Tree recruitment of European tree species at their current upper elevational limits in the Swiss Alps

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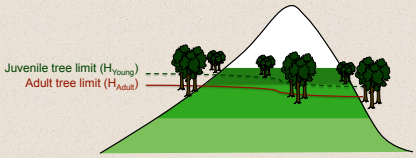
Introduction

Although the physical and physiological mechanisms that determine treeline position are reasonably well understood, explanations for tree species-specific upper elevational limits below the treeline are still lacking.

In addition, once these uppermost positions have been identified, the question arises whether they reflected past expansion events or active ongoing recruitment or even upslope migration.

Assumption



→ In relation to ongoing climate warming we expect a higher upper elevational limit of seedlings and saplings (H_{Young}) as compared to adults (H_{Adult}) of the same species

Study Area

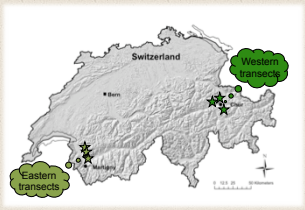


Fig. 1. Location of the six elevational transects

Aims

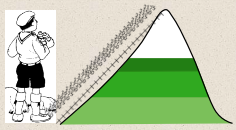
1. To assess current tree recruitment at their upper elevational limits
2. To rank species by the extent their seedlings exceed the elevational limit of adult trees, possibly reflecting effects of the recent climatic warming

Materials & Methods

Table 1: Characteristics of the different age size classes used in the demographic survey.

Size class	Life stage	Criterion
1	Seedlings I	One year old with cotyledons still present
2	Seedlings II	Height < 0.20 m
3	Seedlings III	Height [0.20 m – 0.50 m]
4	Saplings I	Height [0.50 m – 2 m]
5	Saplings II	Height [2 m – 4 m] or height > 4 m and diameter < 0.15 m
6	Adult trees*	Height > 4 m and diameter ≥ 0.15 m

*For *Corylus avellana*, *Sorbus aucuparia*, *Sorbus aria* and *Laburnum alpinum* only the diameter criterion was considered to define them as belonging to size class 6 and we considered these species as reaching adult life stage for size class equal 5 or 6.



Survey Method

- 3 transects within 2 regions (Fig. 1)
- Along each transect, the presence of all tree species were recorded every 25 m elevation step according to six size categories (Tab. 1) from 1000 m to 2200 m.

Results

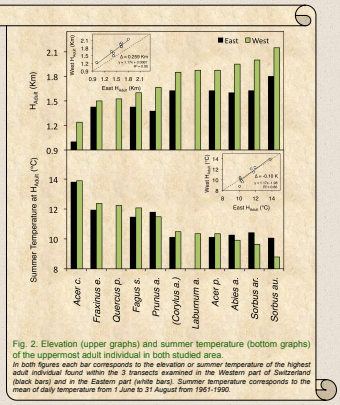


Fig. 2. Elevation (upper graphs) and summer temperature (bottom graphs) of the uppermost adult individual in both studied area.
In both figures each bar corresponds to the elevation or summer temperature of the highest adult individual found within the 3 transects examined in the Western part of Switzerland (black bars) and in the Eastern part (white bars). Summer temperature corresponds to the mean of daily temperature from 1 June to 31 August from 1961-1990.

→ The upper elevational limit of the studied adult trees (H_{Adult}) revealed a consistent pattern of similar relative positions of species among transects and regions (Fig. 2).

→ However, H_{Adult} differed between the two regions and was about 260 m higher for the western transects (Fig. 2, upper graphs). This could largely be explained by regional differences in growing season temperature (Fig. 2, bottom graphs)

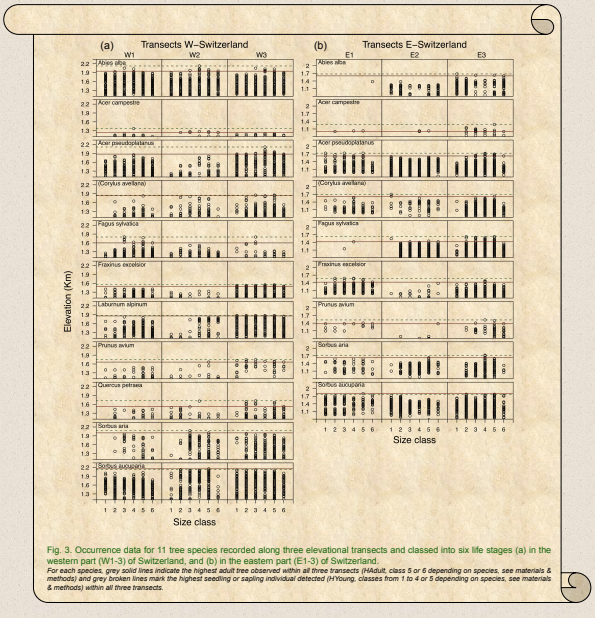


Fig. 3. Occurrence data for 11 tree species recorded along three elevational transects and classed into six life stages (a) in the western part (W1-3) of Switzerland, and (b) in the eastern part (E1-3) of Switzerland.
For each species, grey solid lines indicate the highest adult tree observed within all three transects (HAdult, class 5 or 6 depending on species, see materials & methods) and grey broken lines mark the highest seedling or sapling individual detected (HYoung, classes from 1 to 4 or 5 depending on species, see materials & methods) within all three transects.

Table 2: Elevation differences of seedling limits (HSeedling), sapling limits (HSapling) and young tree limits (HYoung)* related to adult limits (HAdult) in both studied regions (West and East of Switzerland).

	West (n=11)	*P*	East (n=9)	*P*	Overall (n=20)	*P*
$H_{Seedling}$ - H_{Adult}	+ 64 m (± 22)	0.019	+79 m (± 28)	0.022	+71 (±17)	< 0.001
$H_{Sapling}$ - H_{Adult}	+ 78 m (± 32)	0.035	+101 m (± 37)	0.025	+ 88.5 (± 22)	0.001
H_{Young} - H_{Adult}	+ 102 m (± 28)	0.004	+123 (± 28)	0.002	+ 112 (± 19)	< 0.001

P represents probability values from Student's paired sample t-tests between HSeedling/HSapling/HYoung and HAdult.
*i.e. seedlings or saplings

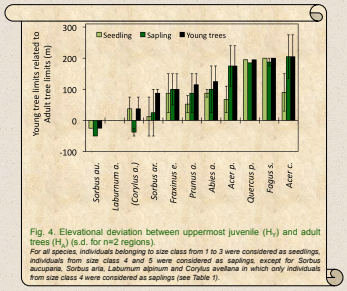


Fig. 4. Elevational deviation between uppermost juvenile (H_Y) and adult trees (H_A) (s.d. for n=2 regions).
For all species, individuals belonging to size class from 1 to 3 were considered as seedlings, individuals from size class 4 and 5 were considered as saplings, except for Sorbus aucuparia, Sorbus aria, Laburnum alpinum and Corylus avellana in which only individuals from size class 4 were considered as saplings (see Table 1).

→ Tree recruitment of both seedlings and saplings was detected significantly beyond adult limits among the 11 studied species (Figs. 4 & 5), in average 71 m higher for seedlings and 89 m higher for saplings (Table 2).

→ This discrepancy is null for Sorbus aucuparia and Laburnum alpinum and reaches about 200 m for Acer campestre, Fagus sylvatica and Quercus petraea (Figs. 4 & 5).

Discussion & Conclusion

The study clearly highlights that **young individuals are currently beyond the adult limits**, suggesting that, at current temperature, **tree recruitment is not a limiting factor to expand tree range area beyond their actual upper elevational limits**. In addition, most of the tree life stages were present around adult limits in both regions, indicating **successful and continuous seedling establishment** in the immediate surrounding of those adults. This result is in agreement with some recent publications **showing an upward shift of tree species limit in the Alps** and could reflect the effect of ongoing climate warming.