REMOVAL METHODS FOR INVASIVE SPECIES AMORPHA FRUTICOSA – EXAMPLE OF ODRANSKO POLJE

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Abstract: *Amorpha fruticosa is an invasive plant species that occurs in wide range of habitat types, including lowland floodplains. It grows very dense and changes the composition of communities by suppressing indigenous species, resulting in significantly reduced variety of flora in the area. In Odransko polje Amorpha fruticosa is widely spread. One of the tasks of Appropriate assessment of project "Flood protection system of Sisak area" was to determine the locations where material for embankment construction should be taken. The locations should be acceptable both from the aspect of nature protection and from the economic point of view (proximity to embankment due to lowering material transport costs, locations which are not private property, etc.). The locations where A. fruticosa is dominant plant were suggested for excavation. This paper will give overview of removal and disposal methods for this invasive species, which reduce the possibility of its spreading and re-appearing. Also, positive impacts of using proposed locations for material excavation will be shown – decrease in A. fruticosa abundance, increase of habitat diversity, increase in the presence of target habitats and target species habitats etc. Additionally, good practices for selection of excavation sites will be given, including guidelines for their sanation and landscape design.*
Keywords: *Amorpha fruticosa, invasive species, Odransko polje, floodplains*

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1. INTRODUCTION

A. fruticosa L. (desert false indigo, false indigo-bush, bastard indigobush) is a deciduous shrub from the legume family (*Fabaceae*), usually 1-2 m high, but can grow up to 6 m. The leaves are pinnately compound, with 5-12 (sometimes up to 17) pairs of elliptical leaflets. The flowers build characteristic upright, thick, 10-15 cm long, dark petal wraps. *A. fruticosa* blossoms from April to June and attracts numerous pollinating insects with numerous noticeable flowers and nectar. After successful pollination and fertilization, a 6-9 mm long, glandular pod develops. In addition to seeds, the *A. fruticosa* spreads rapidly vegetative through stem shoots and root suckers (Nikolić et al. 2014).

A. fruticosa prefers medium-moist to moist soils, with a moderate amount of humus, moderately rich to rich in nitrogen. It is indicator of moderately acidic soils. It prefers areas directly exposed to sunlight and can only tolerate partial shading. It is prone to highly thermophilic habitats of almost sub-Mediterranean features. It occurs in semi-natural and natural habitats (Nikolić et al. 2014).

A. fruticosa, native to North America, was introduced into Europe in the 18th century as an ornamental plant and as a plant for soil stabilization (Nagy et al. 2018). It is also used as a hedge, whether for land delimitation or as a windshield. *A. fruticosa* is a highly appreciated honey plant, which honey is dark red color, translucent and of a pleasant taste, crystallizes slowly and contains 53 % sugar. Bees also collect large quantities of pollen, which is also highly appreciated (Kozuharova et al. 2017). As a honey plant, it has been reported in the literature by honey producers as '*A. fruticosa* pasture' (Nikolić et al. 2014). Shredded seeds are used as a spice while the stem is used for litter (Krpan et al. 2011). The stem parts have an insecticidal effect, so the plant is also used as a repellent (Kozuharova et al. 2017). From the above it can be seen that it is a plant with a wide range of possible uses (Jakovljević et al. 2015).

In Europe, it is considered an invasive species because it forms dense groups of plants in the area where it grows and adversely affects the development of native plant species and reduces biodiversity due to the easy germination of seeds, their easy spread (wind, water) and rapid growth (Novak & Novak 2018). *A. fruticosa* grows in very dense assemblages and reaches extremely high density on occupied surfaces and is almost the only species. It alters the composition of communities by aggressive penetration that slows development of

other plants (Horvat & Franjic 2016). In areas where it grows flora diversity declines dramatically, resulting in negative changes in overall biodiversity and other unwanted habitat changes (food chains, matter circulation etc.) (Horvat & Franjić 2016). It grows much faster than autochthone forest species, and overgrowth and congestion can lead to decay of young forest (Nikolić et al. 2014). Because of its rapid growth and high resilience, *A. fruticosa* has potential as a renewable energy source (Agroklub 2019, Krpan et al. 2011, Krpan et al. 2014).

In Croatia, it is most widely spread in the valleys of the Sava, Drava and Danube rivers, where it aggressively conquers forest areas, causing major problems with the natural regeneration of pedunculate oak and narrow-leafed ash forests (Jakovljević et al. 2015, Krpan et al. 2011). Problems occur where natural restoration has not been properly carried out and weed species emerge (Agroklub 2019). In addition to young forest plantations, it is common in floodplains, along riverbanks and roads.

Considering all the above, *A. fruticosa* is an example of a plant that causes multiple damage on the one hand and is successfully used on the other.

This paper will give overview of removal and disposal methods for this invasive species, which reduce the possibility of its spreading and re-appearing. Also, positive impacts of using proposed locations for material excavation will be shown – decrease in *A. fruticosa* abundance, increase of habitat diversity, increase in the presence of target habitats and target species habitats etc. Additionally, good practices for selection of excavation sites will be given, including guidelines for their sanation and landscape design.

2. ODRANSKO POLJE

Odransko Polje is located on the right bank of the Sava River, between the towns of Velika Gorica and Sisak, about 30 km long and about 8 km wide. The river Odra forms the backbone of the hydrological-hydraulic regime of this area, on which the alluvial forests of pedunculate oaks and wet grasslands depend. The preserved wetland areas are located in the middle and lower reaches of the river and are characterized by great biodiversity. The left bank of Odra, Gornja Posavina, is covered by lowland wet grasslands and pastures - the natural habitat of horse Hrvatski posavac and Posavska goose, as well as endangered species that depend on the mowing of the grasslands and extensive livestock farming. On the right bank, Turopolje, in the forests of pedunculate oak there is a natural habitat for other autochthonous Croatian breed - Turopolje pig, as well as for white-tailed and lesser spotted eagles, and one of the richest areas in Croatia with amphibian and reptile fauna (Glasnović Horvat & Vizner 2011).

The flooding of the Odransko Polje occurs in the cold part of the year (November-April), when the high waters of Kupa enter the Odransko polje through the mouth of Odra near Sisak. As the height difference between the source and the mouth of the river Odra is less than 3 m and the riverbed is relatively shallow, water from the river flood the Odransko Polje (Vita projekt 2019).

There are several protected areas in this area - protected landscapes Turopoljski lug and Odransko Polje and ecological network areas HR2000415 Odransko Polje (Habitats directive site) and HR1000003 Turopolje (Birds directive site) (**Figure 1**). Native animal breeds are a significant value of the natural and cultural heritage of an area and have been maintained in the Odransko Polje thanks to traditional livestock farming, as an important branch of local economy. Traditional animal husbandry enables the maintenance of pastures and wet grasslands, which are habitats for numerous plant and animal species, and represents a special landscape feature of this region. All these are the reasons for declaring Odransko Polje a protected landscape (Općina Lekenik 2019).

As mentioned earlier, *A. fruticosa* is widespread in the valleys of large rivers in continental Croatia, and one of the areas with high representation is the Odransko Polje. According to the map of terrestrial non-forest habitats of the Republic of Croatia (2016), in the ecological network site HR1000003 Turopolje, *A. fruticosa* is spread on between 930.97 ha and 1.578,10 ha, which is between 4.65 % and 7.89 % surface of this area, while in the HR2000415 Odransko polje, *A. fruticosa* is spread on between 813.25 ha and 1.357,46, which is between 5.92 % and 9.88 % surface of the area (**Figure 2**).

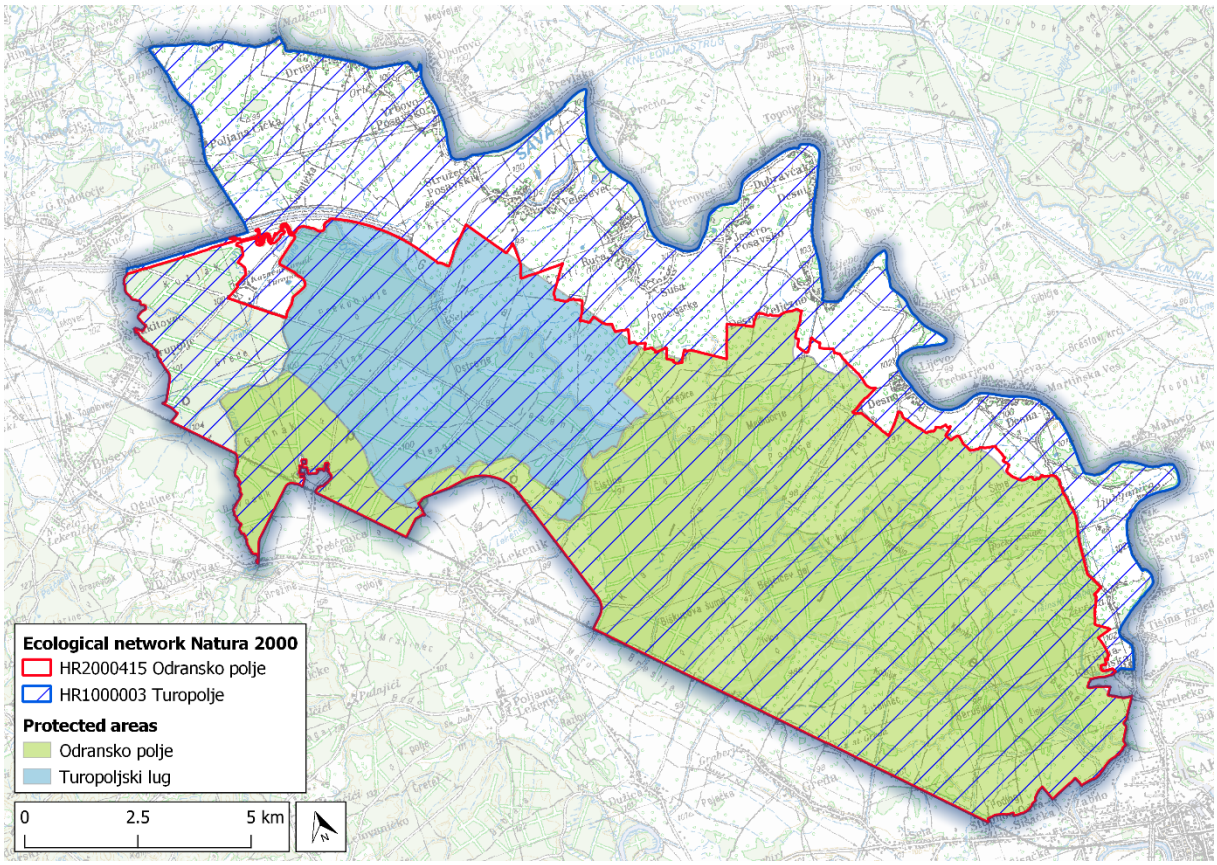

Figure 1. *Protected areas and ecological network areas in Odransko polje*

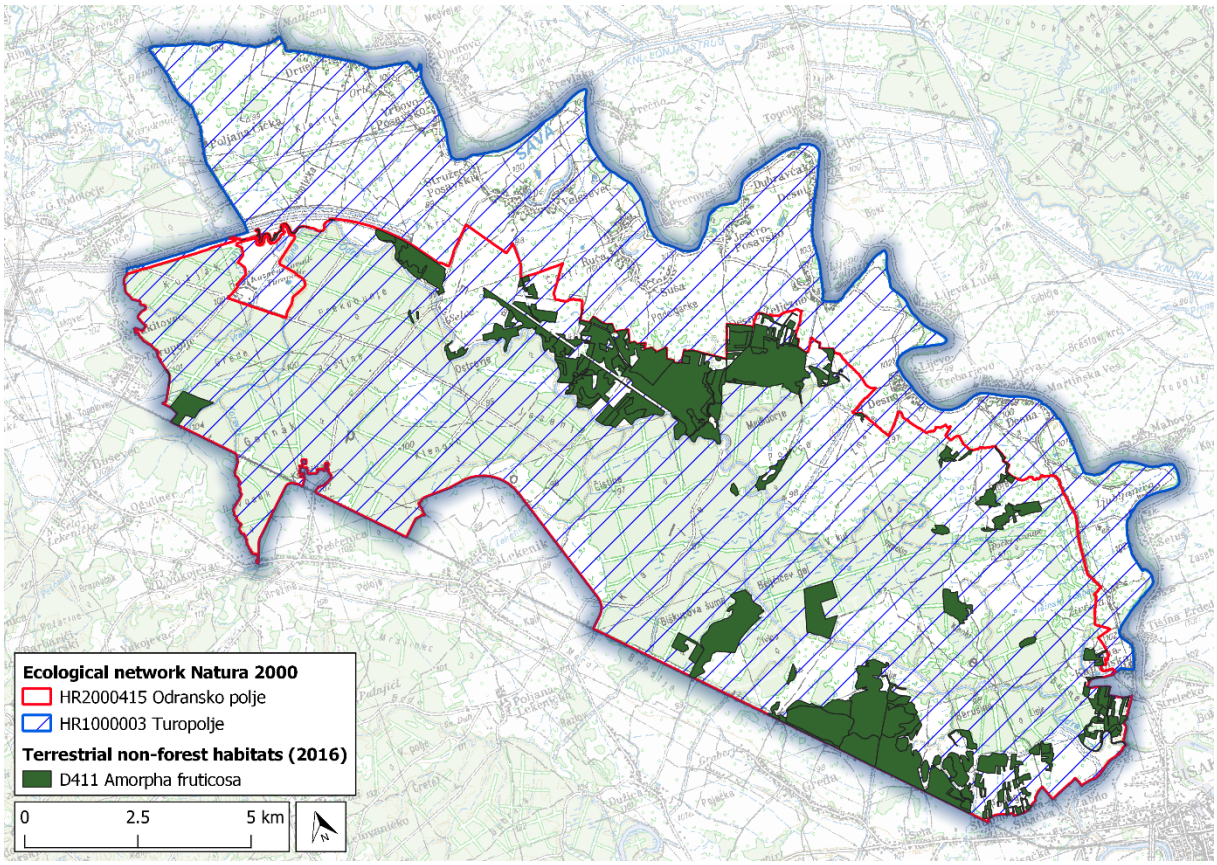

Figure 2. *Areas with Amorpha A. fruticosa in Odransko polje*

3. SISAK AREA FLOOD PROTECTION SYSTEM

The construction of the Sisak area flood protection system is part of a larger flood protection project in the Kupa River basin - Karlovac-Sisak area flood protection. The flood protection system of the Sisak area is based on the construction and reconstruction of embankments, revetments and walls along the Kupa River and the embankment in Odransko Polje. This project will protect settlements along the Kupa River from flood waters of Kupa and settlements along the edge of the Odransko Polje area from flood waters of the Odra. **Figure 3** shows the planned embankments in Odransko Polje. The concept of flood protection of areas along the edge of Odransko Polje is based on "enclosing" the Odransko polje with embankments, while the natural regime of flooding will not change and existing hydrological conditions will be maintained, which will enable the survival of the oak forests and wet grasslands.

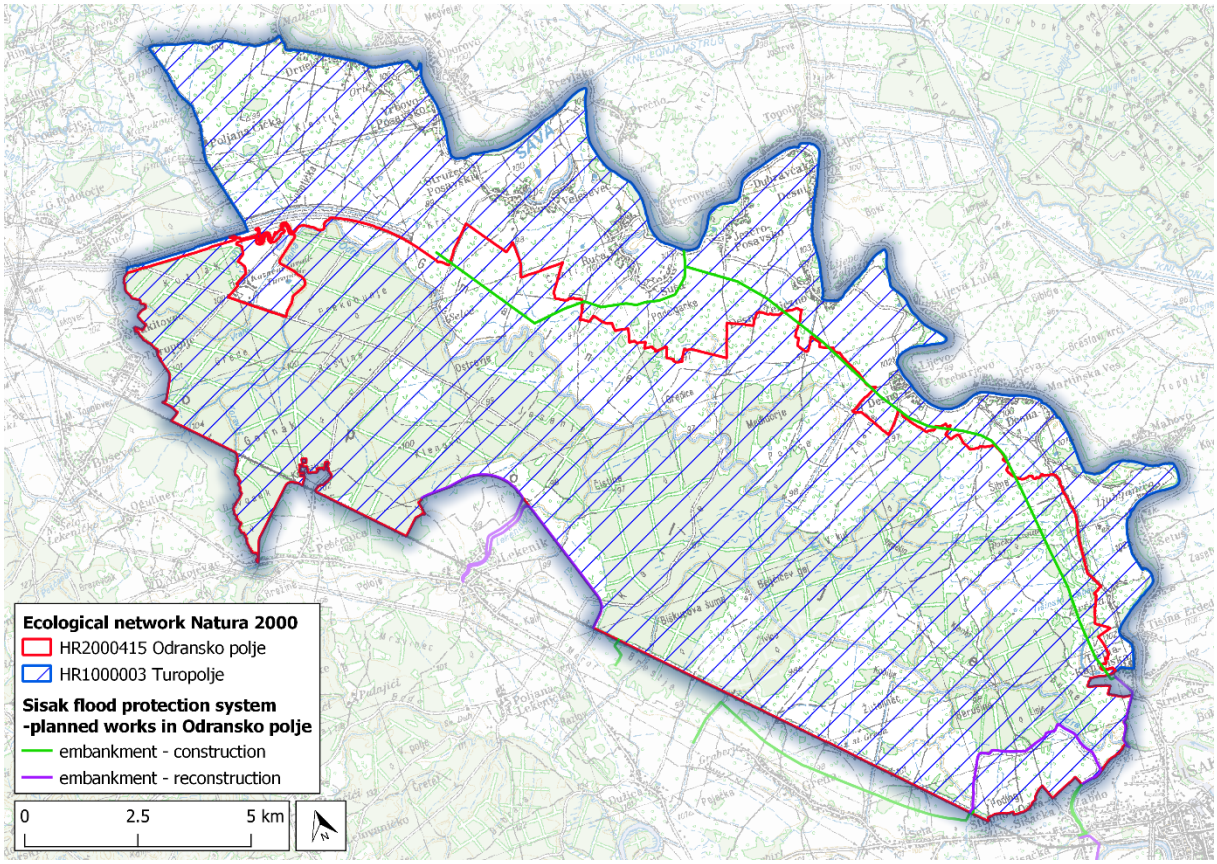

Figure 3. *Planned works in Odransko polje*

4. BORROW PITS

Planned works in Odransko Polje includes construction of about 29 km of embankment and the reconstruction of another 18 km, which requires large quantities of construction material. During the Appropriate assessment of project "Sisak area flood protection system" (2019), the locations of borrow pits that are acceptable from the aspect of nature protection were determined. When proposing and selecting locations, the conditions were set that needed to be met to the maximum extent possible: a) borrow pit should be near construction / reconstruction of the embankment site in order to reduce the cost of transporting the material; b) site locations are owned by the Republic of Croatia in order to reduce land acquisition costs and c) *A. fruticosa* is dominant plant on borrow pits locations.

The use of locations where *A. fruticosa* is present reduces the total area in the Odransko polje where this species is represented. In addition to the positive impact of reduction of *A. fruticosa* spread area, adequate borrow pit design after exploitation of the soil material creates new areas of subnatural habitat types, thus increasing the habitat area suitable for many animal species (invertebrates, amphibians, reptiles, birds). Exploitation of material will result in small depression, which will be filled with precipitation and ground water and small water bodies will be formed. Since the Odransko polje is a natural floodplain where species typical for wet habitats occur, the new water bodies will ideally blend in there. Adequate design of these depressions, as well as forbidding their use for fishing purposes, creates new aquatic and wetland habitats that will allow greater biodiversity of the area.

5. *A. FRUTICOSA* REMOVAL AND DISPOSAL

In order to create the desired habitat conditions at the borrow pits locations, and to prevent the spread of *A. fruticosa* to locations of embankment construction / reconstruction, special attention should be paid to the following:

a) *A. fruticosa* and surface soil layer removal and disposal - Blagojević et al. (2015) state that the quantity of *A. fruticosa* seeds in the soil decreases with the depth and that at a depth of more than 30 cm the quantity of seeds is negligible (Blagojević et al. 2015). Since *A. fruticosa* is very successfully vegetative propagated, in order to prevent its spread and regrowth, residues of plant material (trunks, branches, roots) should be adequately disposed in a safe place after removal (Nikolić et al. 2014). The material can be burned, chopped small, and it can also be deposited in borrow pits and then covered with soil material 1.5 m thick that does not contain parts of the plant. After removal of the overground part of plant and its root, it is also necessary to remove a surface soil layer of at least 0.5 m thickness, in order to reach soil material that will be used for construction / reconstruction of the embankment, which does not contain the seed of the plant. This removed soil layer can also be deposited in the borrow pits and, like the previously removed parts of the plant, covered with uncontaminated soil material. *A. fruticosa* is plant with negative allelopathic potential (Novak et al. 2018). It contains allelochemicals which may be decomposed or transformed in the soil and may have influence on germination and growth of different species. This is also reason why it is necessary to remove at least 0.5 m of surface soil layer, as this will also remove allelochemicals that may have negative impact on plants that are planned to be planted at the edges of borrow pit.

b) Excavating and transporting soil material for embankments - before loading and transporting materials, vehicles and equipment must be thoroughly cleaned and washed to prevent transposal of plant material remains. Also, before excavating material, it is necessary to thoroughly inspect the surface of the site and remove any plant remains. This will reduce the risk of the plant material being transposal to new locations.

c) Borrow pits design - in order to create new subnatural habitats that will increase the biodiversity of the area and provide habitat for many native plant and animal species, the site needs to be design for this purpose. Borrow pits should have irregular shape and irregular surface of the bottom, with as much indentation as possible, slight slopes (1: 3 to 1:20) of terraced form with gradual transitions to deeper parts and, if possible, small islands. Autochthones alluvial forest and marsh vegetation should be planted along the site, which will stabilize the edge of borrow pit and prevent erosion (e.g. *Salix* sp,, *Populus nigra*, *Alnus glutinosa*, *Alnus incana*, *Ulmus minor*, *Ulmus laevis*, *Fraxinus angustifolia*, *Carex* sp., *Phragmites* sp.) This will also contribute significantly to the quality of the habitat, as riparian vegetation is extremely important for species depended on aquatic habitats (shelters, feeding sites and hatcheries of many species are found here). At the highest edges of borrow pit and in area adjacent to the site, it is recommended to form a forest belt with alluvial species. This will allow the development of multiple layers of riparian vegetation, each representing an important micro-habitat for many animal species (Institut IGH d.d. 2016).

6. EXAMPLES OF BORROW PITS DESIGNS

Below are 2 examples of borrow pits design that have a positive impact on the biodiversity of the area.

6.1. Borrow pit in Odransko polje near Desna Martinska Ves settlement

At the site about 2.5 km south of the settlement Desna Martinska Ves, the soil material was excavated about 15 years ago. Depression of irregular shape with different slopes was formed, in which water is present all year (the site dried up only in years with below average rainfall). In addition to the design of the borrow pit shape, no further work was taken, but with this little effort, an area of significant biodiversity was created. The presence of dragonflies, numerous other invertebrates and several species of amphibians was recorded here during location visit in July 2019. This area is regularly flooded in spring, when several fish species migrate from Sava, Kupa and Odra river in flooded areas where depressions like this are used as spawning site (e.g. *Leuciscus aspius*, *Abramis brama*, *Leuciscus idus*, *Chondrostorma nasus* and *Vimba vimba*) (Vita projekt d.o.o., 2019). **Figure 4** shows the current look of the site. Unfortunately, the problem of *A. fruticosa* spread is also present in this area and it is significantly represented north of borrow pit.

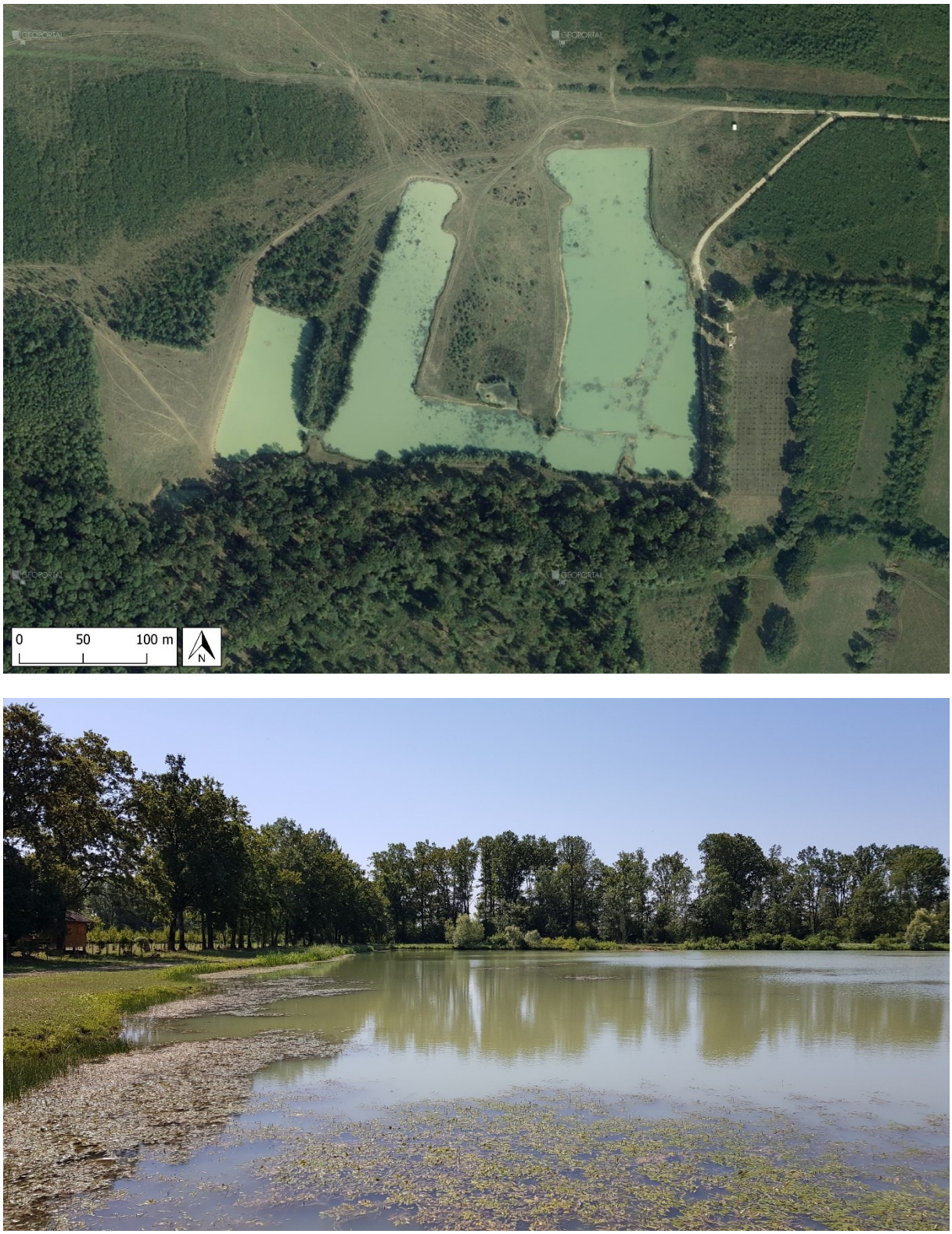

Figure 4. *Borrow pit near Desna Martinska Ves settlement*

6.2. A14 Cambridge to Huntingdon

The construction of the A14 highway between the cities of Cambridge and Huntingdon is a major road project in England. The project includes construction of a new highway and widening and upgrading of an existing road in length of 34 km. About 5,000,000 m³ of soil material was needed for construction and the proposed borrow pits locations were located near the new highway route. Six sites of borrow pits have been selected and their design with main objective of increasing the biodiversity of area after exploitation is planned. The entire area along the planned highway route is characterized by a mosaic of agricultural land, with a small area of forest and aquatic

habitats. In borrow pits design projects, the following conditions were set that needed to be met to the maximum extent possible: create several habitat types that will increase number of species in area and increase the biodiversity of the area; create connected corridors of habitats such as shrubs that will allow the movement of animal species across a wider area; integrate borrow pits into a wider landscape; enable use of the sites for recreational purposes (emphasis on non-intensive use, with only paths and benches); integrate borrow pits in function of flood retention where possible, etc.

In borrow pits designs, care was taken to minimize slopes (slope up to 1:20), which will allow the development of wetland vegetation and the gradual transition from aquatic habitat to terrestrial, and thus greater diversity of micro-habitats. Also, care was taken to ensure that the locations were as protected as possible from noise and disturbing from highway (trees zone), as well as to prevent animals from getting on the road.

Figure 5 shows borrow pit no. 1 before exploitation and visualization of the site after its design, while **Figure 6** shows cross-sections of the coastal area on newly formed water bodies. From the figures can be seen that the formation of several irregular-shaped water bodies with partially developed riparian vegetation is planned. Compared to the current state, where agricultural land and very small areas of forest vegetation is present, habitat diversity will be increased and increase in animal species number and biodiversity can be expected (Highways England 2015).

Figure 5. *Borrow pit no. 1 (a – before exploitation, b – borrow pit design) (Highways England 2015)*

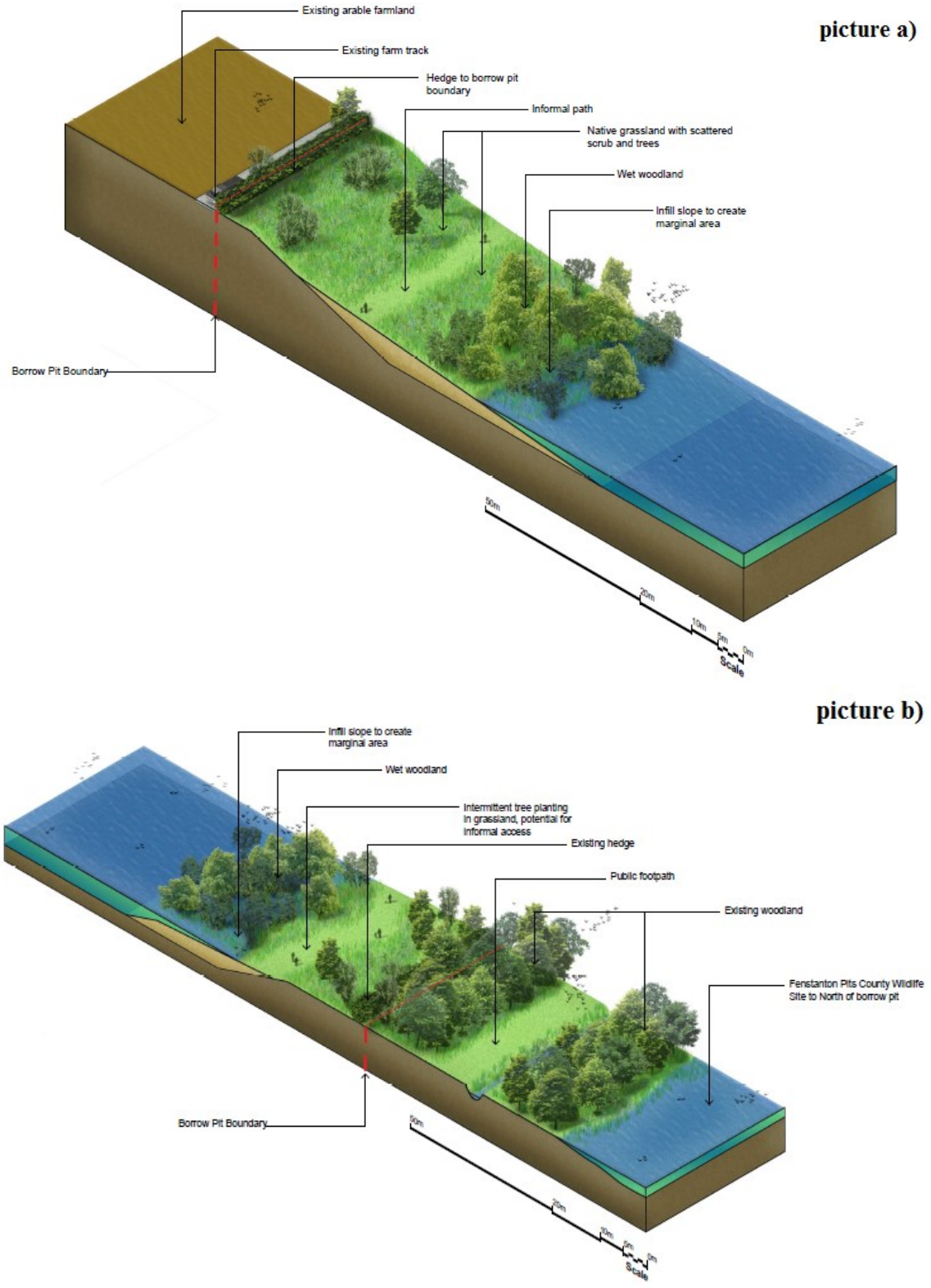

Figure 6. *Cross-sections of the coastal area on newly formed water bodies (a – one costal area, b – two costal area) (Highways England 2015)*

7. CONCLUSION

Borrow pits are necessary for the construction of infrastructural projects such as roads or embankments for flood protection. Borrow pits locations should preferably be located near construction sites to minimize the cost of transporting materials. In addition to meeting the economic requirements of reducing the cost of construction, site locations can also be designed to increase the biodiversity of area. This applies in particular to cases of embankment construction in alluvial plains, where often borrow pits are converted to new water bodies after the material has been exploited.

In this paper, using the example of the Odransko Polje, where the construction and reconstruction of the embankment is planned, and where the invasive plant species *A. fruticosa* is a major problem, it is shown that by carefully selecting the locations of borrow pits, as well as planning their design after exploitation, it is possible to achieve multiple benefits for biodiversity of the area - reduce *A. fruticosa* spread area and increase the area of quality habitats for a large number of animal species. Two examples from Croatia and England are also presented where borrow pits have been designed to increase the biodiversity of the area. Water bodies are important habitats for large numbers of invertebrates, amphibians, reptiles, mammals such as beavers and otters, birds who use them as resting, nesting and wintering areas, and also for a variety of plants. As the wider area of the Odransko Polje is protected in the category of protected landscape, and two ecological network areas are present here, the anticipated positive impacts on biodiversity are even more significant.

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