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HUMAN INDUCED ALTERATIONS IN PLANT BIODIVERSITY OF SĂRĂTURILE STRAND PLAIN - DELTA DUNĂRII

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Abstract: On Sărăturile strand plain the natural flora is almost entirely consisted of herbaceous species, the environmental conditions preventing the appearance and natural evolution of trees. The diversity of flora was modified because of the establishment of a tree plantation with alien plant species in order to fix the mobile sand dunes and to improve the environmental conditions in Sf. Gheorghe town. Some of the species became invasive plant species, *Hippophae rhamnoides* colonizing the sand dunes outside the planted perimeter but contributing the fixation and stabilization of shore sand dunes.

Key words: strand plain, anthropogenic impact, forestry plantation, alien plant species, invasive plant species

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INTRODUCTION

The Danube Delta is one of the last deltas from Europe that has a relative high level of wildness. It has exceptional value in term of its biology, landscape, and culture. Nevertheless some parts of Danube delta have been impacted by anthropogenic activities. In the Danube Delta, the main human intervention - engineering works - began in the second half of the XIX century when the European Commission for Danube has started channeling of Sulina arm for shipping. These works have been followed by dredging and cutting of shallow, narrow canals, before the Second World War (Antipa, 1915) and after, for improvement of fishing productivity, meander cuts and polder construction for agriculture in the Communist epoch. All these activities have been lead to alteration of natural water flux and natural sedimentary flux (Giosan et al., 2013), shoreline change along the Danube Delta Coast (Vespremeanu-Stroe et al., 2007).

The Sărăturile strand plain has experienced human influences in last half of XX century on its biodiversity and on its geomorphology in the *critical zone*, as defined it by Wohl (2013) - Earth's near-surface layer from the tops of the trees down to the deepest groundwater. In the southeastern part of the Sărăturile strand plain the landscape has been changed due to aforestation with non-native plant species mainly for stabilization of moving sands. Typically coastal sand dunes are formed through the trapping of sand by dune vegetation. In the absence of vegetation, the wind act on exposed sand, forming migrating dunes that move back and forth with the wind (Chapman, 1976). The mobile sand dunes can be stabilized by various techniques but the most

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effective method of stabilizing coastal dunes is through the use of vegetation (Woodhouse, 1978). For plants to be successfully established they must have special adaptation characteristics that allow them to survive in a harsh environment. Thus, these plants must be able to tolerate rapid sand accumulation, flooding, salt spray, sandblast, wind and water erosion, wide temperature fluctuations, drought, and low nutrient levels. On the other hand, plants capable of stabilizing coastal dunes can be established in most coastal regions with enough rainfall to support plant growth (Woodhouse, 1978).

The aforestation practice of coastal moving sands was carried out on relatively large scale in the past in coastal areas from European countries like Italy, France (Nordstrom, 2000). Now, aforestation, particularly with exotic species, often quite distant from their original ranges, is considered less desirable than it was in the past, such that in some locations areas of woodland are removed to restore original dune habitat that has greater conservation value (Sturgess, 1999; Nordstrom, 2000). Beside, artificial stabilization of sands with herbaceous or woody plant species contributes to plant invasion. Nowadays is widely accepted that coastal ecosystems are considered amongst the ecosystems most seriously threatened by invasion of alien species, including plants and animals (Chytrý et al., 2009; Pyšek & Richardson, 2010).

Because before afforestation, in the study area there were not natural woody vegetation, initially have been experimented some plant species and then have been chosen suitable plant species for forestry plantation. Also, the topographic surface of strand plain was reshaped significantly (Muşat et al., 1980, Ceuca & Bakoş, 1985). Other alien plant species have been identified (Anastasiu & Negrean, 2006) and the local people most likely have introduced some of them accidentally.

STUDY AREA

The Sărăturile strand plain or beach ridges plain, is one of the three main grounds above sea level, which belongs to marine delta. It is located in southern part of the Danube River delta and is built by the Sf. Gheorghe distributary. The Sărăturile strand plain consists of juxtaposed semi parallel, multiple, and successive beach-ridges, former shorelines of the delta (Brătescu, 1922; Banu & Rudescu 1965; Panin, 1997), built in last 2300 - 1800 years BP (Giosan et al., 2006). It represents net seaward advance of the deltaic coast on the western Black Sea. Each ridge-and-swale couplet represents a former beach and its immediate foreshorestranded by coastal progradation. Because of its origin, the aspect of Sărăturile strand plain exhibits linear ridges alternating with linear depressions that look like *„miniature valleys between flanking beach ridges, called swales"* (Bates & Jackson, 1980, quoted by Otvos, 2000). However, general morphology of the strand plain is flat, without very pronounced ridging. The ridge-and-swale morphology of Sărăturile strand plain is quite distinct on aerial photographs. The elevations range between 0.5 - 4 m above sea level. On the topographical surface, different types of habitats highlight this morphology. The sandy ridges are vegetated with psammophilous and xerophytes plant species, some of them being pioneers species. Because stagnant water or humid conditions prevail in the swales, they are populated with wetland plant communities. On the seaward part, these beach ridges are transformed in dunes field with heights up to 4 m (Giosan et al., 2005). The present shore is complex, with a large beach and vegetated foredunes.

Sedimentologically, the beach ridges are composed of fine sand, and are generally < 3 m above the present sea level (Muşat et al., 1980), most quart-rich sands, which are remarkable aquifers. In the eastern part of Sărăturile strand plain, measurements have been indicate fluctuations of level table of ground water from 50 to 150 cm in relation to topographical surface, according to variation of altitude and season of year (Muşat et al., 1980). The soils are poor in humus content, with high infiltration rates.

The climate is typically temperate continental, very dry, with Pontic influences (Bogdan et al., 1985). Winters are mild and summers are warm. A previously analysis of climatic and bioclimatic index for Sărăturile area (Strat, 2010), shows positive trend of mean annual air

temperature (11.3 °C for 1990-2004 interval, with 0.3 °C more than the average of 1896-1960 interval) and negative trend of precipitation, from 396, 1 mm (1896-1960) to 273, 4 mm (1990-2004) which means increase of aridity conditions. The mean monthly temperatures range from 0.6ºC in January to 23 ºC in July. Dominant winds blow from Northeast, North (Bogdan et al., 1985). The others climatic parameters are: mean sunshine duration – 2370 hours/year, being the sunniest place on Romanian Black Sea coast for 1961-2000 interval (Soare, 2008) and mean air humidity - 82%.

Bioclimatic assessment of the Grindul Sărăturile according to Rivas-Martinez method (Rivas-Martínez et al., 1999) shows changes of bioclimatic conditions, from Mediterranean pluviseasonal continental type to Mediterranean xeric continental type, in terms of ombrotype, due to decrease of annual precipitation amount and their distribution during the seasons (Strat, 2010).

Mentions about plant species diversity are in papers about flora of Danube Delta (Dihoru & Negrean, 1976; Ciocârlan, 1994, 2000, 2011; Anastasiu & Negrean, 2006), as well as in papers about Sărăturile area (Muşat et al., 1980; Roman, 1992; Strat, 2005, 2008, 2009; Doroftei et al., 2011; Zamfirescu, 2011; Negrea et al., 2013).

Until afforestation, only woody species on the Sărăturile strand plain were sea buckthorn and tamarisk, on mobile and high dunes, and a few white poplar suckers (Muşat et al., 1980).

In the Sărăturile strand plain there are a big variety of natural habitats, some of them are habitats European of importance (Doniţă et al., 2005).

The only settlement from this area is Sf. Gheorghe village. It is located very close to left riverbank St. Gheorghe arm of Danube, and at around 2 km away from seashore. The village has approximately 800 inhabitants. Fishing and tourism are main activities of local people.

The present study was carried out to investigate the effect of human activity on landforms and species diversity of Sărăturile strand plain.

AFORESTATION WORKS

Unlike Letea and Caraorman strand plains, on Sărăturile has not been developed a natural forest. A possible explanation could be that Sărăturile is younger than first two and the main environmental factors have not been suitable so that, by ecological succession, herbaceous vegetation to followed by the forest ecosystem development. Moreover, given the climatic characteristics, Danube Delta belongs to western edge of Pontic steppe.

At the end of six decade of XX century, on the southeastern part of Sărăturile strand plain have begun works for setting up a forest plantation. Afforestation has been conducted to protect Sf. Gheorghe village from sea winds, to stabilize mobile dunes, to avoid inundation of village by wind blown sand, to establish a forest industry, and enhance environmental quality.

The afforestation operations, which were a real challenge for Romanian silviculture (Ceuca & Bakoş, 1985), began in 1969 and are divided into three characteristic interventions:

1. Reconfiguration of topography by movement of sediments, excavations trenches, levees, channelization, alteration of level table of ground water. The purpose of these works was to prepare the land for planting. Plowing, enrichment of substratum with organic and mineral nutrients and irrigations also has been applied. To stabilize sands were created windbreaks orientated east-west, perpendicular to the prevailing wind direction. They consisted of two rows of *H. rhamnoides* and one row of *Elaeagnus angustifolia.*

The area designated for aforrestation was about 120 ha, located north of the Sf. Gheorghe village, parallel with the beach, along 5 km (Muşat et al., 1980). From this area, 20 ha were chosen for an experimental plot to test species adaptability to local environmental conditions.

Before afforestation, the area supported sparse vegetation characterized by several herbaceous plant species (Muşat et al., 1980; Ceuca & Bakoş, 1985): *Cynodon dactylon, Agropyron intermedium, Dianthus basarabicus, Euphorbia gerardiana, Artemisia arenaria, Scabiosa ucrainica, Bromus tectorum, Phragmites communis, Potentilla reptans, Teucrium*

scardium, Agrostis stolonifera, Mentha pelagium, Statice gmelini, Juncus maritimus, Juncus jerardi, Chenopodium rubrum, Salicornia europeae, Suaeda maritime, Aeluropus littoralis.

2. Choosing and planting species in experimental plot and monitoring of species.

3. Planting entire surface of forestry plantation and monitoring of species. The plant species planted were (Muşat et al., 1980; Ceuca & Bakoş, 1985): white poplar (*Populus alba* L.), euro-american poplar (*P. deltoides x nigra*), Chinese poplar (*Populus simonii*), white willow (*Salix alba* L.), weeping willow (*Salix babylonica* L.), black locust (*Robinia pseudacacia* L.), maple (*Acer platanoides* L., *A. tataricum* L., Acer negundo L.), wild pear (*Pirus pyraster* L.), tamarisk (*Tamarix ramosissima* L.), sea buckthorn (*Hippophae rhamnoides* L.), Russian olive (*Elaeagnus angustifolia* L), hawthorn (*Crataegus pentagyna)* Waldst & Kit. Ex Willd, black locust without thorns (*Amorpha fruticosa* L.), creeping willow (*Salix arenaria* L.), Scots pine (*Pinus sylvestris* L.), Douglas spruce (*Pseudotsuga menziesii*), larch (*Larix deciduas L.*), black pine (*P. nigra* L.), red cedar (*Juniperus virginiana* L.), pedunculate oak (*Quercus pedunculiflora* Koch), red oak (*Q. borealis* Mich.), cork oak (*Q. suber* L.), Paulownia tomentosa honey locust (*Gleditsia triacanthos L.),* white mulberry (*Morus alba L.), J*apanese pagoda tree (*Sophora japonica* L.), *Fraxinus pallisae* Wilmott, black alder (*Alnus glutinosa* L.), grey alder (*Alnus incana* L.), common dogwood (*Cornus sanguinea L.), dog rose (Rosa sp.),* wild privet (*Ligustrum vulgare L.),* wild black cherry (*Prunus serotina* L.), cherry plum (*Prunus cerasifera* Ehrh.), tree of heaven (*Ailanthus altissima* Mill.), black walnut (*Juglans nigra* L.).

From all these species only some of them have been successful, depending on the type of minor relief where they have been planted, the control factors being level table of ground water and salts content (Muşat et al., 1980; Mănescu & Traci, 1995). Among the species that have well adapted is noted: *Elaeagnus angustifolia, Tamarix ramosissima, Hippophae rhamnoides, Robinia pseudoacacia, Pinus sylvestris, P. nigra, Juniperus virginiana, Populus alba, Populus deltoids x nigra, Alnus glutinosa, Alnus incana, Morus alba, Rosa sp., Ligustrum vulgare.* On the other hand, among the species that did not survive are: larch, Douglas spruce, pedunculate oak cork oak, red oak, Paulownia, black walnut.

ALIEN AND INVASIVE PLANT SPECIES

According to Anastasiu and Negrean (2006), in Danube Delta have been identified 36 alien vascular taxa, some of them have invasive status and others become spontaneous only casually and are not able to produce new stable populations on long term, in the new conditions.

Some of alien plant species, weeds or not, have been introduced accidentally or through deliberate introductions in private gardens of the locals. Dumping of garden waste at the edges of village is a major source of weed infestations. Taking in account that Sf. Gheorghe arm is a way of transport, diaspores of the species could be brought in Sărăturile area by navy traffic. Zoochory, especially by birds, is another way.

H. rhamnoides has been considered a desirable plant species for sand stabilization from Sărăturile because it is one of the few woody plants that thrive on the coast (Groves, 1958) and because is very suitable for protection of forestry plantation.

If inside of forestry plantation sea buckthorn was deliberate planted, although with some caution due of its invasion potential (Muşat et al., 1980), on the mobile sand dunes from outside the forestry plantation, sea buckthorn is an invader. The invasive nature of the *H. rhamnoides* become conspicuous in the years following the start of forestration works Probably, initially it was spread of frugivorous birds that can carry and distribute viable seed. Then, its abundance and distribution has increased greatly because of vegetative spreading, by rhizome growth and layering. Dunes invaded by *H. rhamnoides* and *Elaeagnos angustifolia* become transformed from almost desert landscape, with sparse and widely spaced vegetation, into highly modified bush lands with dense, even impenetrable thickets. This process has taken place in 5-10 years, from 1976 to 1986, after afforestations works that was made in 1969-1975 period (Mănescu & Traci, 1995).

Considering this impact, *H. rhamnoides* is a biogeomorphological agent due its contribution to formation and stabilization of dunes, and a *„transformer"* (Richardson et al., 2008) or an *„ecosystem engineer"*, according to Conser & Connor (2008), because it creates habitats for other species. Anyway, in the others places from Europe, *H. rhamnoides* is dominant plant species in the pioneer scrub vegetation on calcareous coastal sand dunes (Zoon, 1995), and some of dunes that are naturally populated with sea-buckthorn are habitats of European importance (Council Directive 92/43/EEC). Sărăturile is a typical site from Romania with shore dunes covered with sea buckthorn scrub. Due to N-fixation by the symbiotic actinomycete *Frankia* in its root nodules and the subsequent accumulation of nitrogen *Hippophaë* is likely an important facilitating factor in the succession in dune vegetation (Zoon, 1995). The observations made in forestry plantations revealed that grows and development of some species (*Pinus nigra*, *P. sylvestris*, *Juniperus virginiana*, *Populus alba*, *Morus alba*, *Rosa sp*., *Ligustrum vugare*) was stimulated after that area was invaded by seabuckthorn (Mănescu & Traci, 1995).

On the other hand, the expansion of *Hippophaë rhamnoides* could be a serious threat to the plant species richness of open coastal dunes because very dense shrublands of this plant is associated with a decline in native plant species richness of the dunes and replacement of some rare species (Iserman et al., 2007).

However, according with our observations, in the last 15 years, on the coastal dunes of the Sărăturile, these scrubs gradually degenerate. Many sea buckthorn bushes were dried and others are less vigorous. The observed senescence of part of *H. rhamnoides* from Sărăturile strand plain is difficult to explain but in Netherlands, degeneration of *Hippophaë* scrub from calcareous dunes was found to be associated with the presence of plant-feeding nematodes (Oremus & Otten, 1981; Zoon, 1995).

The alien plant species that occur spontaneously on Sărăturile strand plain or escaped from gardens are: *Eclipta prostrata* (L.) L., *Eclipta prostrata* (L.) L., *Iva xanthifolia* Nutt*, Lindernia dubia* (L.) Pennell (Anastasiu, 2010), *Euphorbia humifusa* Willd., *Petunia parviflora* Juss., *Datura inoxia* Mill., *Solidago gigantea* Aiton, *Oenothera biennis.*

The alien noxious species that we identified in ours surveys on southern part of Sărăturile strand plain, as invasive species, is Xanthium strumarium L. This plant has been invaded the high beach and foredune.

According to Doroftei & Covaliu (2009) and our personal observation during 2003-2011, another alien taxa are ligneous species cultivated in the gardens of villagers. These are: maple ash (*Acer negundo* L.), staghorn sumac *(Rhus hirta* L.), common holly (*Ilex aquifolium* L.), b*ox wood (Buxus sempervirens* L.), Honey locust *(Gleditsia triacanthos* L.), Japanese honeysuckle (*Lonicera japonica* Thunb.), *Viburnum macrocephalum* Fort., *Thuja occidentalis* L., *Thuja orientalis* L., Chinese wisteria *(Wisteria sinensis* (Sims) Sweet), golden currant (*Ribes aureum* Pursh.), horse-chestnut *(Aesculus hippocastanum* L.), black walnut *(Juglans nigra* L.), *Hibiscus syriacus* L., pink silk tree *(Albizia julibrissin* Durazz.), fig (*Ficus carica* L.), white mulberry *(Morus alba* L.), black mulberry (*Morus nigra* L.), jasmine (*Jasminum officinale* L.), quince *(Cydonia oblonga* Miller), plum (*Prunus domestica* L.), *Rosa rugosa* Thunb., false Spiraea *(Sorbaria sorbifolia* (L.) A.Br.), *Spirea vanhouttei* (Briot) Zabel, wolfberry *(Lycium barbarum* L.), Virginia creeper *(Parthenocissus quinquefolia* (L.) Planchon).

CONCLUSIONS

Alien plant species, both herbaceous and ligneous, are present in Danube Delta and subsequently in Sărăturile strand plain because these have been cultivated in private gardens, polders, riverbanks, and forestry plantations. Some of alien plant species are invasive plant species and others could be in near future. A few alien plant species intentionally introduced have been escaped from manmade habitats becoming widespread in Danube Delta and officially declared invasive species. Among them, on Sărăturile occur *Ailanthus altissima*, *Robinia pseudacacia*, *Morus alba*, *Acer negundo.* A forestry plantation was established in the 1970s on Sărăturile strand plain to provide provide enhancements to the quality of life for inhabitants of Sf. Gheorghe village.

This anthropogenic forest changed the landscape. Though sea buckthorn and Russian olive have been escaped from forestry plantation and invaded coastal dune, they are not perceived as invasive species because of positive impact from geomorphologic point of view: they stabilizes the shifting sands. For Danube Delta it is absolutely necessary to exist a strict control of cultivated species (for ornamental, agricultural, technical forestry reasons) and to develop a system for constant monitoring of unintentionally introduced species.

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