Chapter 12
Predicting the Potential Distribution of *Ailanthus altissima*, an Invasive Terrestrial Plant Species in Măcin Mountains National Park (Romania)

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Abstract Under current global change conditions, invasive species show an increasing tendency to spread over larger areas in close relationship with their triggering environmental driving forces. Current research is seeking to assess the potential distribution of the invasive terrestrial plant species (ITPS) *Ailanthus altissima* in a natural protected area, the Măcin Mountains National Park (II IUCN category). The protected area is located in the southeastern part of Romania, sheltering a combination of Pontic, steppe, and well-preserved sub-Mediterranean and Balkan forest ecosystems. The authors propose a geographic GIS-based quantitative statistical analysis (potential distribution model, ITPS-PODISMOD) of *A. altissima* using bivariate analysis that takes into consideration the relationship between variables, such as *A. altissima* as the dependent variable and its driving factors as independent variables. Concurrently, each driving factor was ranked depending on the relationships between the analysed species and its ecological conditions. Thus, an ITPS-PODISMOD map displaying areas with different potential distribution of *A. altissima* in relationship to the key environmental driving factors has resulted.

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12.1 Introduction

Biological invasions range among the most critical ecological environmental and social threats to biodiversity, human health, and ecosystem services, especially under the intensification and diversification of global environmental change-driven impacts (Charles and Dukes 2006; Bailey et al. 2007; McGeoch et al. 2010), thus becoming key components of global change (Shea and Chesson 2002; Arim et al. 2006) through their high adaptive capacity that enables them to penetrate natural geographic barriers or political boundaries (Richardson et al. 2000; Anastasiu and Negrean 2005; Anastasiu et al. 2008; Andreu and Vila 2010). Invasive species are renowned for their remarkable spatiotemporal dynamics, thus becoming successfully established and spread over extended areas in Europe, causing major environmental and socioeconomic damage (Pyšek and Hume 2005; Lambdon et al. 2008), especially in protected areas, where they disturb habitat structure and functioning. In Romania, investigations of adventive species with a systematic and floristic character were synthesised by Săvulescu and Nyárády (1957–1972), Ciocârlan (2009), and Sîrbu et al. (2011). During past years, an increase of neophytes has been estimated (Anastasiu and Negrean 2005; Oprea and Sârbu 2010); thus, currently the adventive flora of Romania includes more than 671 species (17.2 % of the Romanian flora), of which 112 are considered invasive (Sîrbu and Oprea 2011). The current research is to be an important step in developing GIS-based modelling techniques for the assessment of the potential distribution of *Ailanthus altissima* (hereafter *A. altissima*) in relationship to the key environmental driving forces.

Ailanthus altissima ("tree of heaven") is a well-known invasive tree in many parts of the world, with an excellent ability to establish in natural and degraded sites where it can reduce biodiversity and change the abiotic characteristics of the invaded ecosystems (Vila et al. 2006; Badalamenti and La Mantia 2012). A deciduous tree originating in China, it was introduced into Europe in the second half of the eighteenth century as an ornamental plant. Ever since then it has spread all over Europe (Sîrbu and Oprea 2011), especially in the Mediterranean basin (Traveset et al. 2008). The species has a capacity for increased spreading and growth. It is known for its allergenic pollen and the toxic substance its bark and leaves produces (allelopathic) that prevent the establishment of other plant species (Feret 1985; Lawrence et al. 1991; Badalamenti and La Mantia 2012). It also shows increased tolerance to abandoned fields, railroad embankments, wastelands, and other disturbed sites, as well as to a wide range of pH conditions (Feret 1985) and extreme weather phenomena, such as drought (Trifilo et al. 2004). In naturally forested areas, it may establish in areas disturbed by storms, infestations related to insects, or even forest fires (DiTomaso et al. 2006). In Romania *A. altissima* was introduced as an ornamental tree and for the protection of degraded and inclined terrain (Sîrbu and Oprea 2011).

The control of this species is rather difficult because the mechanical eradication method stimulates resprouting from the remaining trunk and roots (Burch and Zedaker 2003); therefore, this method must be combined with chemical control techniques (Meloche and Murphy 2006). In Măcin Mountains National Park, the tree of heaven mainly affects the grasslands, forest outskirts, and disturbed sites by competing with and displacing the native vegetation.

12.2 Study Area

Măcin Mountains National Park is located in the southeastern part of Romania (North Dobrogea Massif) in the Steppic biogeographic region (Fig. 12.1). It hosts a complex flora and fauna in a mixture of Pontic, steppe, and well-preserved sub-Mediterranean and Balkan forest ecosystems (e.g., Luncaviţa beech forest, a Tertiary relict).

The Park is the only protected area in Romania sheltering old Hercynian Mountains with low altitudes (467 m maximum altitude; Ţuţuiatu Peak) and a mountain-like aspect, underlain by granites and crystalline schists (Fig. 12.2).

Măcin Mountains National Park was established in 2000 (II IUCN category – National Park), also including two scientific reserves, *Moroianu* and *Valea Fagilor*, which overlap SPA Măcin-Niculiţel and SCI Munţii Măcinului under the Natura 2000 European Network in Romania. The protected area covers a total surface of 11,321 ha, hosting 187 bird species (60 % vulnerable or rare), 41 mammalian species, and 11 reptile species that have been identified and protected under the Berna Convention; there are also 72 rare vascular plant species (Petrescu 2004). Among of the protected species are *Vipera ammodytes montandoni*, *Elaphe quatorlineata*, *Testudo graeca ibera* (Fig. 12.3), *Celtis glabrata*, *Achillea ochroleuca*, *Campanula romanica*, and *Dianthus nardiformis* (Fig. 12.3).

12.3 Integrated Methodology and Data

In the current research assessment the authors carried out comprehensive cross-referencing of the geographic and biological scientific literature coupled with complex investigations of the spatial data (e.g., GIS processing of the most relevant spatial input: topographic map, soil map, DEM, aerial photographs) and statistical data, as well as field surveys following a stepwise approach which included several succeeding stages (Fig. 12.4).

ITPS mapping and geospatial database elaboration on A. altissima and the related driving forces relied on various sources covering both raster and vector information at different scales (Table 12.1).

To achieve more accurate information, GPS (global positioning systems) measurements were conducted as well. The resultant mapped areas do not represent

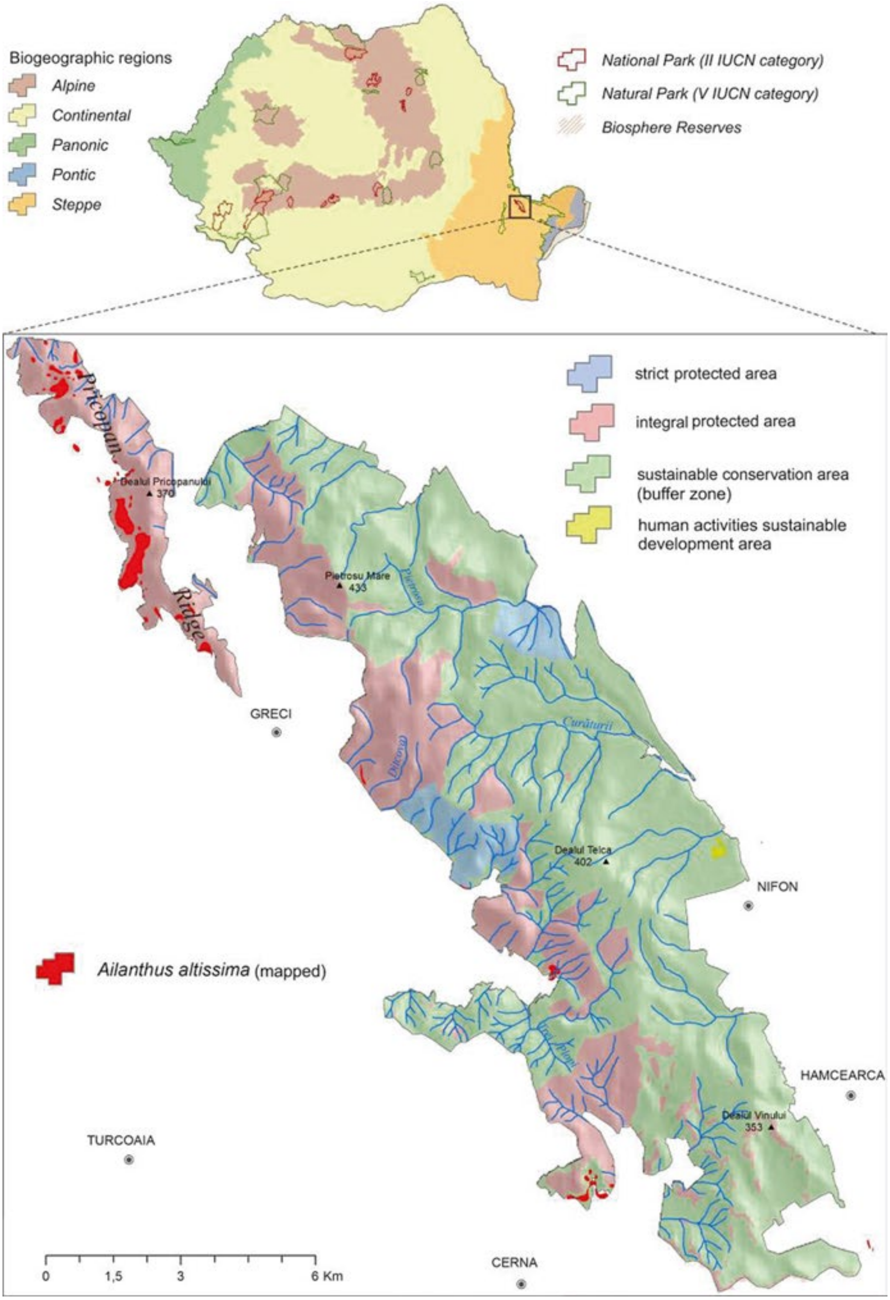

Fig. 12.1 Location of Măcin Mountains National Park in the major Romanian protected areas network and the distribution of *Ailanthus altissima* (mapped areas) in relationship to protected area zoning

Fig. 12.2 Pricopan Ridge in Măcin Mountains National Park (Photograph courtesy of Gheorghe Kucsicsa)

Fig. 12.3 *Dianthus nardiformis* and *Testudo graeca ibera* in Pricopan Ridge (Photograph courtesy of Gheorghe Kucsicsa)

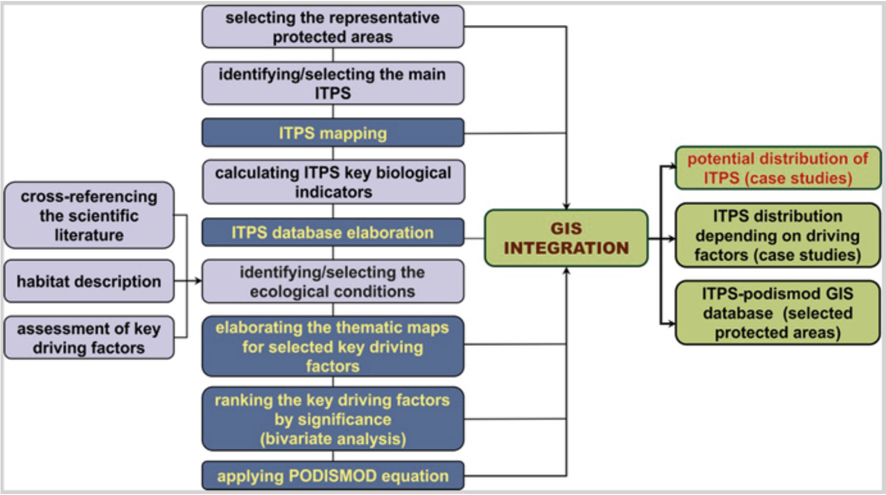

Fig. 12.4 Integrated methodology for the assessment of potential distribution of invasive terrestrial plant species (ITPS)

Table 12.1 Raster/vectorial sources and derived information

Layer	File type	Scale, resolution	Processed by
Soil type (S_T)	Vector	1:200,000	Soil map
Soil texture (S_{TXT})	Vector	1:200,000	Soil map
Land use/land cover (LUC)	Vector	1:100,000	Corine Land Cover database (2006)
Derived layers			
Hypsometry (H)	Raster	30 m	DEM
Slope exposure (S_E)	Raster	30 m	DEM
Slope declivity (S_D)	Raster	30 m	DEM

areas entirely covered with the identified invasive species as they display different coverage/abundance of the analysed ITPS within various habitat types. Moreover, key biological indicators (abundance, coverage, frequency) were computed. The information was then stored in the GIS environment as polygon and point geo-data types, based on which a ***GIS-based model (PODISMOD– ITPS)***, seeking to predict species spreading potential, was developed (Kucsicsa et al. 2013). The focal aim of the model was to identify similar ecological requirements of species in various habitat types (other than in the areas where the species were originally found) to assess the distribution potential in a certain region (Dumitraşcu et al. 2014). Several driving forces (e.g., pedological, geomorphological) were analysed, of which those with direct and indirect impact on species distribution and spread were selected. Consequently, based on the interactions between ITPS and their ecological requirements, *thematic maps* displaying the selected key driving forces triggering species development and spread were elaborated (e.g., soil type, soil texture, land use).

Two of the main steps of the ITPS assessment were *to rank and to weight the key driving factors by importance* using *bivariate analysis*, taking into consideration the relationship between two variables, that is, *A. altissima* (the dependent variable) and its driving factors (the independent variables).

The *rank (R)* values derive from the ratio values (r) calculated using the frequency analysis between pixels representing the *A. altissima* location and the total number of pixels representing each class of driving factors. For uniformity of results, the values were represented in percent, calculated depending of the total sum of the ratio values. Thus, the mathematical relationship can be expressed as follows:

$$\mathrm{R} = (r \times 100) / \sum r \tag{12.1}$$

$$r = p / t \tag{12.2}$$

where r is the ratio, p represents the number of pixels with ITPS (presence), and t represents the total number of pixels of driving factor class.

Consequently, the resulted values were grouped into five classes, based on which the authors were able to establish the ranking of the selected driving key factors to complete the potential distribution of species (very low, low, medium, high, and very high).

Assigning the *weight (W).* Not all selected driving factors can be categorized as having equal weight in ITPS distribution. In the study area, it was observed that the development of *A. altissima* is conditioned to a larger extent by soil type and to a smaller extent by slope exposure. As a result, driving forces classification based on weight (W) assignment is essential as it relies on both on expert judgement attribution based on specialist knowledge and expertise and on the scientific literature. Depending on the relationships between the ecological conditions and ITPS, each driving factor was evaluated on a 1 to 3 scale, higher values being assigned to the most important ones in the ITPS distribution. The final index was computed based on grid-type information, according to the following mathematical operation:

$$\mathbf{PODISMOD} = \mathbf{S}_{\mathbf{T}\boldsymbol{WR}} + \mathbf{S}_{\mathbf{TXT}\boldsymbol{WR}} + \mathbf{LUC}_{\boldsymbol{WR}} + \mathbf{H}_{\boldsymbol{WR}} + \mathbf{S}_{\mathbf{D}\boldsymbol{WR}} + \mathbf{S}_{\mathbf{E}\boldsymbol{WR}}$$

where PODISMOD = potential distribution model, R = rank, W = weight *(1…3)*, and $\mathbf{S_T}$, $\mathbf{S_{TXT}}$, **LUC, H,** $\mathbf{S_D}$, $\mathbf{S_E}$ = selected driving factors.

Finally, comparative graphs showcasing the spread of *A. altissima* in the mapped areas in relationship to PODISMOD spatial distribution classes were constructed.

12.4 Results and Discussion

Spread and habitat description of *A. altissima*. In the study area, the species was identified and mapped on 110.5 ha, mainly in the northwestern part, namely, the northern slope of Pricopan Ridge, close to Cheia Peak (260 m) and southwest of Pricopan Hill Peak (370 m) (Fig. 12.5). Significant areas were also mapped in close proximity to Cerna locality, on the southern slope of Şeaua Mare Ridge (northeast of Cerna locality, at the southwestern extremity of the Park area), and on Valea

Fig. 12.5 *A. altissima* invading natural pastures on the slopes of Pricopan Ridge and on abandoned arable land (Photograph courtesy of Gheorghe Kucsicsa)

Table 12.2 *Ailanthus altissima* recorded in different types of natural and seminatural plant communities/Natura 2000 habitats

Vegetation units	Plant community (Natura 2000 habitat type)
Slopes	*Quercetum pedunculiflorae* Borza 1937 (**91I0***Euro-Siberian steppic woods with *Quercus* spp.)
Broad-leaved forests	*Tilio tomentosae – Carpinetum betuli* Doniţă 1968 (**91Z0** Moesian Silver lime woods)
Open areas	1. *Medicagini minimae – Festucetum valesiacae* Wagner 1941; 2. *Botriochloetum* (*Andropogonetum*) *ischaemi* (Krist. 1937) Pop 1977; (**6250** *Pannonic loess steppic grasslands)
Rocky areas	1. *Agropyro – Thymetum zygoidi* Dihoru (1969) 1970; 2. *Festucetum callieri* Şerbãnescu 1965 apud. Dihoru 1969; 3. *Agropyro-Kochietum prostratae* Zólyomi (1957) 1958, (**6240** *Subpannonic steppic grasslands)
Sparsely vegetated areas	1. *Agrostetum stoloniferae* (Ujvarosi 1941) Burduja 1956; 2. *Agrostideto-Festucetum pratensis* Soó 1949; 3. *Ranunculo repentis – Alopecuretum pratensis* Ellmauer 1933, (**6510** Lowland hay meadows *(Alopecurus pratensis, Sanguisorba officinalis*)

Plopilor (north of Trei Plopi Valley) and Valea Jug slopes (northeast of Greci town) in broad-leaved forests, open areas, slopes, rocky areas and sparsely vegetated areas (Table 12.2).

In relationship to Park zoning, of the entire mapped surface with *A. altissima*, 80 % overlaps the *integral protected area*, 11 % the *sustainable conservation area (buffer zone)*, and only 0.5 % the *strict protected area*. The species was also recorded outside the Park area (8.5 %), close to its boundaries, thus representing a potential threat to protected area ecosystems (Fig. 12.1).

In relationship to the analysed driving factors, the areas mapped with *A. altissima* overlap and intersect various environmental conditions. In the study area *A. altissima* tolerates different environmental conditions, from sunny and semi-sunny slopes (94.4 %), with slopes ranging from 5° to 20°, to open areas or natural grasslands (65 %). It also prefers some specific soil types (litosoils and kastanozeoms) and textures (loamy and clay loam) with a high mineral content, thus proving the species preference for contaminated and degraded terrains (Table 12.3).

The tendency of *A. altissima* to develop within certain habitat types allowed the authors to select eight key areas for in-depth investigations where relevant biological indices were applied. The results revealed species preference for open areas (croplands) and semi-sunny slope exposure, driven by the highest abundance values registered in Strigoaie Valley (western slope of Pricopan Ridge). On the other hand, the lowest values are registered in the Carada Valley (southwest of Ditcova Valley/ Valea Ditcova), where the forest-covered areas do not represent a favourable habitat for *A. altissima*. In terms of frequency, Toader Mocanu (northern slope of Pricopan Ridge) and Izvoarele Valleys (western slope of Pricopan Ridge) rank first because of the rather reduced declivity and favourable soil texture, which enabled the development of a wider variety of phytocoenosis, whereas Carada Valley and

Table 12.3 Distribution of *A. altissima* on the mapped areas in relationship to the key environmental driving factors

By hypsometry (m)	%	**By declivity (°)**	%	**By slope exposure**	%
<50	2.9	<5	1.5	Shadowed slopes	5.6
50–100	26.3	5–10	29.2	Semi-shadowed slopes	36.3
100–150	42.5	10–15	23.1	Sunny	58.1
150–200	23.6	15–20	24.6		
>200	4.7	>20	21.5		

By soil type	%	**By soil texture**	%
Chernozems	1.0	Clay loam	34.1
Fluvisols	2.3	Loamy	41.2
kastanozeoms	28.2	Loamy sand …loamy	2.9
litosoils	37.1	Sandy	0.0
Grey-luvic phaeozems	3.7	Varied texture	21.7
Haplc chernozems	6.0		
Haplic luvisols	0.0		
Rocky areas	21.7		

By land use[a]	%
Discontinuous urban fabric	0
Mineral extraction sites	0
Nonirrigated arable land	6
Vineyards	0
Pastures	5
Land principally occupied by agriculture, with significant areas of natural vegetation	2
Broad-leaved forests	13
Natural grasslands	65
Sparsely vegetated areas	9

% = percent of total invasive terrestrial plant species (ITPS) mapped

[a] According to the Corine land cover (2006)

Cozluk Valley (southwest of Teica Hill/Dealul Teica) display the lowest rates from the reduced diversity of phytocoenosis (Fig. 12.6).

The coverage indicator shows more balanced values between the analysed test areas, ranging between 1 (the lowest) in Toader Mocanu, Strigoaie, Carabalu (south, southwest of Greci town) and Cozluk Valleys and 3 (the highest) in Largă Valley (western slope of Pricopan Ridge). La Chernoagă (northern slope of Pricopan Ridge), Carada, and Izvoarele Valley display mean values of this biological indicator (Fig. 12.6).

PODISMOD *A. altissima*. To apply the potential distribution model for *A. altissima*, six key driving factors were taken into consideration: *soil type*, *soil texture*, *land use/land cover*, *hypsometry*, *slope declivity*, and *slope exposure* (Table 12.4).

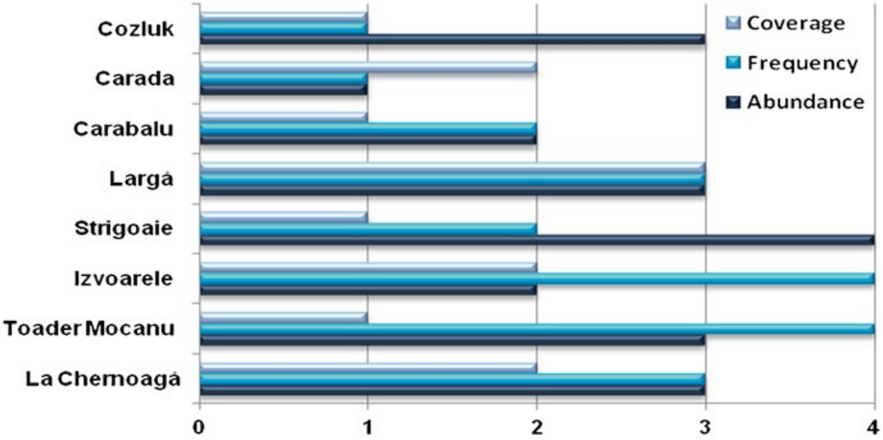

Fig. 12.6 Biological indices for *A. altissima* in Măcin Mountains National Park

Table 12.4 The selected key drivers of *A. altissima* and the assigned weight values (W)

Driving forces	S_T	S_{TXT}	LUC	H	S_D	S_E
W	3	2	2	1	2	3

PODISMOD Values. The application of the bivariate statistical analysis in the study area revealed that the low and very low potential distribution covered 60 %, especially on the eastern and northeastern slopes of Măcin Mountains where large oak, hornbeam, ash and linden forests are found. Areas displaying medium potential distribution cover nearly 26 %, mostly found on the upper slopes of the Valea Plopilor and Cerna basins. Medium values overlap areas located near Dealu Vinului (323 m) and along Pietrosu and Curătura valleys.

High and very high potential distribution covers 14 % of the Park area, on the western and southwestern slopes of Măcin Mountains, predominantly on the southern half of Pricopan Ridge, Şaua Mare Ridge, Moroianu Hill and forest glades (Fig. 12.7).

Comparing the plots where *A. altissima* was found with the spatial distribution of the PODISMOD classes indicated that 70 % of the mapped areas overlap the high and very high potential distribution, whereas approximately 5 % match with low and very low potential values (Fig. 12.8).

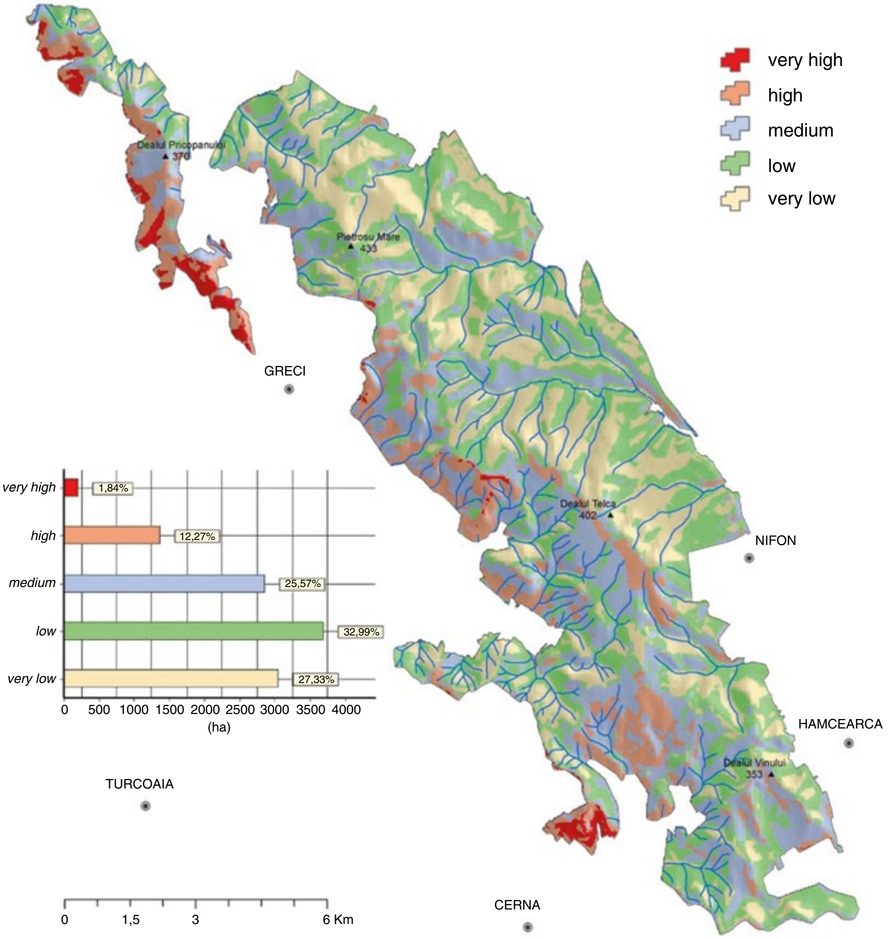

Fig. 12.7 PODISMOD of *A. altissima* in Măcin Mountains National Park

12.5 Conclusions

Relating the mapped areas of *A. altissima* to the habitat requirements of the species, in terms of natural and human-induced environmental conditions, allowed the authors to develop a spatial model that could identify areas with different distribution potentials. The overall PODISMOD analysis relies on spatial grid data, which had led to the generalisation of information, depending on the chosen pixel size. Hence, selection of the best resolution depending on the scale of the thematic maps considered (driving factors) and species mapping accuracy become the important

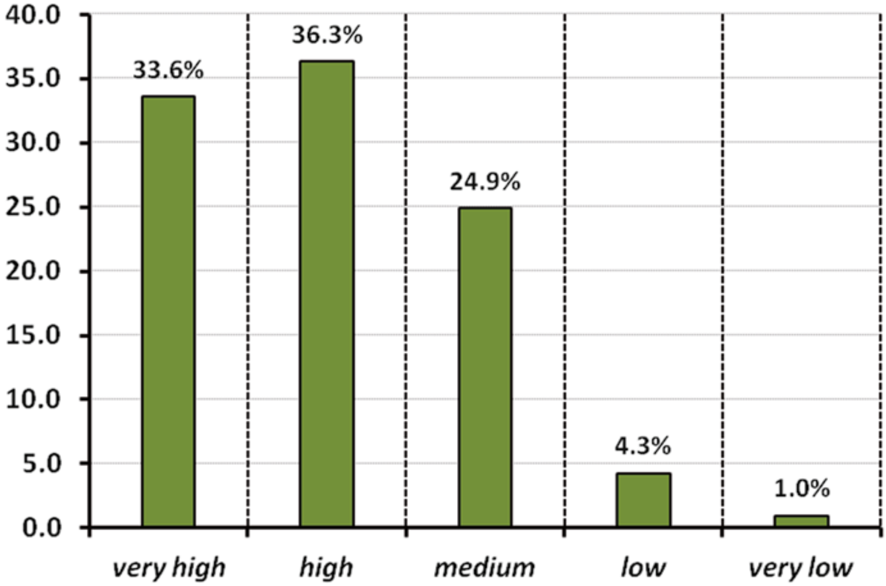

Fig. 12.8 Distribution of *A. altissima* (mapped areas) in relationship to PODISMOD

issues to be taken into consideration. Similar to other GIS-based methodologies, the current one can, to some extent, provide fairly accurate results, mostly in relationship to the scale and surveying year of the topographic maps used. Regarding the field surveys, in some cases accessibility is limited by the different local relief conditions or the lack or insufficiency of infrastructure. As a result, it is recommended to perform joint field campaigns with the personnel of protected areas (rangers, biologists, foresters) who have good knowledge of the local environment.

The final output of the current study will become an essential tool for decision makers in biodiversity conservation and invasive species monitoring, especially in protected areas.

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