Coppice forest and invasive species: the case of *Ailanthus altissima*, a successful survivor in Eastern and Central Europe

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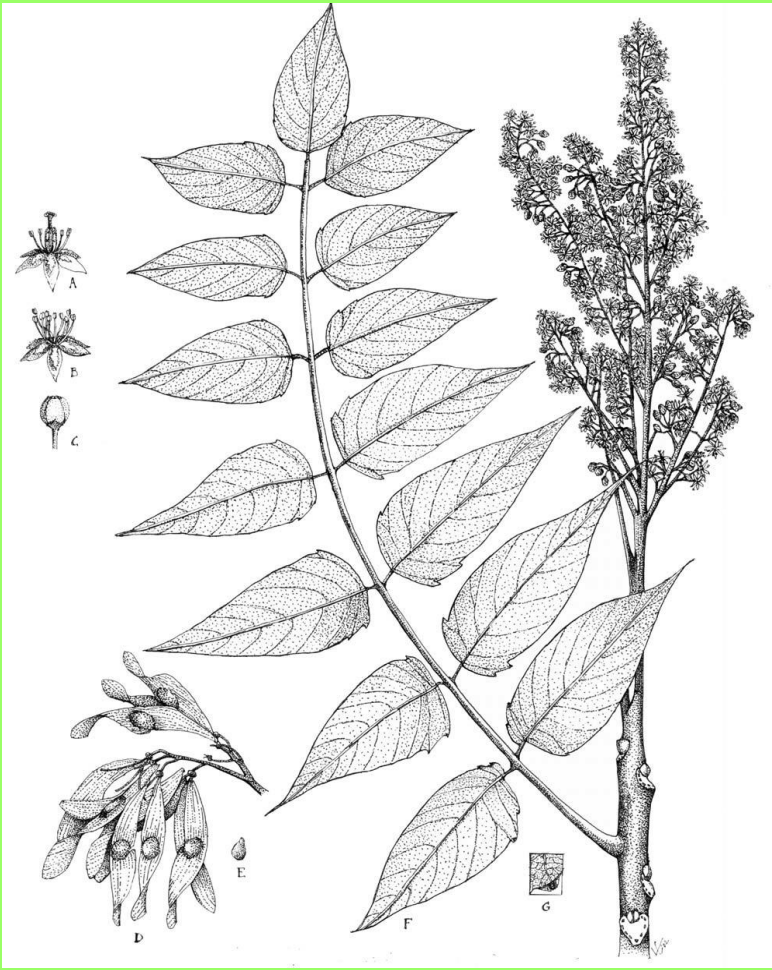
Ailanthus altissima

The *Ailanthus* genus (Simaroubaceae):

5 (Nooteboom,1962) –15 (Engler, 1931) species in India and in the Far East.

The only temperate zone representative: Tree of Heaven (*Ailanthus altissima*).



Ailanthus sp.- Native species in Europe (Tertiary)

- *Ailanthus confucii* Unger, in the Northern hemisphere Tertiary:
  - Paleocene → Pleistocene **-** North America,
  - Eocene → Pleistocene **-** East Asia,
  - **Eocene to Pliocene in Europe**, the oldest known occurrence in Messel, Germany (Corbett &Manchester, 2004).

Aillanthus altissima: Tree of heaven?

- the names (tree of heaven, sky-tree)

→ the high species' ability to grow/attain height quickly

- outstanding fertility and competitive ability
- extension startegy: sprouting without damages

(*Andrašev 2016*)

Range of *Ailanthus altissima*

Native to Northern-Central China, Northern Vietnam, Northern Korea

Secondary range: →1784 → Europe and United States

- United States → all over the country + Western Canada + Mexico
  1840 → East Coast favoured ornamental, in most nurseries.
  1890→ California
- Africa: Algeria, South Africa; South America: Argentina, Chile;
- Australia and New Zealand ("unwanted organism"),
- Asia: China, Japan, Pakistan, India, Indonesia, Republic of Korea, Malaysia,

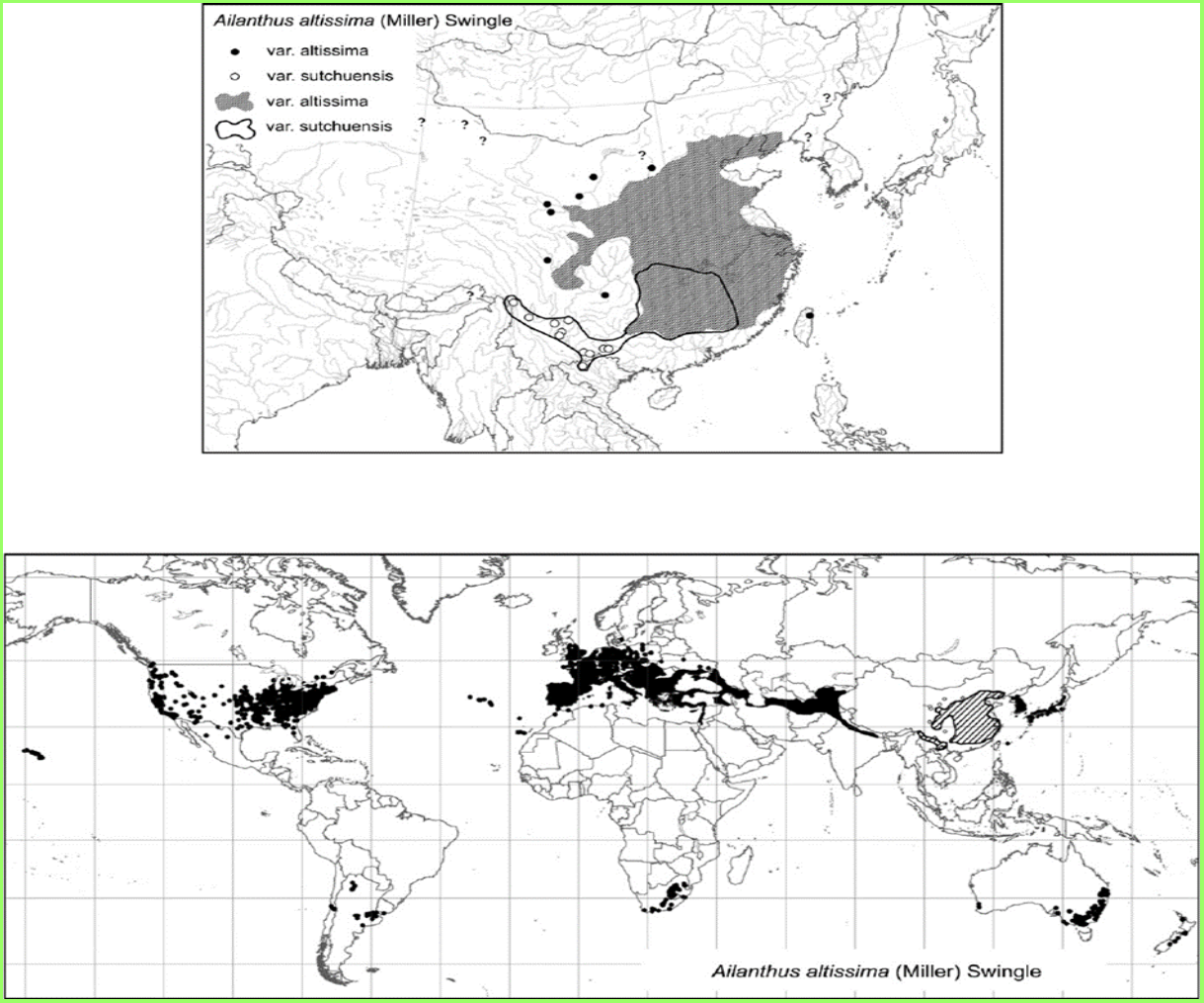
Middle East: Turkey,Iran, Israel

Range of *Ailanthus altissima* - Europe

- across Europe, both in rural and urban areas:
  - Western Europe: UK, Belgium, the Netherlands, Germany
  - Central and South Eastern Europe along and around the Danube river basin: Switzerland, Slovakia, Czech Republic, Hungary, Serbia, FYROM.
  - Mediterranean + Adriatic Basins +Southern Europe: Spain, Portugal, France, Malta, Italy, Slovenia, Croatia, Albania, Montenegro, Bosnia and Hercegovina, Greece.

Ailanthus altissima – rapid global extension

Distribution data compiled and mapped by E. J. Jager & E. Welk, AG Chorology, Institute for Biology Halle/Saale (from Kowarik & Säumel 2007).



Ailanthus altissima in SEE-occurence

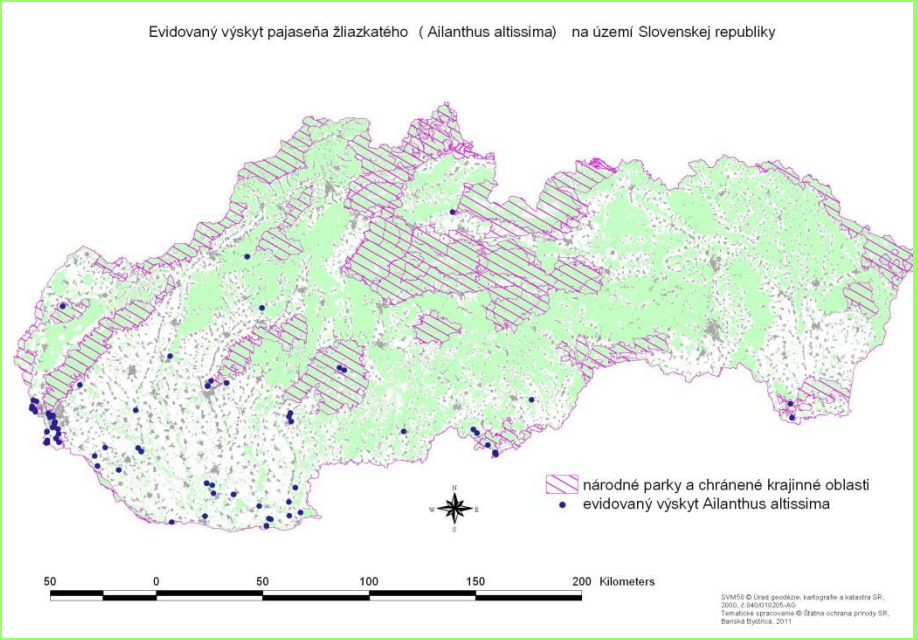
- Hungary 1841-1843
- Romania:1866 (Transylvania) and 1871 (Moldova)
- Slovakia and the Czech Republic: 1874

Ailanthus altissima in SEE– distribution - 2012

Ailanthus altissima
n Hungary (not completed yet!)

Hungary

Udvardy, Zagyvai 2012



Recorded distribution of ailanthus in Slovakia- 2012 ☺
www.sopsr.sk

Spatial distribution – a competitive advantage of *Ailanthus altissima*

- **Clumping (→120m length, → 0,4 ha surface):** concentrated patches of seedlings from dispersed seed clusters or ramets produced by one (clonal growth) or more individuals in:
  - open grazing areas
  - coppice forest
  - clear-cut forests, Call and Nilsen (2003)
  - gaps colonization in managed forest or strict protected areas (Knapp and Canham, 2000).

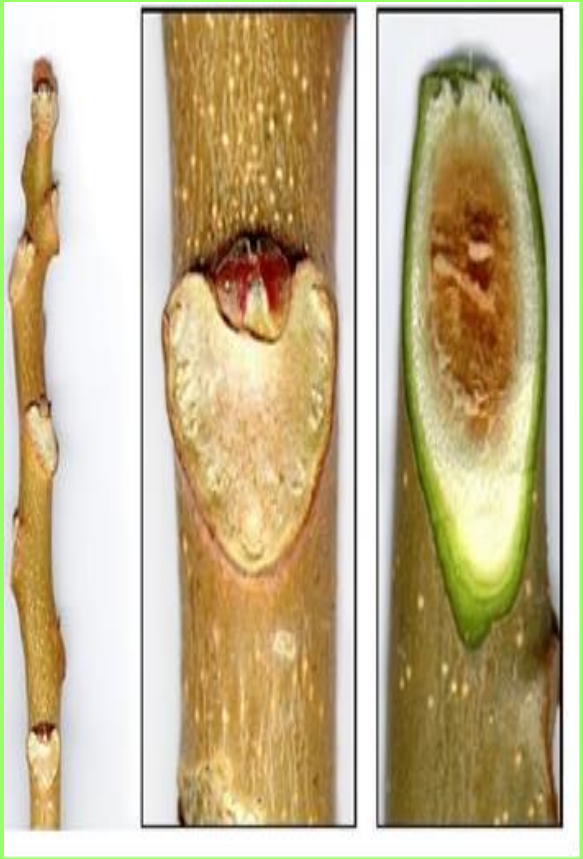
Ailanthus altissima

in protected areas of Slovakia

Ailanthus altissima invasiveness- sexual reproduction

- - A. altissima sexuality is a controversial matter.
  - Most opinions: a dioecious tree (female flowers have stamina without pollen).
  - Others: flowers might be bisexual or the trees monoecious.
- - Annualy prolific: one of the greatest average tree seed production (> 2 million seeds)
- - "exceptionally fecund even in competitive, closed-canopy forest stands„ (USDA)
- -phenological advantage: flower bud break: late but lasts longer.

Ailanthus altissima invasiveness- vegetative reproduction



- **One ramet → 0.4 ha** (preexisting hypocotyl buds, adventitious buds, cataphylls axillary buds, roots and stem rapid growth
- **Powerful strategy to sprout** without damage (only young trees) is rare for trees (except *Rosa* and *Salix*)
- Coppicing, cultivation, browsing, any natural **disturbances** (frost,fire, mutilation the stem or the roots) **are stimulating *A. altissima* sprouting**
- Shoot fragments **can set** adventitious shoots and roots

Ailanthus altissima invasiveness – propagules dispersal

- Prefer **transportation corridors**: (Call and Nilsen, 2003; Huebner, 2003; McDonald and Urban, 2006)
- **Water**: rivers are vectors for propagules (sexual and asexual) and open spaces for wind dispersal
- **Wind**: well adapted samaras –medium dispersal distance 120 m (Bory and Clair-Maczulajtys, 1980), e.g. samaras „climb the mountain through the valley" (by local wind in Western Romania on the Danube tributaries, unpublished data)
- Birds (Miller 1990).
- Rodents
- Hazard (people, machinery...)

Ailanthus altissima invasiveness – soil and pollution tolerance & adaptability

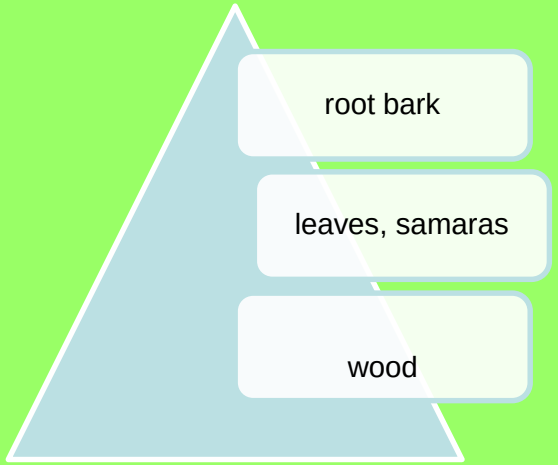
- **bad site conditions tolerant** (*indiferent* to soil fertility, Kowarik& Sauomel 2007) and adaptable to a broad range of natural and artificial soils：drought & poor soils, barren rocky substrates → sandy or clayey loams → calcarous dry and shallow soils → artificial depositions of gravel, sand and other materials, saline soils (roots can be submerged in sea water), acid soils → alkaline soils (Dirr1976; Kowarik and Bocker1984; Miller1990; Singh et al.1992; Udvardy 1998; Kiviat, 2004; Bachman 2005, Kowarik&Saumel, 2007)
- **urban & industrial area conditions highly tolerant** (Kovacs et al.1982;Ranft and Dassler,1970;Danin 2000;Huebner 2003)
- ozone sensitive (Gravano et al., 2003)

Ailanthus altissima invasiveness – strategic adaptability to drought

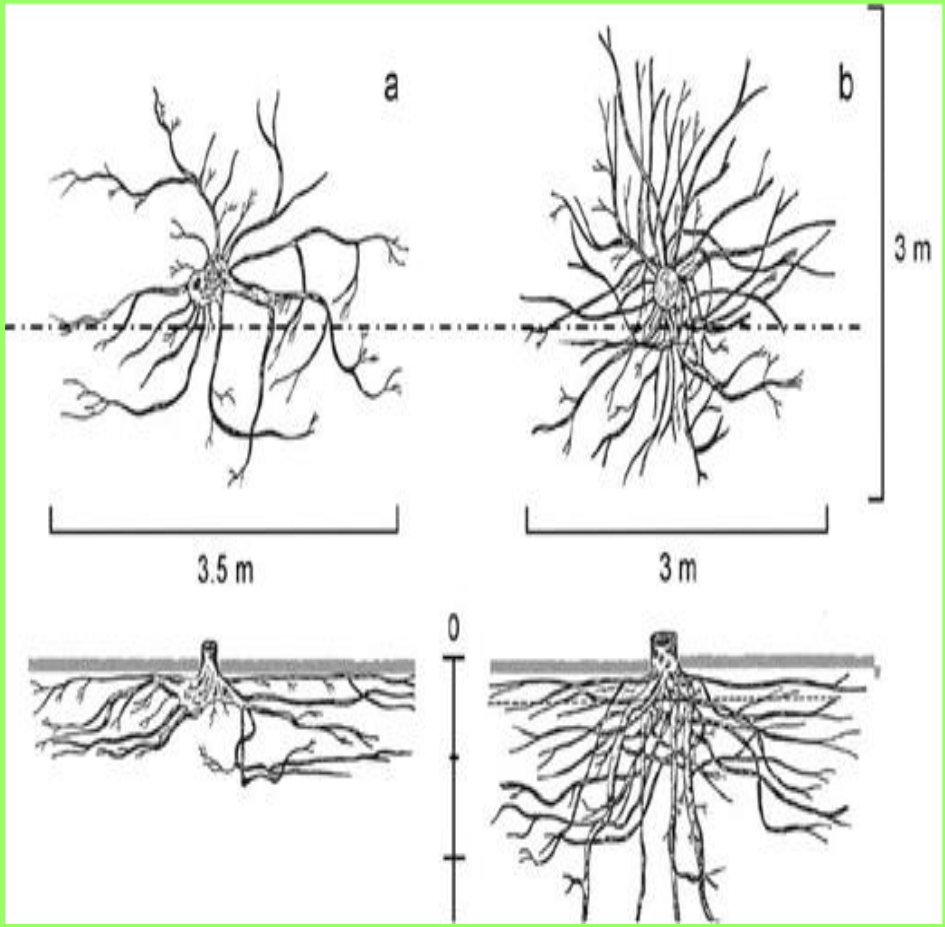
- **rapid water transfer from roots to the leaves** (large ring porous wood structure) & **reducing transpiration in hot days** by summer branch drop (Kowarik 1983, Harris 1983, Lepart et al.1991)
- highly effective water-saving mechanisms that involve reduced **water loss by leaves** (stomatal closure) and **reduced root hydraulic conductance** (Trifilo et al. 2004)

Ailanthus altissima invasiveness – allelopathy

- The root bark, bark of other plant parts, leaves, samaras and wood of *Ailanthus* contain, with decreasing intensity, allelopathic compounds that are toxic to numerous woody and herbaceous species in the laboratory (Mergen, 1959; Heisey, 1990, 1996; Lawrence et al., 1991).
- The quassinoid compound *ailanthone* was identified as the most effective phytotoxic component (Lin et al., 1995; Heisey, 1996)



Ailanthus altissima invasiveness – rooting system



- 2-year-old seedlings developed lateral coarse, unbranched and widely spread roots up to 2.00m long (Kowarik& Saumel 2007).
- Root sprouting - pre-existing primordia or suppressed buds (rare except *Rosa* and *Salix)*

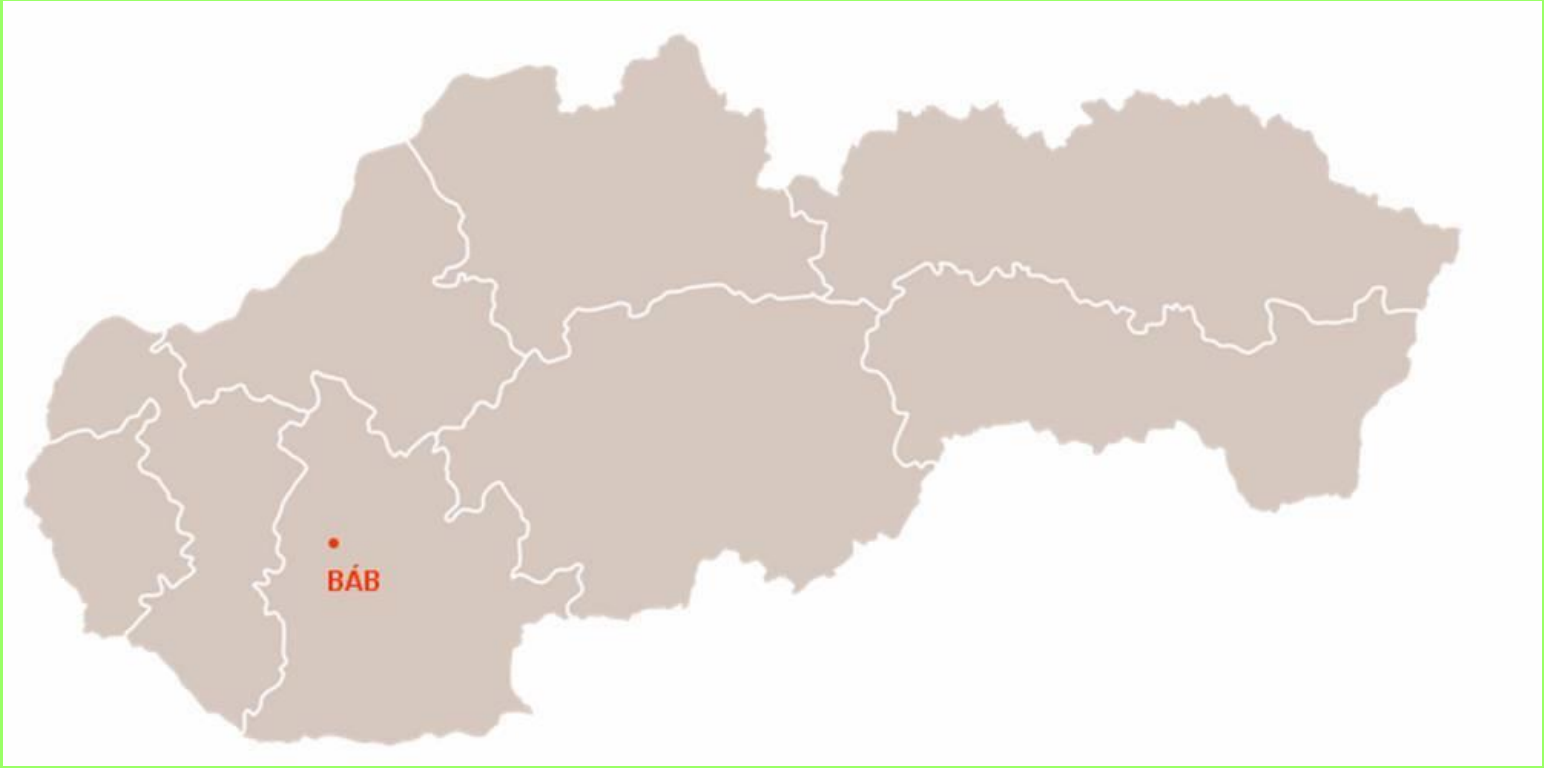
Ailanthus altissima – natural invasiveness limits

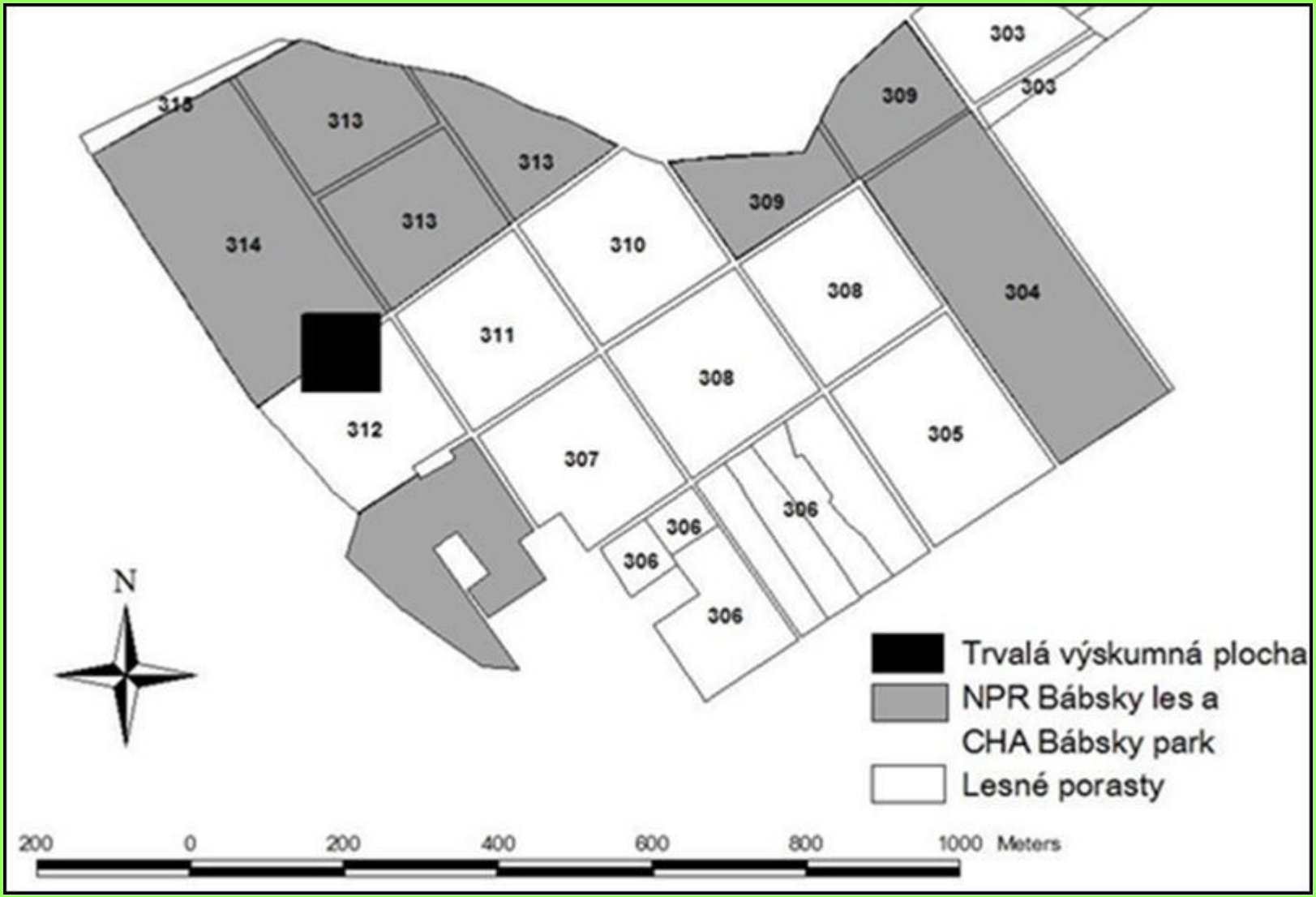
- Ailanthus is classified as a **shade-intolerant**, early successional species (Knapp and Canham, 2000)

- **Frost injury** to young plants + upper shoot parts of older plants due to a long growth period + delayed hard frost.

- **the only decline** of *Ailanthus altissima* in Styria, Austria (35 year-old →very young trees: dieback of branches beginning in the upper crown and bark necroses extending down the stem), Infection with microfungi from agricultural soil: *Verticillium* sp., *Phomopsis ailanthi*, *Nectria coccinea*, *Fusarium* sp.,*Botryosphaeriamelanops*, *Cytospora* sp., *Nectria peziza* and *Gibberella moricola*.

Research area – location

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NPR Bábsky les a
CHA Bábsky park
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Canopied coppice forest in process of aging – 2015

10 years after clear cut (2006)

2 years after clear cut (2014)

Methods

2 steps

1. **Analysis - changes in biodiversity** (phytoceonological relevés - 2015).

- 3 sampling plots =3 x 400 m^2.
- Braun-Blanquet Method (1964) (presence of species and their relative abundance (cover in %)

2. **Evaluation of stand composition and habitat preferences of *Ailanthus altissima***

- *Multivariate methods* biodiversity evaluation - principal component analysis (PCA) (Canoco 4.5 and CanoDraw 4):
  - coefficient of importance (abundance × class of species persistence) of spontaneous plants in relation with habitat type in 3 variants:
    1. Clear cut in 2006;
    2. Clear cut in 2014
    3. Canopied coppice forest in process of aging at present; .

Results

The herb layer of clear cuts → dominated by nitrophilous species (*Sambucus ebulus, Galium aparine* etc.) ***Ailanthus altissima*** **outcompete the forest tree native species (rapid growth, allelopathy, nitrogen accumulation** ...)

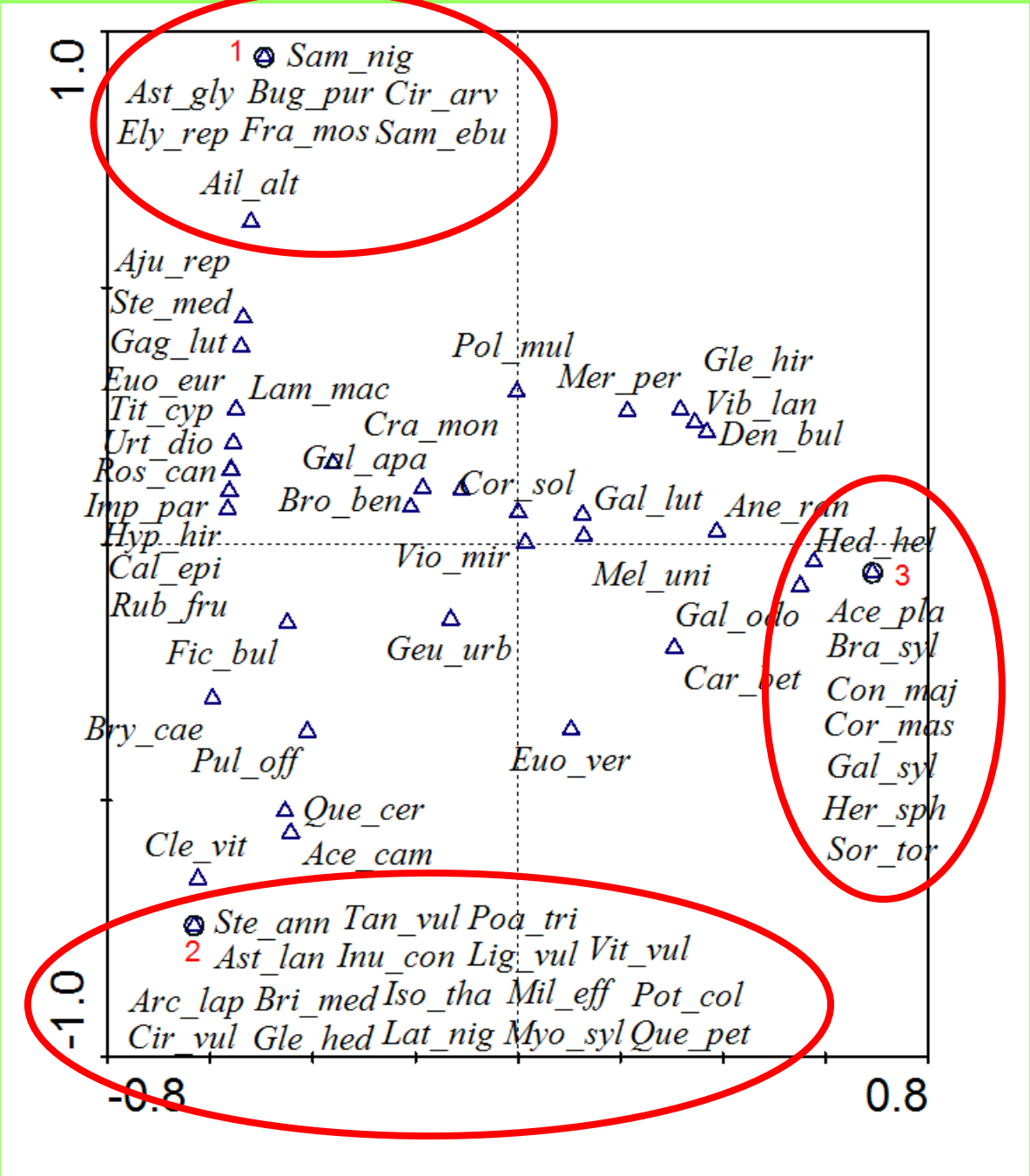
Variants species composition

coeficient of importance = f (abundance x persistance)

Species	Clear1	Clear2	Forest
Acer campestre	5	79,17	13,33333
Acer platanoides			5
Ailanthus altissima	117,8875	27,67	
Ajuga reptans	4,666667	2,00	
Anemone ranunculoides	6	4,00	30,85714
Arctium lappa		4,00	
Aster lanceolatus	2		
Astragalus glycyphyllos		4,00	
Brachypodium sylvaticum			4
Briza media		1,00	
Bromus benekenii	5,230769	5,00	4
Bryum caespitosum	50	141,11	
Lithospermum purpureo.	3		
Calamagrostis epigejos	5	5,00	
Carpinus betulus	15	116,94	314,1667
Cirsium arvense	4		
Cirsium vulgare		10,56	
Clematis vitalba	4	70,30	
Convallaria majalis			3
Cornus mas			100
Corydalis solida	5	4,40	7,6
Crataegus monogyna	5	4	5
Dentaria bulbifera	5,25		12,72727
Elytrigia repens	5		
Euonymus europaeus	5	4,00	
Euonymus verrucosus		4,00	5
Ficaria bulbifera	15,375	29,63	5,333333
Fragaria moschata	2		
Gagea lutea	4,4	3,00	
Galeobdolon luteum	7	5,85	5,428571
Galium aparine	8,529412	6,86	18,52941
Galium odoratum	4,2	11,43	126,3889
Galium sylvaticum			9,75
Geum urbanum	8,333333	17,50	14,33333
Glechoma hederacea		3,00	
Glechoma hirsuta	11		23,82353
Hedera helix	25	21,11	455,556
Heracleum sphondylium			5
Hypericum hirsutum	4	4	
Impatiens parviflora	4	4,00	
Inula conyzae		25,00	
Isopyrum thalictroides		1,00	
Lamium maculatum	21,66667	17,33	7,2
Lathyrus niger		2,00	
Ligustrum vulgare		5,00	
Melica uniflora	17,66667	17,67	43,33333
Mercurialis perennis	162,2222	23,33	281,6667
Milium effusum		4,00	
Myosotis sylvatica		1,00	
Poa trivialis		6,18	
Polygonatum multiflorum	6,75	2,00	6,6
Potentilla collina		1,00	
Pulmonaria officinalis	21,66667	91,67	20
Quercus cerris	15	147,78	23,33333
Quercus petraea agg.		25,00	
Rosa canina agg.	5	5,00	
Rubus fruticosus agg.	13,82353	15,00	
Sambucus ebulus	242		
Sambucus nigra	5		
Sorbus torminalis			5
Stelaria media		2,00	
Stenactis annua	8	4	
Tanacetum vulgare		2,00	
Tithymalus cyparissias	9,142857	8,31	
Urtica dioica	18,52941	16,76	
Viburnum lantanum	5		13,33333
Viola mirabilis	5	5,63	9,117647
Vitis vulpina		5,00	

Principal Components Analisys (PCA)

1. Clearing in 2014
2. Clearing in 2006
3. Well canopied coppice forest



Results – 2015

Clearing in 2014

Sambucus ebulus, Ailanthus altissima, Galium aparine, Geum urbanum, Mercurialis perennis, Pulmonaria officinalis, Urtica dioica etc.

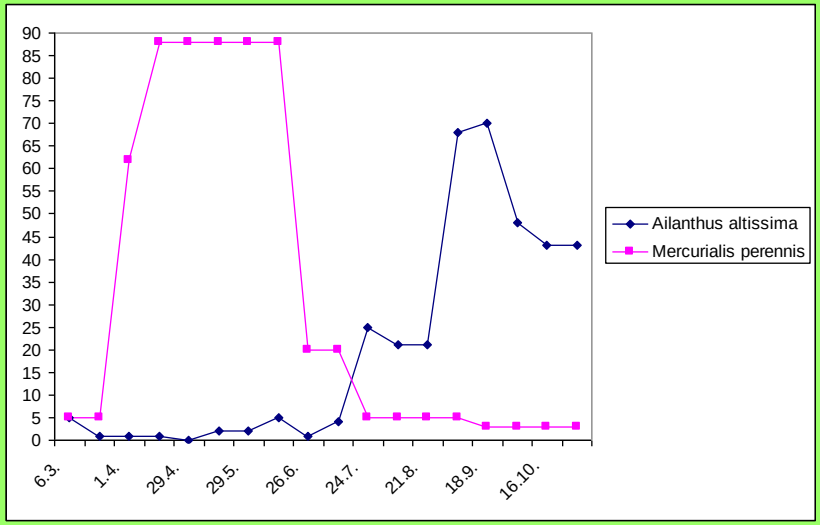
Clearing in 2006

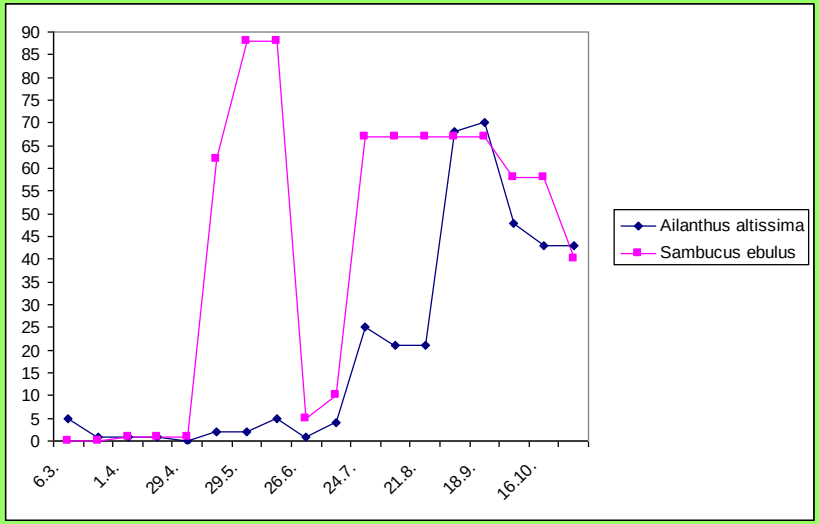
Quercus cerris, Carpinus betulus, Ailanthus altissima, Galium odoratum, Mercurialis perennis etc.

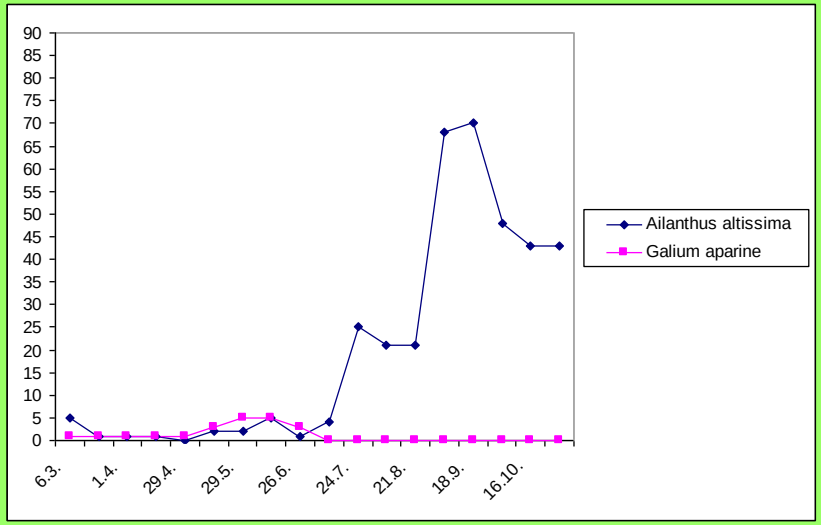
Well canopied aged oak coppice forest

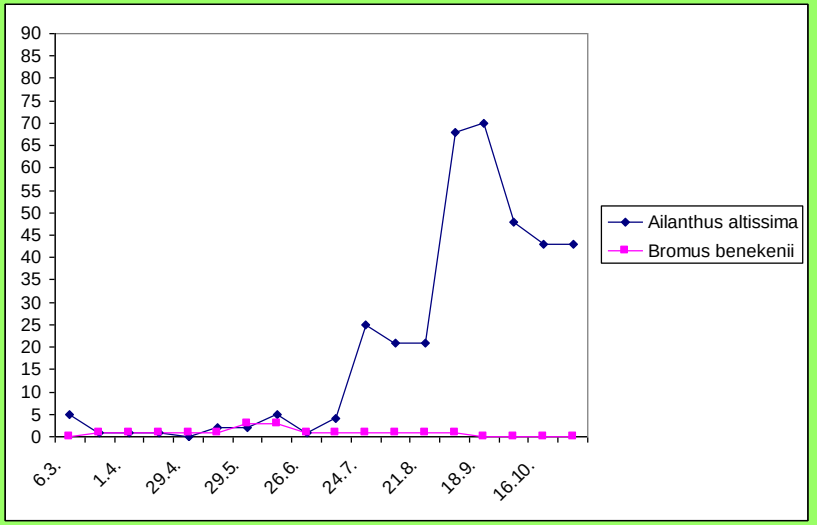
Quercus cerris, Acer campestre etc.

Species Competition (clearing 2014, *Ailanthus* cut 3 times/year) (x: time horizon in 2015, y: abundance in %)



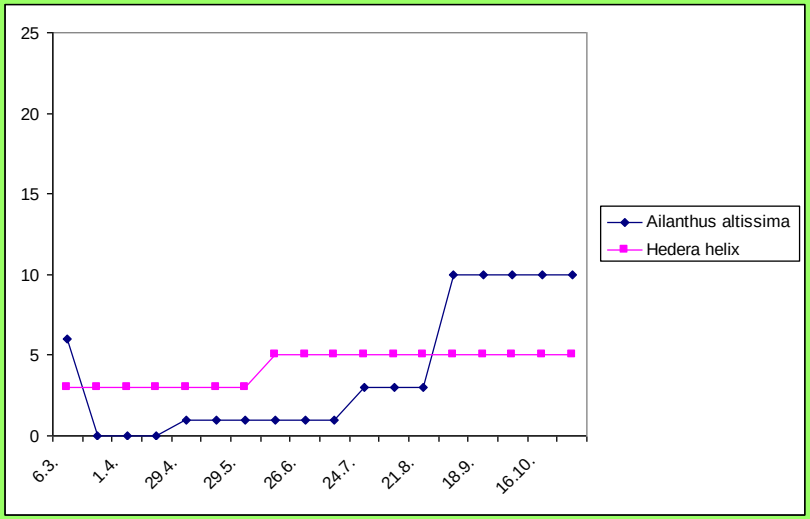


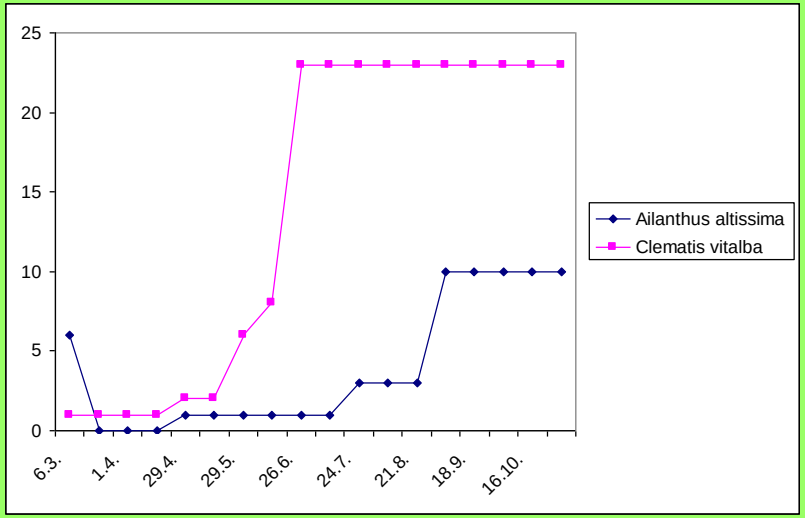


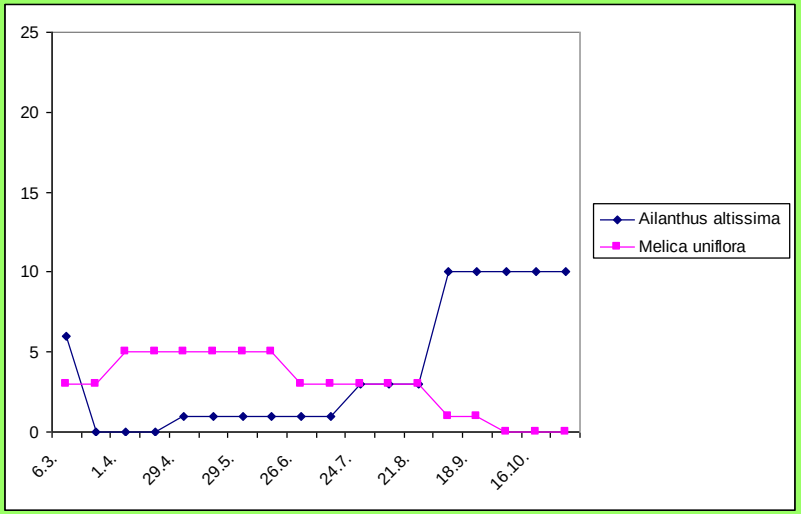


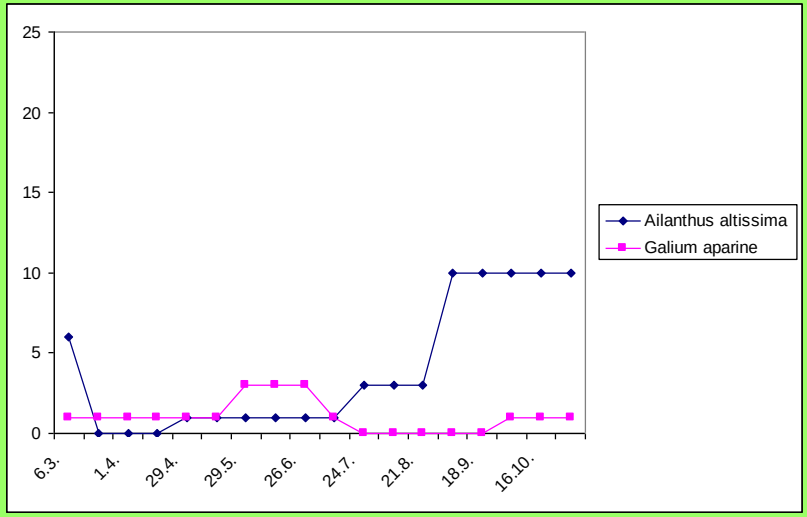
Mercurialis perennis: different optimum than *Ailanthus altissima*,
Sambucus ebulus quicker re-grow than *Ailanthus altissima*,
Galium aparine and *Bromus benekenii*: disappeared when *Ailanthus altissima* dominated (more study needed)

Species Competition 2015 - Ailanthus cut 3x/year (clear cut 2006) (x: time horizon in 2015, y: abundance in %)





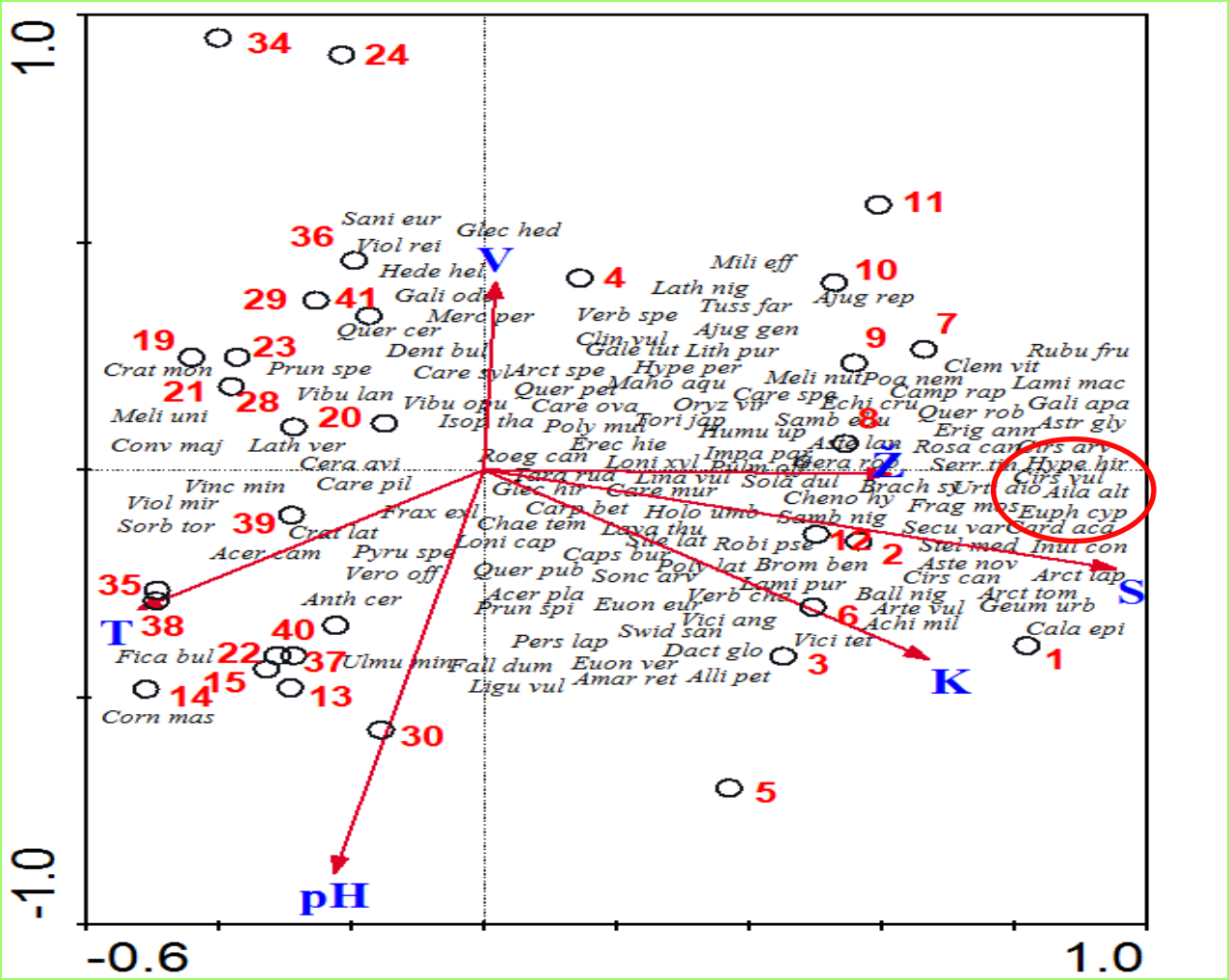




Hedera helix and *Clematis vitalba*: in process of spreading,
Melica uniflora: out-competed and *Galium aparine*: disappeared when *Ailanthus altissima* dominated (more study needed)

Ailanthus altissima → ecological factors

Slovakia, 2014, Bábsky les



Ellenberg values:

V – water,

Ž – nutrients,

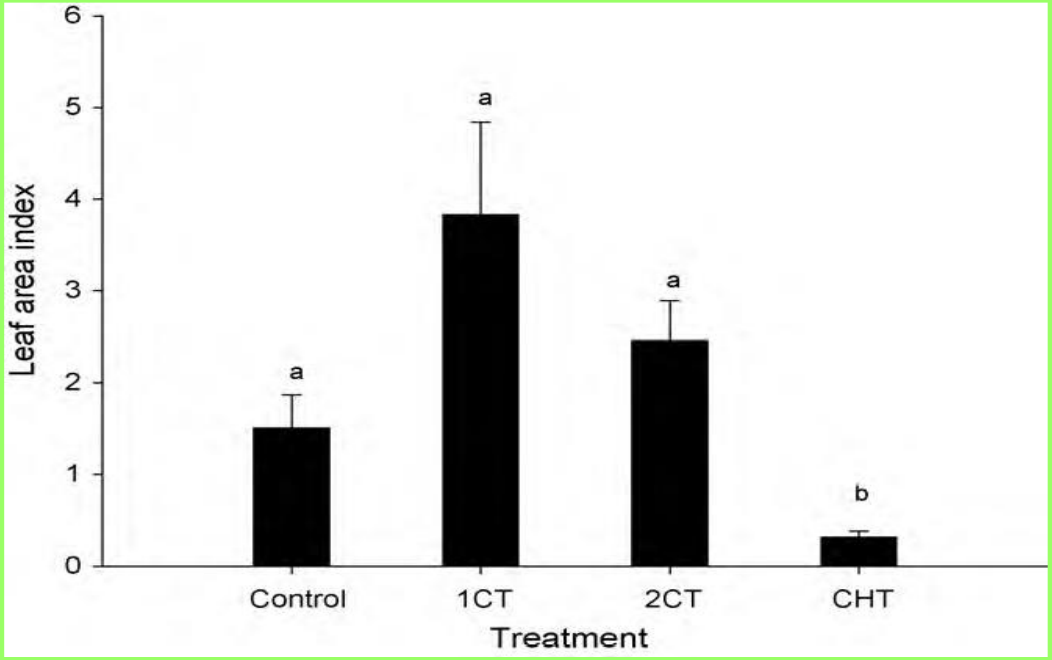
S – light,

K – continentality,

pH – soil reaction,

T - temperature

Control of *Ailanthus altissima*



Control;
1CT: one cut stump treatment;
2CT: double cut stump treatment;
CHT: cut stump with glyphosate application treatment.
(Kruskal–Wallis test).

Soraya Constán-Navaa, Andreu Boneta, Estrella Pastora, María José Lledóa, 2010

Conclusion - *Ailanthus altissima* a perfect invador naturalized in many temperate regions

Ailanthus altissima a perfect invador naturalized in many temperate regions

- flowering maturity normally > 3 - 4 years, easy pollinated by insects
- no danger of late frost (in blossom in June, July, August)
- very prolific annual fruiting & sprouting,
- easy propagule dispersion by wind, water, animals, hazard
- succesful natural regeneration (30-90% viable seeds)
- rapid rooting & growth
- allelopathic by roots, seeds and bark, inhibit growth of other seedlings and herbs,
- accumulate nitrogen in soils

Conclusions

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Ailanthus altissima:

- **shade-intolerant**, ozon sensitive
- high tolerance to clima, polution & infertile soils
- no important pests&parasits or predators
- very difficult control

Conclusions

Occurence of ***Ailanthus altissima*** is strongly correlated with any **disturbance of forest canopy**

Conclusions

Occurence of ***Ailanthus altissima*** is strongly correlated with light and nutrients and no correlated with pH value

In the present-day context of climate-change*, Ailanthus altissima* is a good competitor to other tree and herbal species in coppice forests, clear cuttings and in forest gaps

Thank you !