Theses of the university doctoral (PhD) dissertation

POSSIBILITIES FOR CLOSE-TO-THE-NATURE FORESTRY MANAGEMENT IN THE FORESTS OF SZATMÁR-BEREG PLAIN

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1. INTRODUCTION AND OBJECTIVE

Mankind's relationship with the forest has undergone significant changes in the past centuries. In the background of ongoing changes, besides the change of ownership, there lies the increasingly limited availability of forestry assets and the increasingly evident social changes. The principle of forest maintenance has not changed in the past 200 years: not reducing the forest area nor the amount of wood that can be harvested from the forest year after year. At the heart of the expectations of society one cannot fail to see the role of the forest in environmental protection and in nature conservation. In the last one or two decades more and more foresters have come to realize that the cutting forest management is the method to be followed in only tree plantations, and in natural forests we have to use a different one. As the saying of the ancient Egyptians goes ‘The Way is the Purpose’, due to the extremely long cultivation cycles, is more valid in forestry than any other sector in economy. Our present forest management prefers forest management procedures that focus on forest protection and public well-being functions of it by not declining timber production. Nowadays, it is clear that the path of the future can only be a Close-to-Nature forestry management, where the biologists’ and ecologists’ rather protective view is manifested as well as the well-researched biological and economic knowledge of foresters’. It only intervenes in the forest life in such a way that it does not interfere with its integrity, its operability, and leaves no lasting wounds. This can only be achieved by continuous forest coverings, by the following of natural forest cycles.

The objective of my dissertation is to describe a new type of multi-faceted knowledge that is a major challenge for future thinking and acting forestry compared to our traditional, cutting-edge, wood-oriented forest management. However, it is important to emphasize that knowledge on flat-land, hard-wood forests and on hornbeam-oak forests is extremely poor, so this work does not provide an exclusive method for such forest management, but is trying to provide a framework for managing the problems of other similar areas which the foresters familiar with the area should apply customized interventions within. My aim is also to evaluate the eco-physiological parameters underpinning the correctness of the method with a wide-ranging examination of the eco-physiological plasticity of the renewed stand.

2. MATERIAL AND METHODS

2.1. Presentation of the research area

The examined sites are located in the Upper Tisza mid-region on the Szatmár-Bereg Plains (Bockerek Forest). Neighbouring small regions are the Rétköz and the Bodrogköz. According to the forestry categorization, they are situated in the *Great Plain macroregion an in the the Szatmár-Bereg Plain* region. Considering the geographic location of Szatmár-Bereg Plain, it is the area east of the lines of Kraszna and the Tisza rivers. Significant part of the region extends across the state borders. The area lies at an altitude between 96.4 and 223.0 metres above sea level, functioning as flood area before. Two smaller volcanic hills in the plain are the Nagy-hegy (155.6 m) and the Kaszonyi-hegy (223m) peaks.
The climate of the region lies in the transitional zone between the moderately warm and moderately cool climatic belt. On the one hand, the continental climate of the Great Hungarian Plain and the other the mountain climate of the Carpathians show a noticeable effect. Its continental being is largely apparent from the difference between minimum and maximum temperatures. The precipitation conditions are much more favourable than in the majority of the Great Plain. Relief in our experimental area (Bockerek Forest), varies between 2 and 5 metres. The sedimentation of the region was slow and is derived from the flooding of the rivers. The alluvium of smaller and larger rivers stayed in the flooded areas for months, thus, the finest sediment, the clay was deposited. However, sediments rich in clay benefitted the emergence of woody vegetation, resulting in flood plain/alluvial forest soils. Climatic conditions enabled the formation of certain types of brown forest soils at the higher horizons, namely the lessivated brown forest soil and the lessivated pseudo-gley brown forest soil.

2.2. Applied Methods

2.2.3. Field methods of undergrowth and re-examination

The exact location of the surveys

The investigations were carried out in the Bockerek Forest, situated between Gelénes and Vámosatya settlements, in the subcompartments Gelénes 2/B, 11/H and 14/A. The Bockerek Forest is part of the Szatmár-Bereg Landscape Protection Area, with a Nature Reserve and Strictly Protected Areas (11/H). In the Bockerek Forest we have designated 3 reproduction cutting sampling areas, used in the area since 2003, to investigate the impact on the regrowth-structure and the undergrowth. The subcompartment Gelénes 2/B is (not only in the Bockerek area, but throughout the Szatmár-Bereg Plane) the single one, where several steps of the experimental renewal have been realized. In addition, in the subcompartments 11/H, 14/A, where the intervention had already been executed, we were able to record the first phase of a new reproduction cutting based on the experiences in the subcompartment 2/B (Figure 1).

Figure 1. Location of the research area (Gelénes, Bockerek Forest). The subcompartments examined are indicated by red arrows.

Field Recording Methods, Evaluation of Data

Field surveys were conducted in 2012. The sampling areas were in all cases 30 m2 sampling circles of which centre was marked with a mark-stake for later retrieval. The randomly selected samples (3 × 6, a total of 18 pieces) of the 2/B forest subcompartment, that had already reached its size by the time of the survey, were placed in order to represent the inner- (final harvest in 2003.), the middle- (preparatory cutting in 2003 final harvest in 2007.) and the near-edge (preparatory cutting in 2007., final cutting in 2011.) parts of the subcompartment. In subcompartments 14 / A, opened in 2009, and in 11 / H, opened in 2011., 3 gaps were examined each in 3 repetitions (Southern shaded, the central and the Northern sunny segments). The renewal, which had already reached its final size (however small numbers of samples are available here) is an important part of our investigation, as the long term effects of the intervention can only be studied in this site in the whole region. For each sampling circle, the vegetation composition was recorded in April and July. In the regrowth, the tree and shrub species not exceeding 2 m height were recorded individually (including the surviving specimens had been cut off previously in the nursing process). In the sampling area the species of herb cover were recorded in A-D value and then during the internal processing, we converted these values into percentages (according to the mean value of the A-D categories). During the evaluation always the larger values recorded during the spring and summer surveys were taken into account. The undergrowth cover in the sampling area was estimated in A-D values (Jakucs and Précsényi 1981). Sociability of the species was determined based on Borhidi's sociability categories (1993). During the subsequent evaluations, we set a 'forest' category, in which the generalist, competitor and specialist species fall and a 'weed' category with species tolerant to disturbance. Binary t-testing/probation was used to evaluate the changes in sociability groups with significant proportion.

2.2.4. The eco-physiological measurements method

The plant material

Eco-physiological studies were performed in two sizes of gap. On the one hand, in

Bockerek Forest Gelénes 2F subcompartment is a 180 m diameter major gap (MaG) and on the other hand in three minor gaps (15metres in diameter) (MiG) in subcompartment Gelénes 11H.). The investigations took place early in the spring and summer, and in MaG 24-26 April 2012; 13-13 August 2012, July 9-11, 2014, in the MiG from 6 to 10 July and 10 to 10 July 2014. In the case of both size and the forest interior (FI), the following two dominant species were examined: Pediculate oak (*Quercus robur* L.) and Common hornbeam (*Carpinus betulus* L.). In the case of large gap, we focused mainly on the examination of specimens in the inner circle (IC), in which both sun leaves and shade leaves were measured we also examined specimens in the external circle (EC). At the same time, the soil conditions of the middle (MC) and outer (EC) circles of the large gap were also studied. We compared the eco-physiological parameters of specimens in different aspects of light (North, South, East, West) in case of the minor gaps.

Climatic conditions of the test years

To characterize the weather conditions of the vegetation periods we used the values of the monthly precipitation and the monthly average temperature. For the numerical characterization of possible droughts, the Bagnouls-Gaussen (1953) xerotermic index was used for.

Soil moisture measurement method

Soil moisture measurement was carried out using a thermogravimetric method similar to the plant samples. On days of the outdoor measurement and sampling, we took soil samples from depths of 0-30 in the middle of the gaps and in the forest interior at around noon (12-14pm). In the major gap (MaG), soil samples were taken from the inner circle and form the middle and external circles (MC and EC).

Elemental analysis

In order to perform elemental analysis of the soil, inductively coupled plasma optical emission (ICP-OES) measurements were performed with IRIS Intrepid II XSP ICP-OES (Thermo Electron Corporation, Germany) in a triple repetition.

Dry matter content measurement

The dry matter of plants was measured by thermogravimetric method. We used OHAUS Explorer (Switzerland) analytical scales for the measurements. The specific leaf area (SLA) value was used for numerical characterization of plant dry matter content and leaf structure (Garnier et al., 2001).

Determination of photosynthetic pigments

<u>Measurement of relative chlorophyll content</u>

The relative chlorophyll content measurement (SPAD index) was performed with SPAD-502 (Minolta, Japan) relative chlorophyll meter.

<u>Quantitative and qualitative examination of photosynthetic pigments</u>

For the determination of photosynthetic pigments, i.e. chlorophylls a and b, and carotenoid content, fresh leaves were extracted according to Moran and Porath method (1989). The amount of chlorophylls a and b, and carotenoid was calculated according to the equation proposed by Wellburne (1994).

Measurement of chlorophyll fluorescence induction parameters

In vivo chlorophyll fluorescence, the fast and slow phase of chlorophyll fluorescence induction (Schreiber et al., 1986) was studied with a PAM 2000 fluorometer (WALZ Gmbh, Germany).

For processing results and statistical analyzes, Microsoft Excel 2010, and SigmaPlot 12.0. programs were used.

3. RESULTS AND DISCUSSION

3.1. Results of undergrowth and regrowth-examination

It can be stated that in all three forest subcompartments, the closed, multi-storey, highly shadowed hornbeam-oak stand have a relatively undeveloped grass layer. In two, 400-square-metre (conventional) coenological recordings/surveys (Gelénes 2/A, directly adjacent to 2/B) we found 24 and 32 herbaceous species respectively. With 15 and 20% respective coverage. Here, some species of early spring aspect (eg. *Anemone* sp., *Corydalis cava*) can reach larger coverage, but later aspects (due to shading) are poor in species and show low coverage. The current situation is also influenced by the huge game population of the area.

In the renewed area of the Gelénes 2B subcompartment in three different-stage gaps 90 herbaceous species, (final cuttings in 2003 (IC), 2007 (MC) and 2011 (EC), in the early-staged gaps of the Gelénes 11/H and 14/A. subcompartments a total of 120 herbaceous species and in the regrowth 17 woody plant species of (mostly seedlings) were detected. The reason for the difference in the number of herbaceous species is relatively easy to explain, in the 2/B forest subcompartment we collected data on 5 relatively similar sampling areas in the field, while in the other two subcompartments the 18 sampling areas were scattered in large diverse sites. It is part of the reason for the difference in the number of the herbaceous species that the subcompartments 11/H and 14/A differed in their respective ages (1 and 3 years old) during the survey. At the final size renewal area (Gelénes 2/B), the initial extremely high number of species later showed a significant gradual decline.

The decline is mainly due to the weeds, that appear right after the opening of the forest (disappearance is caused by the appearance and the competitive effect of perennial species). In the case of forest species, the initial decline is due to the shrinking of the shade-requiring species (in case of these species it is expected that after the desired coverage is regenerated or as early as the closed stocks of narrow pole phase shows, they will reappear). There are fewer well-founded conclusions to draw about the change in the covering values, including the effect of the overshading in the 9th year of the regrowth (young). During the renewal, both in forestry or nature-conserving sites, invasive weeds appeared in little numbers. In the first phase, the rapidly disappearing Conyza canadensis, while in later phases the role of Calamagrostis epigeios can be mentioned. In this positively-judged result, the gentle (harmless) cultivation and the fast-closing, appropriate regeneration probably played a role that these species do not cover large-scale areas in compartments of Bockerek forest.

In the first phase gaps of the renewing works of the Gelénes 11/H and 14/A. subcompartments we analysed the records taken on the south (overshadowed), middle (partially shadowed) and north (sunlit) sides.
In regards of the age distribution of the gaps (1 and 3 years) and gap sizes (750 and 1500 m^2) we did not find a significant difference in the species composition and dominance values of herbaceous vegetation. The reason for the high number of species (120 species) found during the surveys is that both shade-tolerant species and the light-loving species which are tolerant to disturbance at a larger scale, were present in the gaps. The larger gaps would have unequivocally benefitted the latter species.
Examining the herbaceous vegetation of different positions in the gap, it is evident that the forest species were present in roughly the same number of species in the different parts of the gaps, whereas their coverage in the southern (shaded) parts was significantly higher than that found in the central and northern parts. The number of weed species and their coverage in the middle part of the gaps was significantly higher than those found at the edges. The relatively low (average 66%) herbaceous cover in the northern gap parts (receiving abundant sunshine) can not be explained by a remarkable closure of the regrowth, it is most probably because the site is abundant in sunshine and it is dry for forest and long stemmed herbaceous plants.
One protected plant species (*Gagea spathacea*) was observed in the gaps, also it was found in significantly higher density (due fences against the game) than in adjacent forest stocks. In the subcompartments surveyed and in closed hornbeam-oak stands in their adjacent neighborhood *Dryopteris carthusiana*, *Platanthera sp.* and the occurrence of *Listera ovata* were recorded. The lack of this species in the gaps is considered a mere accident rather than the adverse effect rejuvenating.

3.2. Features of the regrowth

A regrowth, consisting of 17 tree and shrub species, was recorded in the first phase gaps of the regeneration works of the Gelénes 11/H and 14/A. subcompartments. Coverage values varied between 2-5% in 1-year-old gaps, between 15-80% in 3-year-old gaps while seedlings number in 1-year-old gaps varied between 2-40, in 3-year-old gaps it was between 50-600.
(Sampling area size 30m^2)
As regards to the silvicultural aspect, it is highly important to note that the associate tree species were determinant (*Acer campestre*, *Carpinus betulus*), but in the three-years-old gaps the commercially important *Quercus robur*, was present in all sample areas in number of individuals of (1-60). In different positions in the 6 sample areas of the two forest subcompartments (shadowed N, in the M and in the abundant in sunshine N parts) the lowest number of seedlings both in the cases of the preferred *Quercus robur* and *Carpinus betulus* were found in the middle of the gaps. The highest number in case of *Quercus robur* appeared in the Northern parts (abundant in sunshine) of the gaps as the maximum number of *Carpinus betulus* seedlings appeared in the shaded Southern sample sites. The massive number of seedling in these sites suggests that without being nursed specimens of oak don't have the slightest chance. An interesting further detail is that the pioneer species (*Populus alba*, *Salix caprea*), which were missing from the closed forests of the area, were present in more than 50% of the samples. Gaining its

final boundaries, the renewal area of the Gelénes 2/B forest subcompartment shows similar tendencies, which means that associate species (mainly *Carpinus betulus* or *Cornus sanguinea*) exhibit great vitality, but their proportion decreases as the renewal progresses.

Quercus robur was found with one exception in all the sample areas, and the inner (9-year-old) circle (not in number, but in size and position) was decisive. This position dominance was the consequence of the nursing, that is, the presence of oak here is not only down to the successful natural renewal (and blank filling) but in addition to it the conscious, extensive forest cultivation. The oak was present in the outer (1-year) renewal circle, half of the records, here only from a natural rejuvenation.

3.3. Results and evaluation of eco-physiological studies

3.3.1. Change in dry matter content of plants

The examined species have a relatively high dry matter content (DM%) (Table 1). In the spring, there is no significant difference between the dry matter content of the specimens inside the forest and those situated in the IC of the gaps. Oak seedlings are practically not found inside the forest, especially not adequately replicated in the area.

Table 1 Dry matter content (DM%) of regrowth (oak and hornbeam) in spring (April 2012) and summer (August 2012) (n=6, ± se) (FI: Forest interior, IC: large gap inner circle, EC: large gap external circle; nd: no data)

	spring		summer			
	FI	IC	FI	IC		NeC
				sun leaf	shade leaf	
horbeam	68.35 ±0,2	69.1 ±0.2	54.9 ±1.3	48.9 ±0.3	55.9 ±1.6	44.6 ±0.6
oak	n.d.	73.7 ±0.1	n.d.	48.4 ±0.6	54.9 ±1.4	46.9 ±2.1

According to our results, in spring the dry matter content in oak is 7% higher than in hornbeam. In the summer, this difference disappears in regards of both sun and shade leaves of the two species. Both species have 12-13% higher dry matter content in shadow leaves than in sun leaves. Leaves of shade tolerant species and shadow leaves are characterized by higher dry matter content and greater density, which contributes to larger-scale physical and pest protection, which is decisive for leaf life. In the summer of 2014, we also collected samples from living specimens from different aspects of the minor gaps. Differences in regards dry matter content in oak and hornbeam is shown in Figure 2.

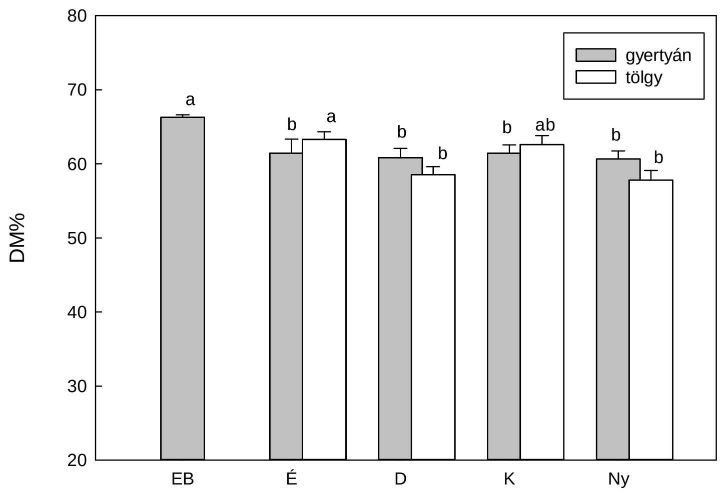

Figure 2. The dry matter content (DM%) of oak and hornbeam leaves from different aspects of the gap (N: North: S: South, E: East, W: West) and the forest interior (FI). The averages of the columns are significantly different (p≤0.05, n=9, ± s.e.)

The dry matter content of the hornbeam leaves (66.2% ±0.3) collected from forest interior is significantly different from that of the leaves originated from any other sites. The dry matter content of the leaves from FI is 8-10% higher than that of specimen's from the same gap. There is no significant difference in the dry matter content in samples taken from hornbeam in the different aspects of the gap. In the case of oak, the leaves from the northern and eastern aspects of the gap have a significantly higher dry matter content. It can exceed hornbeam values as the 2012 spring records of the inner and the near-edge circles of the large gap show. In the summer of 2014, the dry matter content of hornbeam and oak shadow and light leaves were also measured. Results are shown in Table 2.

Table 2 Dry matter content of oak and hornbeam (DM%) (July 2014) (n = 6, ± se) (FI: forest interior; IC: large gap, inner circle; large gap, external: EC; nd: no data) (comparison of oak-hornbeam values p≤0.05; values compared to shadow leaf data ** p <0.01; *** p <0.001)

	FI	IC		EC
		sun leaf	shadow leaf	
hornbeam	66.3 ±0.3***	44.1 ±1.8**	55.3 ±0.5	48.7 ±0.7***
oak	n.d.	49.2 ±0.9***, [a]	54.9 ±0.9	50.3 ±0.5***, [a]

There is significant difference found in regards the dry matter content of the leaves when comparing sun leaves to external circle specimens. However, there is no significant difference in the dry matter content in regards of the shadow leaves. Within a given species (either oak or hornbeam) light, EC, FI specimen leaves' dry matter content is significantly different, in comparison to that of shadow leaves.

In accordance to the literature data, and the summer 2012 results, the dry matter content of the shadow leaves exceeds that of the light leaves. In the case of hornbeam the shadow leaves' dry matter content was 23% higher in summer 2012 and 21% higher in summer 2014 than that in the sun leaves. In case of oak in 2012, the same sort of difference is 22%, whereas in 2014 it is 11% comparing the dry matter content between the shadow and the sun leaves.

It is a common knowledge that oak is a more sun-type species than hornbeam. By the results we have so far the hornbeam is more shade tolerant, and this fact, along with the one that its seeds spread easily, has a major role in hornbeam expansion. From the point of view of regrowth regeneration, the species' shade tolerance is advantageous, since regrowth still can start to grow efficiently when smaller gaps or leans are freshly created.

At the same time, from the forestry point of view, the hornbeam represents less commercial value, less utility, less mass production, and its massive regrowth would result in a large depreciation of the oak and even beech forests. Light as an environmental factor has a particularly important role in the regeneration of our forests, the availability of light for the inner stands is essential to the regeneration of the forest (Barbier et al., 2008). According to the results of Diekmann (1996) and Götmark (2007), *Quercus robur* shows medium light demand, it needs 30-50% light availability for optimum growth. According to our results, in 2014, the oak light leaves dry matter production was about 10% more than that of hornbeam's.

3.3.2. The specific leaf area (SLA) values

The specific leaf area (SLA) is recognized for the numerical characterization of plant production, plant dry matter content and leaf structure. The value is calculated as the ratio of the fresh leaf area and its dry matter content. It consists of two components: leaf thickness and leaf density. Its value shows difference between species, but can also be used to characterize the adaptation of species to different environmental factors. The results of the spring and summer specific leaf areas of the two species examined are shown in Table 3

Table 3 The content of the specific leaf area (SLA, cm^{-2} g^{-1}) of oak and hornbeam regrowth in spring (April 2012) and summer (August 2012) (n=6, ±se)) (FI: forest interior; IC: large gap, inner circle; large gap external circle: EC; nd: no data

	spring		summer			
	FI	IC	FI	IC		EC
SLA (cm^{-2} g^{-1})				sun leaf	shadow leaf	
hornbeam	376.4±4.3	393.5±6.5	376±1.2	239.8±2.8	375.7±39	182.1±3.6
oak	n.d.	313.6±0.4	n.d.	163.4±7.2	289.3±16	176.9±6.2

In the spring, in the case of oak, the amount of dry matter accumulated in a given leaf area is higher than in the case of hornbeam, with a difference of about 20%. The higher SLA values in relation with higher DM represent higher N-content and higher net-photosynthetic capacity. While the difference in dry matter content between species disappeared by summer, in the case of SLA it is only so for the external circle (EC). In cases of both the light and the shadow leaves, in the given leaf area, the amount of dry matter content is higher in the case of the oak than that in case of the hornbeam. The difference in case of light leaves is higher (32%) than in shadow leaves (23%) between the species. Comparing the shadow and light leaves SLA, we found that the SLA value of the shadow leaves is about 40% higher for both cases of the oak and hornbeam. Due to the shielding effect of the canopy, the degree of solar irradiance decreases, especially in the range of visible light. The amount of active photosynthetic light is less and both change the quantitative and qualitative characteristics of the incident light. Shadow leaves are relatively thin, with low leaf density. The amount of palisade parenchymal cells per unit area is low. Increasing the amount of light decreases the SLA value. The value of SLA is an important parameter and is related to the ratio in which the stored chemical energy is utilized for plant growth and dry matter accumulation. At the same time, the value of SLA is quite sensitive to the internal and functional changes of the plant and the external changes of the environment.

In the cases of the minor gaps (summer 2014), the values of the specific leaf area (SLA) of oak and hornbeam specimens living in the different aspects of the gap are shown in Figure 3

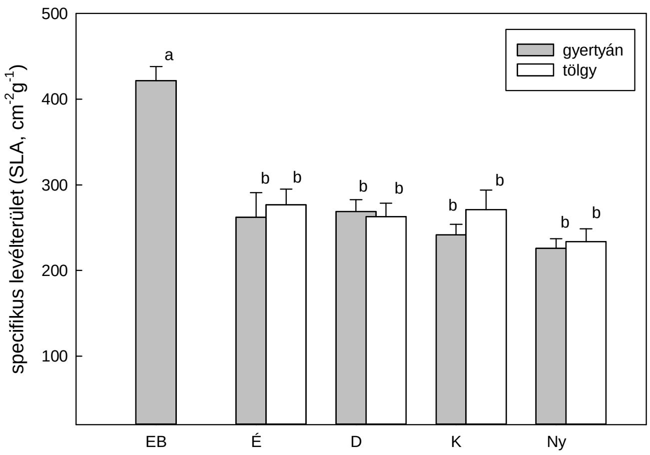

Figure 3 The value of the specific leaf area (SLA, $cm^{-2}g^{-1}$) of the leaves of oak and hornbeam specimens from different aspect of the gap (N: North, S: South, E: East, W: West) and the forest interior (FI), [ab] The averages of the columns of the different letters of alphabet are significantly different (p≤0.05, n=9, ± s.e.)

According to our results only the FI hornbeam SLA values differ significantly from the other values, and significant difference can not be measured in the case of any species. Bartha and Raisz (2002) performed morphological study on European beech taxons. He found that the leaf location in the crown and the aspect as compass direction might simply happen due to the difference in light conditions.

The northern sun leaves in comparism with the southern ones are longer, wider, less hairy, more rounded. They bear more veins and have shorter petiole and their widest part is pushed to the tip. Similarly, the shadow leaves differ from the sun ones, but actual, significant result can not be measured. In the summer of 2014, The large gap, inner circle specimens' shadow and light leaf and near edge hornbeam and oak leaves SLA values were determined, the results are shown in Table 4.

Table 4 Regrowth (oak and hornbeam) specimens' specific leaf area (SLA, cm-2g-1) (July 2014), (n = 6, ± se) (IF: inner forest; IC: large gap, inner circle; NeC large gap near edge circle; n.d. no data (oak-hornbeam values compared [a] p≤0,05; values compared to shadow leaf data ** p <0.01; *** p <0.001)

	FI	IC		EC
		sun leaf	shadow leaf	
hornbeam	376±1.2***	144.9 ±5.1**	255.6 ±9.4	143.8 ±3.1**
oak	n.d.	121.6 ±1.4***,[a]	184.2 ±13***,[a]	129.5 ±4.5***,[a]

In SLA there is a significant difference between the two species in regards of the light and shadow leaves and leaves of specimens in the near edge circle. Within a given species, compared to the values of the shadow leaves, the SLA values of the light leaves and leaves from the near edge circle and the inner forest are significantly different for both hornbeam and oak. Examination of the SLA value is important since with the element content of the leaf and the chlorophyll / nitrogen ratio is closely correlated with the degree of illumination. These features of the leaf are important in addition to the light intensity to maximize growth, as they are closely related to photosynthetic capacity and plant carbon turnover.

3.3.3. Quality and quantity of photosynthetic pigments

In addition to the relative chlorophyll content, quantitative control of chlorophyll-a and -b was also performed on dry matter. According to the results of Figure 4, in the early spring period there was no significant difference in regards light leaf of chlorophyll-a, -b, between forest interior and the large gap inner circle oak specimens.

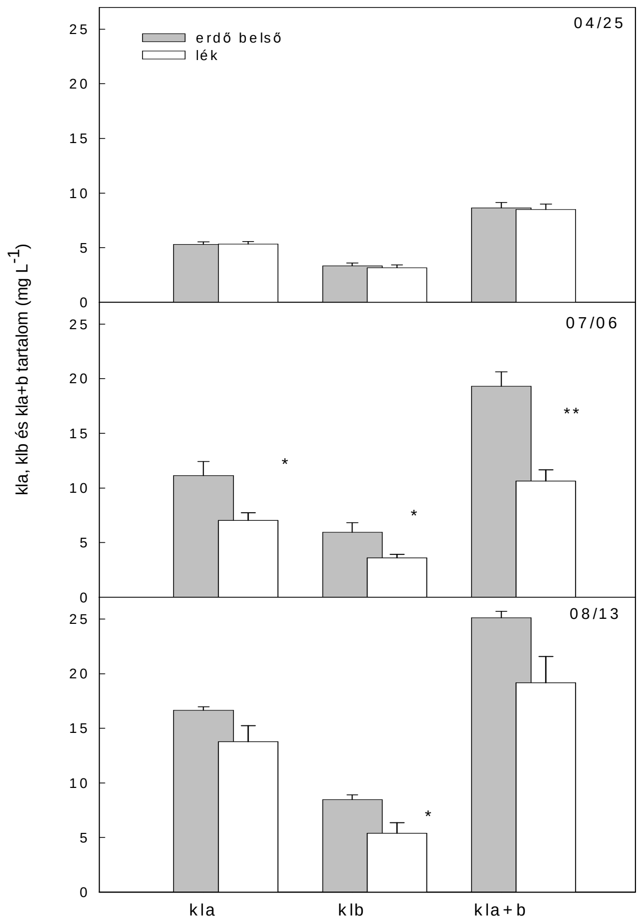

Figure 4 Chlorophyll-a (kla), chlorophyll-b (klb) and total chlorophyll (kla + b) content seasonal (April 25th (25/04), July 6th (06/07) and August 13th (13/08)) change in an forest interior

(erdőbelső) and in a gap (lék) in an oak stand. Significant difference between the inner forest and the gap results p <0.05 *, p <0.01 ** n=6, ± s.e.

By June there is a significant difference between the total chlorophyll content of leaves in gap and inner stands, which is due both to the lower values of chlorophyll-a and chlorophyll-b content measured in gaps. In the case of open gap oak specimens, 40 to 46% lower chlorophyll values were measured. In higher light intensity habitats, lower chlorophyll content is characteristic, smaller proportion of light-collecting complexes are found in the lower light intensity stands, in this case in the inner stand. At the third sampling time, a trend similar to July was observed, but only a decrease in chlorophyll-b content in the gap was significant. The seasonal change of the chlorophyll content of the hornbeam is shown in Fig. 5.

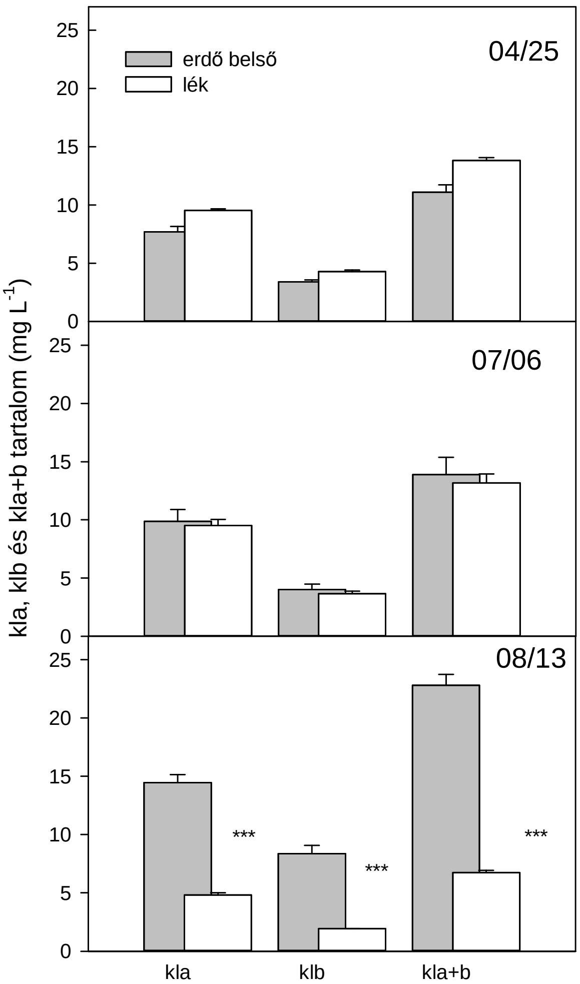

Figure 5 Chlorophyll-a (kla), chlorophyll-b (klb) and total chlorophyll (kla+b) content seasonal (April 25th (25/04), July 6th (06/07) and August 13th (13/08)) change in an forest interior and in a gap in an hornbeam stand. Significant difference between the inner forest and the gap results p<0.001*** n=6, ±s.e.

There is no significant difference between the chlorophyll content of the inner stands and the gap specimens neither in April nor in July. At the same time, in August the chlorophyll content of hornbeam specimens is 60-70% smaller than that of the inner stand ones, which is much greater than that found in oak. In the case of hornbeam, chlorophyll-a content is less in the gap, also, not just the chlorophyll-b like in case of the oak. The reduction of chlorophyll content might also be a kind of oxidative stress control process at high light intensity.

Table 5 Seasonal changes in the ratio of chlorophyll-a and -b (chla/clb) (April 25th., July 6th., and August 13th.) in different production sites of pedunculate oak (forest interior and inner gap)). Significant difference shows between the inner stand and the gap results p <0.05 *, p <0.01 ** n = 6, ± s.e.

chla/chlb	April 25th	July 6th	August 13th
Forest interior	1.63 ±0.01	1.78 ±0.10	1.97 ±0.12
Inner gap	1.71 ±0.31	1.94 ±0.11*	2.64 ±0.10**

Table 6 Seasonal changes in the ratio of chlorophyll-a and -b (cla / clb) (April 25th., July 6th., and August 13th.) in different production sites of hornbeam (inner stand and inner gap)). Significant difference shows between the inner stand and the gap results p<0.01** n=6, ±s.e.

chla/chlb	April 25th	July 6th	August13th
Forest interior	1.44 ±0.01	2.48 ±0.06	1.75 ±0.18
Inner gap	1.45 ±0.01	2.61 ±0.03	2.49 ±0.12**

The chlorophyll-a and -b ratio increases due to higher light intensity for both cases of oak and hornbeam (Tables 5 and 6). According to our results seasonally examined at each sampling time significant difference showed in July and August with oak and in August with hornbeam. The higher chla / chlb ratio in the oak was primarily due to the lower chlorophyll-b content, while in the hornbeam the chlorophyll content itself decreased, too in August. The oak is typically characterized by chlorophyll on low dry matter content. Plants exposed by high intensity light, in comparism with shade plants have less thylakoids in their chloroplasts, also, they have less the chla+b pigment protein complexes as well.

Carotenoids are parts of the plant antioxidant system, and play important the in the protection of photosynthetic apparatus. It is a general fact that increasing light intensity increases the intensity of the photosynthesis. At the same time, depending on the species – and it might as well on the variety – the plant's photosynthesis system is saturated with higher illumination and is unable to capture more carbon dioxide at any light intensity. The excess energy generated may become damaging to the photosystem since free radicals may form. There is no species based difference between the carotenoid content of the shadow leaves, but at high light intensity the oak is characterized by higher carotenoid content, which contributes to its better adaptability to higher light intensity. The greater physiological plasticity of oak is supported by the fact that the drier summer in 2012 oak had higher carotenoid content. A given, high stress intensity factor increases the amount of potentially damaging energy that is unnecessarily absorbed and carotenoids have a major role in preventing the plant from its negative effects.

The carotenoid content of the leaves from different forest interior aspects shows a species related, significant difference in the east and north. Oak is characterized by higher carotenoid content (5-10%), except for southern aspects, but no significant morphological difference shows there.

3.3.4. Changes in the parameters of chlorophyll fluorescence induction

To overcome the effects of unnecessarily bound excessive light, plants have multiple mechanisms at short-term and long-term adaptation mechanisms at different organizational levels. The emergence of the gap also results in changes in several abiotic factors. Inside the gap and in its immediate vicinity, other light, temperature and moisture conditions are found in relation to the original forest, which affect the quantitative and qualitative development of the regrowth.

The photosynthetic efficiency and physiological plasticity of the species is important for their recovery success, as photosynthesis is a physiological process that basically determines dry matter growth. Being removed from their natural habitat, most cases, specimens can adapt to their environmental conditions, mainly biochemically, and partly anatomically and morphologically.

There are many molecular-level acclimatization mechanisms known to play a role in non-photochemical extinction mechanisms, which have a major role in high light intensity. Non-photochemical extinction mechanisms have a role in re-radiation and use of the excessive excitation energy due to the change in chlorophyll-chlorophyll and chlorophyll-carotenoid interactions.

Chlorophyll fluorescence is one way to reradiate the excessive excitation energy in the form of light. Based on the characteristic points of the re-radiation induction curve, several parameters describing the operation and organization of the photosynthetic system were described (Fv/Fm, Fv/Fo, Fm/Fo). Thus, the Fv/Fm value, which characterizes the potential / maximum photochemical efficiency of PS II. It is widely used as an indicator for inhibiting photosynthetic processes. The measurement of chlorophyll fluorescence is widely used in fast in vivo and in situ procedures for ornamental trees and conifers. The maximum photochemical activity of oak species (Figure 6) is significantly higher than that of the hornbeam’s, with the exception of Western aspect where it is also higher but the difference is not significant. The deviation is 5-7%, which can be judged significant at this value. There is no difference between the species in the maximum fluorescence value.

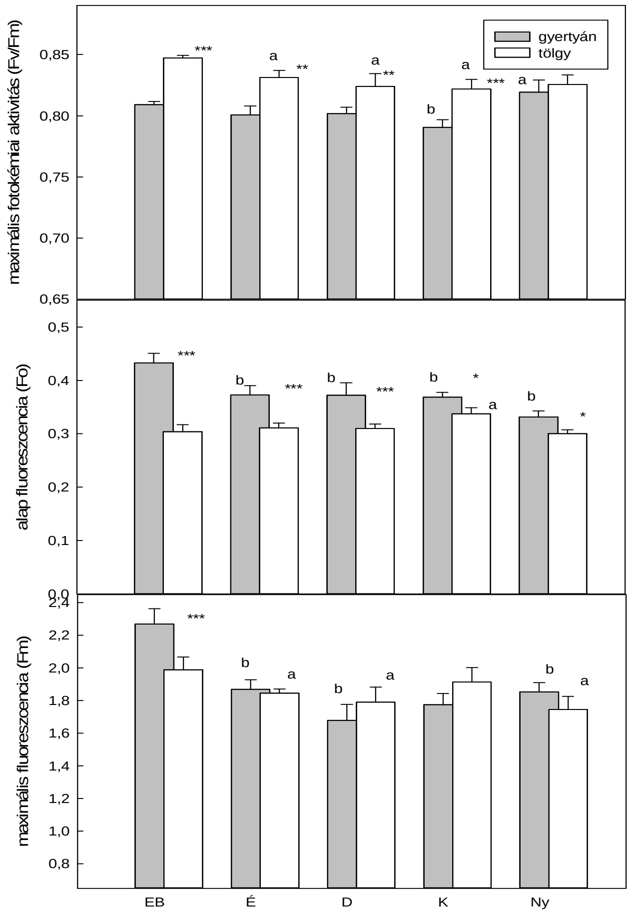

Figure 6 The maximum photochemical activity (Fv / Fm) of the oak and hornbeam leaves of the oak and hornbeam species from different gap aspects (N: North: D: South, K: East, Ny: West) and the inner stand (IS) basic fluorescence (Fo) and maximum fluorescence (Fm). July, 2014, n=9, ± s.e. ([a, b] Significant difference between FI (EB) and the different gap aspects in the species at p≤0,05, significant difference between species * p ± 0 , 05; ** p <0.01; *** p <0.001)

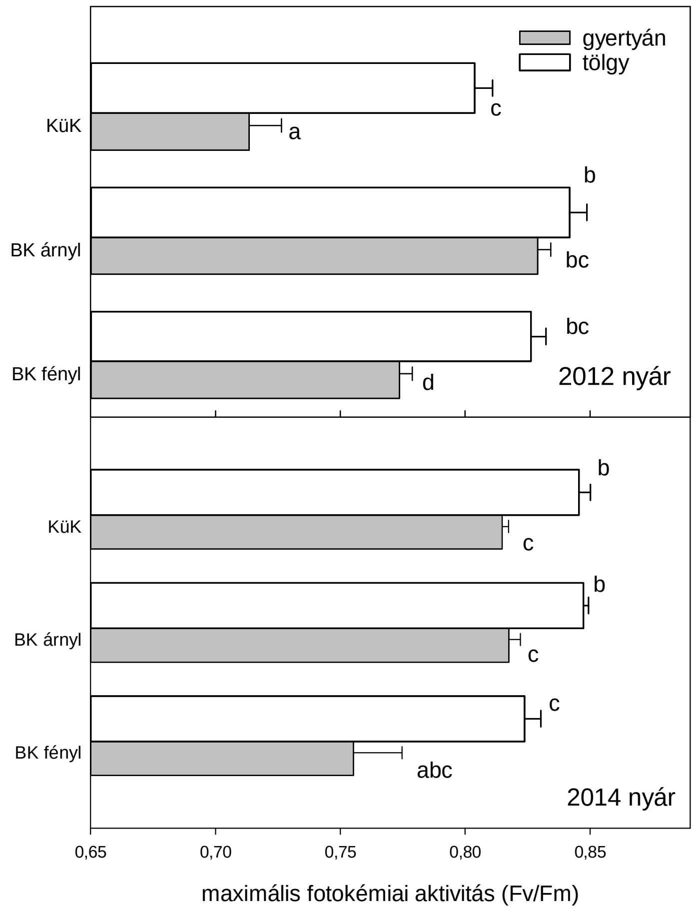

Figure 7 Maximum photochemical activity (Fv/Fm) of oak and hornbeam specimens examined in the summer of 2012 and 2014 in the large gap. (BK = inner circle; KüK = external circle), Inner circle sun leaves (BK fény) inner circle shadow leaves (BK árny). n=9, ±s.e.; (there is no significant difference between the column values with the same letters)

Both the 2012 and the 2014 summer months the maximum photochemical activity of oak is higher than that of hornbeam's. The difference in case of the shadow leaves is smaller in both years, but 10-12% difference can be measured in regards of the oak in areas exposed to light. In 2012, Fv/Fm values are generally lower, but this is 1-2% difference for oak but typically this is not significant. In the case of hornbeam, the maximum photochemical activity values are more than 10% lower in the drier year of 2012, mainly in the near edge circle. At that time, the soil moisture content was lower than in the inner circle, to which hornbeam was more responsive. Beyond its carotenoid content the ecological plasticity of the oak is caracterized by higher maximum photochemical activity in the drier summer of 2012.

The reason for the difference between the Fv/Fm values of the species, as we also observed examining the minor gaps, is the difference in the value of Fo, the baseline fluorescence. Seasonally evaluated the physiological plasticity of the examined regrowth based on the parameters of chlorophyll fluorescence measurements we compared the 2012 and 2014 summer data (Table 7.)

Table 7 Regrowth (oak and hornbeam) specimens' chlorophyll fluorescence parameters (PS II potencial/maximum photochemical efficiency (Fv/Fm), actual photochemical efficiency of PSII (Yield), electron transport rate (ETR), photochemical and non-photochemical the ratio of chlorophyll fluorescence quenching processes (qP/qN), relative fluorescence decrease (R_{Fd})) in the summer of 2012 and 2014 to the shadow (shadow) and sun leaves (sun) of the specimens in the inner circle of the larger gap. Different letter indications indicate a significant difference in the given intra-range averages at $p \leq 0.05$ (n = 3, ± s.e.).

	2012				2014			
	hornbeam		*oak*		*hornbeam*		*oak*	
	sun	shade	sun	shade	sun	shade	sun	shade
Fv/Fm	$0,77\pm0,02^{a}$	$0,83\pm0,01^{b}$	$0,81\pm0,01^{b}$	$0,84\pm0,02^{b}$	$0,79\pm0,0^{a}$	$0,80\pm0,03^{ab}$	$0,83\pm0,02^{b}$	$0,85\pm0,01^{b}$
Yield	$0,16\pm0,02^{a}$	$0,11\pm0,02^{a}$	$0,36\pm0,02^{b}$	$0,27\pm0,01^{c}$	$0,3\pm0,07^{bc}$	$0,23\pm0,03^{c}$	$0,47\pm0,05^{d}$	$0,39\pm0,07^{b}$
ETR	103 ± 10^{a}	70 ± 14^{b}	231 ± 14^{c}	175 ± 6^{d}	196 ± 51^{d}	151 ± 20^{e}	308 ± 35^{f}	257 ± 43^{c}
qP/qN	$0,43\pm0,04^{a}$	$0,25\pm0,05^{b}$	$0,83\pm0,07^{c}$	$0,63\pm0,03^{d}$	$0,74\pm0,2^{de}$	$0,54\pm0,08^{ad}$	$1,3\pm0,5^{f}$	$0,91\pm0,18^{f}$
R_{Fd}	$2,83\pm0,5^{a}$	$2,27\pm0,5^{a}$	$2,84\pm0,2^{a}$	$2,02\pm0,5^{b}$	$2,54\pm0,2^{a}$	$2,75\pm0,1^{a}$	$2,75\pm0,4^{a}$	$2,76\pm0,3^{a}$

There is no significant difference between the species in terms of maximum photochemical activity, the hornbeam light leaves show a lower value compared to the others in both 2012 and 2014. The actual photochemical efficiency was higher in case of the oak (by an average 50-60%) in both test years. Light leaves show higher value than the shadow leaves, the difference is higher for both species in the drier year 2012 (hornbeam: 32%; oak: 25%) than in 2014 (hornbeam: 24%, oak: 18%). In 2014, the difference between the current photochemical efficiency of the light and shadow leaves is 8-7% lower, which can be explained by the wetter weather/longer intervals of cloud cover. The the oak regrowth light leaves ETR value in the rainy year 2014, has the highest value, which supports its excellent capability for light acclimatization. This value is somewhat lower in the year 2012, but this is commonly attributable to the 2012 ETR values since we measured the inhibition of electron transport. When evaluating the qP/qN ratio, we can conclude that the reason for the differences between species in 2012 is that the oak-type photochemical work (qP), that is the energy devoted to carbohydrate production, is higher than that of hornbeam. In 2014, the difference between species and between shadow and light leaves remained, but the resulting higher values were the result of the lower qN value of the non-photochemical quenching process. Based on the R_{Fd} value, which can be used as a vitality index, there is no difference between the species, the values of oak shadow leaves in 2012 only show significant difference to other values. The index can also be used to evaluate the entire photosynthetic process, that is, carbon fixation activity. According to our results, values of 2.5 and above refer to adequate photosynthetic activity, below 1 to strong stress. Based on these, under given conditions the regrowth vitality can be described as adequate.

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4. NEW SCIENTIFIC RESULTS

1. In the case of both examined species (*Quercus robur*, *Carpinus betulus*), as a result of the gap formation, high light intensity resulted in lower SLA values. The low light intensity of the forest interior increased SLA, which plays an important role in maximizing the carbon gains of a given area by a given species.
2. In the spring the hornbeam has more chlorophyll content than the oak. However, later during the vegetation period, oak chlorophyll content exceeds that of hornbeam. The greater physiological plasticity of oak is supported by the fact that in the drier summer in 2012 oak had higher carotenoid content.
3. According to the examined aspect-related parameters, the development of the oak specimens on the northern aspects is more favourable, and according to forestry results the northern aspects of the gap provide higher decree of regrowth survival.
4. Based on the chlorophyll fluorescence parameters, the ability of the oak to adapt to higher light intensity can be justified. Due to its higher ratio of non-photochemical quenching processes oak has higher acclimatization capability than hornbeam.
5. The reason for the high number of species found in the coenological surveys is that the shade tolerant and the sunt loving disturbance-tolerant species were present, and larger gaps were expected to have been more favourable by the latter ones, however when examining different positions within the gaps, it is noteworthy that the forest species were present in the same number of species in different aspects of the gaps.
6. In the different aspects of the investigated gaps (shaded S., middle, and sunny N), the number overgrowth (seedlings and saplings) of *Quercus robur* and the *Carpinus betulus*, which are the most preferred species in the renewal, was the lowest in the middle of the gaps. In the Northern aspects of the gaps he oak was represented in the highest number as hornbeam was the highest in the Southern (shady) aspects. In Southern (shady) sample areas, hornbeam dominance can only be limited by nursing.
7. At the completed forest regeneration, the initial outstanding decree of diversity dropped gradually, for which the disappearance of the weed species, which directly occurred during the opening of the forest, is responsible.
8. Forestry or nature conservation weeds appeared in remarkably small during the course of the renewal. In this positively-judged result, gentle production, rapid closure and proper regrowth played the leading role.
9. Based on the results of botanical and eco-physiological results, it can be stated that the on the northern aspects of the gaps are more favourable for regrowth survival.

5. PRACTICAL UTILIZATION OF RESULTS

1. In the case of pediculate oak, experiences gained in the stands of sessile oak and Turkey oak can be used only limited due to high light intensity demand and competition-sensitivity of the pediculate oak.
2. In order to bring as much light as possible, instead of the circular one, elongated ellipse shape should be preferred. South-S-Western aspect and 0.15 ha gap size is optimal.
3. At the same time as the gap is opened, on the south side, a half-tree-length (cca 30 m) thinning has to be performed in the stand removing 50-70% of it so as to provide more light. In this way, we promote seed production and raise the amount of solar irradiance. For closed multi-storey stands, this is explicitly desirable.
4. Based on the botanical recordings and the eco-physiological test results, which suggest that the northern aspects of the gaps are more favourable for regrowth survival, it is recommended to continue the expansion of the gap to the north, in a so-called 'hat' form.
5. 4-5. years after opening the gap on the north side of it in a 25-30 m wide thinning is performed in order to gain closure reduction to 50%.
6. From a practical point of view, it is important, that the mother's stock should be removed as soon as possible after performing the thinning due to the seedlings' high light demand,
7. With following the periodicity seed/acorn yield of oak and the regrowth development the final harvest is performed and both the thinning and the final harvest should follow the pattern we began. With 4 interventions, the regeneration reaches the 2 ha area in 15-20 years.
8. Controlling of the associate species is not feasible in industrial sizes.
9. If case of a non-sufficient regeneration of the main tree species it is recommended to carry out artificial supplementation with local, genetically identical propagation material, with nest nut seeding. Thinning also benefits the process since it promotes higher yield of seed crop.
10. Regarding the conservation aspect, there is always an intact seed tree cluster left.

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List of publications related to the dissertation

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