



Development of an electronic questionnaire for field studies of invasive plant species in the Carpathian National Nature Park

Petro Nasadiuk*

Postgraduate Student
Ivan Franko National University of Lviv
79005, 4 Hrushevskiyi Str., Lviv, Ukraine
<https://orcid.org/0009-0008-8189-4945>

Zvenyslava Mamchur

PhD in Biological Sciences, Associate Professor
Ivan Franko National University of Lviv
79005, 4 Hrushevskiyi Str., Lviv, Ukraine
<https://orcid.org/0000-0003-0527-5639>

Oksana Tymchuk

Scientist
Carpathian National Nature Park
78500, 6 Stus Str., Yaremche, Ukraine
<https://orcid.org/0009-0000-4728-9401>

Abstract. The relevance of the study was conditioned by the need for standardised, reproducible, and geospatially linked monitoring of invasive alien plant species in the complex mountain landscapes of the Carpathian National Nature Park, where the combination of high-altitude zoning, diversity of habitats, and natural and anthropogenic distribution corridors creates increased risks of their naturalisation and expansion. The purpose of the study was to create a standardised questionnaire to unify the process of recording data on invasive species, ensure correct geospatial binding of observations, and establish prerequisites for their further spatial analysis in the ArcGIS environment. The survey form, developed in ArcGIS Survey123, covered a wide range of ecological, biological, and abiotic parameters, including data on the taxonomic affiliation of the species, projective coverage, ontogenetic state of the population, soil characteristics, microclimatic indicators, and the level of anthropogenic impact. The proposed approach allowed improving the accuracy of monitoring invasive species and integrating the data obtained into national observation databases. The design of the questionnaire was based on the principles of maximum compatibility, followed by analysis in a geographic information system and publication in global biodiversity repositories. This approach opened up the possibility of comparative analysis, merging with citizen observations, and using data to assess risks and prioritise invasion responses. Methodically, the questionnaire covered 8 logical sections: (1) general information and geolinking; (2) description of the site with classes of ecosystem types in accordance with contemporary global typology; (3) characteristics of the population of an invasive species, including area, density, age structure, dynamics; (4) ontogenetic spectrum with quantitative accounting by stage; (5) soil and microclimatic indicators with the possibility of field determination of acidity and humidity; (6) threats and damage to plants and ecosystems; (7) soil litter as a potential seed bank; (8) additional comments

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*Corresponding author





and photo documentation. It provided for collecting photos from different angles, uploading them with spatial reference to records, and forming a complete digital footprint for further quality audit

Keywords: phytoinvasions; monitoring; alien species biota; habitats; biodiversity; ecosystems; nature reserve fund

INTRODUCTION

Invasive alien plant species (IAPS) are one of the key factors for biodiversity loss and ecosystem disruption, which necessitates their early detection, systematic monitoring, and coordinated management, particularly at the level of protected areas (IUCN, 2020). Invasive species can significantly transform the structure of natural communities, displace native flora, disrupt biogeochemical cycles and trophic relationships, and reduce the ecological stability of biocoenoses. As noted by P.P. Nasadiuk & Z.I. Mamchur (2025), in the European policy and management context, the invasion response framework is supported by taxon lists and prevention, early detection, and management procedures, further highlighting the importance of standardised primary data. For mountain ecosystems of the Carpathians, the urgency of the problem is compounded by the mosaic of high-altitude belts, the variety of habitat types, and recreational load, which forms multidirectional vectors of IAPS propagation along linear corridors (roads, trails, river valleys), as emphasised by L.A. Santoianni *et al.* (2024). The study by M. Renčo *et al.* (2024) showed that roadsides and hiking trails act as important linear corridors for the distribution of atypical, in particular, invasive flora elements in natural ecosystems. Violation of the soil cover, changes in the microclimate, increased illumination and regular anthropogenic impact create favourable conditions for the penetration, consolidation, and further spread of alien species, which can lead to transformation of the species composition of plant communities and changes in the structure of local biocoenoses.

K. Najberek *et al.* (2024) noted that mountain roads act as key corridors for the spread of invasive plants, as soil disturbances and other anthropogenic factors near roads significantly increase the likelihood of alien species appearing. It was found that their distribution is most often associated with warm, well-lit and disturbed ecosystems, while natural communities far from roads have higher resistance to invasion. Analysis by P.K. Rai & J.S. Singh (2020) focuses on

the environmental, socio-economic, and medical implications of the spread of invasive alien plant species. The researchers found that such species significantly alter the structure of ecosystems, reduce biodiversity, disrupt ecosystem services, and can pose risks to human health, highlighting the need for integrated approaches to their monitoring and management. For the Carpathian region, one of the illustrative examples is the influence of *Impatiens parviflora* in beech forests. For the territory of the Carpathian National Nature Park (CNNP), the issue of detection and control of invasive species is of particular importance, given its importance for the preservation of natural ecosystems, the protection of rare, relict, and endemic plant species, and for the tourist attractiveness of the territory and the high number of visitors throughout the year (Danko *et al.*, 2024). Despite the high scientific value of this territory, information on the distribution of IAPS within the CNNP remains limited and fragmented.

As emphasised by E.M. Geurts *et al.* (2023) and P.P. Nasadiuk & Z.I. Mamchur (2025), the available open observation platforms (in particular GBIF, iNaturalist, UkrBIN) provide an important array of data, but in mountainous areas there are often spatial gaps and heterogeneity of collection protocols, which makes it difficult to compare and use records in application management. This, in turn, creates the basis for population analysis of time series construction and dynamic modelling (subject to long-term surveys), including assessment of ecosystem characteristics, quantitative assessment of the effects of invasive transformer species and indication of changes in the provision and maintenance of ecosystem services. In turn, R. Montagnetti & G. Guarino (2021) described the benefits of using the QField mobile application for field geo-linked data collection, in particular, that it allows transferring projects from desktop GIS (QGIS) to Android devices, significantly reducing the time and cost of data entry, eliminating the need for paper documentation, and providing efficient digital registration and analysis of spatial



information directly in the field. As noted by M. Silva del Pozo *et al.* (2023), the development of a digital questionnaire that combines standardised field protocols with a geographic information system (GIS) and a GIS-oriented data structure and the ability to publish in open repositories is a prerequisite for effective monitoring and adaptive management of bioinvasions. The purpose of the study was to develop and substantiate a GIS-oriented digital questionnaire for monitoring invasive plants in CNNP with the integration of geoanalysis and the preparation of data for open exchange.

MATERIALS AND METHODS

The questionnaire “Populations – field study of invasive plants on the territory of CNNP” was designed specifically for the conditions of the CNNP, taking into consideration orography, slope exposures, altitude zones, and a set of habitats characteristic of the park territory. The terminology of relief elements (ridge, slope, foothill, hollow, scree, terrace, shoreline), and soils and habitats was established based on generalised data on abiotic conditions and nature chronicles of the park, in particular, R.L. Kravchynskyi *et al.* (2025) and Carpathian National Nature Park (n.d.). The standardised design of the questionnaire combined population indicators (density, generativity, age structure, if necessary – vital elements) with a phytocoenotic context (Braun-Blanquet tiering and coverage) and related abiotic characteristics (soil, microclimate, habitat type). The development of the questionnaire was based on methodological recommendations for field research developed by the Ivan Franko Lviv National University and supplemented with author’s thematic blocks. The questionnaire was implemented in the ArcGIS Survey123 environment, which is one of the ArcGIS Pro products as a mobile form with the ability to collect and then synchronise data offline. The design of the field structure, their binding nature, and response types was carried out in accordance with the recommendations of the platform for creating questionnaires and managing geo-linking/media data – ArcGIS Survey123 (n.d.). The choice of Survey123 was conditioned by full compatibility with GISenvironment: export of data to tabular formats (CSV/Excel), file geobases, and Feature Layer, followed by analysis and mapping in ArcGIS Pro (with the connection of background

layers, digital terrain models, cadastral and thematic layers). The form contained 9 sections:

1. General data: executor, date/time (automatically).

2. Site description: Site description included geomorphological and microrelief features, exposure, steepness, altitude, and classification of the ecosystem type. For the typification of ecosystems, consistent classes were used, correlated with the functional typology of Earth ecosystems in accordance with D.A. Keith *et al.* (2022). The size of the accounting (model) area was set by a discrete set of standard sizes, which was consistent with approaches to choosing the size of test areas in European phytosociological practice, in particular by M. Chytrý & Z. Otýpková (2003). The spatial boundaries of the “study area” were fixed by a polygon or point on the map, which corresponded to detailed mapping approaches for studying the structure of populations and the spatial grouping organisation by M.B. Gaponenko & A.M. Gnatiuk (2013).

3. Population characteristics: taxon (Lat./Eng.), the degree of invasiveness, including the “transformer” category (according to V.V. Protopova & M.V. Shevera (2019)), habitat area, density within the model plot, age structure, presence of generative individuals, assessment of dynamics during repeated visits. The methodological basis for the establishment of these blocks was made up of recommendations on population ecology and methodology for studying plant populations by O.S. Abduloieva & N.I. Karpenko (2012), L. Zaviolova (2019), V. Kyyak & A. Malynovsky (2020).

4. Ontogenetic spectrum: quantitative accounting by stage s , p , j , im , v , $g1-g3$, ss , s , allowed assessing the progression of invasion, interpreting the life state of the population, its recovery, and potential expansion trajectory. If necessary, it is possible to use an algorithm for assessing the vitality of individuals and the vitality structure of populations. The combination of the ontogenetic spectrum with vital approaches provides a transition from a static “section” to a dynamic assessment of population processes.

5. Coverage and phytocoenotic context assessment: the Braun-Blanquet coverage scale with separate sub-blocks for tree, shrub, grass, moss-lichen tiers and the proportion of areas without vegetation was used to assess the participation of

invasive species and vertical vegetation structure. The field application of the scale was consistent with the standard Braun-Blanquet operating procedure and contemporary approaches to its interpretation by I.V. Prystupa (2017), Realising dynamic value... (2021). Accounting for coverage by Braun-Blanquet for different tiers of vegetation allowed transferring the results to the plane of phytosociological descriptions and comparing them between locations and seasons.

6. Soil and microclimatic parameters: soil type, field humidity (touch test/instrument), pH, soil and air temperature, illumination, fertility indicators, sampling methods and measurement accuracy requirements were consistent with the guidelines for harmonised soil monitoring and field description by N. Cools & B. De Vos (2020).

7. Threats and damage: erosion, flooding, fires, windbreaks, grazing, recreational load, forestry activities, etc. – in the logic of the link “disturbance factors → habitat vulnerability”, considering the role of linear corridors and attendance in the spread of IAPS. The list of threats was checked against local sources of CNNP and for zoning vulnerabilities in habitats, including R.L. Kravchynskiy *et al.* (2025) and Carpathian National Nature Park (n.d.). The IAPS risk assessment was provided in accordance with the guidelines of Order of the Ministry of Environmental Protection and Natural Resources of Ukraine No. 290 (2024) and Environmental Impact Classification for Alien Taxa (EICAT) IUCN (2020).

8. Soil litter: thickness, composition, degree of decomposition, humidity, presence of seedlings/seeds of IAPS. The block was critical for transformer species that modify phytocoenoses through seed banks and changes in fuel load; methodological guidelines – International Co-Operational Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests, n.d.) and field guidelines for soil description, and classification of high activity of invasive species, in particular by H.E. Roy *et al.* (2024).

9. Additional comments/media to clarify the context of the post.

The spatial boundaries of the study area were fixed by a polygon on the map; model areas were defined by discrete dimensions (0.5×0.5 ; 1×1 ; 2×2 ; 5×5 ; 10×10 m), which corresponds to the practice of European phytosociological studies

by J. DánielFerreira *et al.* (2024) and M. Chytrý & Z. Otýpková (2003). For linear sections (roadsides/trails, river valleys), the route bypass was combined with detailed cell mapping, according to the method of spatial analysis of populations by M.B. Gaponenko & A.M. Gnatiuk (2013). The inclusion of corridor habitats was supported by empirical data on the role of infrastructure in the spread of IAPS provided by M. Jurišić *et al.* (2023) and J. DánielFerreira *et al.* (2024). There were: mandatory fields for key attributes; questions with standardised answer options; photo recording from different angles; automatic recording of coordinates/altitude/time; export to tables and GISlayers for further analysis in ArcGIS Pro (including the connection of DEM, soil, hydrographic network, and other layers).

The developed electronic questionnaire was tested in June–August 2025 on the territory of the CNNP. Testing was conducted along designated hiking trails within the regulated recreation zone, specifically at the following locations: Divochi Slozy, Animal enclosure farm, Dovbush Trail, Polonyna Borsuchyna, Mount Yahidna, Mount Markovytsia, Polonyna Chornohorytsia, the Rudiak raised bog, and partially along the routes to Mount Hoverla and Mount Shpytsi. Additionally, the study covered areas of stationary recreation, including the recreational sites Zhonka, Berizhok, Bohonchuk, Tyrlych, Zarusliak, Lisnychivka, Hoverla, Dzherelo, Zhenets, Vorotyshche, and the trout farm of the Hoverlianske Forestry and other adjacent territories. Field studies were conducted in a wide altitude range and covered various types of mountain ecosystems, in particular beech and fir-beech forests, spruce forests of the upper mountain belt, swamp complexes and coastal-aquatic biotopes, and anthropogenically transformed habitats (roadsides, forest edges, parking/recreation areas). Such an ecosystem spectrum allowed testing the functionality of the questionnaire under conditions of different vegetation cover structure, mosaic of habitats, and variability of microclimatic parameters. Testing was carried out both in areas with stable cellular coverage, and in areas with its complete or partial absence, which allowed checking the correctness of offline data collection, their further synchronisation, and the preservation of geospatial binding of records. Testing confirmed the operability of the form in various field

conditions, including hard-to-reach mountain areas and areas of intense recreational load.

RESULTS AND DISCUSSION

The developed electronic questionnaire provides structured recording of both individual individuals and full-fledged populations/foci of invasive plant species using point and polygonal geometry. Table 1 shows the structure of the questionnaire,

where each parameter is accompanied by a brief instruction for field determination, and attached photo recording samples. Due to the implementation in ArcGIS Survey123, all records are exported to Tabular formats (CSV/Excel) and directly exported to GISenvironment as Feature Layer layers for further mapping, spatial analysis, and attaching external layers in ArcGIS Pro (terrain models, soil models, hydrographic network models, etc.).

Table 1. Populations – field study of invasive plants on the territory of CNNP

Parameter/Question	Hint	Answer/Options to choose from
General data		
Researcher name		Text
Date and time		Automatically
Description of the study area		
Location name	Specify the name of the area, route, or specific location	
Microrelief	<ul style="list-style-type: none"> ● Ridge – the highest line of a ridge or hill. ● Slope – sloping part of a mountain or hill. ● Foothill – lower part of the slope. ● Terrace – flat ledge on a slope or above a river. ● Hollow – depression in the terrain, often wet. ● Shoreline – areas adjacent to the riverbed. ● Rocks – open outcrops of hard rock. ● Scree – embankment of stone fragments under a slope. 	Ridge/Slope/Foothill/Terrace/Hollow/Shoreline/Rocks/Scree
Where exactly is the study area located?	Roadsides, trails, forests, meadows (up to 2 m from the edge), forest, meadow, shoreline, etc.	Text
Altitude above sea level	If information is available, or it can be added later during GIS analysis	Number
Slope steepness	<p>Methods: Clinometer (or built-in compass) – accurate measurement of the tilt angle. Mobile applications (for example, Clinometer, Theodolite, or GPS applications with slope detection function).</p> <p>0-3° – plain 3-7° – gentle, barely noticeable slope 7-15° – noticeable, but easy to walk 15-25° – steep, requires effort 25-35° – very steep, sometimes requires support >35° – steep slope/cliff, almost vertical</p>	0-3° 3-7° 7-15° 15-25° 25-35° >35°
Slope exposure	<p>What is required: a compass or an application that detects slope exposure on the phone. How to determine:</p> <ol style="list-style-type: none"> 1. Stand face down the slope (in the direction where the water flows). 2. Measure the azimuth (angle in degrees from north). 3. Translate to direction: <ul style="list-style-type: none"> ● 0° = N (north) ● 45° = NE (northeast) ● 90° = E (east) ● 135° = SE (southeast) ● 180° = S (south) ● 225° = SW (southwest) ● 270° = W (west) ● 315° = NW (northwest) <p>If the slope is almost flat → “plain”.</p>	N NE E SE S SW W NW Plain

Table 1. Continued

Parameter/Question	Hint	Answer/Options to choose from
Ecosystem type	Select	Alpine meadows/Subalpine meadows/ Scattered woodland/Coniferous forests/ Beech forests/Mixed forests/Wetlands/Rocky areas/Forest edges/Mountain pastures/ Water bodies/Urbanised areas/ Agricultural landscape/Other
Location description	Specify important additional information	Text
Photo shared	General photo of the population at the growth site	Add a photo
Boundaries of the study area	Draw a polygon on the map that marks the boundaries of the entire study area (NOT an accounting, model area)	Draw a polygon on the map
Size of the accounting (model) area (m)	Select	0.5 × 0.5 1 × 1 2 × 2 5 × 5 10 × 10
Population characteristics (single plant)		
Taxon	Latin name of the invasive species (dominant invasive species on the site)	Text
Household name	Ukrainian household name	Text
Degree of invasiveness	Select	Transformer Highly invasive Invasive Introduced Naturalised Undetermined
Population occupied area (m ²)	Approximate area of the entire plot within which accounting (model) squares are laid (m ²)	Number
Stage of ontogenesis	Question only for fixing a single plant	s – seed; p – seedling; j – juvenile; im – immature; v – vegetative adult; g1 – generative 1 (beginning of flowering, single flowers); g2 – generative 2 (mass flowering); g3 – generative 3 (fruiting, seeds); ss – subsenile plant (ageing, losing generative characteristics); s – senile plant (end of life cycle)
Age structure	Mostly young/Mixed/Mostly old	Text
Presence of generative individuals	Select	Yes No Other
Population dynamics assessment	This question applies only to repeated surveys of the same site conducted in different periods. If this is the first survey, the field remains empty or “Not applicable” is selected	Growing Stable Decreases Unknown Not applicable
Population density	Individuals per m ² – for an accounting (model) plot	Number
Braun-Blanquet coverage for the species under study	Select	i – only one individual r – single individuals, coverage <1% + – multiple individuals, coverage <1% 1 – numerous individuals, coverage 1-5% 2 – coverage 6-25% 3 – coverage 26-50% 4 – coverage 51-75% 5 – coverage 76-100%
T – Braun-Blanquet coverage for wood tier	Tent (upper wooden tier). Tall trees that form the forest crown (spruce, beech, fir)	0% <1% 1-5% 6-25% 26-50% 51-75% 76-100%

Table 1. Continued

Parameter/ Question	Hint	Answer/Options to choose from
S – Braun-Blanquet coverage for shrub tier	Undergrowth Bushes, young trees 0.5-5 m May also include undergrowth of tree species	0% <1% 1-5% 6-25% 26-50% 51-75% 76-100%
H – Braun-Blanquet coverage for grass tier	All grass species, including young seedlings <0.5 m Here, the coverage of invasive species is most often determined	0% <1% 1-5% 6-25% 26-50% 51-75% 76-100%
B – Braun-Blanquet coverage for moss-lichen tier	All herbaceous species, including young seedlings <0.5 m	0% <1% 1-5% 6-25% 26-50% 51-75% 76-100%
W – Braun-Blanquet coverage for areas without vegetation		0% < 1% 1-5% 6-25% 26-50% 51-75% 76-100%
Photo square of the accounting (model) plot		Add a photo
Other invasive plant species	Specify other invasive plant species in the study area	Text
Other plant species	Specify other plant species in the study area	Text
Presence of other groups of organisms	Mark all available groups, additional information can be provided in the following question (multiple choice)	Lichens Fungi Insects Arachnids Molluscs Amphibians Reptiles Mammals Other
Description of other groups of organisms (if additional information is available)	Features and names, if any, and other groups of organisms that are not specified in the previous question	Text
Additional photo		Add a photo
Ontogenetic spectrum of the accounting (model) plot		
s – seed	Quantity per m ²	Number
p – seedling	Number of individuals per m ²	Number
j – juvenile	Number of individuals per m ²	Number
im – immature	Number of individuals per m ²	Number
v – vegetative adult	Number of individuals per m ²	Number
g1 – generative 1 (beginning of flowering, single flowers)	Number of individuals per m ²	Number
g2 – generative 2 (mass flowering)	Number of individuals per m ²	Number



Table 1. Continued

Parameter/Question	Hint	Answer/Options to choose from
g3 – generative 3 (fruiting, seeds)	Number of individuals per m ²	Number
ss – subsenile plant (ageing, losing generative characteristics)	Number of individuals per m ²	Number
s – senile plant (end of life cycle)	Number of individuals per m ²	Number
Photo square of the accounting (model) plot		Add a photo
Photo flower	Photo of a plant flower (if any) or fruit (seed)	
Photo sheet	Close-up photo of the sheet	Add a photo
Additional photo	Additional photo that contains important information	Add a photo
Comment on the population structure	Additional information and features	
Soil characteristics		
Soil type	<p>Specify according to the prompts below, including additional information if necessary:</p> <ul style="list-style-type: none"> ● Mountain-forest brown soils: forest zones (beech, fir, spruce); dark brown in colour, loose in texture, high in humus, with stony inclusions. ● Soddy-podzolic: lower parts of slopes, forest edges; a lighter upper horizon, beneath which lies a distinct whitish podzolic layer. ● Mountain-meadow: subalpine and alpine meadows; dark humus horizon, well-developed turf, high moisture content. ● Peat (swamp): swamps, sphagnum areas; dark brown or black colour, fibrous structure, saturated with water, elastic. ● Gravelly/stony: scree, steep slopes; a small amount of fine soil, rock fragments predominate. ● Rendzinas (on limestone): limestone outcrops and scree; a thin dark humus horizon over limestone fragments; positive reaction with HCl (effervescence). ● Loams: slopes, terraces; sticky when wet, retain shape when compressed. ● Sandy loams: scree, deluvial deposits; easily crumbling, do not retain their shape, the sand fraction is well felt. 	Text
Soil moisture	Field touch test	Dry Moderate Wet Waterlogged Water on the surface
Soil pH	According to the device's indicators (if any)	Number
Soil moisture	According to the device's indicators (if any)	Number
Soil temperature	According to the device's indicators (if any)	Number
Soil illumination	According to the device's indicators (if any)	Number
Soil fertility indicator	According to the device's indicators (if any)	Number
Air temperature	According to the device's indicators (if any)	Number
Air humidity	According to the device's indicators (if any)	Number
Threats or damage to the population / ecosystem		
Signs of drought	The studied and surrounding plants are withered, wilted, the soil is hard and dry, etc.	Yes/No
Signs of flooding	The soil is waterlogged, water on the surface, other signs of flooding of the site (presence of eroded soil, deposited sand, etc.)	Yes/No



Table 1. Continued

Parameter/Question	Hint	Answer/Options to choose from
Signs of fire	Burned area, or the presence of burned bushes, trees, etc. – except for specially designated places for bonfires	Yes/No
Signs of soil erosion		Missing/Local/Medium/Strong
Signs of landslides		Yes/No
Signs of windfall		Yes/No
Signs of grazing	Traces of livestock (driving cattle), animal droppings, grazed areas	Yes/No
Signs of recreational stress	Multiple choice	Garbage/Trails/Camping/Damage/Campfires/Transportation/Missing/Other
Signs of forestry/deforestation	Multiple choice	Fresh stumps/Old stumps/Track/Skidding tracks/Wood warehouses/Cutting area/Sanitary logging/Other
Additional information	If necessary	
Photo	If necessary	
Plant damage		
Type of damage	Multiple choice	Pests/Fungi/Gnawing/Icing/Drought/None/Other
Detailing of damage	Include both natural (pests, icing) and recreational (cutting, trampling)	
Photo of a damaged plant		
Soil litter		
Thickness of soil litter		Less than 1 cm/1-3 cm/3-5 cm/>5 cm
Litter composition		Leaves/Needles/Grass residues/Mosses/Lichens/Branches/Bark/Debris/Other
Degree of decomposition		Fresh/Partially decomposed /Fully decomposed
Litter humidity		Dry/Moderately wet/Wet
Presence of seedlings/seeds of invasive species in the litter		Yes/No
Photo		
Additional comments		
Additional comments		Text

Note: GPS – Global Positioning System

Source: compiled by the authors

Table 1 contains blocks of questions about population structure, Braun-Blanquet vegetation cover, ontogenetic composition, related species, soil characteristics, and anthropogenic or natural impact factors. This structure provides a systematic collection of quantitative and qualitative data necessary for further analysis of the distribution and state of invasive plant populations. The questionnaire is suitable for use in citizen science programmes, considering the EU policy and

organisational framework, in particular, Commission Implementing Regulation (EU) 2024/574 (2024) and V. Lush *et al.* (2024). To this end, the system features multiple-choice questions, simple hints, mandatory photos, and geotagging of entries. A total of 44 localities of invasive plant populations and 36 localities of single growth of the following invasive plants were documented: *Impatiens glandulifera*, *I. parviflora*, *Heracleum sosnowskyi*, *Bidens frondosa*, *Echinocystis lobata*,

Reynoutria japonica, *Erigeron annuus*, *E. canadensis*, *Robinia pseudoacacia*, *Solidago canadensis*, *Helianthus tuberosus*, *Rudbeckia laciniata*. Figure 1

shows the ArcGIS Survey123 interface (Data tab) with a map and attribute table of completed entries in the invasive plant questionnaire in CNNP.

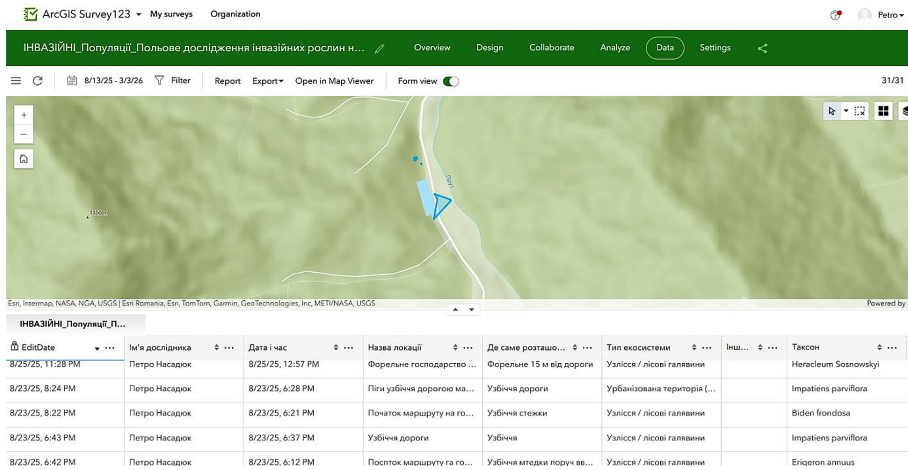


Figure 1. Example of a report from ArcGIS Survey123

Source: compiled by the authors

Figure 1 shows several geo-linked observations (blue polygons) along the road infrastructure and riverbed; the table showed key fields: date and time of the study, name of the researcher, name of the location, type of ecosystem, and the taxon. Among the recorded taxa – *Heracleum Sosnovskyi*, *Impatiens parviflora*, *Bidens frondosa*, *Erigeron annuus*, fixation sites were specified as roadsides/trails, forest edges, etc., which indicated the dominance of linear and marginal habitats in the sample. Records were grouped by routes (for example, “Trout farm”) and had timestamps (25.08.2025),

which confirmed field data entry with subsequent viewing and analysis on the map. The proposed questionnaire can be easily adapted for recording and population analysis of habitats of rare, relict, and endemic species both on the territory of the CNNP and in other protected areas of Ukrainian Carpathians. To do this, in the section “Population characteristics”, it was proposed to remove the parameter “Degree of invasiveness” and supplement the form with a specialised block of questions focused on the protected status and demographic indicators of such species (Table 2).

Table 2. Block of questions for rare, relict, and endemic species

Is the species endemic to the Carpathians?	Select	Yes/No/Unknown
Is the species relict for the Carpathians?	Select	Yes/No/Unknown
Is the species listed in the Red Book of Ukraine?	Select	Yes/No/Unknown/Needs verification
Does the species have an international protected status?	Multiple choice	IUCN (Specify the category in the following question: CR, EN, VU, NT, LC)/CITES/Bern Convention/Emerald Network/None/Other
Additional information on international protection status	Additional information (also specify the IUCN category: CR, EN, VU, NT, LC – if applicable)	Text

Note: IUCN – International Union for Conservation of Nature; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; CITES – Convention on International Trade in Endangered Species of Wild Fauna and Flora

Source: compiled by the authors

Table 2 systematises the collection of data on rare, relict, and endemic species, including national and international protected status and the possibility of additional detail. In the context of interpreting population data for IAPS, the study was based on the methodological foundations summarised by V. Kyyak & A. Malynovsky (2020), who considered the population as a basic unit of accounting for biodiversity and insist on assessing the structure (age/ontogenetic, spatial, sexual), self-renewal and strategies of the species in specific ecological niches; they considered vitality to be an integral indicator of the state, synthesising key individual and group parameters of growth, development, and reproduction. This established the basis of the survey form: blocks on the ontogenetic spectrum, the proportion of generative individuals, density, and coverage (as a proxy for vital activity), and on the regeneration niche (soil litter/seed bank, microsites), allow tracking intrapopulation diversity and self-maintenance mechanisms in different CNNP habitats. In particular, the typical stages of degradation of rare populations described by the researchers under pessimistic conditions (simplification of spatial structure, ageing or pseudo-rejuvenation, drop in vitality, extinction of generation, decrease in area/number/density) were operationalised through mandatory mapping of population polygons, fixing the dynamics of the generative contour, which is consistent with the authors' approaches to diagnosing population trends in mountain systems. Such integration of population and environmental indicators in the digital questionnaire allows continuing the line of standardised field collection and moving from one-time statements to monitoring the vitality/self-healing of IAPS populations in space and time. P. Pyšek *et al.* (2020) summarised that biological invasions pose a large-scale systemic risk and require early detection and coordinated action, with standardised primary data being key for policy and management. The proposed tool is consistent with these results, since it provides the most standardised, geospatial data collection and the ability to quickly map invasion foci. Simultaneously, the difference lies in the focus: within the framework of this study, the emphasis was placed on operational implementation (form structure, reference books, export to

GIS), while P. Pyšek *et al.* established mainly conceptually-political framework. K. Ingenloff (2025) detailed approaches to updating and publishing monitoring data in Darwin Core using the Humboldt Extension, suitable for event recording and protocol documentation.

The proposed field and metadata mapping complies with these practices and ensures that the collected records are ready for integration into GBIF/UkrBIN. M. Jurišić *et al.* (2023) showed that zoning of environmental vulnerability combined with traffic forecasting allows identifying “hot spots” of risk in protected areas, which was especially important for mountain parks. In this study, this was considered through mandatory localisation fields (roadsides, hiking trails, river valleys) and site polygon mapping in Survey123. A common feature was the spatially oriented approach to risk assessment; the difference lied in the subject of observation: here, the focus was on IAPS populations, whereas M. Jurišić *et al.* analysed the vulnerability of territories in general. J. Dániel-Ferreira *et al.* (2024) demonstrated by field studies in central Sweden that roadsides with high environmental value are vulnerable to expansion of *Lupinus polyphyllus*, and linear media act as effective channels for its propagation. The proposed questionnaire institutionalised this sensitivity through the field “Where exactly is the site located?” and a threat assessment unit that allows easily aggregating records for further corridor analysis. The difference is in the breadth of taxa: the study by Swedish researchers focused on one species, while the proposed form covered the entire spectrum of IAPS, including transformer species. A. Mihaly & V. Roman (2024) showed that spatial kits for monitoring invasive tree species in the forests of Zakarpattia allow localising foci and supporting management decisions. The developed model confirmed the validity of spatially oriented data, but extended it to non-seasonal herbaceous and shrubby invasions by combining indicators of cover, ontogenetic structure, and soil characteristics. Realising dynamic value... (2021) formalised the standard operating procedure (SOP 26) to apply the Braun-Blanquet scale in field protocols, emphasising the unification of procedures and the possibility of comparable assessments between different projects. In this paper, the scale was integrated as the core of the phytocoenotic block with separate accounting of

vegetation tiers, which fully corresponds to SOP 26 and simplifies further transformation of ordinal classes into quantitative indicators for analytical needs.

CONCLUSIONS

The developed electronic questionnaire in the ArcGIS Survey123 environment provides standardised, reproducible, and geospatially linked collection of primary data on IAPS on the territory of CNNP. The structure of the tool integrates population indicators (density, ontogenetic spectrum), phytocoenotic context (Braun-Blanquet coverage assessment divided into tiers), abiotic characteristics (soil and microclimatic parameters, soil litter status), and the threat and damage module. This approach increased the explanatory capacity of field observations of the stages of the invasive process and formed a reliable basis for adaptive management. The questionnaire was adapted to the specifics of CNNP mountain landscapes: orography, slope exposures, altitude zones, and the most common ecosystem types and disturbance factors for the park were considered. Mandatory fields, controlled reference books, photo audits, and automatic geo-linking were implemented, which reduced inter-observer variability and facilitates quality control. The native integration with ArcGIS Pro allows quickly mapping points and polygons, and connecting external GIS layers (DEN, soil, hydrographic network, infrastructure), and organisation of further spatial analysis. The study demonstrated

the effectiveness of the transition from episodic observations to systematic monitoring of invasive species, which allowed accurate detection and mapping of foci, monitoring population dynamics during repeated surveys, comparing indicators between sites and seasons, and quickly generating data for management decisions and reporting. Further development should be directed to the introduction of stratified sampling by altitude zones and habitat types, regular repeated surveys, expansion of sensors (GNSS, pH, humidity, PAR), and setting up an automated data publishing pipeline in Darwin Core. This evolution will strengthen evidence-based solutions for the prevention, early detection, and control of invasive species in the Carpathian mountain ecosystems. The tool can also be used for early detection of new invasive taxa, mapping of overgrowth foci, monitoring the effectiveness of spread control measures, assessing impacts on rare and sensitive environments, and for operational reporting and management planning with cost minimisation and unification of data circulation.

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CONFLICT OF INTEREST

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Розробка електронного опитувальника для польових досліджень інвазійних видів рослин на території Карпатського національного природного парку

Петро Насадюк

Аспірант
Львівський національний університет імені Івана Франка
79005, вул. Грушевського, 4, м. Львів, Україна
<https://orcid.org/0009-0008-8189-4945>

Звенислава Мамчур

Кандидат біологічних наук, доцент
Львівський національний університет імені Івана Франка
79005, вул. Грушевського, 4, м. Львів, Україна
<https://orcid.org/0000-0003-0527-5639>

Оксана Тимчук

Науковець
Карпатський національний природний парк
78500, вул. Стуса, 6, м. Яремче, Україна
<https://orcid.org/0009-0000-4728-9401>

Анотація. Актуальність дослідження зумовлена потребою у стандартизованому, відтворюваному та геопросторово прив'язаному моніторингу інвазійних чужорідних видів рослин у складних гірських ландшафтах Карпатського національного природного парку, де поєднання висотної поясності, різноманіття оселищ і природних та антропогенних коридорів поширення створює підвищені ризики їх натуралізації та експансії. Метою статті було створення стандартизованого опитувальника для уніфікації процесу фіксації даних про інвазійні види, забезпечення коректної геопросторової прив'язки спостережень та створення передумов для їх подальшого просторового аналізу у середовищі ArcGIS. Форма, розроблена в ArcGIS Survey123, охопила широкий спектр екологічних, біологічних та абіотичних параметрів, зокрема дані про таксономічну приналежність виду, проективне покриття, онтогенетичний стан популяції, характеристики ґрунту, мікрокліматичні показники та рівень антропогенного впливу. Запропонований підхід дозволяє підвищити точність моніторингу інвазійних видів та інтегрувати отримані дані у загальнонаціональній базі спостережень. Конструкція опитувальника базувалася на принципах максимальної сумісності з подальшим аналізом у географічну інформаційну систему та публікацією у глобальних репозиторіях біорізноманіття. Такий підхід відкриває можливість для порівняльних аналізів, злиття з громадянськими спостереженнями і використання даних при оцінюванні ризиків і пріоритетизації реагування на інвазії. Методично опитувальник охопив вісім логічних секцій: (1) загальні відомості та геоприв'язка; (2) опис ділянки з класами типів екосистем відповідно до сучасної глобальної типології; (3) характеристика популяції інвазійного виду, включно з площею, щільністю, віковою структурою, динамікою; (4) онтогенетичний спектр з кількісним обліком по стадіях; (5) ґрунтові й мікрокліматичні показники з можливістю польового визначення кислотності та вологості; (6) загрози й пошкодження рослин і екосистем; (7) ґрунтова підстилка як потенційний банк насіння; (8) додаткові коментарі та фотодокументація. Передбачено збір фотознімків різних ракурсів, їх завантаження з просторовою прив'язкою до записів та формування повного цифрового сліду для подальшого аудиту якості

Ключові слова: фітоінвазії; моніторинг; чужорідні види біоти; оселища; біорізноманіття; екосистеми; природно-заповідний фонд