Regeneration dynamics in an alluvial dense ash (*Fraxinus excelsior* L.) stand

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Abstract

Broadleaves regeneration dynamics and the succession mechanism were studied within a transect of 14 m × 56 m in a dense 80-year-old ash stand situated on an alluvial soil. For this purpose, abundance and height of all naturally regenerated species at different development stages were analyzed and their distribution over the juvenile and older growth stages determined.

The study reveals that from the main broadleaved tree species, *Quercus robur* and *Fagus sylvatica* regeneration scarcely occur at any growth stages. No *Fraxinus excelsior* regeneration, except 1 unit, taller than sapling (1.5-4 m) can be found on this soil type. On the contrary, *Acer pseudoplatanus* represents different development stages (seedling, sapling, thicket, small pole and large pole) and in stand patches where an understorey is practically lacking, its regeneration is well developed. Results generally show that at the juvenile and older growth stages *Acer* proceeds *Fraxinus* and regeneration is largely dominated by the invasive *Acer*. It is expected that this succession process will continue and that *Acer* will overcome in the overstorey and even gradually form an almost single-species dominating stage. Direct interventions are unavoidable in order to regulate the primary mixture patterns.

1. Introduction

In recent decades, replacement of ash (*Fraxinus excelsior* L.) by sycamore (*Acer pseudoplatanus)* has been reported by some authors. The first suggestion that sycamore in the ash stand might follow this pattern was made by Brotherton (1973). Work by Merton (1970), Van Miegroet *et al.* (1981) and Taylor (1982, 1985) seems to support this. Waters and Savill (1992) report, that without doubt, the characteristics of many of the ashwoods have changed by invasion of sycamore. Fears have been expressed about the threat sycamore poses by invading native ash woods. These were first raised by Watt (1925) as a result of observations made in his study of Sussex beechwoods. Scurfield (1959) was concerned that sycamore might expand at the expense of ash woods in the peak district. Peterken (1981) states that sycamore expansion has been mainly in the ash-wych elm woods. He also notes that the *Tilio-Acerion* woodlands of central Europe, described by Klotzli (1970), occur on sites mainly corresponding to some of Britains familiar ash woodland types. In addition, data, which he presents, show that hazel/ash woods and calcareous beech woods have a significant presence of sycamore. On the other hand some reports show that sycamore is regenerating much more freely in European forests than it did before. Many foresters attribute this to more intensive thinning in recent times. Others argue that it might be the result of improved topsoil conditions due to nitrogen input from atmospheric pollution. The effects of this factor on the forest dynamics is a feature that certainly needs further consideration (Joyce, 1998).

Such a phenomenon can be also observed in the ash stand of the Aelmoeseneie Experimental Forest, located in Flanders (northern Belgium). In this site, apparently, ash regeneration at the growth stages of sapling, thicket and pole is conspicuously absent. By contrast, sycamore looks that in some parts and especially in small canopy gaps benefits from different growth stages. Generally, concerning to the poor abundance and the lack of the higher growth stages of ash and, by contrast, the frequent presence of the well-distributed sycamore regeneration, it seems likely that stand climax will be replaced by sycamore and/or that the ecological conditions of the ash stand will be altered in favour of sycamore. This current study aims to clarify some characteristics of broadleaved trees regeneration, especially sycamore and ash, and also to find the possible attitude and mechanism of the stand succession.

2. Materials & methods

In this study, in a one hectare standard dense ash stand of the Aelmoeseneie Experimental Forest (a research forest belong to the university of Gent), located in Flanders (northern Belgium), a transect of 14 m × 56 m, situated along a brook and on an alluvial clay soil, was sampled. Soil was identified as a typical mull humus type, with characteristics as given in Table 1 (Zahedi, 1998). All dominating trees of the stand were about 80 years old. Herbal vegetation dominating in the stand was *Holcus mollis*.

Table 1. *Soil acidity (pH) and C/N - ratio of humus layers, and the depth of undecomposed litter measured in the alluvial soil type*

Humus type	PH	C/N ratio	Litter thickness (mm)
Typical mull	5.3-6.5	8-12	0-2

Transect analysis was executed during the summer. First, all trees higher than 15 m were tagged and then the following characteristics were determined:

-diameter at breast height (1.3 meters), obtained by averaging perpendicular measurements;
-tree height (use of Blume - Leiss height meter);
-basal area;

-crown dimensions of each tree (crown length in the 4 prevailing wind directions + extra readings when necessary for very irregular crown);
-position of all trees.

In addition, frequency, diameter and total height for the individuals between 1.5 m and 15 m, divided over 4 height categories (1.5-4, 4-7, 7-10 and 10-15 m), were measured. Then crown dimensions and the position of the individuals within the confine of transect were recorded. Profile drawing of all trees and shrubs with a height > 1.5 m in the central area of the transect (8 m × 60 m) was executed by using the SVS Program (Stand Visualization System, Version 2.13). In order to obtain a more detailed survey, frequency, diameter and total height of seedlings and saplings, ranged between 15 cm and 150 cm, as well as their situation on the ground were recorded. Besides, the frequency condition of 1 to 2 years old seedlings (mostly with a height 10-15 cm) was studied at the axe of transect in 8 circular plots, with a radius of 1.78 m (area = 10 m^2).

3. Results

3.1. Characteristics of trees (with top height > 15 m)

From all trees measured in the transect the highest share, with 52.2 %, allocates to *Fraxinus* and thereafter with 34.8%, 6.5% and 6.5% to *Acer*, *Populus* and *Quercus* (Table 2). The largest trees are *Populus* and *Fraxinus*, with an average of 42.0 cm and 34.7 cm in d. b. h., respectively. *Populus* and *Fraxinus* with 32.3 m and 28.4 m in height are dominant trees in this transect. *Acer* and *Quercus*, being several meters shorter in height, are co-dominant trees. *Acer* includes 0.6 m^2/10 are of the basal area, while *Fraxinus* with 2.2 m^2/10 are (66.7% of total basal area) demonstrates the greatest share of the basal area among the tree species. Likewise, the portion of the basal area for *Quercus* is 0.1 m^2/10 are and for *Populus* is limited to less than 0.4 m^2/10 are.

Table 2. *Some characteristics of tree species higher than 15 m*

Species	Frequency (N/10 are)	Frequency (%)	Mean diameter (cm)	Mean total height (m)	Mean basal area (m^2/10 are)
Acer pseudoplatanus	16	34.8	22.4	19.9	0.6
Fraxinus excelsior	24	52.2	34.7	28.4	2.2
Populus euramericana	3	6.5	42.0	32.3	0.4
Quercus robur	3	6.5	22.0	21.0	0.1
Total	46	100			3.5

3.2. Characteristics of underwoods and shrubs

Corylus avellana, apparently established by man-made, with 98%, has the greatest share among the underwoods and shrubs (Table 3). *Crataegus monogyna* and *Sambucus nigra,* each one with 1%, make up the other underwood and shrub elements. In all, on this site, frequency of naturally regenerated underwoods and shrubs is entirely poor.

Table 3. *Frequency of underwoods and shrubs (per 10 are)*

	Height class (m)				
Species	1.5-4	4-7	7-10	Total	(%)
Corylus avellana	29	51	21	101	98
Crataegus monogyna		1		1	1
Sambucus nigra		1		1	1
Total	29	53	21	103	100

3.3. Establishment of sapling, thicket and pole groups (1.5 m < height < 15 m)

Acer regeneration is much more frequent than *Fraxinus* regeneration (Table 4, Fig. 1). From the first regeneration recorded in this stand, out of 159 individual trees, only 1 *Fraxinus*, with a height between 1.5 m and 4 m, and apparently reproduced by sprouting, is present. No *Fraxinus* can be found at higher height classes in this transect, dominated by *Fraxinus* trees in the upper storey. On the contrary, *Acer* in all height categories is relatively well presented. With the exception of 1 *Fagus,* with a height between 4 m and 7 m, regeneration of other broadleaved tree species (e.g. *Quercus*) in either of the four height categories is conspicuously missing.

Table 4. *Frequency of regenerated tree species (per 10 are) greater than 1.5 m and smaller than 15 m at different height classes*

	Height class (m)					
Species	1.5-4	4-7	7-10	10-15	Total	(%)
Acer pseudoplatanus	83	39	31	4	157	98.8
Fraxinus excelsior	1				1	0.6
Fagus sylvatica		1			1	0.6
Total	84	40	31	4	159	100

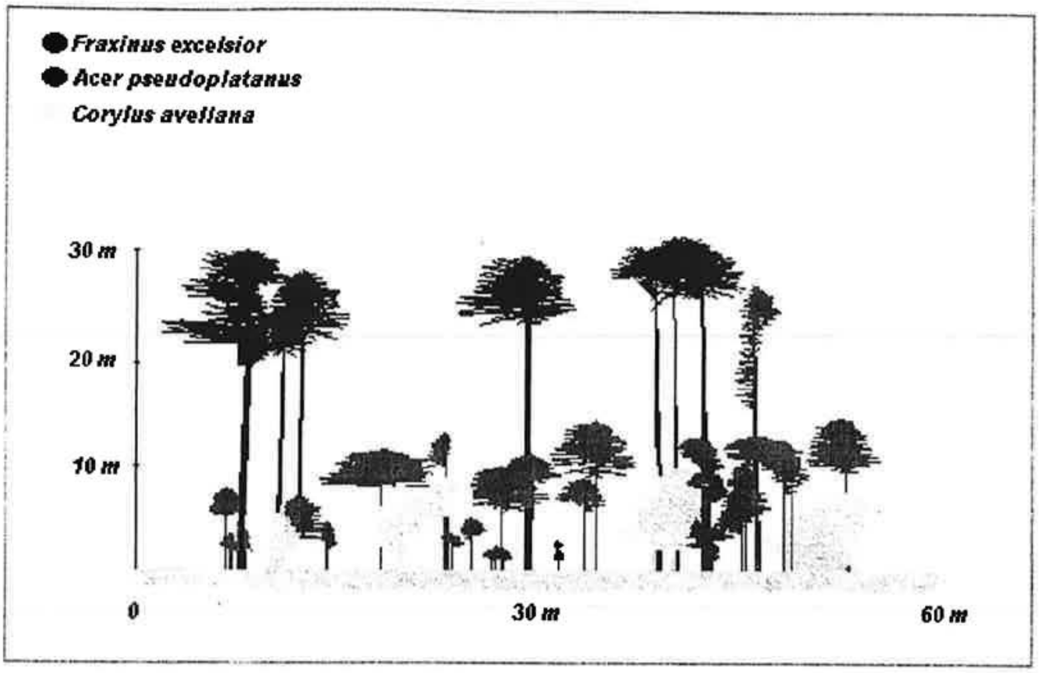

Figure 1. *Vertical structure (a part of transect area, 8 m × 60 m) of trees and shrubs with a height > 1.5 m.*
(The elements of the upperstorey are mainly Fraxinus excelsior and of the understorey are often Acer pseudoplatanus saplings and thickets and Corylus avellana underwoods).

3.4. Characteristics of older seedlings (15 cm < height < 150 cm)

In this transect, broadleaves regeneration amounts to 494 individuals/10 are (Table 5). The most abundant regeneration is presented by *Acer*, with 312 individuals/10 are. Thereafter, from the tree species, *Q. robur* with 21, *Fraxinus* with 10, *Fagus* with 6, *Q. rubra* and *Sorbus* each one with 5, *Prunus* with 4 and *Castanea* with 1 unit/10 are occur on this site. From the shrubs, *Sambucus, Ribes* and *Corylus* are present with 47, 45 and 38 individuals/10 are, respectively.

Generally, with the exception of *Acer* that abundantly spreads over all height classes, broadleaved tree species and specially *Fraxinus* have a very poor regeneration and are merely observed at height class of 15-30 cm. In reality, on this soil type with height classes > 51-70 cm only *Acer* is existing, while other tree species are drastically lacking. Most of underwoods and shrubs are present at height categories ranging between 15-30 cm and 51-70 cm. Only *Corylus*, likely originated from sprouting, is found at higher categories of this classification. Distribution of the seedlings and saplings is plotted in Fig. 2. The concentration of seedlings in parts of the transect is related to the absence of understorey.

The regenerated species show a progressive decrease in frequency with increased height (15-150 cm) (Fig. 3). Correlation coefficient (r) for nonlinear (power) function model is 0.860.

Table 5. *Frequency of seedlings and saplings (per 10 are) at different height classes (between 0.15 and 1.5 m)*

Species	Height class (cm)							Total	(%)
	15-30	31-50	51-70	71-90	91-110	111-130	131-150		
Acer pseudoplatanus	91	39	46	51	30	22	33	312	63.2
Castanea sativa		1						1	0.2
Corylus avellana	15	10	5	3	1	4		38	7.7
Fagus sylvatica	6							6	1.2
Fraxinus excelsior	10							10	2.0
Prunus avium	1		3					4	0.8
Quercus robur	21							21	4.3
Quercus rubra	5							5	1.0
Ribes rubrum	23	17	5					45	9.1
Sambucus nigra	4	3	39	1				47	9.5
Sorbus aucuparia	3	1	1					5	1
Total	179	71	99	55	31	26	33	494	100

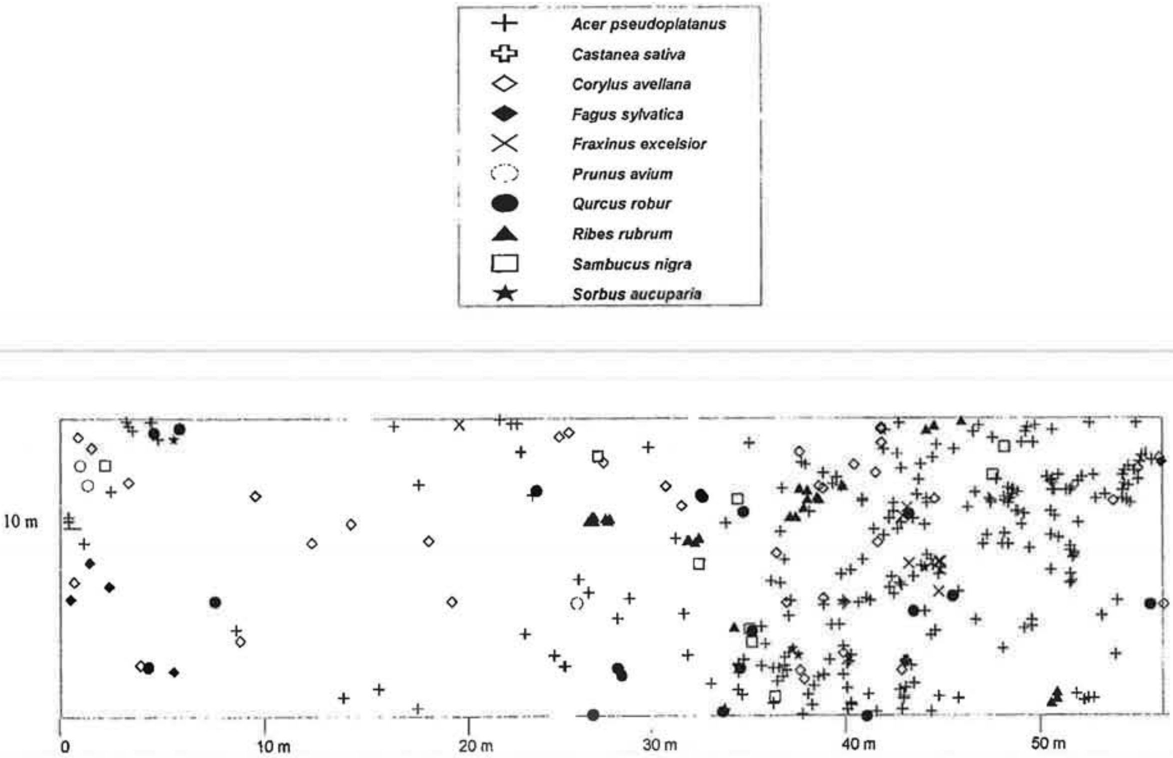

Figure 2. *Distribution of regenerated tree and shrub species with a height between 15 cm and 150 cm*

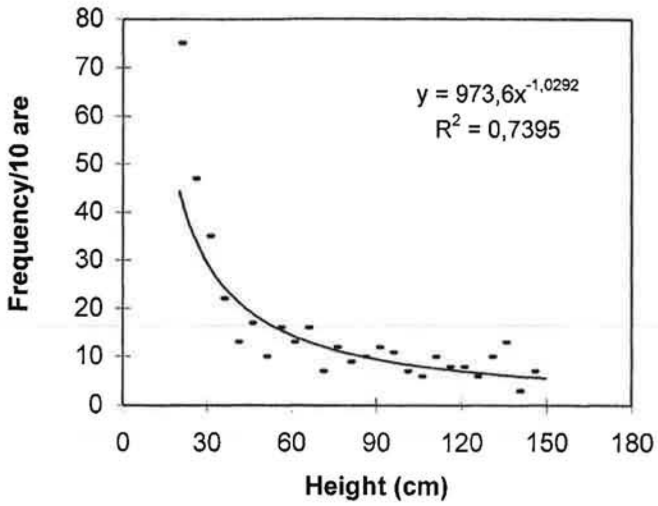

Figure 3. *Relationship between height (15-150 cm) and frequency of the regenerated species.*

3.5. Characteristics of younger seedlings (height < 15 cm)

The records obtained (Table 6) in 8 circular plots of 10 m^2 reveal that the variety of the regenerated tree species, occurring only with 2 tree species, is extremely poor. In spite of the presence of oak and beech mother trees in and around this stand, regeneration of these trees in all investigated plots is conspicuously absent. In all, of the broadleaved tree species, only *Fraxinus* and *Acer* regeneration is present. The *Corylus* shrub layer in the understorey, together with the relatively dense dominant trees, causes the low light intensity (lower than 2.6% of the full light) and consequently hinders the establishment of seedlings. A dense *Holcus mollis*, occurring in patches, restricts the seed germination of the broadleaved tree species, too.

Frequency of young seedlings is fairly well presented (4963/10 are) (see Table 6). *Fraxinus* with 73.3% and *Acer* with 88.7% demonstrate respectively the most abundant 6-month-old (h < 10 cm) and 18-month-old seedlings.

Generally, the records show that with increasing age, *Fraxinus* frequency alters in favour of *Acer*, as clearly demonstrated by Table 6.

Table 6. *Frequency of regeneration of 6 and 18-month-old seedlings*

Species	6-month-old seedlings (h < 10 cm) N/10 are	(%)	18-month-old seedlings (10 < h < 15 cm) N/10 are	(%)	Total/10 are	(%)
Acer pseudoplatanus	1300	26.2	788	88.7	2088	35.7
Corylus avellana	-	-	13	4.0	13	0.2
Fraxinus excelsior	3638	73.3	88	9.9	3726	63.7
Sambucus nigra	25	0.5	-	-	25	0.4
Total	4963	100	889	100	5852	100

3.6. Height growth curve and distribution of the stand

Generally, total height progressively increases with rising d. b. h. (Fig. 4). There is a significant positive correlation (r = 0.95), with logarithmic function model, between diameter and height of trees. As Fig. 4 clearly illustrates, the number of trees with height between 15 m and 25 m is very limited. It appears that in this stand, two stories, an overstorey and an understorey, are existing whereas trees in the middlestorey are poorly observed. However, the records reveal (see Table 1) that the majority of trees with height between 15 m and 25 m are *Acer* thickets and poles, which already appeared in canopy gaps after the small gaps formation about 3 decades ago. It is evident that, if the canopy opens up further, *Acers* will reach the overstorey. Most of the overstorey trees benefit from a total height between 28 m and 32 m and a diameter between 30 cm and 50 cm (see Fig. 4). As a matter of fact, these indicators present the characteristics of a two-storied stand in the investigated site.

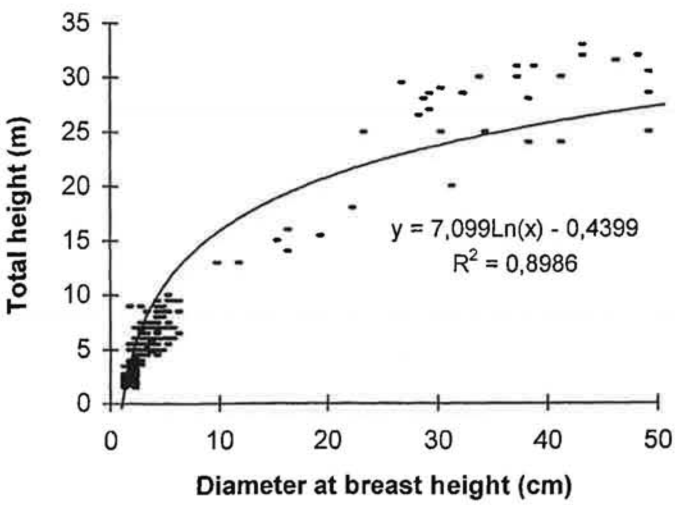

Figure 4. *Relationship between diameter and height of trees and shrubs.*

4. Discussion

The present study shows that the number of *Fraxinus*, with a height smaller than 10 cm (6-month-old seedlings), is as noticeable as of *Acer*. This is obviously due to the annual or biannual and prolific seed production pattern of these species. Abundance of *Acer* and *Fraxinus* with a height of 10-15 cm (18-month-old seedlings) suddenly decreases. However, in the investigated site and on the alluvial soil *Acer* seedlings is more frequent than *Fraxinus* seedlings. Other tree species, particularly *Quercus robur* and *Fagus sylvatica,* in all height classes appear virtually poor. On this soil type, number of *Fraxinus* at height classes > 10-15 cm is drastically poor (Fig. 5). Indeed not any *Fraxinus*, other than 1 individual higher than 1.5 m, can be found on this site. On the contrary, *Acer* represents various height classes and different growth stages of development (sapling, thicket, small pole and large pole). In this stand *Acer* individuals are clearly nearing the reversed J-curve, which is typical for all aged stands. Light intensity is a main restricting factor for the establishment and the growth of *Fraxinus* and likely for other high valuable indigenous species, particularly *Quercus.* Generally, it seems that in patches of stand, where a dense *Holcus mollis* occurs, seed germination and, indeed, regeneration is limited.

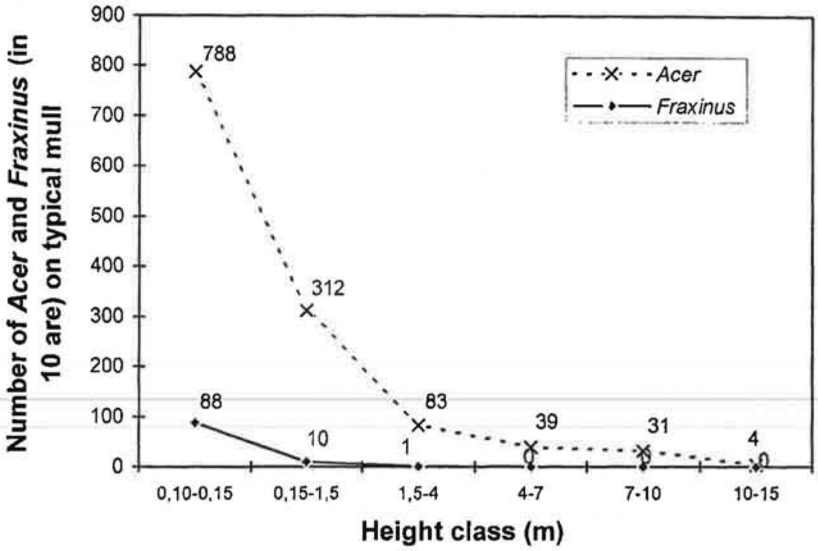

Figure 5. *Frequency distribution of Acer and Fraxinus regeneration at different height classes.*

It is noticeable that no real middle stratum occurs in this site. In parts of the site, where understorey is essentially missing, *Acer* regeneration is well distributed. The results also show that in all height classes, with the exception of height classes < 10 cm, *Fraxinus* succeeded by *Acer* and regeneration is thoroughly dominated by the aggressive *Acer*, whereas an evolution towards *Acer* is also remarked. In other words, in the ash stand an alteration in primary phase is made in favour of *Acer.*

Generally, alternation phenomenon between ash and sycamore has also been posed by some authors. Van Miegroet *et al.* (1981) cite that, at the end of the second vegetation period, the mean survival rate of ash reaches 11%, corresponding to one-seventh that of sycamore; indeed, the relationship between the two species rapidly changes during the early phases of development, shifting numerical dominance from ash to sycamore. Generally, sycamore-regeneration consolidates early, whereas ash suffers from the severe reduction in numbers. Both species prove their early tolerance by establishing under a dense canopy, but sycamore undoubtedly is the more tolerant and resistant.

Similarly, in the investigation site, it seems that if the regeneration of stand shifts towards the development of *Acer*, *Acer* will likely reach the overstorey and form gradually a dominant storey. In fact, it is expected that the existence of an alteration will not be unlikely. It can be stated that in this forest, with dominant *Fraxinus* trees, an evolution towards *Acer* is expectable. As a matter of fact, the regeneration is largely dominated by the invasive species like *Acer*, particularly where the middle storey and understorey (*Corylus avellana*) are absent.

Invasion of sycamore in ash stand and alternation in formation of stand can also be supported by Okali (1966), Taylor (1982), Waters and Savill (1992). They state that there is no doubt that sycamore invasion in many woods will result in a reduction in the abundance of ash in favour of sycamore. Sycamore is without doubt going to change the characteristics of many of the ash/wych elm (*Fraxinus-Ulmus*) woodlands and possibly other types of ash woodlands, although it is doubtful whether the consequence of such changes will be grave.

As a finding of Waters and Savill (1992), in the investigated site, sycamore would not be able to invade the whole of the stand simultaneously, but it would more likely proceed in a 'wavefront' into any area. Besides, the occasional small gaps formed in the stand would be appeared and filled at irregular times. The results of these processes would be a gradual aggression by sycamore. In fact, it shows the necessity for direct interventions in order to regulate the primary patterns of mixture.

On the whole, it can be concluded that invasion of sycamore in ash woodlands is a reality. If sycamore is not sufficiently controlled, it is expected that in the first phase sycamore will dominate the understorey, whereas it will prevent the regeneration of all other species. However, it will, very soon, form an almost single-species dominated stage in forest succession. It can be advised that, provided the removal of some sycamores and hazels and the enjoyment of regeneration from more radiation amount, it is desirable to create a mixed forest dominated by ash but with a considerable admixture of indigenous broadleaved trees. Cherry is very suitable for mixing ash (Pryor, 1985; Stevenson, 1985), and ash also does well in group selection with sycamore and beech (Savill, 1991).

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