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Rapid GIS-Based Model for Vulnerability Assessment of Medicinal Plants: a Case Study of the Varna District (North-Eastern Bulgaria)

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***Abstract*—Wild medicinal and aromatic plants represent renewable natural resources and a valuable product for Bulgaria's export. Despite the appropriate regulatory framework, there is unregulated overharvesting of medicinal plants, such as collection of plants in non-permitted quantities and collection of plants included in prohibited lists. These illegal practices in combination with the negative anthropogenic impact, lead to a cumulative negative effect on natural habitats. In accordance with the Bulgarian strategy for sustainable use of biological resources, studying, assessment, and monitoring of the natural distribution, abundance, structure, and dynamics of the wild populations are required. In order to obtain correct quantitative data, it is necessary to carry out long-term studies, especially on the effect of overexploitation. Constantly changing demand and market trends for quantities and types of medicinal plants, as well as changing negative anthropogenic factors, requires establishment of dynamic models for rapid vulnerability assessment of wild medicinal and aromatic plants. The aim of the present study is to present and discuss some theoretical aspects of Rapid Model for Vulnerability Assessment of Medicinal Plants (RMVAMP) as well as model validation in case study of the Varna District (Noth-eastern Bulgaria). This model is based on explicit criteria and on a weighted value scheme for scoring each taxon, rather than intuitive interpretation of experts in conventional assessments. Unlike other rapid methods, which predicts vulnerability of plants to overharvesting, RMVAMP assesses more aspects and critical factors which directly affect the target medicinal species. Cumulative weighted values were incorporated in GIS environment. The natural habitats in the Varna District were categorised into classes of vulnerability and were indicated on the created map using color scale. The natural habitats of herbs that should be restricted were defined.**

Keywords*— Medicinal Plants, North-Eastern Bulgaria Varna District, Vulnerability Assessment.

I. Introduction

Wild medicinal and aromatic plants represent an important component of biodiversity and renewable natural resources as well as a valuable product for Bulgaria's export [1], [2]. In recent decades, there has been an increase in the quantities of medicinal plants collected for export by herbalists, in contrast with the decreasing quantities collected for personal use. The growing need for raw materials for the pharmaceutical and cosmetic industries, and the desire for quick profits, are leading to pressure to increase the quantities collected. Despite the appropriate legal and regulatory framework, there is unregulated overharvesting of medicinal plants, such as collection of plants in non-permitted quantities or collection of plants included in prohibited lists [3]. These illegal practices in combination with the negative anthropogenic impact, lead to a cumulative negative effect on natural habitats [2], [3]. In accordance with scientific theoretical approaches [4], [5], the Bulgarian strategy for sustainable use of biological resources, studying, assessment, and monitoring of the natural distribution, abundance, structure, and dynamics of the wild populations are required [6]. In order to obtain correct quantitative data, it is necessary to carry out long-term studies, especially on the effect of overexploitation [7]. Constantly changing demand and market trends for quantities and types of medicinal plants, as well as changing negative anthropogenic factors, requires establishment of dynamic models for rapid vulnerability assessment of wild medicinal and aromatic plants [3].

One of the most used tools for assessment of the extent of existing and potential threats to the medicinal plants is Rapid Vulnerability Assessment (RVA) [8] - [11]. The RVA was tested, validated, and modified in series of studies, e. g. [1], [3], [12], [13].

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The need to assess not only individual medicinal plant species, but also their communities, habitats, and areas to which attention should be paid requires development of approaches consisting of evaluation systems. Unlike the classical models for conservation significance, they are based on cumulative criterion schemes for identification and prioritization of conservation territories with medicinal plants [3], [6].

Clearly and precisely formulated evaluation criteria of the assessments are reliable base for developing GIS-based models, which comprise dynamic geographical maps of habitats with assessment scale and associated numerous data sets [14].

The aim of the present study is to present and discuss some theoretical aspects of Rapid Model for Vulnerability Assessment of Medicinal Plants (RMVAMP) as well as model validation in case study of the Varna District (Noth-eastern Bulgaria). The natural habitats in the Varna District were categorised into classes of vulnerability and were indicated on the created map using color scale. The natural habitats of herbs that should be restricted were defined.

II. Material and Methods

Varna District comprises 12 municipalities with 3819.5 km^2, distributed as follows: forests - 27.8%, arable lands - 59.6%, grasslands – 5,4%, and urban zones - 7.2%. The climate inland is moderate temperate, and similar to Mediterranean climate along the Black Sea coast, with milder winters and cooler summers [15].

The studies of the spatial distribution of the plant communities were based on literature data of the distribution of plant species in the study area [14], [16], [17], [18] and were detailed and refined with data from field observations and remote sensing during the vegetation periods from 2018 to 2024 yr.

Conservation status, as well as endemics and relics were determined after [17], [19].

A regional plant species assessment scheme based on the Rapid Vulnerability Assessment [8] - [11] and concept of plant biodiversity hotspots [6], [14], [20], [21] was used. The summarized scheme modified after Vergiev [6], based on 2 groups of criteria, that comprise the distribution and conservation status of plant taxa, as well as socioeconomic criteria is presented in Table 1. In order to evaluate the vulnerability of each species, ten criteria were used. Each of the predictors has a score assignation where 0 is not applicable, 1 indicating low vulnerability, and other scores indicating ascending order of high vulnerability.

International conservation status criterion is evaluated by Annexes II and V to Council Directive 92/43 / EEC on the conservation of natural habitats and of wild fauna and flora; Annex I to the Convention on the Conservation of European Wildlife and Natural Habitats (Berne Convention), Annex II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

TABLE 1 SUMMARY SCHEME OF CRITERIA FOR THE ASSESSMENT OF PLANT TAXA MODIFIED AFTER [6], [13], [22].

Code	**Criterion**	
	Predictors	*Score*
C1	Presence and distribution of the species in floristic regions and subregions of Bulgaria	
	Only in the study region	5
	From 2 to 15 regions	1
	From 16 to 29 regions	0
C2	Criteria of population fragmentation	
	Highly fragmented	5
	Low fragmented	3
	Unfragmented	0
C3	Criterion "National conservation status" (Included in the Bulgarian Biological Diversity Act)	
	Included in Annex 2	3
	Included in Annex 3	3
	Included in Annex 4	2
	Not included	0
C4	Red Data Book Criterion	
	CR Critically Endangere	4
	EN Endangered	3
	VU Vulnerable	2
	NT Nearly Endangered	1
	LC Low Affected	0
	DD/NE, Insufficient Data, Not Rated	0
	N/A	0
C5	Endemics and Relics	
	Endemic to Bulgaria	5
	Endemic to Bolcan Peninsula	3
	Relics	2
	N/A	0
C6	International conservation status criterion	
	IUCN	2
	Directive 92/43/EEC	2
	Berne Convention	2
	CITES	2
	N/A	0
C7	Plant parts used	
	Whole plants	4
	Roots, Rhizome	3
	Flower, Seed, and Inflorescence	2
	Leaves	1
C8	Resource origin	
	Only from cultivation	4
	Wild and small-scale cultivation	3
	Wild and trial cultivation	2
	Only from wild	1
C9	User group	
	Local people	4
	Local people and Local exchange	3
	Local people and trade	2
	Local people, local exchange and trade	1
C10	Life forms	
	Long lived perennial	4
	Short lived perennial	3
	Biennial	2
	Annual	1

The evaluation of each individual taxon was obtained as the sum of the points of each of the criteria, after applying the relevant coefficients of significance of the criterion according to the formula:

$$Ai = 0.5xC1i + 0.5xC2i + 1.25xC3i + 1xC4i + 1.25xC5i + 1.5xC6i + 2xC7i + 0.5xC8i + 0.5xC9i + 2xC8i \quad (1)$$

where,

A*i* - general assessment of the taxon *i*

*C*1*i* - *C*610*i* - estimates by criteria C1 to C10 for taxon *i*.

A dynamic GIS-based model was built and applied using the Model Builder module of ArcView Spatial Analyst (ArcGIS v.10.0 ESRI Inc.). The study area was separated into grid cells (2500 m ×2500 m). The general assessment of each cell was calculated according to the formula:

$$E = \frac{\sum_{k=1}^{n} An}{n} \quad (2)$$

where,

E - general assessment of the territory

A - assessment of each individual taxon

n - total number of assessed taxa in the territory.

When drawing the maps, the following were used: UTM Zone 35 North map projection, WGS84 terrestrial coordinate system and the Baltic altitude system. The collected field and remote sensing data were organized in attribute tables and assigned to the layers in vector format using relational classes in a GIS environment using base maps and Digital Terrain Model (DTM).

III. Results and Discussion

The approach Rapid Vulnerability Assessment is based on the understanding that a relatively small set of factors has a disproportionate impact on the likelihood that a medicinal plant species will be used in a sustainable manner [8] - [11]. The assessment is calculated by summing the points of an average of 5 – 7 predictors. Organized in this way, the assessment provides information about species that are threatened by overexploitation easily and quickly. However, it is often necessary to make a comprehensive assessment of a certain area, and not just of individual species. In such cases, the simple sum of the species estimates does not provide reliable information, and the model needs to be upgraded.

Unlike other rapid methods, which predicts vulnerability of plants to overharvesting, Rapid Model for Vulnerability Assessment of Medicinal Plants assesses more aspects and critical factors which directly affect the targeted medicinal species in certain area.

The predictors are divided into two groups of criteria. The first group represents ecological criteria such as distribution and conservation status of the species. Distribution is predicted by presence of each species in one or more floristic regions and subregions of Bulgaria. The main hypothesis is that widely distributed species are less vulnerable than narrowly distributed species [13]. Predictor of population fragmentation shows the possibility of population recovery. In the case of high fragmentation, the species will be more vulnerable. Conservation status is assessed by four criteria for international and Bulgarian status. Cumulative assignment in more conservation categories define species as more vulnerable.

The second group represents socioeconomic status of the species. The predictors "Used parts" and "Life forms of the plants" are based on the idea that leaves harvesting is less vulnerable than those of roots, rhizome and whole plant [13]. Harvesting of the plants from only wild population is more vulnerable, as well as species with many user groups are more vulnerable than single user group [13], [22].

The assessment is based on an adequate inventory of the flora the study area. For this purpose, a list of flora was prepared based on literature data, as well as unpublished own studies.

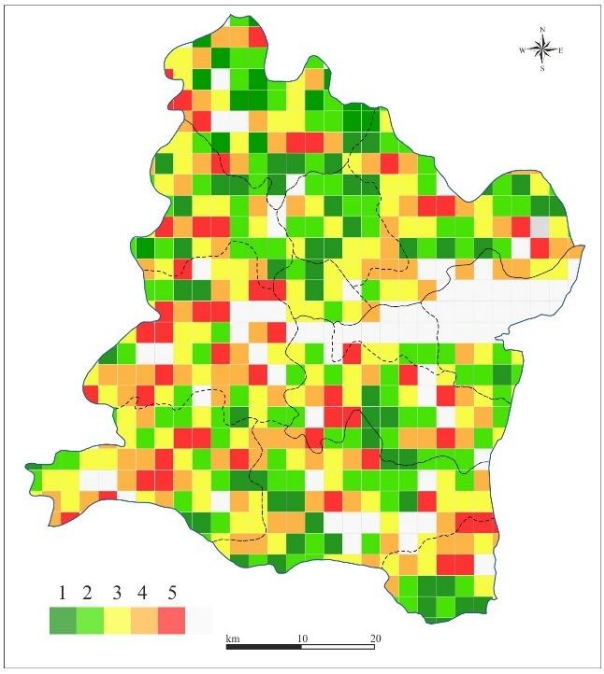

Fig. 1. Vulnerability assessment of medicinal plants. From 1 – non vulnerable to 5 – highly vulnerable. White cells represents urbanised teritories.

The established total number of plant species found in the region was 938. 467 of them were recognized as medical and aromatic plants and were assessed.

Although the model is aimed at identifying the vulnerability of individual locations, it can also be applied to identify the vulnerability of individual species. As a

result of the analysis, the following groups of medicinal plants can be identified:

1) Vulnerable species: *Frangula alnus* Mill., *Sedum acre* L. *Artemisia alba* Turra; *Galium odoratum* (L.) Scop.; *Echinops sphaerocephalus* L.; *Asarum europaeum* L.; *Galanthus nivalis* L.; *Helichrysum arenarium* (L.) Moench; *Valeriana officinalis* L.; *Glaucium flavum* Crantz; *Convallaria majalis* L.; *Cercis siliquastrum* L.; *Lilium martagon* L.;

2) Highly vulnerable species: *Paeonia peregrina* Mill.; *Primula veris* L.; *Carlina acanthifolia* All.; *Berberis vulgaris* L.; *Alchemilla vulgaris* L. ; *Leucojum aestivum* L.; *Ruscus aculeatus* L.; *Orchis morio* L.; *Orchis purpurea* Huds.; *Orchis simia* L.; *Cyclamen coum* Mill.; *Artemisia lerchiana* Weber; *Asparagus officinalis* L.; *Ephedra distachya* L.; *Platanthera bifolia* (L.) L. C. Rich.; *Ruta graveolens* L.

Cumulative weighted values were incorporated in GIS environment. The natural habitats in the Varna District were categorised into classes of vulnerability and were indicated on the created map using colour scale (Fig. 1).

Applying the constructed model and as a result of the "overlay" analysis, all values within the areas of overlap of the polygons were summarized and 37 zones of high vulnerability were identified.

The identification of areas with a degree of vulnerability is only the first step in a long and tough process of protecting the habitats of medicinal and aromatic plants.

Our role as scientists is to investigate and to analyze, followed by prioritizing and using limited resources for the protection of medicinal plants. This should be accompanied by the implementation of the entire set of regulatory documents and punitive instruments for the preservation of natural habitats.

In my opinion, educational initiatives are also extremely important to inform about the available medicinal plants in each area, along with small projects for the protection and expansion of habitats.

IV. Conclusions

This study presents analysis of theoretical aspects of Rapid Model for Vulnerability Assessment of Medicinal Plants (RMVAMP). The factors that contribute to the vulnerability of medical and aromatic plants are based on two groups: ecological criteria and socioeconomic criteria. Cumulative assignment in more predictors defines species as more vulnerable.

The established total number of plant species found in the region was 938. 467 of them were recognized as medical and aromatic plants and were assessed.

Cumulative weighted values were incorporated in GIS environment. The natural habitats in the Varna District were categorised into classes of vulnerability and were indicated on map using colour scale.

Applying the constructed model and as a result of the "overlay" analysis, all values within the areas of overlap of the polygons were summarized and 37 zones of high vulnerability were identified. The natural habitats of herbs that should be restricted were defined.

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