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ARIEŞ RIVER VALLEY AS MIGRATION CORRIDOR FOR ALIEN PLANT SPECIES AND CONTAMINATION SOURCE FOR THE SURROUNDING GRASSLANDS AND AGRICULTURAL FIELDS

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Abstract

In the Transylvanian region, the Arieş Valley stretches along the course of the Arieş River, ending as tributary of Mureş River. As well as these areas of great biodiversity value, the Arieş Valley (drainage area of 2,540 km^2) also crosses the region where local people set their villages and towns and use the surrounding areas as grasslands for grazing, mowing and fields for agriculture. The grassland types are present in patches, those used for hay production are scattered among agricultural fields and human settlements.
Evidence from statistical analysis of the vegetation cover of a riparian area of Arieş River Valley indicates that in the inventorying plots with low species diversity, there is a dominance of one or two species with individuals unequally distributed within and between plots. The layer 1-5 m is dominated by alien invasive species: *Fallopia japonica, Helianthus tuberosus, Impatiens glanduligera,* the studied area of Arieş River Valley becoming a source for these alien species to invade the surrounding grasslands and agricultural fields. Especially *Fallopia japonica* individuals form compact patches invading the pastures and agricultural fields and the local farmers cannot use the land any more for fulfilling their own needs. The invasive species replace the native species from the grasslands and make the agricultural field inappropriate for crops cultivation. The river acts as a migration corridor for the alien species helping them to spread by seeds or fragments and invade new places, especially during spring and/or autumn floods, and a contamination source for the surrounding grasslands and agricultural fields.

Key words: *alien, Arieş, corridor, migration, plants*.

INTRODUCTION

Rivers of the world connect large areas and diverse landscapes. River valleys are mostly regarded as ecological corridors related with the conservation biology and nature conservation (Gallé et al., 1995; Dombrowski et al., 2002). The riparian zones are the most important structural and functional elements connecting aquatic and terrestrial areas (Malm Renöfält, 2004; Rodriguez-Iturbe at al., 2009). Riparian zones, comprising ecosystems situated along the different type of water bodies, are the subject of alien/non-native/exotic plants invasion, playing an important role as a corridor especially at the regional scale in their spread and establishment in the native plant communities (Souza et al., 2011). The riparian zones also behave as filters for nutrients, critical areas for biogeochemical processes, providers for resources and shade, stabilization of stream banks, etc. (Rodriguez-Iturbe et al, 2009). These corridors are hydrological connected, this connection being both the cause of the high species diversity and serve as dispersal vector for alien species invasion (Miyawaki and Washitani, 2004; Malm Renöfält et al., 2005 Kalusová et al., 2014)
Studies developed on rivers of the world (inland waterways) as corridors for invasion enable predictions about: increase in the rate of colonization, increase in the diversity of donor area and the origin of alien species, diversification of the vector of spread, increase of speed of colonization, strong shift of the taxonomic structures of the communities, dramatic reduction (occasionally local extirpation) of native species, invasive exotic species becoming a vector of spread for highly pathogenic parasites and diseases (Parker et al., 1999; Sher and Hyatt, 1999; Slynko et al., 2002; Karatayev et al., 2008; Rood and

Kalischuk, 2008; Hejda et al., 2009; Panov et al, 2009, Resasco et al., 2014).

The migration of a species consists in any change in its spatial distribution or any change in distribution of successfully established mature plants along its life cycle and generations (Sauer, 1988; Turnbull et al., 2007; Gardner and Engelhardt, 2008). The species occurring naturally in an area dispersing independent of human intervention are defined as native (indigenous) species. The species not occurring naturally in an area (it has not long history) and its dispersal depends on direct or indirect human intervention are defined as alien/non-native/non-indigenous/exotic. The alien are defined as naturalized species when, following introduction, the species established self-sustaining populations in the wild and have a long history together with native species in the resident communities. The native and alien plant species become invasive when ones established in natural or semi-natural habitats they change and threaten native biological diversity and ecological processes and cause economic losses (Panov et al., 2009; Sîrbu and Oprea, 2011; SRBMP, 2013).

The main factors determining the spread of the alien species are: disturbance regime gradient, physic, chemical and geo-morphological attributes, influences of humans and climatic (Planty-Tabacchi et al., 2001; Ervin et al., 2006; Montserrat et al., 2007; Früh et al., 2012; Moles et al., 2012).

Disturbance and propagule pressure are regarded as individual factors that strongly influence invasion process (Kinlan and Gaines, 2003; Britton-Simmons and Abbot, 2008; Früh et al., 2012).

The alien species are widely investigated in respect for species diversity, temporal trends, geographical patterns and ideas have been identified for future research (MacIsaac et al., 2001; Heger and Trepl, 2003; Lambdon et al., 2008; Moles et al., 2003; Török et al., 2003; Pienimäki and Leppäkoski, 2004; McGeoch et al., 2006; Zaiko et al., 2011).

The invasion of alien plant species is regarded as one of the biggest threat of the Romanian biodiversity (Anastasiu and Negrean, 2005). The alien invasive and potentially invasive plant species from the Romanian territory have been identified and the impact on natural and semi natural habitats were assessed for prevention and control measures (Anastasiu and Negrean, 2005, 2006, 2008, 2009; Dihoru, 2004; Sîrbu and Oprea, 2010) and preliminary studies were developed on wetlands (Anastasiu et al., 2008). A very comprehensive work regarding the adventive plant species from Romanian Flora was published by Sîrbu and Oprea (2011).

The richness and diversity of vegetation on Arieş catchment area was studied over decades but the studies were focused mainly on calcareous sites, gorges, and other interesting sites from the floristic point of view and recently on grasslands between Lupşa and Turda (Pál, 2010).

Are lacking studies focused on slopes, banks and floodplain of Arieş River Valley.

MATERIALS AND METHODS

In the Transylvanian region, the Arieş River Valley stretches from west to east the Gilău-Muntele Mare Massif in the left and Metaliferi Mountains in the right, ending as tributary of Mureş River. The present hydrogeomorphology is due to the human activity along the centuries, intensified in the last decades resulting in major changes of the natural relief. The numerous human settlements and ore mining activities modified the natural environment provoking intensified erosion and pollution processes, forming quarries, dumps tailing ponds and artificial terraces (Pál, 2010).

As well as these areas of great biodiversity value, the Arieş Valley (drainage area of 2,540 km^2) also crosses the region where local people set their villages and towns and use the surrounding areas as grasslands for grazing, mowing and fields for agriculture. Friedel and Linard (2008) stipulate that in the Arieş River basin the lad use categories comprise: pasture, 19.9%; range (grasses), 15.8%; and agricultural (generic and row crops), 13.8%. The areas at the confluence with Seşii Valley (belonging to the middle sector of Arieş River Valley) had been chosen because the water rich in pollutants from Seşii rivulet flows into Arieş River and percolate in the surrounding areas being a major disturbing driver in the area (Figure 1).

The maximum altitude is 478 m a.s.l. and the minimum altitude is 464 m a.s.l. due to the irregularities of the studied area. Scattered among higher areas are low areas where the water is retained for longer time during year, following the flooding, forming small wetlands with hygrophilous vegetation.

In 2014 we recorded the species composition and percentage cover of the vegetation in 91 plots, each of 2 m^2 (Figure 1). The plots were set in the riparian area to cover 92,500 m^2 representing the total coverage of the riparian vegetation. The plots were numbered starting with those in the vicinity of water course, beginning from the new formed area due to the river meander, going on rows, alternatively, till the riparian area ended in private grasslands and agricultural fields.

In every plot we recorded the vascular plant species according with the natural height layers: 0-1 m (herbaceous and new offsprings of tall herbaceous, shrubs and trees), 1-5 m (tall herbaceous, shrubs and offsprings of taller shrubs and trees), 5-15 m (tall shrubs and small trees and offsprings of tall trees) and 15-30 m (tall trees). Species identification and synonymy, their natural spread and ecological characterization were accomplished according with Ciocârlan (2009) and Sârbu et al. (2013).

From the total number of 150 vascular plant species recorded, in the present paper we highlight only alien species.

For the statistical analysis we used XLSTAT 2014.2.06 and it comprise Multidimensional Scaling (MDS) for 0-1 m height layer level and Bray-Curtis similarity (single linkage) for 1-5 m height layer level.

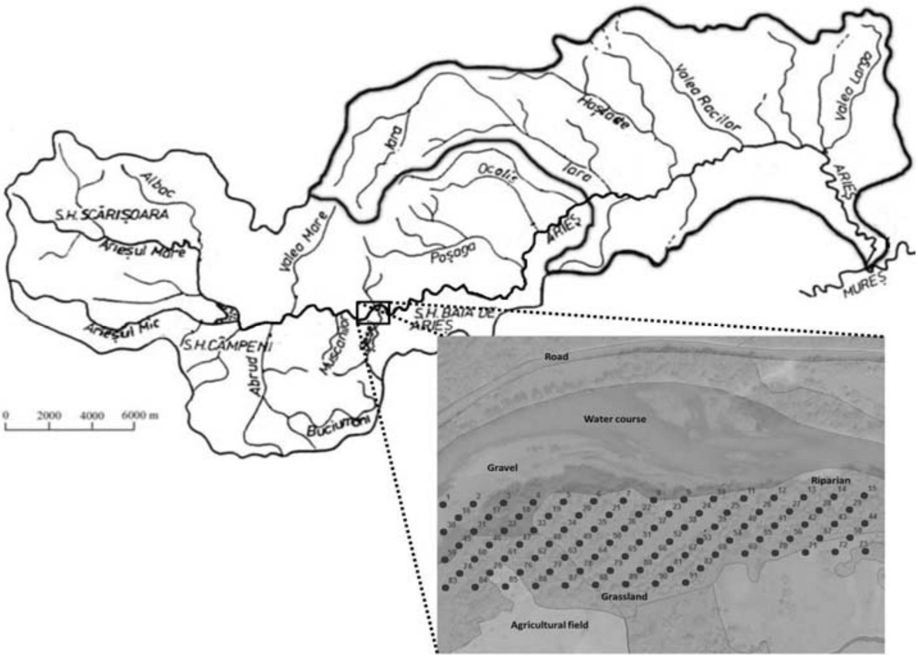

Figure 1. Arieş River basin – hydrometric network map (modified after Socorovchi et al., 2002). Studied area and the location of sampling plots on Arieş Valley at the confluence with Seşii Valley

RESULTS AND DISCUSSIONS

The grassland and agricultural fields are present on Arieş River Valley in small patches, those used for hay production are scattered among agricultural fields and human settlements. In the area where the sampling plots were settled, the grassland and agricultural fields are small private areas, in the mosaic of riparian areas along Arieş River.

The percentages of the species presented below are bases on the presence-absence of the species in the total number of investigated plots. In the layer 0-1 m height we registered: 3.34% *Erigeron annuus* (L.) Pers. (*Stenactis annua* (L.) Less.), 0.89% *Fallopia japonica*

(Houtt.) Ronse Decr. (*Polygonum cuspidatum* Siebold et. Zucc.; *Reynoutria japonica* Houtt.), 0.44% *Galinsoga parviflora* Cav*,* 1.45% *Lysimachia nummularia* L., 0.78% *Oenothera biennis* L., 1.11% *Oxalis fontana* Bunge (*O. stricta* auct. non L.; *O. europaea* Jord.), 0.56% *Robinia pseudoacacia* L.

The Multidimensional Scaling (MDS) for 0-1 m height layer level shows the structural similarity among the plots. The isolated plots are those situated in the patches formed by agricultural fields, grasslands and newly formed areas of the river meander (Figure 2).

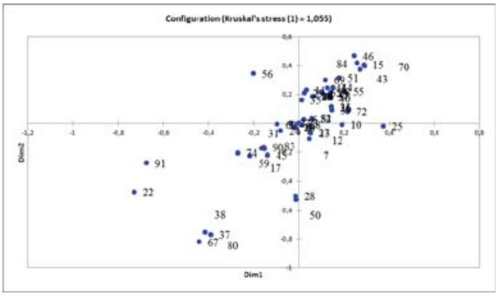

Figure 2. The Multidimensional Scaling (MDS) of the sampling plots based on the percentage coverage of the recorded plans species for 0-1 m height layer

The highest species diversity is in the grasslands and agricultural fields, these areas comprising also the offspring of both invasive rhizomatous herbaceous perennial knotweed species (*F. Japonica*) and tree *R. pseudoacacia*. The species diversity is low in the layer 1-5 m height, this being dominated by alien herbaceous adult species: the annual *Impatiens glanduligera* (3.83%), perennial *Fallopia japonica* (49.53%) and, *Helianthus tuberosus* (4.50%), and saplings of tree *Robinia pseudoacacia* (1.69%). The total coverage of this layer consists from the coverage of shrubs, saplings of trees, tall perennial herbaceous and annuals as it is shown in Bray-Curtis similarity Bray-Curtis (single linkage) (Figure 3).

The dominance of 1-5 m height layer (Figure 4) is due to tall herbaceous native perennial *Dryopteris filix-mas* (L.) Schott in the most plots growing together with *Fallopia japonica* displaying the same coverage in the investigated plots.

Robinia pseudoacacia is present in 17.65% of the plots in the layer 5-15 m height together with native shrubs and trees, and in the layer 15-30 m height, the species is present in 14.37% of the plots together with other tall trees characteristic for riparian Arieş River Valley.

The spatial distribution analysis of the species in the plots (Figure 4) highlighted that the most representative layer is 1-5 m height comprising all the alien species recorded in the area. The species density (above ground biomass) in most of the plots allows only a few native shrubs (Figure 3) and trees to survive, the only survivors being old trees established before the mass development of the alien species.

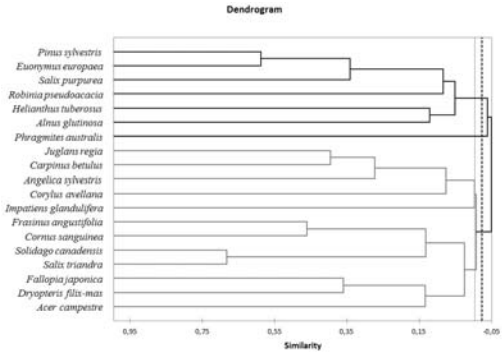

Figure 3. Similarity among the species coverage based on the percentage coverage of recorded vegetation of 1-5 m height layer

Apart of heavy metal pollution, another impact on old trees is their cutting by humans for fire or other purposes.

The clearing of the riparian forests creates gaps suitable for alien species allowing them to invade the riparian territory and surrounding areas.

All the herbaceous perennial species inventoried in the riparian area of Arieş River Valley are clonal plants, the predominant vegetative reproduction make them more resistant to the disturbance occurring in the riparian area, including water and soil pollution. The ramets can escape the intense polluted patches and find the more suitable patches in the nearby areas (Kershaw, 1980). Alien invasive species are able to change ecosystem function and soil properties, they have a highly significant negative impact for denitrifiers abundance, modify the potential microbial activity ecosystems (Dassonvile et al., 2011).

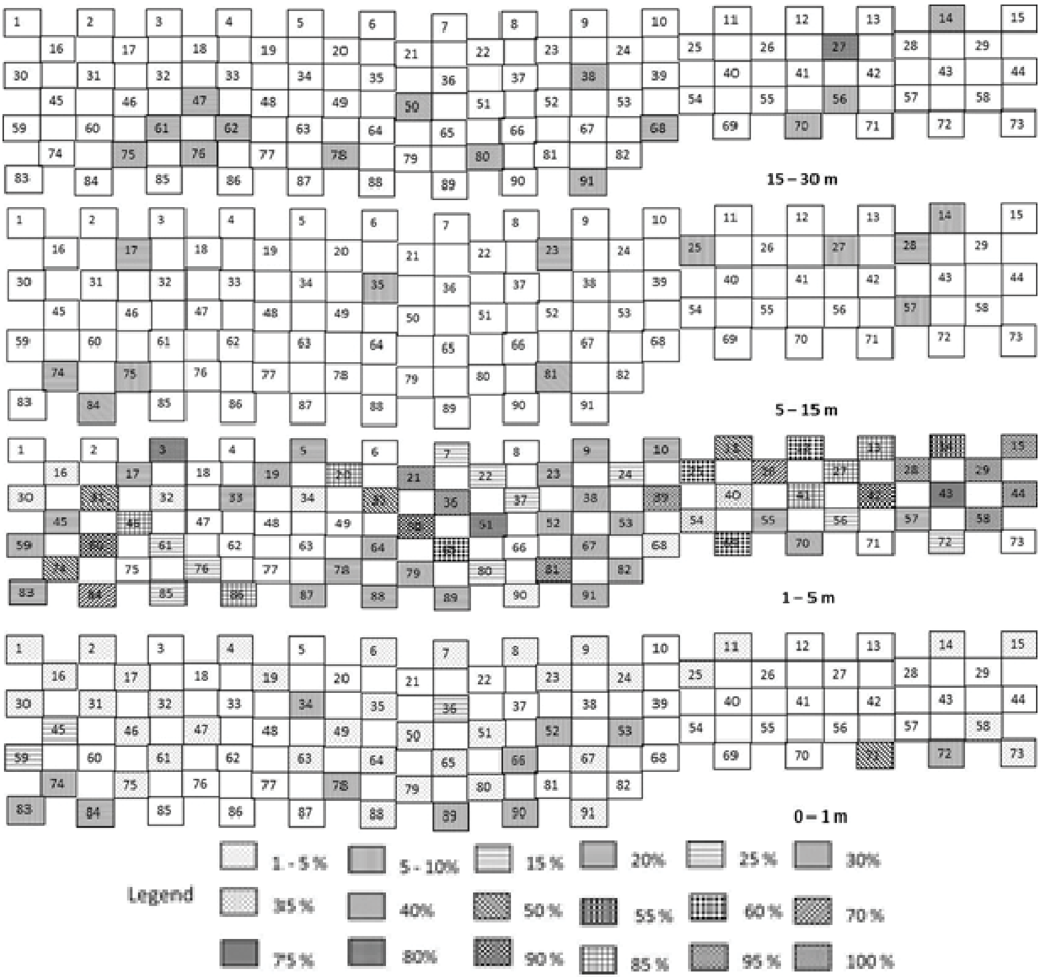

Figure 4. The spatial distribution analysis of the alien species in the inventorying plots

Cushman and Gaffney (2010) stipulate that the exotic clonal plants cause significant community-level effect because they are superior competitors in the riparian areas. Propagating predominantly clonally, they exhibit rapid growth dominating the vegetation of riparian corridor, compete more efficiently for resources and moisture, are more anchored in the soil escaping during intense flood velocity. The knotweed occurs particularly along the stream and riparian corridors (Claeson et al., 2014) *Fallopia* has a wide ecological niche that enables it to establish in different ecosystems (Dassonvile et al., 2011). Because the species display a rhizomatous growth, spread clonally, it may form monocultures very quickly reducing local species diversity, thus suggesting that clonal growth trait is possible to increase the impact and/or invasiveness of introduced species (Bailey et al., 2009; Aguilera et al., 2010). Their biological and ecological traits (tall stature, high biomass, high growth rate and fecundity, efficient dispersal) make them more successful as invasive species (Čuda et al., 2014).

The high species density and low diversity in the layer 1-5 m height with the dominance of alien species make the area a reservoir (recipient habitats) with propagules, a source for nearby areas invasion especially during river flooding. The farmers owning the agricultural lands and grasslands in the studied area were complaining about the more and more areas occupied with alien species over the years especially after flooding. Especially *F. japonica* forms monotype stands in grasslands and potato fields.

We argue that the riparian studied area situated in the vicinity of water flow behave as a reservoir for the propagules (seeds, plant fragments) brought here by water and sediment from upstream during flood. Once the alien plant species establish and develop in the riparian area, via wind, water, animals or other dispersal mechanism specific to every species (anemochory, zoochory, hydrochory, etc.) they spread in the agricultural fields and grasslands. Following establishment and development also in these areas, they might disperse from there laterally in other areas and/or back in the riparian area and also downstream invading more areas. Zedler and Kercher (2004) stipulate that the agricultural fields and urbanized catchments fed the wetlands through surface water thus making them more prone to invasive species development. Kowarik (2003) specified that invasion is the result of interplay of anthropogenic and biological mechanisms.

The invasion success is regulated by: biotic factors at local scale (neighbourhood and community) where the environmental conditions are more homogenous and biotic interactions can influence invasion and abiotic extrinsic factors (i.e. propagules pressure and disturbance) at a larger scale where the environmental conditions are more heterogeneous (Souza et al., 2011).

CONCLUSIONS

The offspring of alien plant species recorded in agricultural lands and grassland on a sector of Arieş River Valley and compact stands of adult clonal individuals of alien species shows that the riparian area behave like a reservoir for alien species invading the agricultural land and grasslands nearby the Arieş River. Especially *F. japonica* individuals form compact patches invading the pastures and agricultural fields and the local farmers cannot use the land any more for their own needs. Due to their dispersal mechanisms and intensified factors helpinh the dispersal, the area of Arieş River Valley is a source (recipient) for these alien species to invade the surrounding grasslands and agricultural fields and the areas downstream, behaving also as corridor for alien invasive species, from local to regional scale. The connections among the areas, especially the hydrologic one, make them more prone to alien species invasion. Also, the disturbance in the area is major due to pollution, direct human intervention (tree cutting, trash brought by the river during floods, etc.) increase its suitability for alien species development.

Arieş River acts as a migration corridor for the alien species helping them to spread by seeds or fragments and invade new places, especially during spring and/or autumn floods.

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REFERENCES

Aguilera A.G., Alpert P., Dukes J.S., Harrington R., 2010. Impact of the invasive plant *Fallopia japonica* (Houtt.) on plant communities and ecosystem processes. Biological Invasions, 12: 1243-1252.

Anastasiu P., Negrean G., 2005. Alien plants in Romania (I). Analele ştiinţifice ale Universităţii "Al. I. Cuza" Iaşi, Biologie vegetală, LI (II): 87-96.

Anastasiu P., Negrean G., 2006. Alien vascular plants in Dobrogea (Romania) and their impact on different types of habitats, plant, fungal and habitat diversity investigation and conservation. Proceedings of IV BBC – Sofia, 590-596.

Anastasiu P., Negrean G., 2008. New alien plants to Romania. Analele Univ. din Craiova. Seria Agricultură, Montanologie, Cadastru. 38/B: 1-10.

Anastasiu P., Negrean G., 2009. Neophytes in Romania. In: Rácosy L., Momeu L. (Eds.), Neobiota din România, Presa Universitară Clujeană, 66-97.

Anastasiu P., Negrean G., Başnou C., Sîrbu C., Oprea A., 2008. A preliminary study on the neophytes of wetlands in Romania. Biological invasions–from ecology to conservation. Neobiota, 7: 180-190.

Bailey J.P., Bímová K., MandáK B., 2009. Asexual spread versus sexual reproduction and evolution in Japanese knotweed s.l. sets the stage for the 'Battle of the Clones'. Biological Invasions, 11: 1189-1203.

Britton-Simmon K.H., Abbot K.C., 2008. Short- and long-term effects of disturbance and propagule pressure on a biological invasion. Journal of Ecology, 96: 68-77.

Ciocârlan V., 2009. The illustrated flora of Romania, Pteridophyta et Spermatophyta. Editura Ceres, 1141 p.

Claeson S.M., LeRoy C.J., Barry J.R., Kuehn K.A., 2014. Impact of invasive riparian knotweed on litter decomposition, aquatic fungi, and macroinvertebrates, Biological Invasions, 16: 1531-1544.

Cushman J.H, Gaffney K.A., 2010. Community-level consequence of invasion: impacts of exotic clonal plants on riparian vegetation. Biological Invasions, 12: 2765-2776.

Čuda J., Skálová H., Janovský Z., Pyšek P., 2014. Habitat requirements, short-term population dynamics and coexistence of native and invasive Impatiens species: a field study. Biological Invasion, 16: 177-190.

Dassonvile N., Gillaumaud N., Piola F., Meerts P., Poly F., 2011. Niche construction by invasive Asian knotweed (species complex *Fallopia*): impact on activity, abundance and community structure of denitrifiers and nitrifiers. Biological Invasions, 13: 1115-1133.

Dihoru G., 2004. Invasive plants in Romanian's flora. Analele Universitatii din Craiova, IX (XLV): 73-82.

Dombrowski A., Głowacki Z., Kovalchuk I., Nikiforov M., Michalczyk Z., Szwajgier W., Wojciechowski K.H., 2002. Bug River Valley as the ecological corridor. State-threats-protection. IUCN Office for Central Europe (Foundation IUCN Poland), 145 p.

Ervin G., Smothers M., Holly C., Anderson C., Linville J., 2006. Relative importance of wetland type versus anthropogenic activities in determining site invisibility. Biological Invasion, 8: 1425-1432.

Friedel M.J., Linard J.I., 2008. Initial Sediment Transport Model of the Mining Affected Aries River Basin, Romania. Open-File Report 2008-1171, 23 p.

Früh D., Stoll S., Haase P., 2012. Physicochemical and morphological degradation of stream and river habitats increases invasion risk. Biological Invasions, 14: 2243-2253.

Gallé L., Margóczi K., Kovács É., Györffy Gy., Körmöczi L. and Németh L., 1995. River valleys: Are they ecological corridors? Tiscia, 29: 53-58.

Gardner R.H., Engerlardt K.A.M., 2008. Spatial processes that maintain biodiversity in plant communities. Perspective in Plant Ecology, Evolution and Systematics, 9: 211-228.

Heger T., Trepl L., 2003. Predicting biological invasion. Biological Invasions, 5: 313-321.

Hejda M., Pyšek P., Jarošik V., 2009. Impact of invasive plants on the species richness, diversity and composition of invaded communities. Journal of Ecology, 97: 393-403.

Kalusová V., Milan Chytrý M., Robert K., Peet R.K., Thomas R., Wentworth T.R., 2014. Alien species pool influences the level of habitat invasion in intercontinental exchange of alien plants. Global Ecology and Biogeography, DOI: 10.1111/geb.12209, 1-10.

Karatayev A., Mastitsky S.E., Burlakova L.E., Olenin S., 2008. Past, current, and future of the Central European corridor for aquatic invasion in Belarus. Biological Invasions, 10: 215-232.

Kershaw K.A., 1980. Quantitative and Dynamic plant ecology. Butler & Tanner Ltd., Great Britain, 308 p.

Kinlan B.P., Gaines S.D., 2003. Propagule dispersal in marine and terrestrial environments: a community perspective. Ecology, 84 (8): 2007-2020.

Kowarik I., 2003. Human agency in biological invasions: secondary releases foster naturalization and population expansion of alien plant species. Biological Invasions, 5: 293-312.

Lambdon P.W., Pyšek P., Basnou C., Hejda M., Arianoutsou M., Essl F., Jarošík V., Pergl J., Winter M., Anastasiu P., Andriopoulos P., Bazos I., Brundu G., Celesti-Grapow L., Chassot P., Vilà M., 2008. Alien flora of Europe: species diversity, temporal trends, geographical patterns and research needs. Preslia, 80: 101-149.

Lockwood J.L., Hoopes M.F., Marchetti M.P., 2007. Invasion Ecology, Blackwell Publishing, 304 p.

MacIsaac H.J., Grigorovich I.A., Ricciardi A., 2001. Reassessment of species invasion concepts: the Great Lake basin as model. Biological Invasions, 3: 405-416.

Malm Renöfält B., 2004. Vegetation patterns and processes in riparian landscapes. Doctoral dissertation, Solfjädern Offset AB, 31 p.

Malm Renöfält B., Roland Jansson R., Christer Nilsson C., 2005. Spatial patterns of plant invasiveness in a riparian corridor. Landscape Ecology, 20:165-176.

McGeoch M.A., Chown S.L., Kalwij J.M., 2006. A global indicator for biological invasion. Conservation Biology, 20(6): 1635-1646.

Miyawaki S., Washitani I., 2004. Invasive Alien Plant Species in Riparian Areas of Japan: The Contribution of Agricultural Weeds, Revegetation Species and Aquacultural Species. Global Environmental Research, 8(1): 89-101.

Moles A.T., Gruber M.A., Bonser S.P., 2008. A new framework for predicting invasive plant species. Journal of Ecology, 96: 13-17.

Moles A.T., Flores-Moreno H., Bonser S.P., Warton D.I., Helm A.,Warman L., Eldridge D.J., Jurado E., Hemmings F.A., Reich P.B., Cavender-Bares J., Eric W., Seabloom E.W., Mayfield M.M., Sheil D., Djietror J.C., Peri P.L., Enrico L., Cabido M.R., Setterfield S.A., Caroline E.R., Lehmann C.S.A., Thomson F.J., 2012. Invasions: the trail behind, the path ahead, and a test of a disturbing idea, Journal of Ecology, 100: 116-127.

Montserrat V., Joan P., Xavier F., 2007. Regional assessment of plant invasions across different habitat types. Journal of Vegetation Sceince, 18: 35-42.

Pál F.J., 2010. Grasslands of the Arieş Valley between Lupşa and Turda. Structure, Ecology, Sustainable Management. Presa Universitară Clujeană, 250 p.

Panov V.E., Alexandrov B., Arbačiauskas K., Binimelis R., Copp G.H., Grabowski M., Lucy F., Leuven R.S., Nehring S., Paunović M., Semenchenko V., O Son M., 2009. Assessing the Risks of Aquatic Species Invasions via European Inland Waterways: From Concepts to Environmental Indicators. Integrated Environmental Assessment and Management, 5 (1): 110-126.

Parker I.M., Simberloff D., Lonsdale W.M., Goodell K., Wonham M., Kareiva P.M., Williamson M.H., Von Holle B., Moyle P.B., Byers J.E., Goldwasser L., 1999. Impact: toward a framework for understanding the cological effects of invaders. Biological invasion, 1: 3-19.

Pienimäki M., Leppäkoski E., 2004. Invasion pressure on Finish Lake district: invasion corridors and barriers. Biological Invasion, 6: 331-346.

Planty-Tabacchi A.M., Tabacchi E., Salinas Bonillo M.J., 2001. Invasions of river corridors by exotic plant species: patterns and causes. In Brundu G., Brock J., Camarda I., Child L., Wade M. (Eds.), Plant invasions: species ecology and ecosystem management, 221-233.

Resasco J., Haddad N.M., Orrock J.L., Shoemaker D.W., Brudvig L.A., Damschen E.I., Tewksbury J.J., Levey D.J., 2014. Landscape corridors can increase invasion by an exotic species and reduce diversity of native species. Ecology, 95(8): 2033-2039.

Rodriguez-Iturbe I., Muneepeerakul R., Bertuzzo E., Levin S.A., Rinaldo A., 2009. River networks as ecological corridors: A complex systems perspective for integrating hydrologic, geomorphologic, and ecologic dynamics. Water Resources Research, 45, W01413, doi: 10.1029/2008WR007124.

Rood S.B., Kalischuk A.R., 2008. Weed Invasion in Alberta's River Valley Corridors. WLA, 16(4): 16-18.

Sauer J.D., 1988. Plant migration. The dynamics of Geographic Patterning in seed plant species. University of California Press, 282 p.

Sher A.A., Hyatt L.A., 1999. The disturbed resource-flux matrix: a new framewrok for patterns of plant invasion. Biological Invasions, 1: 107-114.

Sîrbu C., Oprea A., 2010. Contribution to the Knowledge of the Alien Flora of Romania: *Rudbeckia triloba* L. and *Senecio inaequidens* DC. Not. Bot. Hort. Agrobot. Cluj, 38 (1): 33-36.

Sîrbu C., Oprea A., 2011. Adventive plants in Romanian Flora. Editura Ion Ionescu de la Brad, Iaşi, 733 p.

Sîrbu I., Ştefan N., Oprea A., 2013. Vascular plants from Romania, Illustrated field identifier. Editura Victor B Victor, 1320 p.

Slinko Y.V., Korneva L.G., Rivier I.A., Papchenkov V.G., Scherbina G.H., Orlova M.I., Therriault T.W., 2002. The Caspia-Volga-Baltic Invasion corridor. In Leppäkoski et al. (Eds.), Invasive aquatic species of Europe, Kluwer Academic Publishers, Netherlands, 399-411.

Socorovschi V., Şerban Gh., Bătinaş R., 2002, Hydrological hazards in the lower basin of Arieş River. Revista Riscuri şi Catastrofe, 1: 143-148.

Souza L., Bunn W.A., Weltzin J.F., Sanders N.J., 2011. Similar biotic factors affect early establishment and abundance of an invasive plant species across spatial scale. Biological Invasions, 13: 255-267.

SRBMP, 2013. Background paper no. 7, Invasive alien species. http://www.savacommission.org

Török K., Botta-Dukát Z., Dancza I., Németh I., Mihály B., Magyar D., 2003. Invasion gateway and corridors in the Carpathian Basin: biological invasion in Hungary. Biological Invasion, 5: 349-356.

Turnbull L.A., Coomes D.A., Purves D.W., Rees M., 2007. How spatial structure alters population and community dynamics in a natural plant community. Journal of Ecology, 95: 78-89.

Ward J.V., 1998. Riverine landscapes: biodiversity patterns, disturbance regimes and aquatic conservation. Biological Conservation, 83: 269-278.

Zaiko A., Lehtiniemi M., Narščius A., Olenin S., 2011. Assessment of bioinvasion impacts on a regional scale: a comparative approach. Biological Invasions, 13: 1739-1765.

Zedler J.B., Kercher S., 2004. Causes and consequences of invasive plants in wetlands: opportunities, opportunists, and outcomes. Critical Review in Plant Sceinece, 23(5): 431-452.

*** Addinsoft XLSTAT - Pro 2014, http://www.xlstat.com/en/