

Suppression of alien invasive species by traditional land use forms: *Amorpha fruticosa* L. in the Croatian nature park Lonjsko Polje

Bekämpfung des Neophyten *Amorpha fruticosa* L. mittels traditioneller Landnutzungsmethoden im kroatischen Naturpark Lonjsko Polje

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Schlagwörter: Invasive Art, Rekultivierung, Renaturierung, Beweidung.

Summary: In many European countries the alien invasive species *Amorpha fruticosa* L. is populating a wide spectrum of both human influenced as well as undisturbed habitats, mainly hygrophilous plant communities. In the Croatian nature park Lonjsko Polje, the park authorities tried to either remove or suppress the species which forms dense and high growing stands by using different agricultural methods, including grazing, mowing and chaffing, as well as chaffing with ploughing. To assess the effects of the different treatments height, diameter of root collar, number of shoots as well as biomass of *A. fruticosa* per square meter was measured on sample plots on an experimental area of about 50 ha near the river Sava. Statistical analyses indicate that vegetation stands treated by chaffing plus ploughing exhibited a similar rate of regeneration as they did after only chaffing; therefore additional ploughing is not necessary. Long-term treatments like grazing and mowing strongly reduced height and root diameter of *A. fruticosa.* However, the species could not be removed completely. As a management strategy it is proposed to chaff old *A. fruticosa* stands first. Afterwards the sites should either be used as pasture or hay meadow land. Thereby the competitiveness of the invasive species is reduced to an insignificant fraction until the treatment is discontinued. By applying these forms of land use to suppress *A. fruticosa,* the adjacent placement of pastures and hay meadows can emulate the typical appear-

ance of the Lonjsko Polje landscapes, while providing a wide habitat range for native species.

Zusammenfassung: In zahlreichen europäischen Ländern besiedelt der Neophyt *Amorpha fruticosa* L. eine weite Spanne verschiedener Habitate, darunter sowohl anthropogene als auch naturnahe, und bevorzugt dabei feuchte Standorte. Die Parkverwaltung des kroatischen Naturparks Lonjsko Polje versucht, unter Anwendung landwirtschaftlicher Verfahren wie Mähen, Beweidung, Häckseln sowie Häckseln plus Pflügen, die dichten Bestände der Art zu entfernen oder zumindest zurückzudrängen. Um die Auswirkungen der verschiedenen Methoden zu bewerten, wurden auf einer Versuchsfläche von ca. 50 ha Höhe, Wurzelhalsdurchmesser, Triebzahl und produzierte Biomasse von *A. fruticosa* bestimmt. Die statistische Auswertung zeigte, dass Bestände nach erstmaligem Häckseln das gleiche, starke Regenerationsvermögen aufwiesen wie solche, die anschließend gepflügt wurden. Zusätzliches Pflügen erwies sich demnach als unnötig. Langjährige Bekämpfungsmethoden wie Mähen und Beweiden reduzierten Biomasse, Höhe und Durchmesser stark, die Art verschwand aber nicht gänzlich. Als Managementkonzept wird deshalb vorgeschlagen, *A. fruticosa*-Bestände anfangs zu häckseln und dann sofort und dauerhaft als Heuwiese oder Weide zu nutzen. Dadurch kann die Konkurrenzkraft der Art derart reduziert werden, dass sie eine untergeordnete Stellung innerhalb der Pflanzengesellschaft einnimmt. Diese Form der Nutzung ermöglicht die Wiederherstellung des für die Save-Auen typischen Nebeneinanders von Heuwiesen und Weiden und damit den Erhalt einer hohen Artenvielfalt.

Introduction

Problems generated by alien invasive species are increasing worldwide. The IUCN designates them the "second most significant cause of species extinction worldwide, after habitat destruction" (www.iucn.org 27.01.2009).

One of these problematic plant species is the Fabaceae *Amorpha fruticosa* L. Its native range covers large parts of North America between southern Canada and Mexico (DEHAAN et al. 2006). The deciduous shrub grows up to six meter in height, usually forming dense stands (TUTIN et al. 1992; GREAT PLAINS FLORA ASSOCIATION 1986). It has no high demand for nutrients or soil conditions (D'AURIA & ZAVAGNO 1998) but seems to prefer areas which have an intermediate to high water table or which are at least affected by seasonal inundation. It can, however, also be found in drier areas (SZENTESI 1999). In Europe mainly human-disturbed areas are colonized as part of a succession following abandonment (D'AURIA & ZAVAGNO 1998; TUCOVIĆ et al. 2004). Such sites might include feral poplar-groves, sides of quarry lakes or abandoned fields (D'AURIA & ZAVAGNO 1998). But also natural plant communities are invaded, such as large-sedge swamps, reed swamps and hygrophilous shrub communities, as well as hardwood and softwood alluvial forests and more seldom mesophilous, deciduous forests (D'AURIA & ZAVAGNO 1998; SZENTESI 1999). Today *A. fruticosa* is naturalized in swaths of Central and Southern Europe as well as in several Asian countries from the Middle East to Japan (www.ildis.org 20.11.2008; TUTIN et al. 1992). It was first introduced to Europe in 1724 as an ornamental plant and

to China and Japan after 1940 as measure for soil protection against erosion as well as a source of green manure (HEGI 1960; TUDA et al. 2001).

The Sava floodplain in Croatia is one the largest inundation areas in Europe with up to 790,000 ha of surface regularly undergoing flooding (LÖFFL 1999). It is an ecosystem of major importance for nature conservation with a high biodiversity due to its unique combination of cultural and natural landscape elements. The spatial distribution of the traditional land use types reflects the flooding frequency pattern: areas which are less frequently flooded are used as hay meadows and such with frequent flooding as pastures (in German referred to as "Hutweiden") where cattle, horses and pigs are herded by a shepherd. These large pastures spotted with single oak trees are often in close connection to large alluvial forests, swamps and oxbow lakes (SCHNEIDER-JACOBY & ERN 1990).

A. fruticosa was introduced to the Sava floodplain during the 19th century for improving the stability of railroad embankments. In 1990 it had already spread to every part of the park, locally also to alluvial forests where it inhibits oak regeneration (SCHNEIDER-JACOBY & ERN 1990). During the Balkan War in the early 1990s, the species was able to further colonize large areas as land use was put on hold or drastically changed thereby forbidding agriculture on overgrown sites (personal correspondence with GUGIĆ 2008). For some years the authorities of the Lonjsko Polje Nature Park have been intending to cultivate these former fields by applying agricultural methods like pasturing, mowing, chaffing and ploughing to restore the traditional land use system.

Several studies deal with habitat requirements of *A. fruticosa* (TUCOVIĆ et al. 2004), its influence on natural plant communities (D'AURIA & ZAVAGNO 1998; SKEW 2006) and phytophagous insects (SZENTESI 1999; TUDA et al. 2001) or utilization options (ĐEHAAN et al. 2006). SPAIC (1957) examines the species reactions on herbicides. There are, however, no studies analyzing agricultural methods to suppress *A. fruticosa.*

Therefore this study tries to reduce that gap by assessing pasturing, mowing, chaffing and ploughing as control strategies and focuses on the ability of the species to regenerate after initial treatments and its condition after long-term suppression.

Material and Methods

Study area

The study was carried out during summer 2008 on an area which is located within a bend of the river Sava near the villages Krapje and Drenov Bok on both sides of the oxbow "Krapje Đol", an ornithological reserve (45° 17′ N; 16° 50′ E). The soil is a pseudogley above a mixture of fluvial sediments (LPNPPS 1999). The area served as pasture or arable land until farming stopped or diminished during the 1990s. Thus *A. fruticosa,* which had already been present, was

able to rapidly colonize extended areas, making agricultural utilization impossible (LPNPPS 1999; personal correspondence with GUGIĆ 2008).

In 2004 the vegetation on one section of the area was chaffed. Since then, one part of that section (27.7 ha) has been used as pasture for the park's own cattle herd, the rest as hay meadow (12.6 ha). For this study the pasture was divided into a drier part (24.3 ha), and a wetter part (3.4 ha). The division was performed by optical criteria like pits and indicator species such as *Iris pseudacorus* L., *Juncus effusus* L. and *Carex spec.* The mown variant has been used for hay production since 2004. Like other traditional hay meadows, it is grazed by cows in spring and autumn for short periods of time, and mown one to two times during summer, depending on the weather conditions.

The second section of the study area (2.8 ha) was chaffed in early spring 2008. Afterwards 0.6 ha were additionally ploughed, thereby the damaged rootstocks remained. Until June 2008 *A. fruticosa* shoots grew up to a very dense, about 2 m high impassable stand. Situated adjacently to the chaffed plot, is an old *A. fruticosa* stand with an area of 0.3 ha. It has not been cut or otherwise treated and therefore serves as control version. Records were taken in June 2008. On all versions the last management treatments took place at least in spring of the same year.

Methods

Sample plots of 1 m² each were used for data collection. They were selected for each treatment at random on a map and afterwards localized by GPS in the field. For both the hay meadow and the dry pasture treatment 20 plots were used, while for the other treatments the available area was large enough for only 10 plots each.

The following parameters were measured in June 2008: (1) height and (2) diameter at root collar of at most 30 shoots, (3) the total number of woody *A. fruticosa* shoots per m², and (4) the biomass of *A. fruticosa*. For biomass measurement fresh biomass was harvested, dried under laboratory conditions at 55° C until weight stayed constant and dry weight was calculated.

For data analysis the hypothesis of independence between the different management types was assessed by the method of analysis of variance (ANOVA). For each parameter a Post-hoc Test (Tukey all-pair comparisons) was subsequently applied to evaluate the differences between each management type and parameter (DORMANN & KÜHN 2004). Statistical analyses were carried out in the R system (version 2.8.1, R DEVELOPMENT CORE TEAM 2006).

Results

Height of *A. fruticosa*

In all management treatments *A. fruticosa*-plants are smaller than untreated ($p < 0.001$). While the height of untreated plants is around 2 m (median) and

reaches up to maximum values of around 4 m, on treated plots the median value is only around 1 m or lower.

To avoid bias in the results from the inclusion of seedlings and other less dominant plants, Figure 1 shows the observed heights for those plants in the top 25th percentile according to their height. Also within this percentile height reduction is significant for all management treatments ($p < 0.001$). On plots where *A. fruticosa* was suppressed by chaffing or ploughing for the first time, height reductions to about 175 cm (median), equivalent to 59%, can be observed. There is no significant difference between these two variants of suppression. By contrast, long term management like pasture and mowing decreases height to a significantly lower level ($p < 0.001$): mowing reduces height to 86 cm, equivalent to 29 % of the control, pasturing (both wet and dry) to 44 cm, only 15 % of the height of the untreated plants.

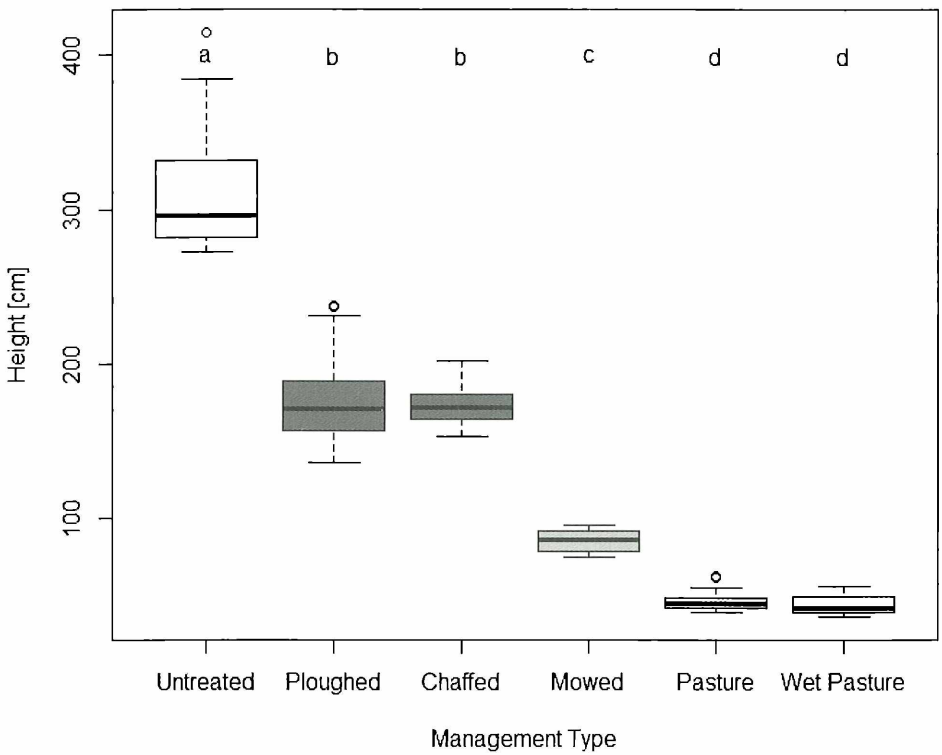

Fig. 1: Height of the highest 25 % of *Amorpha fruticosa* plants. Dark grey: treatments implemented for the first time; light grey: managed for several years; white: untreated sites (control); letters indicate significant differences between treatments.

Diameter of root collar of *A. fruticosa*

All management types reduce the diameter of root collar of *A. fruticosa* significantly ($p < 0.001$) compared to the control (untreated) (Fig. 2). Between the management types there are no significant differences. The median of all management types averages 9.8 mm. This is a diameter reduction to the level of 39 % of the control. The highest decrease is found on pastures with 8 mm, equivalent to 32 % of the control.

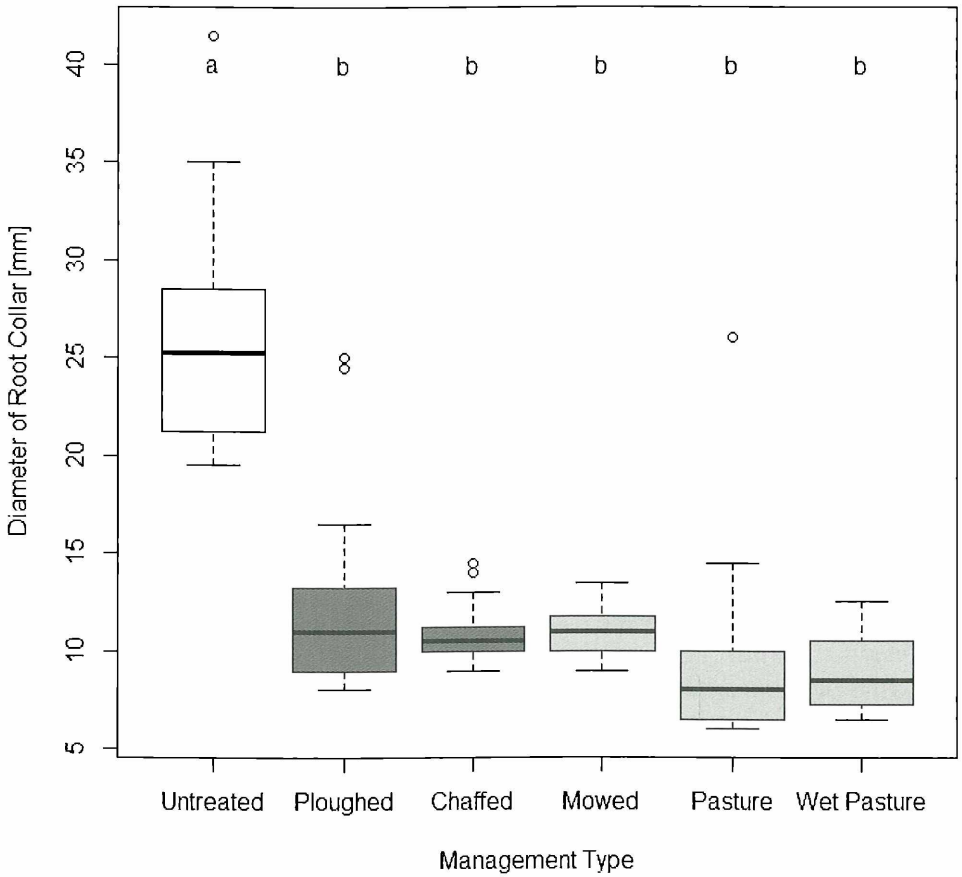

Fig. 2: Diameter of Root Collar of *Amorpha fruticosa*. Dark grey: treatments implemented for the first time; light grey: managed for several years; white: untreated sites (control); letters indicate significant differences between treatments.

Number of *A. fruticosa* shoots

Concerning the number of shoots there are no differences, neither compared to the control nor between the different treatments.

Biomass of *A. fruticosa*

Compared to the untreated plots, all management methods result in significant ($p < 0.001$) decreases of biomass per unit area (Fig. 3). There are no significant differences between the five treatments themselves, but biomass on the long-term managed plots - hay meadow and wet or dry pasture - is on average lower than on those which were treated for the first time by chaffing or ploughing. This becomes also evident by comparing the p-values of the two groups marked in light and dark grey (Tab. 1): The p-values within each group (light grey) are almost 1, while the ones representing the difference between both groups (dark grey) are closer to 0.05.

The medians of the ploughed and chaffed variations are about 0.26 kg/m² (median), indicating a decrease to 20 % compared to the control. The medians of the hay meadow, the dry and the wet pasture are close to zero.

Tab. 1: Significances of biomass of *Amorpha fruticosa.*

	Ploughed	Chaffed	Mowed	Pasture	Wet Pasture
Untreated	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Ploughed		0.9999	0.2866	0.1993	0.2655
Chaffed			0.1718	0.1127	0.1693
Mowed				0.9999	0.9989
Pasture					1

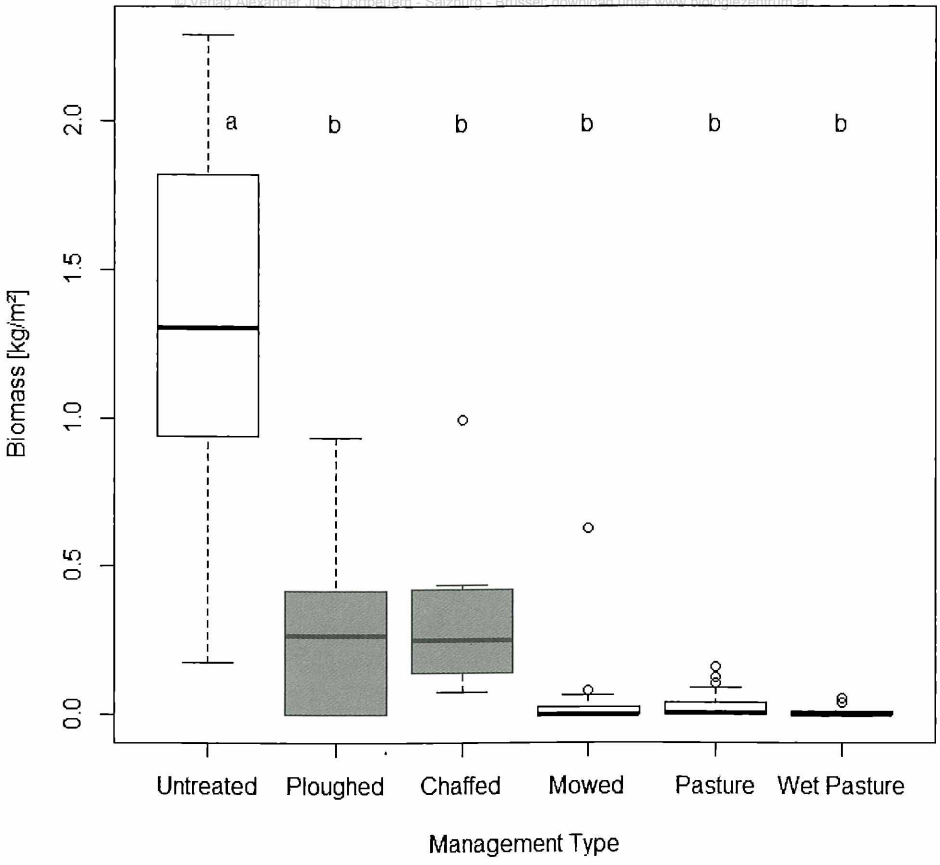

Fig. 3: Biomass of *Amorpha fruticosa* per square meter. Dark grey: treatments implemented for the first time; light grey: managed for several years; white: untreated sites (control); letters indicate significant differences between treatments.

Discussion

All management types reduce the diameter of root collar, height and biomass per m² of *A. fruticosa* significantly. However, among these management types there are differences, especially between those plots treated for the first time and those which had already been managed previously.

After both chaffing and chaffing with ploughing for the first time, *A. fruticosa* is able to regenerate significantly within one growing season. Diameter regenerated to about 40 %, height to about 60 % and biomass to about 20 % of the control. Although the biomass value is rather low the species is still dominant and builds dense stands which are about 2 m high. That low biomass values result from the high proportion of thick, woody stems on untreated plots. As

there are no significant differences between only chaffing and chaffing plus ploughing, ploughing does not give any advantage and is therefore considered unnecessary. Generally cutting of *A. fruticosa*-stems has no effect on the number of shoots, as the values do not change significantly.

On the plots where management has already taken place for some years, the species is much less dominant. The measured parameters are all lower than on the chaffed and ploughed versions, but they show differences between each other, especially between pasture and hay meadow. Only the diameter of root collar is close to that of plots managed for the first time, as plants are not completely removed. They can grow thicker every year but the increment is low due to frequent disturbances. This effect seems to be strongest on pasture as plants are damaged permanently, resulting in the greatest diameter reduction to 32 %. The same effect is true for the stem height, which is also the lowest on wet and dry pastures (15 %). It is also caused by the cows which feed permanently on the young, green parts of the shoots. On the hay meadow, plants are not disturbed as frequently, but had already been treated for at least four years, thus the effect of long term management becomes apparent, as the parameters are lower than on the chaffed and ploughed versions.

On long-term managed sites the medians of biomass are close to zero; there is a high number of test plots which are free of *A. fruticosa*. On the other hand, the number of shoots did not change significantly. This shows that the species, although no longer dominant, is still present. On the hay meadow, it seemed as though the plants were less numerous but thicker, and consisted mainly of higher plants, while on the pasture there are more but thinner and lower plants, because of permanent grazing. Overall there is no significant difference in biomass between those two management types.

Evidently chaffing can only be an initial treatment method to remove old and woody *A. fruticosa* plants. Additional ploughing brings no further advantages.

Although this study has to be considered a case study as all experimental plots were located within an area of about 50 ha, it becomes obvious that only long-term management achieves significant reduction of *A. fruticosa*. Both grazing and mowing decrease biomass to a level close to zero, but height is reduced more efficiently on pastures. Nevertheless, both forms of land use succeed in reducing *A. fruticosa* effectively. This allows the farmers or the park authorities to return to the traditional land use system with a patchwork design of pastures and hay meadows, typical for the Sava floodplain and of major importance to biodiversity. It is to be assumed that *A. fruticosa* will never disappear completely. It will, however, become part of the local plant communities.

Concluding recommendations for a management strategy

As a final result the following management strategy can be recommended to the park authorities to suppress the alien invasive species *A. fruticosa*. The initial treatment in fighting the dominance of the species must be chaffing old *A. fruticosa* stands in spring to remove the woody components. Currently long-term management has to be initiated forcefully, and can consist of either grazing or mowing. Both variants reduce the dominance of the species strongly, but cannot remove it completely. Therefore it is important that the treatments are applied in an uninterrupted manner, as it can be assumed that *A. fruticosa* would otherwise regenerate rapidly.

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