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METHODS OF COMBATING AND CONTROL REGARDING FALSE INDIGO-BUSH IN CLOSE CORRELATION WITH INVASIVE CAPACITY IN THE FORESTRY PLANT COMMUNITIES IN THE JIU-DANUBE CONFLUENCE ZONE

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Abstract

The false indigo-bush – Amorpha fruticosa L. is an invasive shrub, native to south-western North America. It was acclimatized in Europe as an ornamental shrub, its invasive-aggressive nature being noted over time. Areas of this species have greatly expanded in recent years across the country. The current eco-pedo-climatic conditions as well as the geographical position allow the installation of invasive species within these meadow phytocoenoses, some of them having a very high abundance-dominance. Among the species with high abundance-dominance, we studied the species Amorpha fruticosa which has an increase aggressive character both in the Jiu meadow, but especially in the Danube meadow. Although both 2022 and especially 2023 were dry years, the false indigo-bush had a massive development, most populations having a high number of individuals/m^2 within phytocoenoses. This species influences the successional dynamics and the floristic composition of the forest plant communities, occupying increasingly more and more space. Each tested method (mechanical and chemical) has its advantages and challenges and often a combination of strategies is necessary for sustainable management of the species.

Key words*: Amorpha fruticosa, combating methods, forest habitat, invasive species, Jiu-Danube Confluence.*

INTRODUCTION

Amorpha fruticosa L. is also known as shrubby amorpha or indigo-bushand is an invasive species that can have significant negative effects on biological diversity. This plant, originally from North America, was introduced to many regions, including Europe, where it quickly adapted and began to spread. Horticultural strategies emphasize promoting plants with a visually appealing appearance, but these kinds of plants often possess characteristics that predispose them to becoming invasive (Raicu et al., 2024). In Romania it was introduced for ornamental uses and to stabilize river banks. The plant spreads rapidly through flood waters, becoming a major problem for local pastures and hayfields. *Amorpha fruticosa* occupies large territories from protected areas of Mureș Floodplain Natural Park (Suciuet al., 2018)and other un-vegetated or sparsely vegetated shores, water-fringing reed beds and tall helophytes (Anastasiu et al., 2007). The species has incidence in western Romania, being spread along all the waterways (Mureş River, Danube River, Crişul Alb, Crişul Negru, Timiş, Bega, Bârzava) and their affluents, along the terrestrial transport ways, but it started to be found in grasslands too (Sărățeanu, 2010).

Negative effects on biodiversity relate to competition with native species, with *Amorpha fruticosa* tending to compete with native plants for resources such as light, water and nutrients. This can lead to a decrease in the number of native species, thus affecting the diversity of the ecosystem (Grabić et al., 2022). Another effect refers to the modification of the habitat, this invasive species can alter the structure of the habitats by forming monodominance where the false indigo bush becomes dominant, thus limiting the space and resources for other species. In the long term, *Amorpha fruticosa* invasion can destabilize local ecosystems, affecting essential ecological processes such as pollination and seed dispersal.

To control this invasive species, projects have been initiated in various areas of Romania, but the works are complex and expensive, requiring significant financial resources.

The purpose of this research was to evaluate the control methods efficiency generated by the expansion of the invasive species *Amorpha fruticosa* in the area at the confluence of the Jiu River with the Danube.

MATERIALS AND METHODS

The study was made in 2022-2023 in the territory at the confluence of Jiu River and Danube (Figure 1). The Jiu-Danube confluence (43°59′38″N - 23°53′48″E) is a protected area, located in southern Romania, on the administrative territory of Dolj county. The area was declared a Special Avifaunistic Protection Area by Government Decision no. 1284 of October 24, 2007 (regarding the declaration of areas of special avifaunistic protection, as an integral part of the European ecological network: Natura 2000 in Romania) (Hotărâre nr. 1284 din 24 octombrie 2007) and starting from February 2013 the site is protected as a wetland of international importance by the Ramsar Convention (Ramsar.org). The confluence of the Jiu with the Danube is a landscape of flowing waters, ponds and canals, bordered by meadow forests, with areas of pasture and arable land.

Figure 1. Study area-Jiu-Danube Confluence (source: https://www.google.ro/maps)

There are also forests with centuries-old examples of oaks, ash trees, elms, etc.
The analysis of the climatic elements that characterize the territory of the site is specific to the geographical space in the southwest of the country. The air temperature increases slightly from north to south: -2.5^{0}C in Târgu Jiu, respectively -1.8^{0}C in Calafat (in January) and 22.8-23.2^{0}C in July, but also successive increasing with temperature increases above average usual.

Atmospheric precipitation falls in liquid form during most of the year. In winter, there are on average 20 days with snow in the southern part of the site and about 30 days in the north. The multiannual averages of atmospheric precipitation are recorded around 540-550 mm. The great non-periodic variability of precipitation and the frequent advections of warm air cause the occurrence of relatively frequent dryness and drought phenomena in the plains (www.coridoruljiului.ro/PM_ROSCI0045.pdf). The identification of taxa was based on Romanian Flora (Săvulescu T. (Ed), 1952-1976) and Flora Europaea (Tutin et al., 1978). In order to establish the type of plant community and the level of invasiveness of the *Amorpha fruticosa* species within each plant community, sample markets were established, for each plant community 10 phytosociological surveys were carried out. In order to identify and establish the degree of invasiveness, specialized works developed by Pyšek et al. (2004); Pyšek et al., (2005); Pyšek et al. (2012) and Sîrbu & Oprea (2011), as well as the database The European Network on Invasive Alien Species (NOBANIS) (https://www.nobanis.org) were consulted. For the phytocoenotic research in the study area was used the method of phyto-sociologic research of the Central European School elaborated by Braun-Blanquet (1932). The plant communities were identified and distinguished according to the characteristic, edifying, dominant and differential species. For the identification of the plant communities and the coenotaxonomic classification, synthesis works of Coldea (1991), Sanda et al. (1997, 2001), as well as Oberdorfer (1992), Mucina et al. (1993, 2016), Rodwell (2002) were used. In the studied territory, 10 relevés were made within the phytocoenoses edified by Salix alba and *Salix fragilis*. A total of 30 sample plots of 400 m^2 each were considered in our studies, for the 4 plant communities in whose floristic composition *Amorpha fruticosa* populations were analyzed.

Control methods for the species *Amorpha fruticosa*

To restore forest phytocenoses, both from the forestry, bio-conservative and economic point of view, two methods were used: mechanical and chemical control and the economic calculation

regarding the costs of control.The mechanical and chemical control of the invasive species Amorphafruticosa was applied to 50 individuals, within the plant community that is an integral part of the 92A0 habitat in one location, within the administrative radius of the Ostroveni commune.

The mechanical method

Once *Amorpha fruticosa* has established itself in an area, it can form dense colonies, shading out other plants and competing with native species for resources. This ability to rapidly invade new territories complicates mechanical control efforts because constant intervention is needed to prevent spread. This method of mechanical control was achieved by cutting the branches with a chainsaw at a height of 10 cm above the ground, but also by pulling out the shoots and stems of the invasive species *Amorpha fruticosa*.

The chemical method

Chemical control can be effective, but its use must be carefully managed to minimize impact on native species and the environment. It is essential to use herbicides that are selective and do not affect the local flora.The chemical method was also applied in the test surfaces in order to highlight which of the methods is more effective. The chemical method was carried out by injecting the stem of the *Amorpha fruticosa* shrub with a systemic herbicide based on glyphosate, at a height of 10 cm from the ground. The following equipment was used for trunk injection:

- drill with a diameter of 0.6 cm and a length of 10 cm, to make holes in the stem of the shrub (Figure2);

Figure 2. Preparation of *Amorpha fruticosa* stems for herbicide application (photo: Călin Sălceanu)

- a syringe used to apply the herbicide directly into the hole in the stem.

The stem was perforated, to a depth of 4-6 cm, then a quantity of approx. 40 ml of herbicide was inserted directly, avoiding the leakage of the herbicide, in order to prevent contamination of the surrounding environment (Figures 3, 4). The diameter of the stems injected with herbicide did not exceed 3-5 cm, in the case of mature specimens.

The most effective absorption of the herbicide is in autumn, when nutrients from the leaves are transported to the root. 2 l of herbicide were used to inject 50 *Amorpha fruticosa* shrubs, of which 40 were completely dried.

Figure 3. Application of the chemical method for controlling the *Amorpha fruticosa* species in the Jiu-Danube confluent area (photo: Călin Sălceanu)

Figure 4. Herbicide injection of the stem of *Amorpha fruticosa* (photo: Călin Sălceanu)

RESULTS AND DISCUSSIONS

Amorpha fruticosa already covers significant areas (inside and outside protected habitats) in

Romania and the species has the tendency to naturally continuous spreading into new territories. To similar conclusion reached Ciuvăț et al. (2016) and they recommended the opportunity to sustainably control its spread by valuing its biopontential medicinal, food and industrial.

As results of the studies carried out in the Danube meadow, in the area of the confluence of the Jiu with the Danube, *Amorpha fruticosa* invades forest habitats over very large areas. This excessive development of the species causes a very large disturbance of the structure and floristic physiognomy of the poplar and willow plant communities in this area.

Amorpha fruticosa settles in the form of continuous strips along the Danube, with widths between 2 and 30 m, sometimes difficult to penetrate from one side to the other. The extremely developed populations of this species, especially in poplar groves, have a negative impact on the phytocoenoses, acting from the level of the grassy layer to that of the trees, resulting in a decrease in the value of biodiversity and the productivity of these forests. The decrease in the productivity of the poplar groves is automatically reflected in the decrease in the economic efficiency of the forestry in the area.

Phytosociological studies

From a phytosociological point of view, the studies indicate high dominance-abundance of the *Amorpha fruticosa* species in the following forest plant communities: *Salici-Populetum* Meijer-Drees 1936; *Salicetum albae* Issler 1924 (Syn. *Salicetum albae-fragilis* R. Tüxen 1937) and *Salicetum fragilis* Passarge 1957 (Figure 5). The invasive species *Amorpha fruticosa* has a strong negative impact on these types of forests both structurally and functionally, but also economically.

From conservative point of view, the identified plant communities edify Natura 2000 habitats of maximum importance: 91E0* - Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*) (according to the Palearctic Classification it corresponds to 44.3 - Middle European stream ash-alder woods, 44.2 - Boreo-alpine riparian galleries, 44.13 - Middle European white willow forests habitat types) and 92A0 *Salix alba* and *Populus alba* galleries (according to the Palearctic Classification it corresponds to: 44.141, 44.162 and 44.6 forests habitat types).

White poplar and white willow forests included in the plant community - *Salici-Populetum* Meijer-Drees 1936 occupies very large areas (hundreds of km) in the studied area, having a particular importance from an eco-pedological, bio-conservative, but also economic point of view for the entire area of the confluence of the Jiu River with the Danube, as for all hydrographic basins.

These types of white poplar forests, pure or mixed with white willow, generally develop on more developed alluvial soils. Along with the edifying species *Populus alba* and *Salix alba* are also found in the tree layers: *Fraxinus angustifolia, F. pallisiae, Ulmus laevis, U. minor*. A number of species have a high constancy in the structure of phytocenoses: *Vitis vinifera* subsp. *sylvestris, Cornus sanguinea, Humulus lupulus, Galium rubioides, G. palustre, A. tenuifolius, Urtica dioica, Calystegia sepium, Solanum dulcamara, Rubus caesius*. Often, the invasive species *Amorpha fruticosa* has a very high dominant abundance, and is accompanied by other invasive species: *Ailanthus altissima, Erigeron annuus, Oenothera glazioviana, Sicyos angulatus, Ecballium elaterium, Symphyotrichum lanceolatum, Oxalis stricta, Bidens frondosa*. In most of the analyzed phytocoenoses, the invasive species *Amorpha fruticosa* occupies large areas, has an excessive development, suffocating the species in the grassy and shrub state, white poplar and white willow saplings, especially preventing the natural regeneration of ancestral types of forest habitats.

Amorpha fruticosa presents a high degree of interpenetration, often forming an impenetrable network, and the root system is extremely developed, reaching great depths and extending over large surfaces in the horizontal plane. In order for the state of conservation, the structure and functions of this type of forest to have appropriate values, controlling the species is extremely necessary in the Jiu and Danube Valleys.

Another plant community identified and analyzed in the Jiu-Danube confluence area is *Salicetum albae* Issler 1924 (Syn. *Salicetum albae-fragilis* R. Tüxen 1937).

Figure 5. *Amorpha fruticosa* in the plant communities of the studied area (photo: M. Niculescu)

In this area, the phytocoenoses of this plant community have been invaded by several invasive species, but the supremacy is held by *Amorpha fruticosa* and in some phytocoenoses it is in competition with another invasive species *Sicyos angulatus* that also produces structural, functional, bioconservative and economic disturbances in these types of forests.

The edifying species are: *Salix alba* and *Salix fragilis.* In the floristic composition of the phytocoenoses of this plant community, they are also found scattered: *Salix purpurea, Populus canadensis, P. nigra* and *Fraxinus angustifolia.* The grassy layer largely represented by: *Mentha longifolia*, *Agrostis stolonifera*, *Glechoma hederacea*, *Ranunculus repens*, *Urtica dioica*, *Equisetum maximum, Aegopodium podagraria, Stachys palustris, Humulus lupulus, Polygonum hidropiper, Ranunculus ficaria, Stellaria nemorum, Agrostis stolonifera, Eclipta prostrate, Bidens tripartita, Vitis vinifera* ssp. *sylvestris, etc*. is often destroyed or taken over by populations of false indigo-bush.

And within these phytocoenoses, in the floristic structure, in addition to the species characteristic of the plant community, the following invasive species were identified along with *Amorpha fruticosa*: *Ailanthus altissima, Oenothera glazioviana, Bidens frondosus*, *Erigeron annuus, Cyperus difformis*, *Conyza canadensis, Morus alba, Echinocystis lobata, Robinia psudoaccacia, Abutilon theophrasti, Sicyos alngulatus, Reynoutria × bohemica*, *Galinso gaquadriradiata, Symphyotrichum lanceolatum.*
In the researched area, but on smaller areas, the plant community is also found *Salicetum albae-fragilis* Issler 1926 em. Soó 1957.
The phytocoenoses of this association are found in the form of narrow strips, on one side and the other of the Jiu River, close to its confluence with the Danube.
The shrub layer also consists of species like: *Sambucus nigra*, *Corylus avellana*, *Clematis vitalba*, *Hedera helix*, *Viburnum opulus*, *Salix triandra*, *Euonymus europaeus*, *Ligustrum vulgare***,** *Hedera helix*, *Cornus sanguinea, Clematis vitalba.*
In the grassy layer, the following species are found with high constancy: *Aegopodium podagraria*, *Carex remota, C. sylvatica, Equisetum arvense, Lycopus europaeus, Rumex sanguineus, Urtica dioica, Polygonum hidropiper, Petasites albus, Ranunculus ficaria, Stellaria nemorum, Agrostis stolonifera, Bidens tripartita, Brachypodium sylvaticum, Impatiens noli-tangere, Cardamine impatiens, Lysimachia nummularia, Humulus lupulus, Glechoma hederacea,* etc.
In the analyzed phytocoenoses, *Amorpha fruticosa* has a fairly high abundance-dominance, but lower than a number of other invasive species (allochthonous): *Sicyos angulatus, Ailanthus altissima, Oxalis stricta, Phytolacca americana, Ambrosia artemisiilfolia, Erigeron annuus, Gleditsia triacanthos*, *Echinocystis lobata, Falopia dumetorum.*
Following the studies, it was found that these phytocenoses also have a high degree of anthropization.
The three communities of woody plants analyzed have an inadequate state of conservation, the greatest anthropic pressure being exerted by the exuberant development of the *Amorpha fruticosa* species, which modified the floristic structure of the phytocoenoses with a direct impact on the entire natural capital in the studied area and not only that, but also on the vitality and state of health of the wood species from the composition of the forest plots in close correlation with their economic value.

The economic efficiency regarding the control of invasive species *Amorpha fruticosa* within the plant communities in the Jiu-Danube Confluence area

The results of this study show that the species analyzed can be controlled, with all affected individuals dying. Mechanical control alone is not very effective in the long term. Chemical control may be more effective, but requires repeated applications and compliance with rest periods for environmental protection.

Efficiency (%) = no. of shrubs removed/no. of treated shrubs x 100.
40:50 x 100 = 80%.

Costs:
The cost of one liter of Roundup herbicide is 80 Ron x 2 liters = 160 Ron.

The mechanical costs consisted of sawing with a chainsaw, where 2 liters of gasoline were consumed, and the equipment needed to collect the logs (tractor, trailer), to transport the wood and the effort of the staff responsible for transporting the wood resulting from cutting the logs from the height of 10 cm above the ground, generated much higher costs than the chemical control of trees *Amorpha fruticosa*.
Estimation of the costs for controlling the *Amorpha fruticosa* species, on an area of 50 shrubs:
- **Chemical method** – the rate 25 Ron/hour/worker x 8 hours = 200 Ron, plus 2liters of herbicide 80 Ron x 2 liters = 160 Ron, in total 360 Ron to control an area of 500 m^2 of *Amorpha fruticosa*;
- **Mechanical method** – rate 25 Ron/hour/worker x 8 hours = 200 Ron x 2 workers = 400 Ron, total labor cost (400 Ron) plus equipment (300 Ron) = 700 Ron.

Estimated total for mechanical control = 700 Ron;

Estimated total for chemical control = 400 Ron.

As a result of the calculations, mechanical methods are more expensive and require considerable human effort, so they are not always practical for large areas, while for chemical methods, although cheaper,

Amorpha fruticosa is a significant threat to local biodiversity and control measures are needed to prevent its spread and protect native species. The woody plant communities in most of the river basins in Romania present the invasive species in the floristic structure of the phytocoenoses of this specie. Regarding these plant communities, studies were carried out on the state of conservation, anthropogenic impact, threats, pressure on these priority habitats. These studies can be considered the basis of observations and future studies regarding the evolution of habitats, the syndamics of phytocoenoses, floristic composition, physiognomy of phytocoenoses, the range and degree of expansion of priority habitats.

This species has a high constancy within these phytocoenoses, and the dominant abundance varies depending on the eco-pedo-climatic conditions, but most of the time it has a percentage value of over 35%. As for the phytocoenoses analyzed in the Jiu-Danube confluence area, they are characterized by a very high degree of anthropization, the excessive development of the invasive species *Amorpha fruticosa* being one of the disruptive factors that act both from a silvo-biological, silvo-technical, conservative point of view and economic. Thus, it is very important to define and apply methods to control the species to restore these plant communities, especially in the meadow forests of the large hydrographic basins and especially in the Danube basin.

CONCLUSIONS

Amorpha fruticosa reproduces quickly and has a high capacity to adapt to various environmental conditions. This means that even after cutting or uprooting, the plant can quickly regenerate from the roots or remaining shoots, making mechanical methods insufficient to completely eradicate the species. Mechanical control often requires significant resources, both in terms of manpower and the equipment required. Also, plucking efforts must be performed repeatedly, which can become expensive and ineffective in the long run.

Chemical control is considered one of the most effective methods for managing *Amorpha fruticosa*. This is necessary because mechanical methods such as pulling or cutting are not effective enough to eradicate the plant once it has established itself in an area. The use of specific herbicides can help reduce the population of this invasive species and prevent its spread to other habitats.

Chemical control of *Amorpha fruticosa* is a crucial component in managing this invasive plant, but must be done responsibly to protect local ecosystems.

Due to the invasive character of *Amorpha fruticosa* and the difficulties encountered in its control by mechanical methods, it is recommended to use integrated strategies that include chemical control or other more effective methods to manage this invasive species.

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