Integrated methodology for the assessment of Invasive Terrestrial Plant Species potential distribution in the Romanian Protected Areas. A GIS-based approach.

GHEORGHE KUCSICSA
Institute of Geography, Romanian Academy, 12 Dimitrie Racoviţă Street, sector 2, 023993, Bucharest
ROMANIA

INES GRIGORESCU
Institute of Geography, Romanian Academy, 12 Dimitrie Racoviţă Street, sector 2, 023993, Bucharest
ROMANIA

MONICA DUMITRAŞCU
Institute of Geography, Romanian Academy, 12 Dimitrie Racoviţă Street, sector 2, 023993, Bucharest
ROMANIA
inesgrigorescu@yahoo.com http://www.geoinst.ro

Abstract: **-** Geographical Information Systems represent useful tools for the inventorying, monitoring and rapid assessment of Invasive Terrestrial Plant Species' (ITPS) spreading areas and potential distribution. The assessment of ITPS in protected areas has become a new and fundamental direction of research, especially while invasions have turned into real biological hazards for natural ecosystems, thus threatening biodiversity structure and functioning. Taking into consideration the increasing spreading potential of ITPS over the last years as well as the strong connection with their triggering environmental driving forces, even more prediction models arose, mainly focusing on: current and potential distribution, abundance, dynamics, potential impact on the environment and economy etc. Therefore, the current study proposes a geographical GIS-based assessment (potential distribution model) of some of the most important ITPS from the Romanian protected areas which ultimately, will provide valuable potential distribution maps for the analysed species.

Key-Words: - invasive terrestrial plant species (ITPS), potential distribution, GIS assessment, protected area, Romania

1 Introduction

Invasive Terrestrial Plant Species (ITPS) are considered by the *Convention* on *Biological Diversity* as "species and subspecies introduced outside their natural habitat, both past and present, from all taxonomic groups (gametes, seeds, eggs or propagules that might survive and later reproduce)".

Biological invasions are considered among the most critical ecological threats to natural habitats and biodiversity under the current global changes, due to their high adaptive capacity to wide ecological conditions and multiplication potential, thus enabling them to get through natural geographic barriers or political boundaries [1], [2], [3]. As a consequence, their continuous spread favoured their establishment over even larger areas in Europe causing significant and irreversible environmental and socio-economic damages [4], [5].

Relating ITPS with their driving forces of change is compulsory in understanding the causal relationships between them, and ultimately to be able to develop accurate and precise potential distribution models. Therefore, some large-scale geographical factors able to explain the role of environmental driving forces in the distribution of invasive species in some European countries were identified: ***climatic*** (mean annual precipitation, mean annual temperature, temperature amplitude), ***geographical*** (latitude, longitude and area) and ***economic*** (population density, Gross Domestic Product and roads density) [4]. At a smaller scale (e.g. for the Romanian territory) the authors propose as key environmental drivers responsible for the introduction and spread of the ITPS two main categories ***natural*** and ***human-induced*** regrouped into several subsequent smaller categories [6], [7] (Tab. 1).

Table 1. The main environmental driving forces responsible for the introduction and spread of the ITPS in the Romanian protected areas

Major driving forces		**Consequent driving forces**
NATURAL	soil	*soil type, texture*
	relief features	*altitude, slopes exposure, declivity etc.*
	vegetation	*dominant vegetation types, fragmentation*
	water bodies and wetlands	*lakes, rivers, ponds, marches*
	climate	*air/soil temperature, precipitation, air humidity, wind etc.*
	extreme events	*flooding, wind and snow felling, heavy rains*
HUMAN INDUCED	ITPS plantations	*ornamental, recreation, forestry*
	agricultural practices	*crop type, land abandonment, excessive fertilizers*
	forest exploitation	*deforestation, forest infrastructure etc.*
	grazing	*pastures and land degradation*
	urban development	*waste deposits, transport network(roads, railways etc.) etc.*

In Romania the first invasive plants species have been reported at the beginning of 18th century and ever since, additionally relevant information was regularly displayed in several studies, mainly having a systematic and floristic character.

Consequently, an increased number of invasive species were identified and mentioned in different scientific works or floristic lists which were synthesized in “Flora României” (1957-1972) and more recently in “Flora Ilustrată a României” (2000). Currently, the invasive flora of Romania includes over 400 species (13.87% of the Romanian flora) [8].

The assessment of biological invaders’ impact on native vegetation is essential, especially in natural protected areas, due to the sensitive ecosystems they shelter [6]. In the Romanian protected areas, some of the most damaging ITPS in terms of impacts on native flora, are the following: *Ailanthus altissima* (Mureş Floodplain Natural Park, Măcin Mountains National Park, Danube Delta Biosphere Reserve etc.), *Acer negundo* (Mureş Floodplain Natural Park), *Amorpha fruticosa* (Mureş Floodplain Natural Park, Danube Delta Biosphere Reserve, Comana Natural Park etc.), *Falopia japonica* and *Impatiens glandulifera* (Maramureş Mountains Natural Park) etc. [7], [9] (Fig. 1).

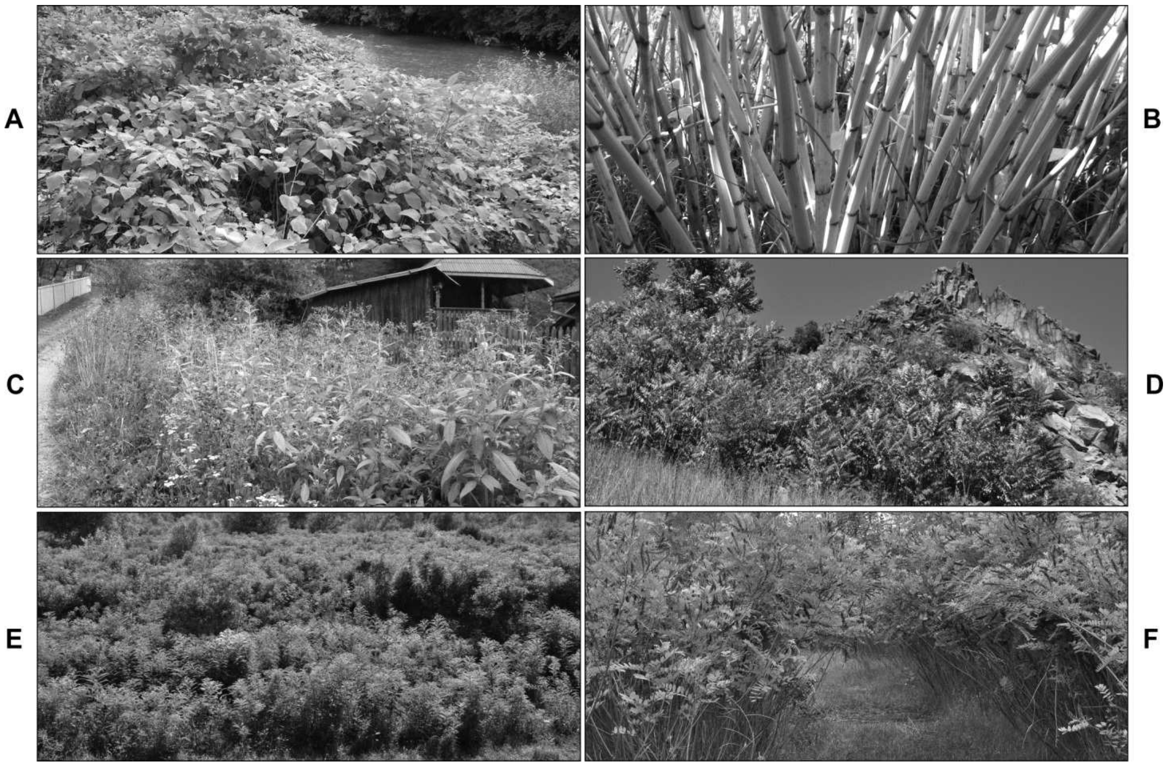

Fig.1. *Fallopia japonica* (A, B) and *Impatiens glandulifera* (C) in Maramureş Mountains Natural Park; *Ailanthus altissima* (D) in Măcin Mountains National Park; *Amorphafruticosa* in Mureş Floodplain Natural Park and Comana Natural Park

ISBN: 978-1-61804-167-8

Table 2. Ranking de key driving factors using Bivariate Analysis (e.g. relation between soil type and *Amorpha fruticosa* in the Mureş Floodplain Natural Park).
For the grid maps, the soil type map was reclassified in ten classes and Amorpha fruticosa distribution map in two classes (1 was assigned to the mapped areas and 0 for the rest of the areas).

SoilType * Amorpha Fruticosa	SoilType (reclass)	NPix	AmorphaFruticosa *1 = AF mapped*	Area	AreaAct	AreaSoilType	AreaMapTotal	AreaMapAct	DensClas	DensMap	Rank
1 * 0	1	265158	0	6628950.0	0.0	6664700.0	173541125.0	100148.0	0.0002	0.0006	**-1.0986**
1 * 1	1	1430	1	35750.0	1430.0	6664700.0	173541125.0	100148.0	0.0002	0.0006	**-1.0986**
2 * 0	2	503560	0	12589000.0	0.0	12595125.0	173541125.0	100148.0	0.0000	0.0006	**-1.7918**
2 * 1	2	245	1	6125.0	245.0	12595125.0	173541125.0	100148.0	0.0000	0.0006	**-1.7918**
3 * 0	3	132967	0	3324175.0	0.0	3406375.0	173541125.0	100148.0	0.0010	0.0006	**0.5108**
3 * 1	3	3288	1	82200.0	3288.0	3406375.0	173541125.0	100148.0	0.0010	0.0006	**0.5108**
4 * 0	4	75925	0	1898125.0	0.0	1898125.0	173541125.0	100148.0	0.0000	0.0006	**-1.7918**
5 * 0	5	3234035	0	80850875.0	0.0	82285550.0	173541125.0	100148.0	0.0007	0.0006	**0.1542**
5 * 1	5	57387	1	1434675.0	57387.0	82285550.0	173541125.0	100148.0	0.0007	0.0006	**0.1542**
6 * 0	6	48490	0	1212250.0	0.0	1212250.0	173541125.0	100148.0	0.0000	0.0006	**-1.7918**
7 * 0	7	2128944	0	53223600.0	0.0	54168550.0	173541125.0	100148.0	0.0007	0.0006	**0.1542**
7 * 1	7	37798	1	944950.0	37798.0	54168550.0	173541125.0	100148.0	0.0007	0.0006	**0.1542**
8 * 0	8	52212	0	1305300.0	0.0	1305300.0	173541125.0	100148.0	0.0000	0.0006	**-1.7918**
9 * 0	9	378085	0	9452125.0	0.0	9452125.0	173541125.0	100148.0	0.0000	0.0006	**-1.7918**
10 * 0	10	22121	0	553025.0	0.0	553025.0	173541125.0	100148.0	0.0000	0.0006	**-1.7918**

RANK = Ln (DensClas/DensMap)

Under the continuous expansion of ITPS, understanding their habitat requirements and relationships with the triggering driving forces had led to the development of various prediction models able to assess different aspects related to: actual and potential distribution, abundance, dynamics, potential impact on the environment and economy etc. Therefore, the current study is aiming to put forward a methodology for invasive species assessment in the Romanian protected areas, founded on a GIS-based geographical approach, in order to elaborate potential ITPS distribution maps.

2 GIS assessment of ITPS potential distribution in Romanian Protected Areas

2.1 ITPS mapping and database elaboration

The spatial information was edited, stored and processed in GIS environment. GIS tools can be helpful for summarizing large datasets for modeling habitat quality and distribution of invasive species [10]. ITPS mapping in the Romanian protected areas was carried out using topographical maps scale 1:25000 and othophotoplans, scale 1:5000.

At the same time, in order to achieve more accurate information, GPS (Global Positioning Systems) measurements were conducted, as well. For each protected area in which ITPS are considered a real threat, the authors computed key biological indicators (abundance, coverage, frequency) and collected soil samples with the aim to highlight the heavy metal (Zn, Cu, Kd, Mn, Pb, Hg etc.), humus and salts content, pH values etc., relevant in identifying the ecological conditions of species. The information was stored as polygon and point geo-data types. The polygon was used for the spatial representation of species with wider areal distribution in a certain area (e.g. *Fallopia japonica, Amorpha fruticosa, Ailanthus altissima*) while the point was used for displaying species with a spot-like spread (e.g. *Impatiens glandulifera*).

2.2 GIS model. PODISMOD–ITPS

ITPS-PODISMOD is a rather simple model to apply, thus seeking to assess the potential distribution of ITPS in relation to the particularities of the main ecological requirements of the specie in a certain area.

The focal aim is to identify similar ecological requirements of species in different habitat types (other than in the areas where the species was originally found) in order to assess the distribution potential in a certain region. The model is the result of grids intersection which represents driving factors and selected ITPS.

Table 3. The *w* (weigh) values assigned to the key drivers of *Amorpha fruticosa* in the Comana Natural Park

Driving forces	Soil type	Soil texture	Wetlands buffer	Land use/land cover	Temporary steams buffer	Railway buffer	Main roads buffer	Slopes exposure
weigh	3	3	2	2	2	2	2	1

ISBN: 978-1-61804-167-8

2.2.1 Thematic maps for driving factors

Depending on ITPS ecological conditions the main driving forces were selected and analysed. Besides the general thematic maps taken into consideration for this investigation (soils, climatic parameters, land use etc.), the Digital Elevation Model (DEM – 30 m resolution) was considered, as well. The latter constitutes its self into essential information in ITPS assessment, out of which layers regarding local relief particularities were generated (hypsometry, slope declivity and slope exposure). Therewith, in the case of some ITPS the distance to certain driving factors is critical.

For instance, in the Comana Natural Park, due to specie's preference for disturbed areas, a direct relationship between *Amorfa fruticosa* and transport infrastructure (especially rail road) was noticed. In the same way, in the Maramureş Mountains Natural Park, the authors noted that *Falopiei japonica*'s abundance is increasingly higher in the proximity of the rivers network. For that reason, around the driving factors (lines, polygons) which were considered significant for the spread of the ITPS were created buffers.

2.2.2 Ranking the key driving factors by significance

The rank *(R)* of each key driving factor was made using the bivariate analysis. The bivariate analysis is one of the simplest forms of the quantitative statistical analysis which takes into consideration the relationship between two variables, in our case between the ITPS (dependent variable) and its driving factors (independents variables).

For example: the relationship between ITPS and soil texture, between ITPS and slope exposure, between ITPS and land use etc. The result is given by the relationship between the (mapped) surface covered with ITPS and the analysed driving factor.

In Table 2 is exemplified the bivariat analysis between *Amorpha fruticosa* and one of its key driving forces (Soil type). The final values (ranks) have derived from the extraction of the natural logarithm (Ln) from DensClas (species' weight on each soil type) and DensMap (species' weight on the total analysed surface). The natural logarithm is used in order to make a distinction between values: the negative ones are the result of a lower weight against the mean value and the positive ones point to a higher weight against the mean values.

Assigning the weight (W). Not all identified driving factors can be categorized as having equal weight in ITPS distribution. For example, in the Maramureş Mountains Natural Park, the authors have noticed the high dependency of species *Fallopia japonica* on the alluvial soils located in the river floodplains (thus, indirectly, on the river network), which explains the increased tolerance to slope's exposure. Therewith, in the Comana Natural Park and Mureş Floodplain Natural Park, it was observed that *Amorpha fruticosa* is conditioned in a larger extent by the vicinity of water bodies and in a smallest extent by the relief particularities.

As a result, driving forces' classification based on weigh (w) assignment is essential. This relays both on expert judgement attribution based on specialists knowledge and expertise (biogeographers, climatologists, soil scientists etc.) and 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 ITPS distribution. For example, in Tab. 3 are represented the weight (w) of eight selected driving forces of *Amorpha fruticosa* in the Comana Natural Park.

The final index was computed according to the following mathematical operation (1):

$$(1) \qquad \mathbf{F1}_{wr} + \mathbf{F2}_{wr} + \mathbf{F3}_{wr} \ldots\ldots \mathbf{Fn}_{wr}$$

where: r = rank (resulting by bivariate analysis); w = weigh *(1…3);* F1, F2, F3 … Fn = selected driving factors.

Therefore, an example of a final map is presented in Fig. 2, where PODISMOD values are classified in five classes: very high, high, medium, low and very low.

ISBN: 978-1-61804-167-8

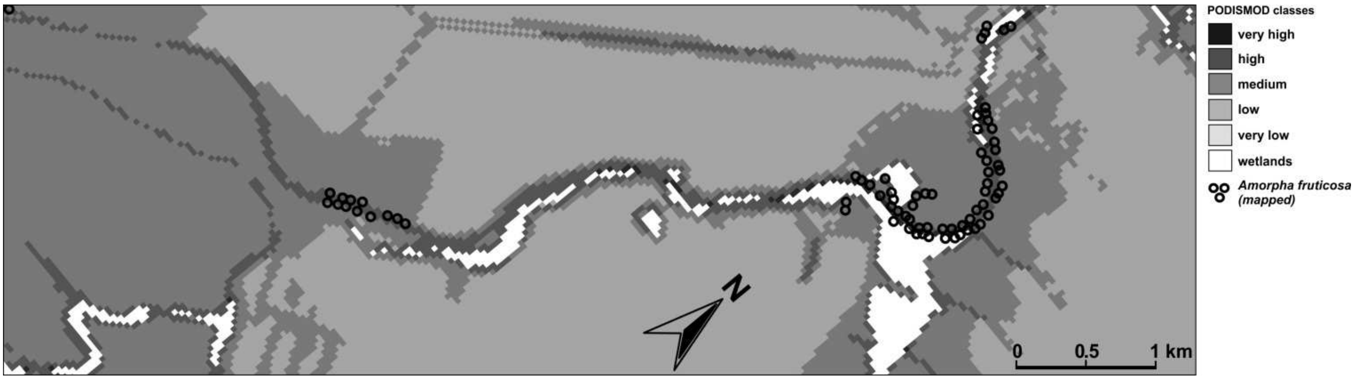

Fig. 2. PODISMOD –*Amorpha fruticosa* in Comana Natural Park (map sample)

4 Conclusion and discussions

The assessment of ITPS in the Romanian protected areas is an important research direction especially since the adventive species have become biological hazards with negative effects, especially on biodiversity.

In this respect, applying an accurate methodology for assessing the spatial potential distribution of invasive species is particularly useful in order to find best measures to eliminate or prevent ITPS as well as including them in the management plans of protected areas.

Just like any methodology used, this one can provide relative results, as well. Primarily due to the mapping accuracy because of the topographic maps used. Then, due to the GPS measurements, in some cases, which are limited because of the low accessibility of areas covered with ITPS (e.g. species located in swamps or crops). In this case a potential solution would be to use the latest orthophotoplans for more correct mapping.

Another problem could be the inability of mapping all areas covered by ITPS. Since protected areas occupy large areas and different relief forms, the accessibility is often limited (local relief conditions, infrastructure etc.). In this case the best solution would be to work together with protected areas' personnel (rangers, biologists, foresters) given that they provide a good knowledge of the terrain.

The PODISMOD analysis is using spatial data grid which can lead to the generalisation of information, depending on the pixel size chosen. In this respect, it is important to take into account the selection of the best resolution depending on the scale of the thematic maps used (driving factors) and the ITPS mapping accuracy. Additionally, the classification of the driving factors, for assigning proper weight and number of classes used, depend on the knowledge and expertise of scientists involved in the PODISMOD assessment.

Acknowledgements

The entire study is developed in the framework of the **FP7 – Building Capacity for Black Sea Catchments Observation and Assessment System supporting Sustainable Development (EnviroGRIDS)**; http://www.envirogrids.net/.

References:

[1] Richardson D.M., Pysek P., Rejmánek M., Barbour M.G., Panetta F.D. and West C.J., Naturalization and invasion of alien plants: concepts and definitions, *Diversity and Distributions*, 6, 93-107, 2000.

[2] Anastasiu P., Negrean G., Başnou C., Sîrbu C. and Oprea A., A preliminary study on the neophytes of wetlands in Romania, *Neobiota. Biological Invasions – from Ecology to Conservation*, vol. **7**, 181-191, 2008.

[3] Andreu J., Vila M., Risk analysis of potential invasive plants in Spain, *Journal for Nature Conservation*, 18, 2010.

[4] Lambdon, PW, Pysek P., Basnou C., Arianoutsou M., Essl F., Hejda M., Jarosik V., Pergl J., Winter M., Anastasiu P., et al., Alien flora of Europe: species diversity, temporal trends, geographical patterns and research needs, *Preslia*, **80 (2)**, 101-149, 2008.

[5] Dumitraşcu M., Grigorescu I., Năstase M., Dragotă C.S., Kucsicsa Gh., The main environmental driving forces of the invasive plant species in the Romanian protected areas, *Procedeengs of BALWOIS Conference on Water Observation and Information Systems for Decision Support*, Ohrid, Macedonia (online), 2010.

[6] Dumitraşcu M, Kucsicsa Gh., Grigorescu I, Dragotă C, Năstase M, Iuşan C, Potential spread of invasive plant species in Romanian protected areas. Case-studies: Comana Natural

Park and Rodna Mountains National Park, *3rd International Symposium on Environmental Weeds and Invasive Plants*. Abstracts, Birmensdorf, Swiss Federal Institute for Forest, Snow and Landscape Research WSL, 2011.

[7] Dumitraşcu M, Grigorescu I, Kucsicsa Gh, Dragotă C, Năstase M**,** Non-native and native invasive terrestrial plant species in Comana Natural Park. Case-studies: Amorpha fruticosa and Crategus monogyna, *Romanian Journal of Geography*, vol. 55 (2), pp. 81-89, 2011, http://www.rjgeo.ro/atasuri/revue%20roumaine_55_2/Dumitrascu%20et%20al.pdf

[8] Anastasiu P., Negrean G., Alien plants in Romania, *Analele ştiinţifice ale Universităţii "Alexandru Ioan Cuza" din Iaşi*, Tomul LI, Biologie vegetală, 2005.

[9] Dumitraşcu M, Kucsicsa Gh, Grigorescu I, Dragotă C, Năstase M, Invasive terrestrial plant species in the Romanian protected areas. Case study: Fallopia japonica in Maramureş Mountains Natural Park, *Geographical Phorum*, XI (1), pp. 45-53, 2012, doi:10.5775/fg.2067-4635.2012.031.i.

[10] Holcombe T., Stohlgren T., Jarnevich C., Invasive species management and research using GIS, *Managing Vertebrate Invasive Species: Proceedings of an International Symposium*, National Wildlife Research Center, Fort Collins, 2007.