# IMPORTANCE OF DWARF MOUNTAIN PINE (*PINUS MUGO* TURRA) FOR SUBALPINE GRASSLANDS IN THE MITIGATION OF CLIMATE CHANGE

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***Abstract***

*Pinus mugo Turra (dwarf mountain pine) is an important species in the altitudinal transition zone of the vegetation levels from the treeline to subalpine grasslands. The purpose of this work is to analyse the literature referring to P. mugo related to the importance of the habitats defined by it, relationships with subalpine grasslands, the impact of climate change on it and the invasive potential in the non-native area where it has been introduced or naturalised. The species habitat is protected in Europe in 278 NATURA 2000 sites (e.g. Mugo - Rhododendretum hirsuti). Numerous researches demonstrated that low to moderate encroachment rates of P. mugo in grasslands are beneficial for the herbaceous vegetation. The presence of dwarf mountain pine in subalpine area helps to the maintenance of cold-adapted species in the conditions of temperatures increase. The high adaptability of P. mugo to variate soil conditions and climatic variations favours its invasion in the sites where it was introduced.*

**Keywords:** *Pinus mugo Turra, dwarf mountain pine, grassland, climate change, invasive species.*

## INTRODUCTION

Dwarf mountain pine scrubland (Figure 1) made the transition from coniferous forest line to alpine grasslands (Chytrý, 2012; Ballian *et al.*, 2016; Feurdean *et al.*, 2016; Di Nuzzo *et al*., 2021; https://www.conifers.org/pi/Pinus_mugo.php, accessed on 9 May 2022).

According with the data from the EU Habitats Directive (1992) and European Environment Agency, the priority habitat 4070* *Pinus mugo* with *Rhododendron hirsutum* (*Mugo-Rhododendretum hirsuti*) is protected in 278 NATURA 2000 sites across Europe from three biogeographical regions (alpine, continental and Mediterranean) (https://eunis.eea.europa.eu/habitats/10088, accessed on 9 May 2022). The *Rhododendron* species that is accompanying dwarf pine in the Romanian Carpathians is *R. myrtifolium* Sch. *et* Ky. closely related with *R. hirsutum* and *R. ferrugineum* from the Alps (https://www.retezat.ro/habitate/18/4070-tufarisuri-de-pinus-mugo-si-

rhododendron-hirsutum-mugo-rhododendretum-hirsuti, accessed on 9 May 2022).

*P. mugo* Turra (common names: dwarf mountain pine, mountain pine, mugo pine and dwarf pine) was mentioned in 2016 in the he *IUCN Red List of Threatened Species* as least concern species. (Farjon, 2017). The lower elevation limit of the dwarf pine range is about 600 meters a.s.l. and the upper elevation limit is 2700 m a.s.l., but the average range is 1000-2300 meters a.s.l. The species is resident in 18 European countries: Albania, Austria, Bosnia - Herzegovina, Bulgaria, Croatia, Czech Republic, Germany, Italy, Montenegro, Northern Macedonia, Poland, Romania, Serbia, Slovakia, Slovenia, Switzerland and Ukraine (Figure 2) (Farjon, 2017, https://www.iucnredlist.org/species/42385/95729675, accessed on 9 May 2022).

The most frequent causes for the increase of the expansion of *P. mugo* is abandonment of the pastures and climate change (Dullinger *et al.*, 2004; Hejkman *et al*., 2005; Tsaryk *et al*., 2006; Švajda *et al.*, 2011; Ballian *et al*., 2016; Cudlin *et al*., 2017; Wielgolaski *et al.*, 2017; Lukasová *et al*., 2021; Di Nuzzo *et al*., 2021).

In this work have been analysed the literature resources referring to dwarf pine (*P. mugo* Turra) in some different situations across its habitats, respectively native, protected and invasive.

Figure 1. *P. mugo* in Maramureșului Mountains (Romania) (photo: Sărățeanu Veronica)

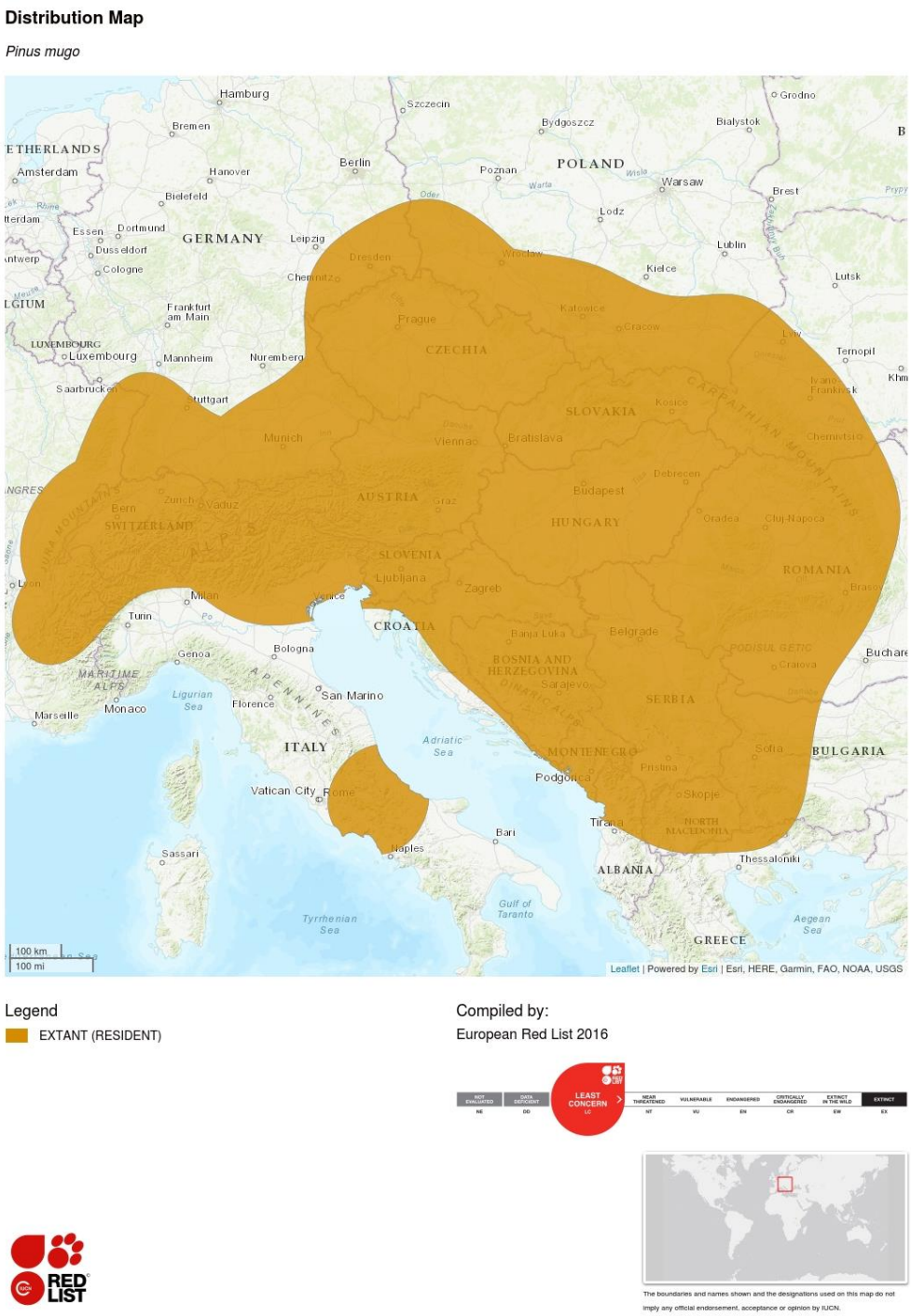


Figure 2. *Pinus mugo* Turra geographic range as resident species according with European Red List 2016. (The IUCN Red List of Threatened Species. Version 2021-3) (Farjol, 2017)

## DISCUSSIONS

### 1. *P. mugo* taxonomy

*P. mugo* Turra belongs to the Family *Pinaceae*, Order *Pinales*, Class *Pinopsida*, Phylum *Tracheophyta*, Kingdom *Plantae*. Synonyms of the species name are the following: *P. mughus* Scop, *P. mugo* Turra subsp. *mugo, P. montana* Mill., *P. mugo* Turra subsp. *rotundata* (Link) Janch. & H. Neumayer (Farjon, 2010; 2017).

According with other authors, the taxonomic classification of *Pinus mugo* species aggregate is complicated due to the great variability of the complex. For this reason, the taxa were grouped in four categories, respectively: arborescent forms (4-25 m tall), transitive forms (2-10 m tall), shrub form (2-3 m tall) and hybrid forms with *P. sylvestris* (Christiensen, 1987; Hamerník and Musil, 2007). The *P. mugo* Turra complex genetics is determined by the spatial distribution of the populations (Heuertz *et al.*, 2010), there being determined hybridisations patterns among the pine species implying interspecific gene flow with consequences on the evolution of the group (Wachowiak *et al*., 2016).

## 2. *P. mugo* habitats

According with Kammer and Möhl (2018) the preference of dwarf pine for the site features is the altitude between 1600 – 2300 a.s.l, predominantly on calcareous bedrock (Dakskobler, 2007) and poorly developed soils with neutral to slightly acid pH (between 6-7), but the species has the ability to grow on a great variety of soils (e.g., acid soils or dry sandy soils) (Aučina *et al*., 2011; Ballian *et al.*, 2016) with long lasting snow cover (Farjol, 2017). Dwarf pine is protected in 278 NATURA 2000 priority sites from 11 EU countries. The protected sites characterised by the presence of this species in the Romanian Carpathians are 24 (see Table 1). The conservation status of the *Mugo-Rhododendretum hirsuti* habitat in Romania is good (Figure 2), but differs across the EU states and across the protected sites (https://eunis.eea.europa.eu/habitats/10088, accessed on 9 May 2022). According with IUCN (2016) the main threats of *P. mugo* habitats are cutting, fire, tourism and climate change, but in the same time it is able to recover even naturally.

## 3. *P. mugo* related to grassland

Grassland vegetation is influenced by natural factors and anthropic factors. From the natural factors, soil and climate are the most influential (Sărățeanu *et al.*, 2020a) In mountain area, grasslands are an important resource, being sometimes the only forage source for the farmers (Samuil *et al.*, 2009, 2011). Often, the grasslands from the upper tree line limit in mountain area appeared or were extended after the removal of *P. mugo* (Hejkman *et al*., 2005; Tsaryk *et al*., 2006; Ballian *et al.*, 2016).

*Table 1*

NATURA 2000 protection sites for 4070* habitats from Romania
(https://eunis.eea.europa.eu/habitats/10088, accessed on 9th May 2022)

| No. | Site code | Site name |
|---|---|---|
| 1 | ROSCI0013 | Bucegi |
| 2 | ROSCI0015 | Buila - Vânturarița |
| 3 | ROSCI0016 | Buteasa |
| 4 | ROSCI0019 | Călimani - Gurghiu |
| 5 | ROSCI0024 | Ceahlău |
| 6 | ROSCI0038 | Ciucaș |
| 7 | ROSCI0047 | Creasta Nemirei |
| 8 | ROSCI0051 | Cușma |
| 9 | ROSCI0069 | Domogled - Valea Cernei |
| 10 | ROSCI0085 | Frumoasa |
| 11 | ROSCI0122 | Munții Făgăraș |
| 12 | ROSCI0124 | Munții Maramureșului |
| 13 | ROSCI0125 | Munții Rodnei |
| 14 | ROSCI0126 | Munții Țarcu |
| 15 | ROSCI0128 | Nordul Gorjului de Est |
| 16 | ROSCI0129 | Nordul Gorjului de Vest |
| 17 | ROSCI0188 | Parâng |
| 18 | ROSCI0194 | Piatra Craiului |
| 19 | ROSCI0208 | Putna - Vrancea |
| 20 | ROSCI0217 | Retezat |
| 21 | ROSCI0260 | Valea Cepelor |
| 22 | ROSCI0292 | Coridorul Rusca Montană - Țarcu - Retezat |
| 23 | ROSCI0324 | Munții Bihor |
| 24 | ROSCI0381 | Râul Târgului - Argeșel - Râușor |

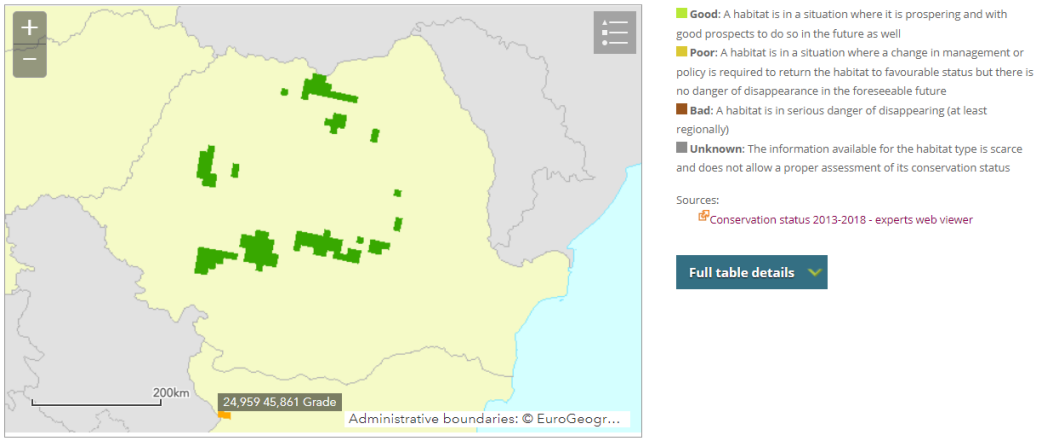


Figure 2. Conservation status of NATURA 2000 protection sites for 4070* habitats from Romania (caption from: https://eunis.eea.europa.eu/habitats/10088, accessed on 9th May 2022)

Thus, dwarf mountain pine appears often scattered on the subalpine grasslands, with denser stands near the tree line area (Czortek *et al*., 2018).

*P. mugo* is very important in the subalpine pastures for the

accumulation of organic matter and soil formation (Bastl *et al.,* 2008; Dirnböck *et al*., 2008).

The effects due to the change of grassland management intensity or abandonment in highland area are confused often with the climate influence when is related with treeline ecotone and the encroachment of the woody vegetation (Cudlín *et al*., 2017). Other authors confirm the great impact of pastoralism change instead of climate change on dwarf pine growth dynamics (Dai, 2017). Other findings claim that both climate and land-use change are influencing the Mediterranean mountain environment, respectively the high temperatures determined the encroachment of dwarf pine in the pastures from the higher altitudes in areas that formerly were grazed (Calderaro *et al*., 2020).

Some of the most frequent disturbances of the subalpine grasslands affected by the encroachment of *P. mugo* are abandonment or intermittent grazing (Richardson, 2006; Soane *et al.*, 2012).

The researches focused on *P. mugo* impact on grassland biodiversity from Swiss Alps highlighted the low influence of low to moderate coverages up to 50% of the dwarf pine (Zehnder *et al*., 2016). In long-term research was observed also a positive influence of dwarf pine encroachment in grasslands at moderate levels on the floristic composition in the Apennines Mountains (Italy) (Calabrese *et al.*, 2018).

In 40 yearlong research on the dynamics of *P. mugo* from Tatra Mountains (Slovakia) Solár and Janiga (2013) found that it has diminished progressively the subalpine grassland surface. Similar results of dwarf pine encroachment in grasslands were obtained in Iezer Mountains (Romanian Carpathians) (Mihai *et al.*, 2007).

Some dwarf pine populations (e.g. from the Italian and French Alps) aren't homogenous and distributed on an altitudinal pattern, they being scattered on grazed grasslands (Carcaillet *et al*., 2009).

In the protected areas from Romania, even in protected grasslands is forbidden to diminish the surface covered with *P. mugo* (Cojocariu *et al*., 2010) according to the legislations (UOG no. 195/2005).

## 4. Impact of climate change on *P. mugo*

Climate change is considered to have impact on tree line ecotone structure, physiognomy and biodiversity (Dullinger *et al.*, 2004; Švajda *et al.*, 2011; Cudlin *et al*., 2017; Wielgolaski *et al.*, 2017; Lukasová *et al*., 2021), respectively influences dwarf pine communities (Alexandrov *et al.,* 2011). Different researches show that temperature increase can determinate the increase of seed viability in *Pinus* species (Germino *et* al., 2002; Giménez-Benavides *et al*., 2005). But with all these, dwarf pine prefers lower temperatures and higher rainfalls, according with researches developed in the Mediterranean area (Vujelić *et al.,* 2010).

According with some researches, dwarf pine growth is significantly influenced by the climate (Palombo *et al.*, 2014; Calderaro *et al*., 2020; Lukasová *et al*., 2021), respectively the temperatures from the previous and current growing season and the rainfalls from April and July (Parobeková *et al*., 2021)). Other researches were focused on the radial growth of *P. mugo* from Călimani Mountains (Romanian Carpathians) using dendroclimatic models, concluding that temperature and rainfalls have impact on the dwarf pine radial growth (Rogojan and Balabașciuc, 2020). Other morphological changes of *P. mugo* determined by high temperatures in the previous winter before the organogenesis is the high rate of abnormal dwarf shoots (Boratyński, *et al*., 2011).

An indirect effect of climate to *P. mugo* refers to hard rainfalls effect on the pest insect reproduction time interval that dimmish their attack on the fructifications. Thus, temperature increase can favour the negative impact of the insect pests in the dwarf pine stands (Vacek *et al*., 2013).

In the Apennines Mountains, was observed a general thermophylization process, by the increase of the thermophilic species, but in the patches with *P. mugo* survive or even increase in abundance the cold-adapted species by creating mesic patches of vegetation in the arid grassland matrix (Calabrese *et al*., 2018) Thus, thermophylization was also observed in Western Carpathians (Slovakia) in the sparsely populated zones with *P. mugo*, e.g. the temperature increase from December determinates the increase of greenness of all dwarf mountain pine MODIS pixels analysed using remote sensing (Lukasová *et al*., 2021).

## 5. *P. mugo* - invasive species

Invasive species can be introduced (alochtonous, alien species) form other geographical regions (Rejmánek and Richardson, 1996; Richardson and Pyšek, 2006; Sărățeanu *et al.*, 2008a) or native (autochtonous) (Valéry *et al*., 2018; Sărățeanu *et al*., 2008a, 2011).

Thus, native species can become invasive due to the disturbance of the environment determined by human activity (Sărățeanu *et al*., 2020b, 2021) as eutrophication, changes at the level of the habitat and land use or even due to global warming (Valéry *et al*., 2018).

Dwarf pine can be found in the NOBANIS database referring to the invasive non-native species from northern Europe and Baltic region (Jørgensen, 2006).

In research regarding the invasive potential (Z score) of 24 invasive and non-invasive *Pinus* species, all of them proved to have invasive capacity (Rejmánek and Richardson, 1996; Richardson, 2006). Thus, *P. mugo* is reported to be invasive in at least one of the geographical regions of the world (Richardson and Rejmánek, 2011).

According with Richardson (2006) *P. mugo* is naturalized in UK, Lithuania, Russia and USA and invasive in New Zeeland, respectively has a ratio of 4/1 of the naturalized/invaded regions.

Some other countries where *P. mugo* was introduced in the 1800s are Denmark, Estonia, Finland, Lithuania, Norway and Sweden (Aučina *et al*., 2011; Brundu and Richardson, 2017).

Other case of *P. mugo* invasion is mentioned in Spain (Montseny Natural Park) due to planted dwarf pines in the 1960s, the invasion process being favoured by cumulated natural and human factors (Bartolomé *et al.*, 2005). Similar is the situation in some grasslands from Sudetes Mountains (Czech Republic) regarding the fast expansions (63% expansion rate in 30 years) of the dwarf pine planted for erosion control, but now affecting the native vegetation and insects (Treml *et al*., 2012).

The researches on non-native dwarf pine populations from the coastal dunes from Lithuania show that this species is able to adapt ectomycorrhizal communities to support its growth and development, but also the regeneration based on natural seedlings (Aučina *et al*., 2011).

The invasion models of *Pinus* applied on three vegetation types, respectively grassland, scrubland and forest in relationship with increasing disturbance levels highlighted the fact that grassland and scrubland are more susceptible to invasion (Higgins and Richardson,1998; Richardson, 2006).

The result proving the invasion of native *P. mugo* in the Venetian Alps abandoned grasslands, access ways, historical sites *etc*. has a negative impact from economical point of view, requiring careful management and control (Cavalli *et al*., 2011).

Biodiversity is mentioned to be affected by the introduced *P. mugo* in grasslands (Zeidler *et al.*, 2012). In Denmark non-native dwarf mountain pine introduced for sand dunes stabilization has negative effects on the vegetation of the grey dune heats where it became invasive. Some of the problems created by the invasion are the diminishing of biodiversity of plants, lichen and mosses in the invaded dune heaths (Johnsen *et al.*, 2005).

**CONCLUSIONS**

*P. mugo* Turra is an important species from the subalpine level of the high European mountains, for numerous reasons, e.g. ecological, economical *etc*., being protected in Europe in 278 NATURA 2000 sites (*Mugo - Rhododendretum hirsuti*).

In numerous researches was evidenced that low to moderate encroachment level of dwarf mountain pine in grasslands are beneficial for the herbaceous vegetation sward, one of the main impacts referring to the increase of biodiversity. In subalpine area it contributes to the maintenance of

cold-adapted species in the conditions of the temperatures increase.

Dwarf mountain pine is highly sensitive to the temperature increase, mostly in the cooler season, this being one of the main driving factors in its expansion in subalpine grasslands.

*P. mugo* adapts well to different soils and climatic variations, this being the main reasons why it became invasive in the stands where it has been introduced.

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**REFERENCES**

1. Alexandrov A., von Wühlisch G., Vendramin G (2011) Conserving the genetic diversity of *Pinus mugo* Turra, Silva Balcanica, 12(1): 5-11.
2. Aučina, A., Rudawska, M., Leski, T., Ryliškis D., Pietras M., Riepšas E. (2011) Ectomycorrhizal fungal communities on seedlings and conspecific trees of *Pinus mugo* grown on the coastal dunes of the Curonian Spit in Lithuania. Mycorrhiza 21, 237–245 https://doi.org/10.1007/s00572-010-0341-3.
3. Ballian D., Ravazzi C., de Rigo D., Caudullo G. (2016) *Pinus mugo* in Europe: distribution, habitat, usage and threats. In: San-Miguel Ayanz J., de Rigo D., Caudullo G., Houston Durrant T., Mauri A. (Eds.), European Atlas of Forest Tree Species. Publ. Off. EU, Luxembourg, pp. e012d81+.
4. Bartolomé J., Boada M., Saurí D., Sánchez S., Plaixats Y.J. (2005) Colonización de pastos por *Abies alba*, *Pinus sylvestris* y *Pinus mugo* en el Parque Natural del Montseny, in Roza Delgado, B. De La; Martínez Fernández, A. Y Carballal Salamea, A., (Eds.), Producciones agroganaderas: gestión eficiente y conservación del medio natural, Actas de la XLV Reunión Científica de la Sociedad Española para el Estudio de los Pastos. (II), Gijón (España): 2005, (volumen II). SERIDA, 2005, p. 841-846.
5. Boratyński A., Dubicki A., Iszkuło G., Jasińska A.K., Boratyńska K., Piórkowska M., Marcysiak K. (2011). How Environmental Signals Affect Frequency of Three-Needle Dwarf Shoots on Pinus mugo. Polish Journal of Environmental Studies, 20(1), 45-52.
6. Brundu G., Richardson D.M. (2017) Code of conduct for invasive alien trees. Convention on the conservation of European wildlife and natural habitats. T-PVS/Inf (2017) 8. https://rm.coe.int/european-code-of-conduct-for-invasive-alien-trees-adopted-version/168076e86e, accessed on 10 May 2022.
7. Calabrese V., Carranza M., Evangelista A., Marchetti M., Stinca A., Stanisci A. (2018) Long-Term Changes in the Composition, Ecology, and Structure of *Pinus*

*mugo* Scrubs in the Apennines (Italy). Diversity, 10(3), 70. https://doi.org/10.3390/d10030070

8. Calderaro C., Cocozza C., Palombo C., Lassese B., Marchetti M., Tognetti R. (2020) Climate–growth relationships at the transition between *Fagus sylvatica* and *Pinus mugo* forest communities in a Mediterranean mountain. Annals of Forest Science 77, 63. https://doi.org/10.1007/s13595-020-00964-y.
9. Carcaillet C., Fauvart N., Roiron P., Terral J.-F., Ali A.A., (2009) A new, isolated and endangered relict population of dwarf pine (*Pinus mugo* Turra) in the northwestern Alps, Comptes Rendus Biologies, 332 (5): 456-463, https://doi.org/10.1016/j.crvi.2008.10.001.
10. Cavalli R., Pellegrini M., Grogolato S., Bietrsato M. (2011) A Strategy for the management of abandoned mountain pasture land colonised by dwarf pine, L'Italia Forestale e Montana, 66 (5): 383-393. http://dx.doi.org/10.4129/ifm.2011.5.02.
11. Christensen K.I. (1987) Taxonomic revision of the *Pinus mugo* complex and *P.* × *rhaetica* (*P. mugo*×*sylvestris*) (*Pinaceae*). Nord J Bot 7:383–408.
12. Chytrý M. (2012) Vegetation of the Czech Republic: diversity, ecology, history and dynamics. – Preslia 84: 427–504.
13. Cojocariu L., Horablaga M.N., Marian F., Bostan C., Mazăre V., Stroia M.S. (2010) Implementation of the Ecological European Network "Natura 2000" in the area of grasslands and hayfields, Research Journal of Agricultural Science, 42 (1): 398-404.
14. Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora - consolidated version 01/01/2007 (EU Habitats Directive), Annex I: natural habitat types of community interest whose conservation requires the designation of special areas of conservation, http://ec.europa.eu/environm...rective/index_en.htm.
15. Cudlín P., Klopčič M., Tognetti R., Máliš F., Alados C.L., Bebi P., Grunewald K., Zhiyanski M., Andonowski V., La Porta N., Bratanova-Doncheva S., Kachaunova E., Edwards Jonášová M., Ninot J.M., Rigling A., Hofgaard A., Hlásny T., Skalák P., Wiegolaski F.E. (2017) Drivers of treeline shift in different European mountains. Climate Research, 73: 135–150. DOI: 10.3354/cr01465.
16. Czortek P., Ratyńska H., Dyderski M. K., Jagodziński A. M., Orczewska A., Jaroszewicz B. (2018) Cessation of livestock grazing and windthrow drive a shift in plant species composition in the Western Tatra Mts Tuexenia 38: 177–196. doi: 10.14471/2018.38.008.
17. Dai L., Palombo C., van Gils H., Rossiter D.G., Tognetti R., Luo G. (2017) "*Pinus mugo* Krummholz Dynamics During Concomitant Change in Pastoralism and Climate in the Central Apennines," Mountain Research and Development, 37(1), 75-86.
18. Dakskobler I. (2006) Calcareous open sedge swards and stony grasslands (*Seslerietalia caeruleae*) on the northern edge of the Trnovski gozd plateau (the Dinaric Mountains, western Slovenia). Hacquetia, volume 5, issue 1, str. 73-112. URN:NBN:SI:doc-WKLO0PAE from http://www.dlib.si.

19. Di Nuzzo L., Vallese C., Benesperi R., Giordani P., Chiarucci A., Di Cecco V., Di Martino L., Di Musciano M.., Gheza G., Lelli C., Spitale D., Nascimbene J. (2021) Contrasting multitaxon responses to climate change in Mediterranean mountains. Sci Rep. 2021 Feb 24;11(1):4438. doi: 10.1038/s41598-021-83866-x. PMID: 33627718; PMCID: PMC7904820.
20. Dirnböck T., Dullinger S., Köck R. (2008) Organic matter accumulation following *Pinus mugo* Turra establishment in subalpine pastures, Plant Ecology & Diversity, 1:1, 59-66, DOI: 10.1080/17550870802260715.
21. Dullinger S., Dirnböck T., Grabherr G. (2004) Modelling climate change-driven treeline shifts: relative effects of temperature increase, dispersal and invasibility, 92 (2): 241-252, https://doi.org/10.1111/j.0022-0477.2004.00872.x.
22. Farjon, A. (2010) A Handbook of the World's Conifers. Koninklijke Brill, Leiden.
23. Farjon, A. (2017) *Pinus mugo*. The IUCN Red List of Threatened Species 2017: e.T42385A95729675. https://dx.doi.org/10.2305/IUCN.UK.2017-2.RLTS.T42385A95729675.en, accessed on 10 May 2022.
24. Feurdean A., Gałka M., Tanţău I., Geantă A., Hutchinson S.M., Hickler T. (2016) Tree and timberline shifts in the northern Romanian Carpathians during the Holocene and the responses to environmental changes, Quaternary Science Reviews, 134: 100-113, https://doi.org/10.1016/j.quascirev.2015.12.020.
25. Germino M.J., Smith W.K., Resor A.C. (2002) Conifer seedling distribution and survival in an alpine-treeline ecotone. Plant Ecol 162:157–168.
26. Giménez-Benavides L., Escudero A., Pérez-García F. (2005) Seed germination of high mountain Mediterranean species: altitudinal, interpopulation and interannual variability. Ecol Res 20:433–444.
27. Hamerník J., Musil I. (2007) The *Pinus mugo* complex – its structuring and general overview of the used nomenclature, Journal of Forest Science, 53, 2007 (6): 253–266.
28. Hejcman M., Nežerková P., Pavlů V., Gaisler J., Lokvenc T., Pavlů L. (2005). Regeneration of Nardus stricta subalpine grasslands in the Giant Mountains (Krkonoše). Acta Soc. Bot. Pol. 74, 253–258.
29. Heuertz M., Teufel J., González Martínez S., Soto de Viana Á. Fady B., Alia R., Vendramin G. G. (2010). Geography determines genetic relationships between species of mountain pine (*Pinus mugo* complex) in western Europe. "Journal of Biogeography", v. 37 (n. 3); pp. 541-556. ISSN 0305-0270. https://doi.org/10.1111/j.1365-2699.2009.02223.x.
30. Higgins S. I. and Richardson D. M. (1998) Pine invasions in the southern hemisphere: modelling interactions between organism, environment and disturbance. Plant. Ecol. 135: 79–93.
31. IUCN (2016) Dwarf Mountain Pine (*Pinus mugo*), European Red List 2016. https://www.iucnredlist.org/species/42385/95729675, accessed on 10 May 2022.
32. Johnsen I, Riis-Nielsen T., Christensen S.N., Ring Petersen M. (2005) Report concerning the intensive monitoring of dune heaths 2002 to 2005 (Action F2). https://naturstyrelsen.dk/media/nst/Attachments/Intensive_monitoring_report_ku.pdf

33. Jørgensen H (2006) NOBANIS—Invasive Alien Species Fact Sheet— *Pinus mugo*. Online Database of the North European and Baltic Network on Invasive Alien Species—NOBANIS. www.nobanis.org.
34. Kammer P.M. and Möhl A. (2018) A guide to frequent and typical plant communities of the European Alps, ALPECOLe - Alpine Ecology and Environments. https://www.geo.uzh.ch/microsite/alpecole/static/course/lessons/08/08g/pdf/08g_plant_comm.pdf, accessed on 9th May 2022.
35. Lukasová V., Bucha T., Mareková L., Buchholcerová A., Bičárová S. (2021) Changes in the Greenness of Mountain Pine (Turra) in the Subalpine Zone Related to the Winter Climate. Remote Sens., 13, 1788. https://doi.org/10.3390/rs13091788.
36. Mihai B., Savulescu I., Sandric I. (2007) Change detection analysis 1986–2002 of vegetation cover in Romania. Mountain Research and Development, 27 (3): 250–258.
37. Palombo C., Battipaglia G., Cherubini P., Chirici G., Garfì V., Lassere B., Lombardi F., Marchetti M., Tognetti R. (2014). Warming-related growth responses at the southern limit distribution of mountain pine (*Pinus mugo* Turra subsp. *mugo*). Journal of Vegetation Science, 25 (2): 571-583. ⟨10.1111/jvs.12101⟩. ⟨hal-03012879⟩.
38. Parobeková Z., Pittner J., Sedmáková D., Saniga M. (2021) Growth dynamic of dwarf pine (*Pinus mugo* Turra) along an altitude gradient, ZLV, 66, 2021 (4): 227-236.
39. Rejmánek M., Richardson D. M. (1996): What attributes make some plant species more invasive? – Ecology 77: 1655–1661.
40. Richardson D.M. (2006) *Pinus*: a model group for unlocking the secrets of alien plant invasions? Preslia 78: 375–388.
41. Richardson D.M., Pyšek, P. (2006) Plant invasions: merging the concepts of species invasiveness and community invasibility. Progress Phys. Geog. 30, 409–431.
42. Richardson D.M., Rejmánek M. (2011) Trees and shrubs as invasive alien species—a global review. Divers Distrib,17:788–809.
43. Rogojan C-C., Balabașciuc M. (2020) Characteristics concerning the radial growth of mountain pine (*Pinus mugo*) from the subalpine ecotone area of Călimani National Park, Romania. Advances in Agriculture & Botanics, 12 (2): 52–57.
44. Samuil C., Vintu V., Iacob T., Saghin G., Trofin, A. (2009), Management of permanent grasslands in North-Eastern Romania, in Eds: Cagaš B., Macháč R., Nedělník J., Alternative functions of grassland. Proceedings of the 15th European Grassland Federation Symposium, Brno, Czech Republic, 7-9 September 2009, pp.234-237.
45. Samuil C., Vintu V., Sirbu C., Popovici I.C. (2012), Influence of fertilization on the vegetation and production of *Festuca valesiaca* L. grassland, Fourrages, 210: 151-157.

46. Sărăţeanu V., Horablaga N.M., Stroia M.C., Butnariu M., Bostan C. (2008a). Assessing the invasive species impact on the grasslands from Western Romania. Scientifical Papers Agriculture, 40 (1): 319-326.
47. Sărăţeanu V., Moisuc A., Oriol I., Butnariu M. (2008b) Influence of some climatic factors on invasive species coverage index in western Romania. Grassland Science in Europe. Uppsala, Sweden, 13: 937-939.
48. Sărățeanu V., Moisuc A, (2011) Influence of *Prunus spinosa* L. shrub on the grassland vegetation in western Romania. Journal of Water and Land Development, 15: 65-17, DOI: 10.2478/v10025-012-0006-z.
49. Sărățeanu V., Cotuna O., Durău C. C., Paraschivu M. (2020a). Influence of some soil features on forest steppe pasture vegetation. Romanian Journal of Grasslands and Forage Crops, 22: 65-79.
50. Sărăţeanu V., Suciu C.T., Cotuna O., Durău C.C., Paraschivu M., (2020b) Adventive species *Asclepias syriaca* L. in disturbed grassland from Western Romania. Romanian Journal of Grasslands and Forage Crops 21, 61-72.
51. Sărăţeanu V., Cotuna O., Durău C., Paraschivu M. (2021) Bracken (*Pteridium aquilinum* (L.) Kuhn), a current issue of the permanent grasslands in Romania, Romanian Journal of Grassland and Forage Crops, 24: 71-79.
52. Soane I. D., R. Scolozzi, A. Gretter, K. Hubacek. (2012) Exploring panarchy in alpine grasslands: an application of adaptive cycle concepts to the conservation of a cultural landscape. Ecology and Society 17 (3): 18. http://dx.doi.org/10.5751/ES-05085-170318
53. Solár J, Janiga M. (2013) Long-term changes in dwarf pine (*Pinus mugo*) cover in the High Tatra Mountains, Slovakia. Mountain Research and Development, 33 (1): 51–62. DOI: 10.1659/MRD JOURNAL-D-12-00079.1.
54. Švajda J., Solár J., Janiga M., Buliak M. (2011) Dwarf Pine (*Pinus mugo*) and Selected Abiotic Habitat Conditions in the Western Tatra Mountains, Mountain Research and Development, 31(3), 220-228,
55. Treml V.,Wild J.,Chuman T., Potůčková M.(2012) Assessing the Change in Cover of Non-Indigenous Dwarf-Pine Using Aerial photographs, a case study from the Hrubý Jeseník Mts., the Sudetes. Journal of Landscape Ecology, 3(2) 90-104. https://doi.org/10.2478/v10285-012-0029-9.
56. Urgency Ordinance of Government no. 195/22.12.2005 regarding the environment protection (Official Monitor no. 1196/30.12.2005, rectification in Official Monitor no. 88/31.01.2006) approved by the Law no. 265/29.06.2006 (Official Monitor no. 586/06.07.2006) modified by the Urgency Ordinance no. 114/17.10.2007 (Official Monitor no. 713/22.10.2007) and by the Urgency Ordinance no. 164/19.11.2008 (Official Monitor no. 808/03.12.2008);
57. Vacek S., Hejcmanová P., Hejcman M., Vacek Z. (2013) Growth, healthy status and seed production of differently aged allochtonous and autochtonous *Pinus mugo* stands in the Giant Mts. over 30 years, Eur J Forest Res (2013) 132:801–813.

58. Valéry L., Fritz H., Lefeuvre J.C., Simberloff D. (2009) Invasive species can also be native. Trends Ecol Evol. 24(11):585; author reply 586. doi: 10.1016/j.tree.2009.07.003. Epub 2009 Sep 15. PMID: 19762116.
59. Vukelić J., Vojniković S., Ugarković D., Bakšić D., Mikac S. (2010) The influence of climate change on tree species distribution in west part of south-east Europe // Climate Change and Variability / Suzanne W. Simard, Mary E. Austin (Eds.) Rijeka: Sciyo, pp. 211-224.
60. Wachowiak W., Żukowska W.B., Wójkiewicz B., Cavers S., Litkowiek M. (2016) Hybridization in contact zone between temperate European pine species. Tree Genetics & Genomes 12, 48: https://doi.org/10.1007/s11295-016-1007-x
61. Wielgolaski F.E., Hofgaard A., Holtmeier F.-K. (2017) Sensitivity to environmental change of the treeline ecotone and its associated biodiversity in European mountains, Climate Research (CR). 2017, 73 151-166. 10.3354/cr01474.
62. Zehnder T., Schneider M.K., Berard J., Kreuzer M., Lüscher A. (2016) Reconciling meat production and biodiversity conservation on marginal pastures. In: Casasús I. (ed.), Lombardi G. (ed.). Mountain pastures and livestock farming facing uncertainty: environmental, technical and socio-economic challenges. Zaragoza: CIHEAM, 2016. (Options Méditerranéennes: Série A. Séminaires Méditerranéens; n. 116), p. 231-235.
63. Zeidler M., Duchoslav M., Banaš M. Lešková M. (2012) Impacts of introduced dwarf pine (*Pinus mugo*) on the diversity and composition of alpine vegetation. Community Ecology, 13 (2): 213-220. https://doi.org/10.1556/ComEc.13.2012.2.11.
64. *** - 4070* - Tufărișuri de *Pinus mugo* și *Rhododendron hirsutum* (*Mugo - Rhododendretum hirsuti*), https://www.retezat.ro/habitate/18/4070-tufarisuri-de-pinus-mugo-si-rhododendron-hirsutum-mugo-rhododendretum-hirsuti, accessed on 9th May 2022.
65. *** - Bushes with *Pinus mugo* and *Rhododendron hirsutum* (*Mugo-Rhododendretum hirsuti*), https://eunis.eea.europa.eu/habitats/10088, accessed on 9th May 2022.
66. *** - *Pinus mugo*, The Gymnosperm Database, https://www.conifers.org/pi/Pinus_mugo.php, accessed on 9th May 2022.