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Invasion patterns of boxelder on sites with different levels of disturbance

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Synopsis

While some tree species are declining others show the tendency of spreading. One of these successful species is boxelder (*Acer negundo* L.), a maple tree. This tree, originally a rare indigenous species to North America, is now spreading there and in Europe and Asia. The strategy type and the ecological requirements were studied in the area of its natural distribution in Wisconsin.

boxelder, invasion pattern, population biology, apophyte, neophyte

1. Introduction

Boxelder, like Norway maple and Sycamore maple (SACHSE & al. 1990), is a weedy tree in both its country of origin (acting there as an "apophyte", plants which lose their confinement to their original plant community, SCHROEDER 1974) and in the areas to which it has been introduced ("hemerochor", taxa coming in only with the direct or indirect help of humans, SCHROEDER 1974). Since its introduction to Europe at the end of the 17th century, boxelder has been spreading. If one assumes that the potential area boxelder could colonize equals the area in which boxelder can survive in culture, then this tree could colonize a similar (suboceanic-subcontinental) but twice as large area in Eurasia as in North America (JÄGER 1975).
Given this background interesting questions arise: what limiting factors affect field site invasion by boxelder? Are boxelder populations persistent or will they vanish over time? The results of this paper will help in valuating the means and success rates of fighting boxelder invasions.

2. Distribution and position of boxelder in vegetation

2.1 Europe

The first appearance of boxelder in Central Europe is according to WEIN (1931) documented for the year 1688 for a garden in Fulham/England; it arrived in Germany in 1699 at Leipzig.
Boxelder is a widely planted ornamental tree but not used in forestry. The tree is spreading in Germany in natural plant communities in river valleys, floodplain forests and bottomland forests, but also in sandy hills and into ruderal plant communities in inner city areas (KOHLER & SUKOPP 1964). Boxelder is found as a bush along roads and railroad tracks (JENTSCH 1982, MEYER 1935) and in semi-natural maple-forests (PASSARGE 1990). Especially on disturbed sites boxelder reaches cover values up to 50% (ROSSEL 1986).

2.2 North America

Boxelder has a wide natural distribution, ranging from scattered occurences in California north to Alberta, south to Arizona and the northern part of Mexico, northeast to Massachusetts, and southeast to Florida (PRESTON 1976). Descriptions suggest that boxelder was originally restricted to alluvial sites, e. g. floodplain forests and bottomland forest. Because of its ability to grow fast on all soil types and its ability to withstand temperature extremes, boxelder was planted widely for shade and in shelterbelts. The tree has been in cultivation for over 200 years, starting in 1688 (OLSON & GABRIEL 1974).
Boxelder is spreading now as a "weed tree" especially in the eastern North America (MAEGLIN & OHMANN 1978), where it is part of various elm-silver maple-woodlands. Boxelder plays an important role in the secondary succession of river banks (VAN AUKEN & BUSH 1985, WIKUM & WALI 1974, WISTENDAHL 1958), of former vineyards (BOERNER 1985), and of road verges (LEVY 1981). In urban plant communities boxelder is among the most frequent tree species (DORNEY & al. 1984, WALDRON & DYCK 1975).

Boxelder has spread widely for the last 40 years from its original plant communities to many disturbed sites. For example, the incidence of boxelder in prairie remnants increased from 2 to 25 stands between 1954 and 1988, apparently due to lack of fire (LEACH 1990). Boxelder saplings only a few years old can not survive fire management (LEACH 1990). J. OCHSNER and V. KLINE (pers. communication) suggest that fire management, which stopped around 1830/40 with the advent of white settlement, restricted boxelder to its natural habitat in southern Wisconsin.
In the developing vegetation of islands in the lower Wisconsin river (younger than 55 years) the percent cover of boxelder does not exceed 2.9% (0.9 - 2.9%, if present), in comparison to Silver maple with 0.1 - 90% for the same time length of succession (FULTON 1987).
In the vegetation of the streamside forest of Hickory Creek (Will County, Illinois), boxelder reaches an importance value of 0.8 (BELL & MORAL 1977). ROBERTSON & al. (1978) calculated an importance value of 2 for old growth and 3.8 for secondary growth of boxelder in the bottomland forest on Horseshoe Lake Island, on the Mississippi alluvial plain in Alexander County, Illinois (on a scale of 0 to 200).

2.2.1 Dominance in the plant communities of the Midwest

In Wisconsin boxelder is found only in the plant communities of the Southwest, reaching here the northern edge of its natural distribution (CURTIS 1959). In natural plant communities boxelder mostly is an understory tree species and seldom reaches the canopy. The dominance of boxelder is correspondingly low. CURTIS (1959) describes boxelder as only characteristic for Southern wet forests, one out of 34 plant communities in Wisconsin. In this Southern wet forest boxelder reaches its maximum importance value of only 1 on a scale of 0 to 100 with a constancy of 22.2. It also occurs in the Southern wet-mesic forest with an importance value of 0.4 and a constancy of 12.3. In the dry segment of Southern xeric forest boxelder occurs scattered (I.V. = 0.6, constancy 10) and very rarely in the dry-mesic segment (CURTIS 1959).

3. Methods

3.1 Site selection

To compare the population structure of boxelder in different habitats, five sites were selected in South central Wisconsin on public land. The field sites were selected to represent a gradient from heavily disturbed to more natural areas. All sites lay within 50 km of Madison, Wisconsin. A natural undisturbed site was not integrated in the study because a site with one mature female boxelder tree (to compare propagation on natural to disturbed sites) could not be found.

3.2 Site descriptions

3.2.1 Starr School Road

Fields and grass lands in Dane County were bought in 1975 for the waterfowl program and farmed until 1977, since when the area lies fallow. The area is drained by several ditches, along which boxelder populations are developing and spreading into the abandoned fields.

3.2.2 Mayville Ledge

Mayville Ledge is a State Natural Area in Dodge County. The area of interest is an abandoned field in the middle of beech-maple woods on the plateau. The field was last managed in 1981.

3.2.3 Deansville

Deansville marsh is a state-owned wildlife area in Dane County. Most of the area consists of disturbed vegetation (drained, grazed or farmed), sedge meadow and shallow marsh. The area of interest for this study is a small forest of the oak-hickory type.

3.2.4 Arboretum

The Arboretum is owned by the University of Wisconsin, Madison and is located in Madison. It consists of several woodland and marsh types. The area of interest for boxelder is northwest of Lake Wingra in a

disturbed woodland west of Ho-nee-um pond. The area once was a sedge meadow, later most likely used to dump soil for the construction of Ho-nee-um pond in 1940.

3.2.5 Waterloo

The Waterloo wildlife area lies in Dodge and Jefferson Counties. The area of interest for boxelder population study is a silver maple woodland north of Stony creek.

3.3 Data selection

For Deansville, Arboretum, and Waterloo inventories of 20 x 50 m^2 were made. At Starr School Road an inventory of 100 x 50 m^2 was made. Each site inventory included all tree species with a girth at breast height (dbh) larger than 10 cm. The average boxelder-seedling density per m^2 was also calculated. These inventories were mapped. The gender of the boxelder trees was determined and a distinction between female, male and non-flowering trees was made. In the Arboretum the distinction between male and non-flowering trees could not be made accurately for each tree, because the flowering period lasted only one week in 1990. For results see table 1 (methods following CURTIS (1959)).
For each field site a random number of trees were cored to determine the age structure and growth rate. A survey for boxelder shrubs from all field sites was conducted, sampling height and age of the individual shrubs to determine the average age at breast height.
In Mayville Ledge a transect through the boxelder succession field was made including all woody species (shrubs and seedlings).
Soil samples for each field site were analysed by the University of Wisconsin Soil Science Institute.

Table 1: Composition and structure of field sites with boxelder invasion. Only trees with a girth larger than 10 cm at breast height (dbh) were used for calculation.

Relative frequency = number of quadrats containing *Acer negundo* divided by the total number of quadrats;
relative density = number of *Acer negundo* trees divided by the total number of individuals of all trees;
relative dominance = total basal area of *Acer negundo* divided by the sum of total basal area of all trees;
I.V. = importance value: sum of relative frequency, relative density, and relative dominance divided by three (following CURTIS 1959).

	Arboretum	Starr School R.	Deansville	Waterloo
Relative frequency	100.0%	56.0%	100.0%	80.0%
Relative density	69.8%	78.0%	17.5%	72.0%
Relative dominance	68.2%	65.1%	9.2%	49.0%
I.V.	79.3	66.4	42.2	67.0
Acer negundo/ha	980	78	32	180
all trees/ha	1390	100	1830	230
age of *Acer negundo* given in years dbh				
- average	16.3	9.2	19.2	30.7
- minimum	8.0	2.3	7.5	14.4
- maximum	27.0	21.0	36.0	45.0
basal area in m^2/ha				
- total	27.2	2.3	28.9	21.5
- *Acer negundo*	18.6	1.4	2.6	10.5
Seedling densitiy for *Acer negundo* given per m^2				
	4.7	0.0038	0.001	0.002
Sex ratio of *Acer negundo* given in females/males				
	-	0.8	0.57	1.14
percentage of today's (1990) *Acer negundo* trees by the end of management				
	0%	15.5%	12.5%	83.3
year	1940	1977	1960/63	1968

4. Results

4.1 Age structure

Sites where an invasion occurred during a short time period show a bell shaped age distribution (Arboretum, Starr School Road, somewhat reduced at Deansville) (Fig. 1). The first two are sites with a boxelder monoculture, in contrast to Deansville (showing the end of a boxelder invasion in an oak-hickory-wood) and Waterloo (showing the extinction of the boxelder population in a Silver maple wood). Obviously none of the populations are still in the process of invasion like Mayville Ledge, a former agricultural field now turned into a "boxelder field" (Fig. 2)

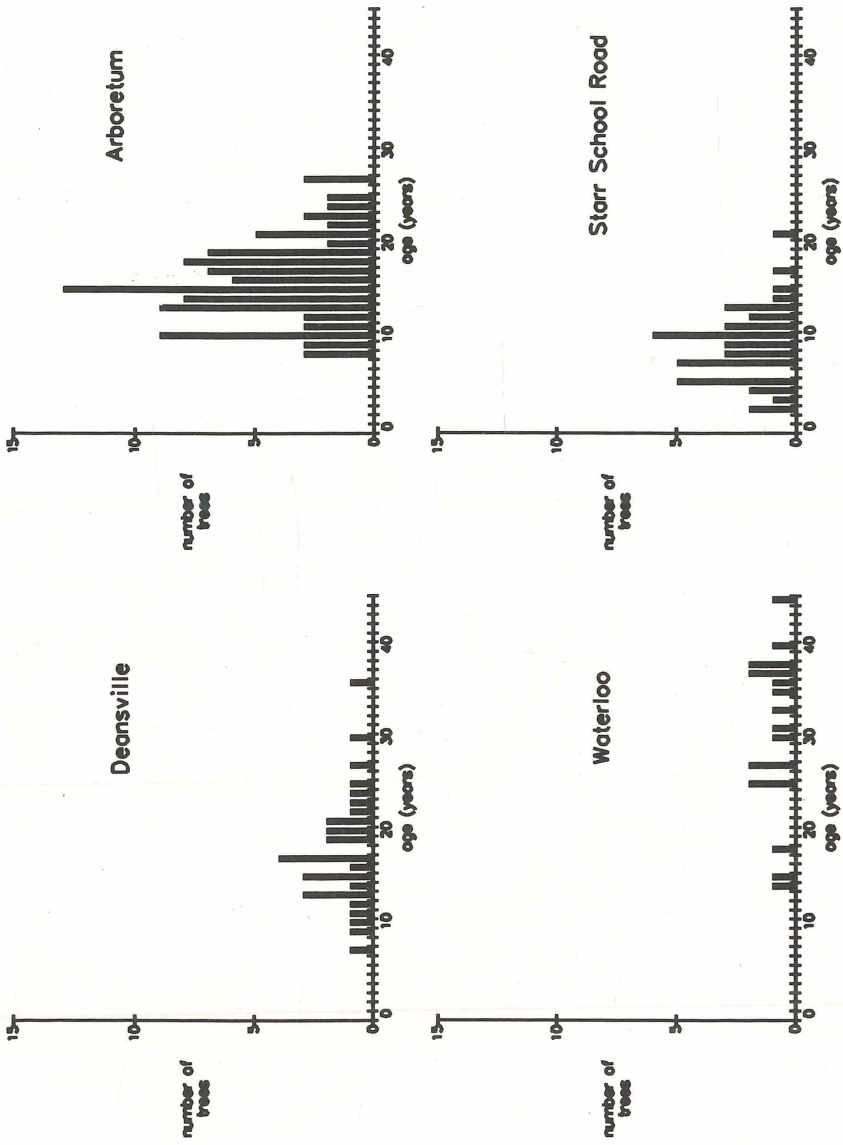

Fig. 1: Age structure (at dbh) of *Acer negundo* populations for the inventories: Deansville, Arboretum, Waterloo, Starr School Road.

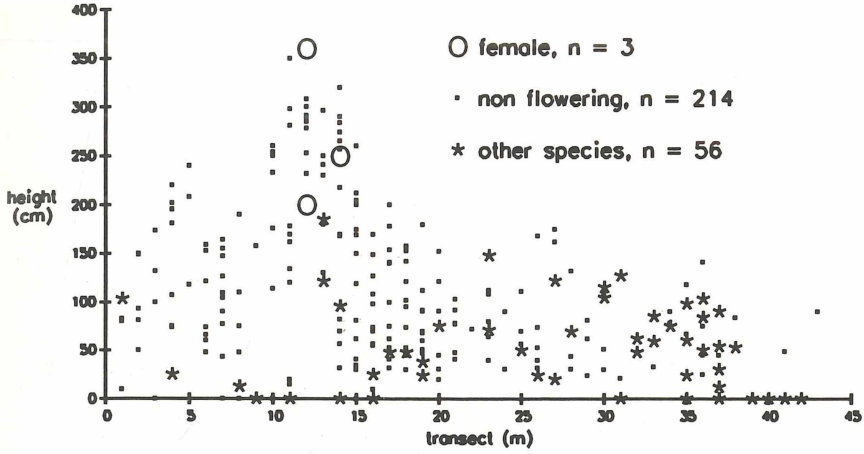

Fig. 2: Transect (2 x 45 m) through *Acer negundo* population in Mayville Ledge.

4.2 Height structure

Height is strongly correlated to age. In the Arboretum boxelder is building the canopy with an understory of buckthorn. At Starr School Road boxelder plays a similar role in the "canopy" (the term canopy is not quite correct here because of the openess of the area). At the other two sites boxelder is scattered in the canopy structure but is clearly not the dominant canopy species (Fig. 3).

4.3 Spatial distribution of the boxelder populations

The observed boxelder populations grow in three different types of patterns:

a) a near monoculture with individuals of boxelder spreading from an area of optimal growth conditions e. g. a drainage ditch in Starr School Road or an island of fruit bearing boxelder trees in Mayville Ledge)

b) a boxelder dominated vegetation with evenly distributed individuals of boxelder (Arboretum, Waterloo)

c) scattered distribution of boxelder individuals in woodlands built by other species (Deansville).

4.4 Occurance of invasion over time

To answer the question whether boxelder was an element of the vegetation on the research sites before management stopped, the dates of purchase/proposal for purchase respectively, or the year of last management, if known, are important (Tab. 1). Those dates are supposed to be the starting point for boxelder invasion. The present age of trees which were already on the research sites can be calculated. We can compare those calculated ages with the age structure on the field sites. Determination of the average age at breast height was 5 years in general for all field sites. Basically four different conditions for invasion can be found:

a) invasion covering a whole area with open soil (Mayville Ledge, abandoned field (Fig. 2))

b) time lag until invasion takes place (Arboretum)

In the Arboretum boxelder apparently did not invade for the first 20 years. This delay of invasion is most likely a result of the dense ground cover in sedge meadows. Later the ground cover opened underneath the crowns of boxelder trees by shading-out or other unknown disturbances of the ground cover. The invasion peak was reached 21 years ago. After that, seedling establishment slowed down because the canopy closed. Shading-out prevents the survival but not the establishment of seedlings of boxelder.

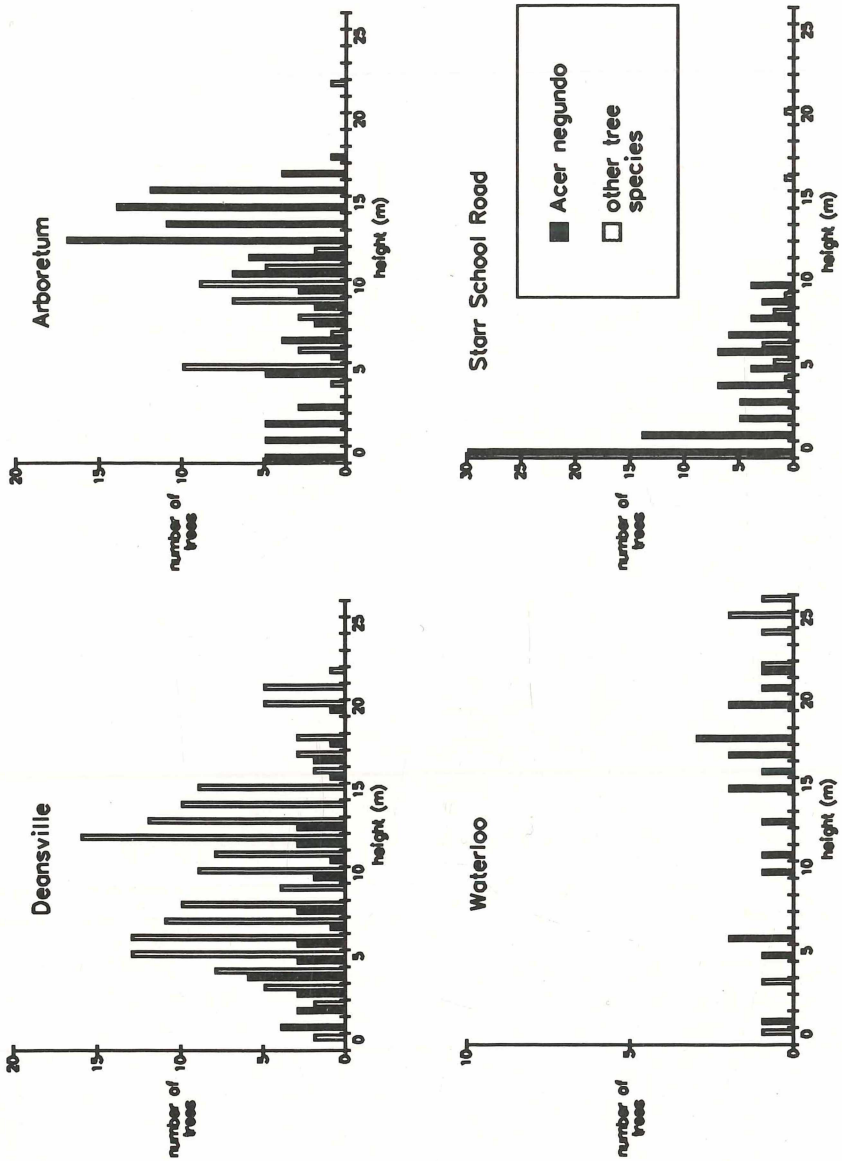

Fig. 3: Height structure of *Acer negundo* populations and other tree species for the inventories: Deansville, Arboretum, Waterloo, Starr School Road.

c) started invasion continues (Deansville, Starr School Road)

At Starr School Road and Deansville boxelder invaded open ground when management of the land ceased. At Starr School Road boxelder was confined to drainage ditches until the end of agricultural management. 15% of the current mature boxelder population were already present at that time. The spread of the population was slowed down by the influx of perennials on the surrounding fields after the end of management. The woodland in Deansville was selectively cleared, leaving only *Quercus alba*. 12% of the current mature boxelder population were present when this management stopped. No regeneration takes

place now because of shading-out of the fruit bearing boxelder trees (prohibiting flowering and fruiting) and dense ground cover.

d) end of invasion (Waterloo)

At Waterloo the data demonstrate that by the end of this site's use as a fuel wood lot 83% of the boxelder trees were already present. This former usage makes their presence plausible, because boxelder is known to vigorously resprout, and therefore might have been selected for fast growing fuel wood (consciously or unconsciously). The age structure shows a senescent population. Since the end of management only two more trees with girth over 10 cm have grown up. A dense ground cover and shading-out by *Acer saccharum* prevent seedling establishment. Without management this woodland might turn into a more natural floodplain forest where boxelder plays only a minor role (see 2.2.1).

4.5 Seedling establishment

Fruits of boxelder need open soil for germination, and for survival at least a half open crown layer (own observations). In its natural habitat these conditions are confined to barren river banks after annual floodwater recession in spring. On sandbanks becoming dry later in the course of the year Silver maple germinates, only occasionally late seedlings of boxelder. Observations show no seedling establishment or very high mortality of boxelder seedlings in dense ground cover or under closed tree canopies.

Planting experiments with boxelder seedlings in plots with high and very low nutrient content respectively, showed a high survival rate of the seedlings in both plots even without artifical watering, if competition by other plant species was prohibited by weeding (SACHSE 1991, unpublished).

5. Discussion and conclusion

The low importance values of boxelder in its natural habitat contrast the high values on the research sites (Tab. 1). Observations show the following scheme (Fig. 4):

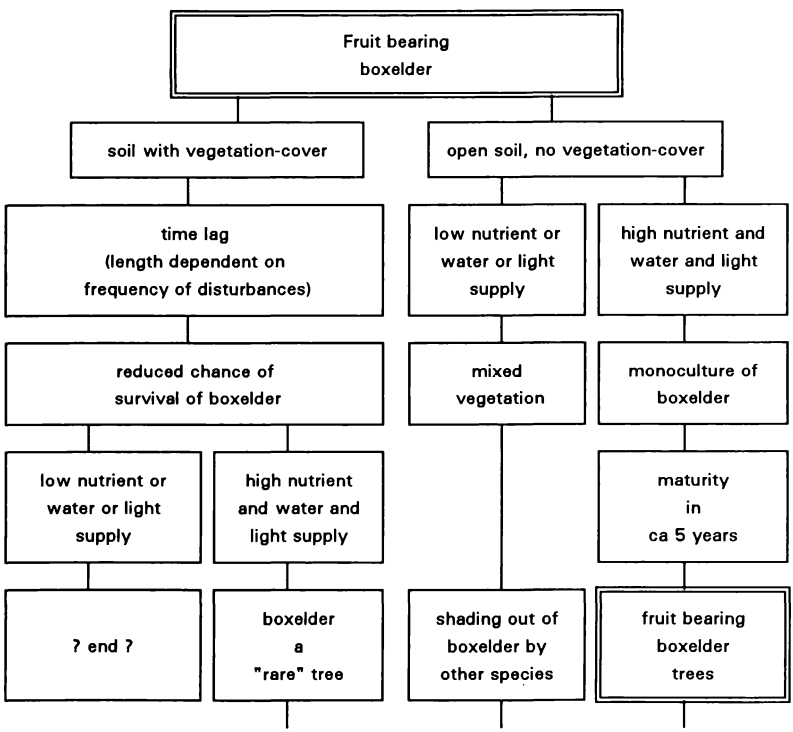

Fig. 4: Invasion scheme for boxelder (*Acer negundo* L.).

Starting with a fruit bearing boxelder, the distinction between vegetation covered soil and open soil is most important. Open soil enables germination and establishment of boxelder. Poor supply of nutrients or water or light can lead to low competitive ability compared to other plant species, and finally to shading-out of the species. The natural habitat of boxelder demands a high ability to adapt to changing moisture levels in the soil; but under dry soil conditions boxelder survives only if there is low competition. With adequate supplies of nutrients, water and light boxelder reacts strongly and, its foliage being very dense, is able to form a monoculture. The short time span of five years until maturity makes a short generation cycle possible.
If the soil is covered with vegetation, establishment of boxelder is dependent on disturbance or on the low chance of the survival of a female together with a male tree. Therefore the chance of survival of the whole species is low. Whether a plant can establish successfully in competition depends on the nutrient conditions. If these are optimal we find the natural living status of boxelder as a rare tree. Under bad nutrient conditions survival of the species is uncertain.
Controlling boxelder is only necessary on areas with open soil (or with phases of open soil) and high nutrient conditions, e. g. disturbed areas. Under different conditions occurence of boxelder is only temporary, and fighting (e. g. stubbing of boxelder and in its consequence open soil) favours persistence of boxelder.

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