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SUSTAINABLE RURAL DEVELOPMENT THROUGH THE UTILIZATION OF INVASIVE ALIEN SHRUBS TO PRODUCE LOCAL BIOENERGY

Csaba Vaszkó[1*]

[1]Doctoral School of Environmental Sciences, Hungarian University of Agriculture and Life Sciences, Gödöllő, Szent István Campus, HUNGARY

[*]corresponding author: csaba.vaszko@greenstreams.hu

Abstract*:* Invasive species are considered the second biggest threat to global biodiversity. *Amorpha fruticosa*, a very aggressive alien invasive plant, has colonised a large part of the floodplains of the Tisza and the Hármas-Körös rivers. This high density shrub increases flood risk, increases the cost of agricultural land use, fragments habitats and reduces biodiversity. A local community, along the river Tisza, started to develop a pilot project to use this shrub as a local natural resource. One of the biggest challenges facing this local community, like many others, is the energy supply to public institutions and households. The initiative is based on the concept that these invasive plants have high energy content and can be converted into bioenergy. The local municipality with other stakeholders set up a pilot project along the river Tisza, began to eradicate this shrub and established a local biomass supply chain to harvest and convert invasive plants into woodchips. The produced woodchips, as bioenergy source is utilized in biomass boilers that produce green heat for local public buildings, as well as transported to a heating plant. On the one hand, in order to prevent the encroachment of invasive alien shrubs and to ensure the continuous production of biomass, the public authority established a native tree plantation for energy. The project has already delivered multiple impacts both for the community and the environment, such as the substitution of natural gas, CO2 emission reduction and heating cost saving annually.

Keywords: invasive alien species; bioenergy; energy plantations; floodplain; biomass; *Amorpha fruticosa*

1. Introduction

According to recent research, the total cumulative cost of Invasive Alien Species (IAS) in Europe between 1960 and 2020 was estimated at US$140.20 billion. Of this, the total cost for Hungary is roughly HUF 1 billion (HAUBROCK ET AL., 2021).

The aim of my work is to investigate a new land use and landscape management system that contributes to the conservation and reconstruction of floodplain habitats along the Tisza (in this case in the village of Tiszatarján and its surroundings) through the control of invasive alien plants and partly ensures the supply of renewable biomass energy sources to the local community within the framework of sustainability. In this article, I will specifically focus on the use of invasive alien plants and short rotation woody energy plantations for energy purposes and its impacts.

The area of work is the municipality of Tiszatarján, whose wider surroundings belong to the "under-developed" category in terms of socio-economic development.

The educational level of the inhabitants is lower than the national average. At a disadvantage, a large proportion of the population (26.7%) is inactive and the majority (33%) is dependent. The employed make up only 32.2% of the population. Most of the dependants are students under 18 years of age (KSH, 2011).

In terms of natural geography, Tiszatarján belongs to the Borsodi-ártér sub-region. It covers an area of 500 km2. The municipality covers an area of 4040 ha and has a population of 1407 inhabitants. It belongs to the North-Hungary region, including Borsod-Abaúj-Zemplén county, and is a settlement of Mezőcsáti district. The Tisza is one of the most important resources of the Borsodi plain. Its high banks are the scene of settlements. The Tisza is the most important ecological corridor in Central Europe. Its biota is a unique asset (DÖVÉNYI, 2010).

The area is between 88 and 93 m above sea level, with floodplains in the north and flood-free areas, but the whole is a perfect plain at floodplain level. It has a low average relative relief and a uniform topography. Due to the gentle slopes, poorly drained areas are common, with extensive flats predominating. The surface is varied by abandoned riverbed generations marking the former course of the Tisza, Sajó-Hernád and Hejő rivers (DÖVÉNYI, 2010).

The floodplain soils of the floodplain are partly formed on the alluvium of the Tisza and partly on loess sediments. Meadow cast, meadow and rough cast soils predominate. The floodplain area, also adjacent to the Tisza, is composed of loamy, clayey loam soils with a physical semi-metallic content of the cast meadow soils, with a higher organic matter content than the raw casts (around 1%) (DÖVÉNYI, 2010).

The river regulation process that began in the 18th century led to the disappearance of floodplain management. This large-scale landscape transformation resulted in a change in forestry and agriculture along the Tisza (ANDRÁSFALVY, 1976). The decline and disappearance of grazing livestock, the appearance of invasive plant species, and the proportion of floodplain croplands changed the landscape of the floodplains along the Tisza (SZIGETVÁRI AND TÓTH, 2008).

Most of the areas abandoned to grazing has been taken over either by croplands or by poplar plantations. The spread of invasive alien plant species has reached alarming proportions in both grassland and arable areas (BÍRÓ, 2010).

Among these, the emergence and expansion of indigo bush (*Amorpha fruticosa*) along the Tisza is significant. Many of the former arable fields, mowed meadows, wooded pastures and grazing areas have been occupied by indigo bush, but indigo bush is also spreading along the banks of wetlands and, in drier periods, in streams. This process makes it difficult to convert and regenerate areas abandoned due to land-use change, alters the direction of natural succession and drastically reduces biodiversity (MOLNÁR AND TÓTH, 1996).

In addition to the rapid degradation of natural values, indigo bush also causes significant material damage and increases vulnerability to climate change (VASZKÓ, 2017). Spreading indigo bush makes forest restoration more difficult, causes significant additional costs for forest maintenance, increases the costs of arable farming and makes it more difficult for water to flow on the floodplain during

flooding, as it reduces run-off, i.e. increases roughness (CSISZÁR 2009, KISS ET AL., 2019).

Amorpha fruticosa has spread aggressively in Central and Eastern Europe in recent decades. In addition to Hungary, the spatial distribution and negative impacts of indigo bush have been studied in Romania. Several studies have focused on the spread of indigo bush in the western parts of Romania and in the Danube Delta (DOROFTEI, 2009). Among the studies on the invasion of indigo bush in the western parts of Romania, S noted that indigo bush spread mainly in abandoned arable fields and in inadequately managed wet grasslands (SĂRĂTEANU, 2010).

In the research on protected areas along the Mures River, it is found that indigo bush was identified mainly along the forest roads edges and forest glades (especially north to Mureș River), as well as along the edges of arable lands (mainly abandoned, unused) (KUCSICSA ET AL., 2018).

2. Materials and methods

2.1. Introduction of the pilot site and the land use interventions

A pilot site was started in the model area in 2006. The designation of pilot site and the land-use change were carried out in cooperation with the local municipality of Tiszatarjan. The first step was the harvesting of indigo bush, am invasive alien species that grows in the floodplain and is therefore also found in the pilot site, and the production of biomass feedstock from it and its use for energy production locally. In addition to restoring floodplain habitats and biodiversity, the aim of the pilot project was to reduce the local municipality's fossil energy consumption and diversify the local land use and economy.

The pilot area is located on the outskirts of Tiszatarján, on the right bank of the Tisza. The pilot area consists of several sites, owned partly by the Municipality of Tiszatarján and partly by a local farmer.

Below I will briefly summarise the parts of the pilot area, its size, the previous and introduced land use and the land owners.

1. A pilot site of 30 hectares on the floodplain, owned by the local municipality. At the start of the intervention, this pilot site consisted of 9 hectares of arable land colonized by indigo bush, 6 hectares of artificial wetland and 15 hectares of softwood floodplain grassland covered with indigo bush. The 9 ha of arable land was harvested in 2007 and a woody energy plantation of white willow was planted in 2008. On the 15 ha of softwood grassland and the surrounding of the 6 ha wetland habitat, the indigo bush was harvested in 2007 and 5 water buffalo were introduced in 2008.

2. a 2.4 ha pilot site on the floodplain, which at the start of the intervention was arable land colonized by indigo bush. This area was harvested in 2007 and

subsequently planted with a woody energy plantation of white willow, owned by the local municipality.

3. a 2.6 ha pilot site on the floodplain, which at the start of the intervention was a cropland colonized by indigo bush. This area was harvested in 2007 and subsequently planted with a woody energy plantation of white willow, owned by a local farmer.

4. A pilot site of 14 ha in the floodplain, which at the start of the intervention was arable land colonized by indigo bush. This area was harvested in 2007 and subsequently planted with a woody energy plantation of white willow, owned by a local farmer.

5. A 40 ha grassland on the floodplain, where extensive grazing with 40 Hungarian Grey Cattle was started in 2008. The land is owned by a local farmer.

2.2. Applied methods for the land-use change and biomass production

In the present study, I will focus on pilot site 1. The parcel identification numbers of the land/properties: 0127/11; 0127/12; 0127/13; 0127/14; 0127/15. In 2006, in cooperation with the local municipality, I identified homogeneous areas of indigo bush in the pilot site and in 2007, the harvesting of indigo bush was started on 12 ha (parcel identification numbers of the land/properties: 0127/14 and 0127/15) using a simple, hand-held, forestry undergrowth mower (STIHL FS 550). The harvesting was carried out exclusively in winter, depending on accessibility and demand. In the first period the indigo bush, without chipping, was transferred to the thermal power plant of AES, located in Tiszapalkonya. In a designated plot of 1 ha, covered with homogeneous indigo bush, 22 tonnes of biomass (23% moisture) were harvested. I obtained the data on the moisture content of the indigo bush sample from the Thermal Power Plant, owned by AES, which was operating in Tiszapalkonya.

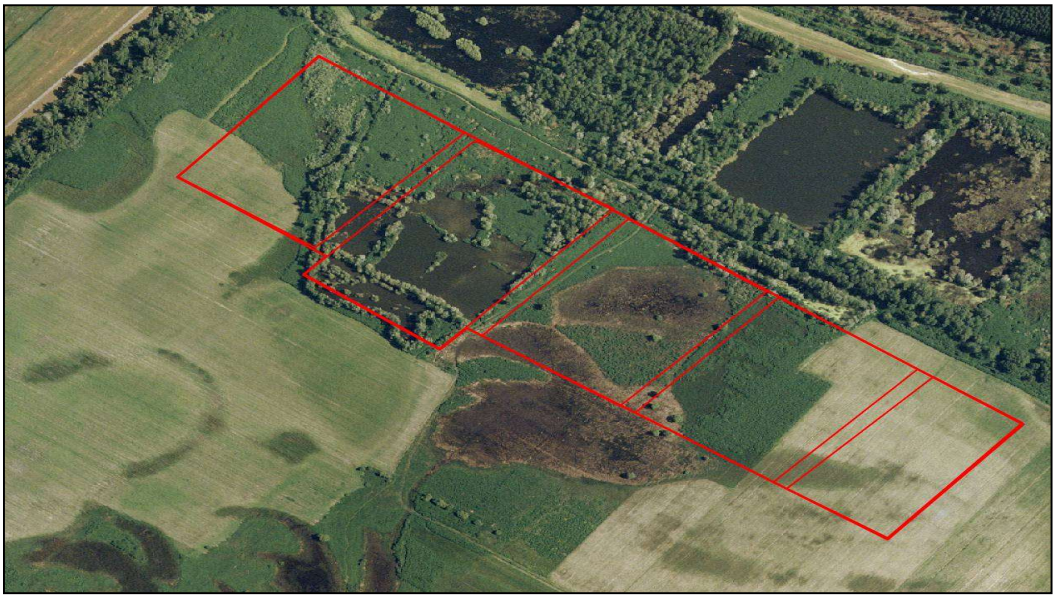

Figure 1: The parcel boundary (red line) of pilot site No 1 on the floodplain in an orthophoto published in 2005

After the harvesting of the indigo bush, a total of 9 hectares of woody energy plantations were planted in 2008, owned and managed by the local municipality. The plantation was planted with Salix express, an intensive-growing, non-GMO willow variety selected from native white willow (Salix alba). The plantation has been planted in several phases, planned to be harvested in 2- or 3-years cycles since 2012, depending on local demand, accessibility and based on plant maturity.

In 2011 the government launched the 'Start Work' model programmes that began in 2011, offering support for the acquisition of machinery and equipment and the implementation of investments, along with 100% funding of employment costs. Under the 'Start work' programme, the municipality of Tiszatarján acquired 8 biomass boilers. All boilers had a capacity of 50kW and were basically designed for combusting biomass chips. The eight solid biomass-fired boilers started to use the indigo bush and willow woodchips, initially in 2011 in three local public buildings (the municipality, a kindergarten and a doctor's surgery). Since 2012, with a short interruption (January 2017), the local public buildings have been using only heating energy from the biomass produced from the local energy plantation and from the biomass feedstock from the indigo bush.

Willow plantations are still managed extensively today. his means that there is no chemical weeding or soil rotation on their land, only mechanical weeding. There have been three harvests so far, in 2012, 2014 and 2016. All three harvests were carried out on parcels 0127/14 and 0127/15. In 2012, 4 atrotonnes (dry ton) of biomass feedstock were harvested on a 1-hectare plot. The next harvest in the plantation is expected in the winter of 2023, for which the local municipality has already obtained a cutting permit from the authorities. The exact location and timing

of the harvest is now being planned. I planned to carry out an assessment of the types and quantities of local biomass feedstocks used since 2011 in 2024. For this purpose, I will measure, together with the local municipality, the daily amount of biomass used in biomass boilers, by biomass type, between November 2023 and April 2024.

Since 2011, when the local municipality stopped supplying biomass to the AES power plants in Tiszapalkonya and Kazincbarcika from either willow plantations or from indigo bush, the biomass boilers have been operating by the municipality have mainly used indigo bush. For this purpose, the indigo bush was at the beginning of the period since 2011 exclusively harvested from municipality-owned land, but later several local landowners offered their land to the municipality for clearing the invasive indigo bush. I will also summarise the areas of origin and land use changes observed in the areas affected by the reduction of indigo bush that have been used for energy purposes in recent years in 2024.

Both the biomass feedstock from the indigo bush and the willow are chipped at a site in the yard of the local municipality. For this purpose, the municipality was able to purchase two wood chippers, also under the Start Work programme in 2011. However, these wood chippers' condition has deteriorated significantly and a new chopping machine is currently being purchased.

Following the harvesting of the indigo bush, water buffalo were introduced in areas where visual inspection showed that it was possible to restore the area to its natural state. Within pilot site 1, extensive grazing (with electric fence powered by a solar PV) was started in 2008 with five water buffalo purchased from the Hortobágy National Park, and a family of four Eurasian beavers was introduced from Germany (Bavaria), also in 2008.

One result of the replication of this project is that in the neighbouring municipality of Tiszakeszi, a local farmer planted a total of 12 hectares of willow plantations in 2016 on a floodplain area along the Tisza and on a land close to the floodplain.

2.3. Local biomass utilization

Consumers of biomass feedstock are institutions managed by the local government. To estimate the heat demand of these institutions, I aggregated the natural gas consumption data from 2005 to 2010. The list of heat consumers considered is presented in Table 1. The main characteristic of the heating of the buildings is the annual thermal energy consumption.

Table 1: Main characteristics of local heat-consuming institutions (based on 2011 aggregated data) and a summary of the energy management introduced in 2011

Institution (energy consumer) Name		Ground floor area m^2	Heated air volume [m^3]	Annual heat consumption [GJ]	Energy management
1.	Municipality	600	2400	301	Renovated in 2010 and using biomass since 2011 constantly)
2.	Elementary school and gym	400 300	1200 1500	570	The operation has been transferred from the municipality to the state and the heating is based on natural gas.
3.	Kindergarten and extension	600 500	1500 1250	520	Using biomass for heating since 2011 constantly.
4.	Surgery and official residence	500	1400	210	Using biomass for heating since 2011 constantly.
5.	Church and parish	820	1800 1100	370	No impact on heating.
6.	2 additional family house official residence	240	650	160	No impact on heating.
	Existing energy consumers			**2131**	

Source: Author's own editing. / Vaszkó (2011)

3. Results

The most important result is the start of the eradication of the invasive alien plant, the indigo bush, in a 89 hectare within the pilot area of the floodplain, managed by the local municipality and a local farmer.

The use of indigo bush and plantation-based biomass feedstock has avoided the purchase of significant amounts of natural gas. For example, in 2009, the use of local biomass saved the local municipality the purchase of natural gas for heating purposes to the value of approximately HUF 3 700 000. This value has gradually increased since then.

In relation to the conservation impacts, grazing with water buffalo in the pilot site is a good complement to mechanical methods of indigo bush eradication, so that after 15 years of grazing the area is free of indigo bush, but continuous grazing is needed to maintain this.

4. Discussion

A local heat supply system has been established on the basis of biomass from the use of the invasive alien indigo bush, which is widespread in the Tisza floodplain, and the installation and operation of energy useful short rotation willow plantations. Since 2011, three buildings in the cooperating local municipality have been using biomass-based heating from local willow plantations and indigo bush replacing natural gas. At the same time, other types of use of the floodplain areas freed from invasive alien plants have been initiated. The model can be extended to both the Tisza and its tributaries' floodplains where the indigo bush has colonized arable lands. The main challenge is to clarify and define land tenure and to determine the size, age and maturity of the indigo bush populations. The replication of the model is limited by the fact that the energy properties of the biomass feedstock from energy useful tree plantations established after the harvesting of indigo bush are significantly below the favourable energy properties of indigo bush in terms of biomass production.

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