RESEARCH ON ALIEN PLANT INVASION ALONG THE LOWER COURSE OF THE SIRET RIVER

ABSTRACT

The thesis comprises 199 pages, including 4 original tables, 35 figures (of which 34 are original) and 4 annexes, and is structured in two parts: i) ***the current state of knowledge*** (together with the introductive sections, this represents 23.4% of the thesis content) and ii) ***personal contribution*** (76.6% of the thesis content).

► **The part one** contains the first chapter of the thesis - *The current state of knowledge on alien* (*non-native*) *plant invasion* (pp. 27-46). This chapter presents the results of the bibliographic study, regarding the following aspects relevant to the aims and objectives of the thesis: definition and classification of alien (non-native) plants; stages of invasion; causes of invasion; the impact of the invasion on natural biodiversity, as well as on the economy and human health; invasion management; the history of floristic and phytosociological research on neophytes in the study area.

► **The second part** of the thesis (pp. 47-197) contains chapters 2-6, conclusions, bibliography and annexes.

● **Chapter 2** is reserved for the presentation of the general aim and objectives of the thesis, as well as the research material and methods.

The aim of the thesis was to contribute to knowledge on the diversity of neophytes, the degree of their invasion, as well as the invasion success of these species, as a support for a suitable management of biological invasion in the lower course of the Siret river. In order to achieve this general aim, in addition to the bibliographic study, we pursued the following **research objectives**: i) description of the particularities of the natural and socio-economic framework of the study territory, in order to identify vulnerabilities to invasion; ii) evaluation of the taxonomic, chorological, biological and ecological diversity of neophytes in the lower course of the Siret river; iii) evaluation the level of neophytes invasion within the area; iv) evaluation of the invasion success of neophytes on the lower course of the Siret river; v) identification and proposal of some objectives and activities for the management of the invasion of neophytes in the study area.

The field floristic and phytosociological research, carried out on the itinerary, between September 2018 and October 2021, in different months of the vegetation time, targeted the alien plant species from the ***neophyte*** category. However, archaeophytes and native species (indigenophytes) have also been recorded during the phytosociological surveys, conducted in parallel with floristic research, as well as from the bibliographic references.

In the presentation of the research material and methods we referred to: the criteria for selecting neophytes; the working method for the inventory and identification

of neophytes; the references used for plant nomenclature; the way of drawing up the systematic and chorological checklist of neophytes; the methods used for identification of EUNIS habitat types and phytosociological research (and how phytosociological data was used); the way of analyzing the diversity of neophytes; methods for assessing the level of neophytes invasion in the lower course of the Siret river and the invasion success of each species; the way for assessing vulnerabilities to invasion and identification of management proposals.

● **Chapter 3**. The study territory is located along the lower course of the Siret river, between the Berești reservoir (upstream) and the confluence of the Siret with the Danube river (downstream). In order to describe the natural and socio-economic framework of this area, the following aspects were analyzed: geomorphology; hydrography; climate; soils; phytogeographical zonning; vegetation; nature protection; settlements and human population; economic activities.

● **Chapter 4**. This chapter presents the results of research on neophytes in the study area, using both own our field data and those from the literature.

The first part of this chapter (**subchapter 4.1**; pp. 74-123) consists on a systematic and chorological checklist of neophytes from the lower course of the Siret river. In this checklist, 42 families of vascular plants are registered, listed in phylogenetic order, and within the families, 105 genera and 151 species (listed alphabetically). One of the species was represented by 2 subspecies, so the total number of taxa (species and subspecies) was 152. The following data were presented for each taxon (species or subspecies): scientific name and main synonyms; vernacular name; life form; geographical origin; way of introduction (and its purpose, if deliberate); the ways of species propagation in nature; species preferences for ecological factors; the types of EUNIS habitats invaded in the study area; syn-taxa to which the species shows the highest fidelity; the abundance-dominance (AD) values of each species in the phytocenoses identified in the study area; invasive status in Romania; chorological data within the study area.

In the **subchapter 4.2** (pp. 123-148), the following data were analyzed: the diversity of neophytes in the lower course of the Siret river; the actuality of historical floristic data; floristic novelties; the status of neophytes from the study area at national and European level; the level of invasion of the study area and of the identified habitats; the invasion success of neophytes.

The diversity of neophytes in the study area was analyzed and represented graphically under taxonomic, arealogic, chorological, biological, ecological and historical terms, and the results were discussed by relating to the previous knowledge in the field. The main conclusions that emerge from the analysis of the diversity of the vascular flora of neophytes in the study area are the following ones: the neophyte flora of the study area was the best represented by some families (Asteraceae, Poaceae, Amaranthaceae, Brassicaceae, Fabaceae, Solanaceae) and genera (*Amaranthus*,

Oenothera, Euphorbia) widespread worldwide, rich in weed species; species native to North America, Asia and the Mediterranean region (i.e. vast territories, with a very great floristic diversity, with natural conditions, at least in some regions, quite similar to those of Romania) predominated compared to those originating in other geographical regions; in terms of life forms, the most numerous species are terophytes (pioneer species, with a generally high prolificacy); the deliberate introduction (mainly of ornamental species) had a much greater contribution to the increase in the number of neophytes in the lower course of the Siret river, compared to the accidental introduction; most neophytes are able to spread in nature by the action of many factors (man, wind, animals, water, etc.); from an ecological point of view, most of the neophytes in the study area are (sub)heliophilous, mesothermophilous, (xero)mesophilous, weakly acid-neutrophilous, (moderately) nitrophilous and do not tolerate soil salinity well. These conclusions are largely in line with literature data, concerning the diversity of alien plants in other Romanian regions or the whole country. As well, some of these conclusions confirm the data in the literature regarding some characteristics of successful invaders.

Some species reported in the literature from the study area (25% of the total) were not found during our field research. On the other hand, between 2018-2021, we identified in the study area three species new for the spontaneous vascular flora of Romania (***Euphorbia glyptosperma***, ***Phleum arenarium***, ***Tarenaya hassleriana***), two species new for Moldova (***Euphorbia prostrata***, ***Perilla frutescens***) and a species new for Muntenia (***Oenothera suaveolens***); numerous other neophytes have now been reported for the first time, either for the counties bordering the lower course of Siret (Galați, Brăila, Vrancea) or for the study area.

The status of neophytes within the study area. The following issues were highlighted here: the national and European invasive status of neophytes registered in the study area; how their occurence and status in Romania are reflected in some European databases (*Euro+Med PlantBase*; *EPPO - European and Mediterranean Plant Protection Organization; DAISIE - Delivery of Alien Invasive Inventories for Europe*); their presence in the quarantine weed lists or in the "black" list of invasive species of European concern (three species from this list are already present in the study area, namely: *Asclepias syriaca*, *Elodea nuttallii* and *Ailanthus altissima*).

The level of neophyte invasion on the study area was expressed by the proportion of neophytes in the total number of taxa, but also as by number of taxa per locality (i.e. sampling "point") and per surface unit. The proportion of neophytes in the total number of taxa of the vascular flora in the study area, increased constantly, between 1950 and 2021, from 3.48% to 10.67%, which illustrates a general trend of amplification of the phenomenon of biological invasion within the area.

The analysis of the number of taxa recorded on both sides of the Siret river indicates a higher level of invasion (expressed by the number of taxa *per* locality or *per* UTM square of 5 × 5 Km) on the left side of the river (where there are more localities

and a higher density of human population) compared to the right side. The highest level of invasion was recorded in some centers of maximum anthropogenic impact on the environment: urban or suburban areas, with intense trade and other economic activities (Galați and the neighbouring upstream localities; Adjud, Mărășești); important road or rail traffic junctions (Galați, Mărășești, Adjud, Barboși - freight sorting train station, Movileni-Șendreni, Hanu Conachi, Cosmești); river ports (Galați); centers for extraction and sorting of river sand and gravel (Doaga, Biliești, Movileni) etc. The positive correlation (widely documented in the literature) between the level of environmental disturbance (generated by the impact of human presence and activity) and the degree of invasion is thus confirmed. This correlation also resulted from the analysis of the number of taxa which invaded different EUNIS habitat types, as well as from the analysis of phytosociological data. Thus, the highest level of invasion (expressed by the number of taxa) was recorded in anthropogenic habitats, strongly disturbed by human activity (*e.g. E5.1- Anthropogenic herb stands*; *J4-Transport networks*; *J3-Extractive industrial sites; I1-Arable land and market gardens; G1.C-Highly artificial broadleaved deciduous forestry plantations; C3.6-Unvegetated or sparsely vegetated shores with soft or mobile sediments* etc.). Also, the analysis of phytosociological data revealed, among others, that the great majority of neophytes are diagnostic for different types of anthropogenic communities which belong to the following vegetation classes (or their subordinate syntaxa): *Sisymbrietea*, *Digitario sanguinalis-Eragrostietea minoris*, *Artemisietea vulgaris*, *Robinietea*, *Epilobietea angustifolii* and *Papaveretalia rhoeadis*.

The evaluation of the invasion success of each neophyte species from the study area, in order to establish the management priorities, was made by assigning a *success score*, using an evaluation scale with values between 0 (failure) and 5 (very high success), for each of the following four indicators: ***i*) *minimum residence time*** (calculated as the difference between the years of the last and the first detection or reporting of each species, in the wild), ***ii*) *frequency in the study area*** (*i.e.* percentage of the number of presence points for each species, out of the total number of data collection points), ***iii*) *proportion of invaded habitat types*** (determined by reporting the number of EUNIS habitats invaded by each species to the total number of habitats identified in the field) and ***iv*)** the ***maximum value of abundance-dominance* (*AD*)** recorded in phytocenoses (by analyzing a total number of 1063 phytosociological relevés, of which 888 from the literature and 175 recorded by us in the field). For each species, the average of the four scores was considered as ***index of invasion success***. Depending on the values of the index of invasion success (between 0 and 5), the neophytes in the study area were grouped into five classes of success, namely: I-very low (56.6% of the total number of taxa), II-low (14.5%), III-moderate (13.8%), IV-high (10.5%) and V-very high (4,6%).

Neophytes with high and very high success of invasion in the lower course of the Siret river were the following ones: *Acer negundo*, *Abutilon theophrasti*, *Ailanthus altissima*, *Amaranthus albus*, *A. blitoides*, *Ambrosia artemisiifolia*, *Amorpha fruticosa*,

Cuscuta campestris, *Datura stramonium*, *Erigeron annuus* ssp. *annuus*, *Iva xanthiifolia*, *Lepidium densiflorum*, *Lycium barbarum*, *Oxalis dillenii*, *Populus carolinensis*, *Robinia pseudoacacia* (class IV), and respectively: *Amaranthus retroflexus*, *Artemisia annua*, *Bassia scoparia*, *Erigeron canadensis*, *Sorghum halepense*, *Xanthium orientale* ssp. *italicum* and *Xanthium spinosum* (class V).

Among the neophytes which have been ranked in the first three classes (very low, low and moderate success), some have a very high invasive potential, and could pose serious threats to river-associated habitats in the future, *e.g.*, *Asclepias syriaca*, *Rudbeckia laciniata*, *Helminthotheca echioides*, *Sicyos angulatus*, *Solidago canadensis* (class I), *Dysphania ambrosioides*, *Fallopia baldschuanica*, *Fraxinus pennsylvanica*, *Helianthus tuberosus* (class II), *Amaranthus crispus*, *A. deflexus*, *A. powellii*, *Elaeagnus angustifolia*, *Elodea canadensis*, *E. nuttallii*, *Euphorbia glyptosperma*, *E. maculata*, *Galinsoga parviflora*, *Gleditsia triacanthos*, *Matricaria discoidea*, *Morus alba*, *M. nigra*, *Oenothera biennis*, *Oxalis corniculata*, *Panicum capillare*, *Parthenocissus inserta*, *Salvia reflexa*, *Trigonella caerulea* and *Veronica persica* (class III).

● **Chapter 5** (pp. 149-169). In this chapter, the arguments that support the importance of applying an adequate management of the invasion of neophytes in the study area were first analyzed; then the causes that determine the vulnerability of this area to biological invasion were highlighted, and finally some proposals have been made which could contribute to an adequate management of neophytes invasion in this area.

The Siret, like all great rivers, is of major ecological and socio-economic importance, and biological invasion has been previously identified as one of the main threats to species and natural habitats, especially in protected areas associated with this river (which was fully confirmed by our field research).

The analysis of the particularities of the natural and socio-economic environment of the study territory revealed that the main ***vulnerabilities*** of this territory to biological invasion are represented by the *high level of environment disturbance* (generated by a long history of uncontrolled introduction of exotic species, the substitution of natural ecosystems with the anthropogenic ones, and an inadequate management of natural resources) as well as *the current low level of systematic activities to prevent invasion, or to eradicate and control invasive neophytes*.

For an effective management of neophytes invasion, it is necessary to draw up a plan with objectives and activities, in which to establish the priorities for each management objective, to allocate the necessary resources (financial, personnel, materials, etc.) and to clearly indicate specific responsibilities (for implementation and control). Of course, such a management plan exceeds the framework of this doctoral thesis. Therefore, we limited ourselves to identifying some proposals for invasion management (prevention; early detection and eradication; control), inspired by our field findings, as well as by specific European / international regulations and the codes of conduct or examples of good practice published in the literature.

Prevention of neophyte invasion in the study area (the most effective and least expensive option in the management of biological invasion) can be achieved by strictly controlling the introduction of new exotic species (based on the prior preparation of a list of invasive or potentially invasive species), as well as by measures to reduce the vulnerability of ecosystems to invasion (*e.g.*, appropriate agro-zootechnical and forestry practices; adequate waste management; reduction of sand mining in the riverbed below a sustainable threshold etc.).

For the ***early detection and eradication*** of new invasive plants, it is necessary to constantly monitor the protected natural areas on the lower course of the Siret, as well as the grounds near the port of Galați, large train stations (Galați, Mărășești, Adjud etc.), main roads and railways, as well as any other areas where high passenger traffic is recorded or where imported goods that may contain seeds of weeds, as impurities, are unloaded, transferred or processed. Exotic plants introduced into the agricultural or horticultural fields should also be constantly monitored for early detection of any tendencies to become invasive.

A total number of 43 neophyte taxa were identified in the lower course of the Siret river, which registered a medium, high or very high invasion success. Although all these neophytes could be taken into account in the control programs, the necessary effort in this respect would not (probably) be sustainable, from an economic and organizational point of view. However, the eradication and/or control of the populations of some of these species is of high priority.

Priority must be given especially to preventing introduction, eradication and control of at least the invasive species of European Community interest (some of which are already registered within the area, as mentioned before) or those covered by national regulations (e.g., *Ambrosia artemisiifolia*), as well as to control of those invasive species affecting natural habitats from the protected areas (e.g., *Robinia pseudoacacia*, within the Hanu Conachi national reserve).

● The main **conclusions** within the thesis are presented on pp. 170-177.

● **The bibliography** (pp. 178-194) contains a number of 318 references which were cited within the thesis.

● The **annexes** to the thesis (pp. 195-199) contain: (1) the list of scientific papers published during the doctoral studies: 5 papers, of which 4 were published in journals indexed in international databases (3 - first author, 1 - co-author) and 1 paper published, as first author, in a national journal; (2) the list of tables; (3) the list of figures; and (4) the list of localities in the study area (from upstream to downstream, on both sides of the river) and the number of neophytes *per* locality.