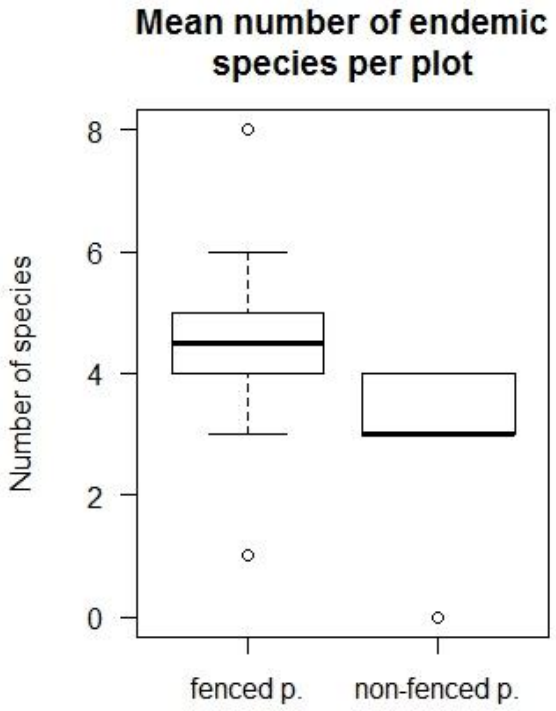
Biotic factors of each study plot, used for the PCA (vegetation cover, number of species in 16m^2-subplot, number of endemic species in 16m^2-subplot and cover of each life form).

site	Plot name	vegetation cover [%]	nr of sp. per 16m^2	nr of endemics per 16m^2	Life form cover [%]				
					Therophytes	Geophytes	Hemicryptophytes	Chamaephyte	Phanerophyte
1	**XER1**	70	52	4	27.8611	0.7498	21.323336	3.35438	46.71139
2	**XER3-1**	70	44	4	11.4559	3.45	51.77834	0.0133209	33.30225
3	**XER3-2**	90	64	6	11.9722	11.8664	50.840879	0.02352	24.120898
4	**XER3-3**	100	56	5	19.34263	20.29949	17.6235269	0.297329	42.437
5	**XER3-4**	100	48	4	33.63393	11.9822979	8.4585838	0	45.92518
6	**XER-EXT1**	45	36	3	11.79775	0.074906	1.947565	1.91011	84.26966
7	**XER-EXT2**	95	45	3	2.49232	20.94387	15.4077	0	61.08628
8	**KAL1**	65	52	3	29.2737	6.90988	43.4393	0.0339	20.004
9	**KAL2**	75	54	1	51.1397	13.304	17.3114	0.03907	18.3991
10	**KAL-EXT**	85	41	3	26.8076	17.1588	37.7324	0.01215	18.228
11	**AMB-EXT**	85	51	0	13.8	0.1	20.68	12.46	52.96
12	**NIA1**	65	49	5	11.1347	0.1933	26.1936	1.101875	61.376
13	**NIA2**	95	49	5	5.50275	0.9338	43.43838	1.35067	48.77438
14	**NIA-EXT**	60	36	4	7.17076	0.16088	12.4339	8.2969	71.937
15	**POR2**	99	47	8	4.52788	4.4395	55.5715	30.93318	4.527885
16	**POR-EXT**	90	42	4	3.85217	2.95267	43.2147	39.22565	10.75479
17	**POR1**	98	69	5	5.50140206	5.10081453	56.8567232	8.75951395	23.7815463

Annex 5

Boxplot representing the mean number of endemic taxa in fenced and non-fenced plots in May 2015. Here we can find a higher mean number of endemic species inside the fences (looking only at plots and subplots of $16m^2$). There is a significant difference ($p < 0.05$) with a median of 4.5 and 3 endemic species in fenced and non-fenced plots, correspondingly.

The mean proportion of endemic species to the total species number in the study plots corresponds to 8.8% in fenced and 7.2% in external plots, which is not significant in both cases. In other words, the proportion of endemic taxa did not significantly change after browsing removal.



Annex 6

Some pictures showing the vegetation in Poria (Figs. A6.1 and A6.2).

Figs. A6.3 to A6.6 clearly show how present sheep and goats are in the different study areas. Fig. A6.7 represents the establishment of AMB-EXT. The last picture (Fig. A6.8) visualizes the difference in vegetation cover between XER3 and its surrounding.



Figure A6.1: *Vegetation in Fokies: browsing is not very obvious.*



Figure A6.2: Phlomis cretica *in POR-EXT, with some browsed flower heads.*



Figure A6.3: *Sheep-path next to NIA2.*



Figure A6.4: *Sheep and goats leaving fur on* Z. abelicea *when browsing and walking around (KAL-EXT).*



Figure A6.5: *Sheep flocks next to XER3.*

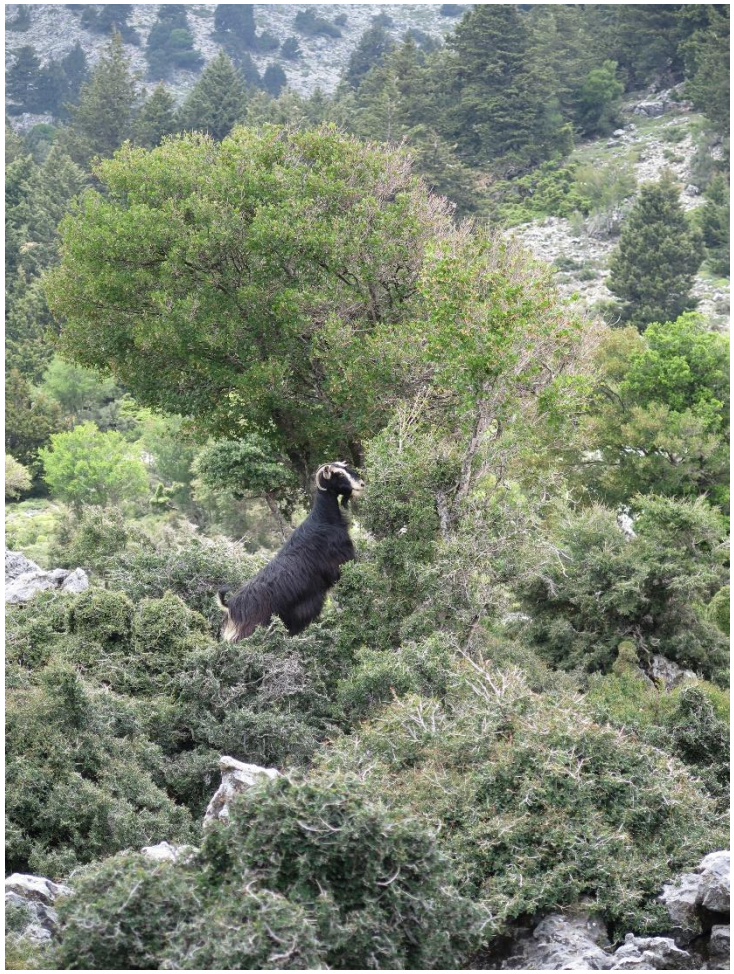


Figure A6.6: *Goat browsing on a* Z. abelicea *shrub in Niato.*



Figure A6.7: *Establishment of AMB-EXT with a measuring tape (4x4m).*



Figure A6.8: *View from the inside of XER3 showing a strong difference in cover values between fenced and non-fenced areas.*