# Final report of the NKFIA K111887 project

Project title: Experimental investigation of the effects of forestry treatments on the forest site, regeneration and biodiversity
Principal investigator: Péter Ódor
Research unit: Centre for Ecological Research Institute of Ecology and Botany
Duration: 2015.01.01. – 2019.12.31 (one year elongation)

## Motivation and aims of the project

In Europe, the most important factor that determine the ecological status of forest ecosystems is forest management. Deforestation, forest use and forest management has a very long history in Europe, which resulted that recently less than one percent of the European forests can be classified as primary forest (exists without direct human influence for more than 80 years). The main aim of forest management is timber production, although other provisioning ecosystem services as livestock grazing, hunting, mushroom and berry picking are also important. Beside these services, the conservational and recreational functions of forests continuously increased in Europe and the global changes also increased their regulating services as climate mitigation, carbon sequestration, soil and water protection. These expectations leaded to the concept of ecologically sustainable forestry, which emphasizes that beside timber production, forest management should maintain the integrity the forest ecosystems, their natural structure, composition, functions and biodiversity. Within these general concept, European forests are managed by a hierarchical way from wilderness areas (without or only conservation management) to exotic tree plantations (managed mainly by economic considerations). However, in the largest part of European forests, the management integrates economical, conservational, and recreational considerations. This integrated forest management is especially valid in Hungary, where 96% of forests are managed for timber production but 40% of the forests have some kind of conservation protection. The two main forestry systems in Europe are the rotation forestry (shelterwood and clear-cutting forestry systems) and continuous cover forestry (tree selection and group selection forestry systems). The main difference between these systems is that in case of rotation forestry relatively large stands are cut and regenerated at the end of the rotation period (80-100 years for oak and beech forests), resulting in even-aged, homogenous stands on landscape scale, while continuous forest cover forestry maintains the forest cover using frequent but fine-scaled interventions resulting in uneven-aged stands. Because the continuous cover forestry is more similar to the natural disturbance dynamics of oak and beech forests than rotation forestry, it is supposed that this type of timer production is more favorable for conservational considerations. However, while rotation forestry has a 200 years old tradition in Hungary, continuous cover forestry are still in an introductory stage; only 4% of the forest area is managed by this system. There are many open questions related to the landscape scaled implementation of this system concerning forestry, conservation and ecology. Still missing the open field experiments that compare these forestry systems. In this project, we established a forest ecological experiment (Pilis Forestry Systems Experiment) that compares the main treatments of these two forestry systems and investigates their effect on forest site (microclimate, soil, litter), biodiversity (including many organism groups) and regeneration. We started a standardized experimental study, in which framework we would like to explore novel results on the field of forest ecology and conservation biology, as well as contribute to the development of forestry and conservation practice.

### General description of the Pilis Forestry System Experiment

The experiment is located in a 40 ha sized, 80 years old oak–hornbeam forest (Fig. 1.). We implemented the following treatments:

1. control (C): closed-canopy mature stand, without harvesting;
2. clear-cutting (CC): a circular clear-cut (diameter: 80 m), surrounded by closed stand;
3. gap-cutting (G): an artificial circular gap in the closed stand (diameter: 20 m, approximately one tree height/gap diameter ratio);
4. preparation cutting (P): 30% of the dominant trees (based on the basal area) was removed in a spatially even arrangement, and the whole secondary canopy and shrub layer were felled (diameter: 80 m),
5. retention tree group (R): within the clear-cuts, a circular group of trees was retained (diameter 20 m, 8–12 individuals).

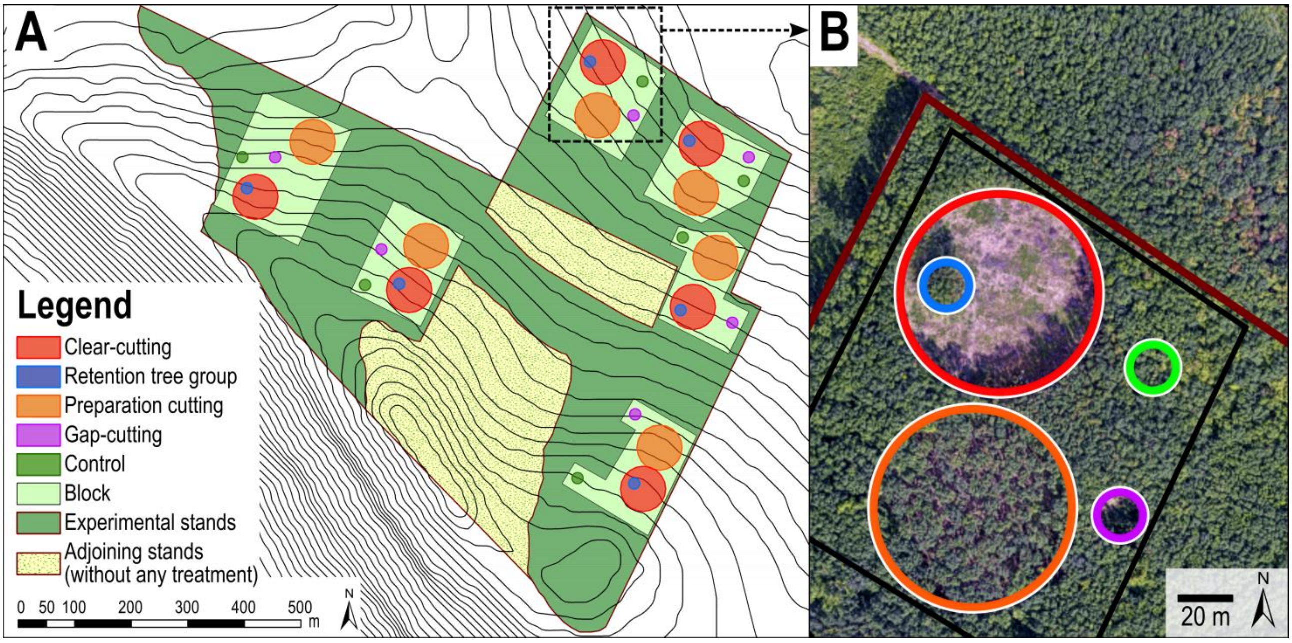


Fig. 1. A) The map of the study area (Pilisszántó–Pilisszentkereszt, Hosszú-hill) and B) aerial photo of a block with the different treatments.

The clear-cut, preparation cut, retention tree group and mature (control) stands are typical landscape elements of the rotation forestry system while gap is the most characteristic element of continuous cover forestry in Hungary. There were six replicates from each treatment in a complete block design, thus altogether 30 plots were sampled. In 2014, in the uncut stand, we recorded the before-treatment state for each studied variables that enable the application of before-after-control-impact (BACI) design during the analysis. Forestry interventions were carried out in the winter of 2014-2015; since then, samplings have been performed in every year with unaltered methodology.

In all treatment, a 6 m × 6 m sized fenced plot was established (Fig. 2). The microclimate was measured within the fenced area. The continuous detection of the studied variables was provided by HOBO H21-002 data loggers recording the following variables: air temperature, air humidity, soil temperature, soil moisture, photosynthetically active radiation. During the project period, these variables were recorded monthly within a time span of 3 days by continuous measurements. Three soil and litter samples were collected in spring and autumn in each year from all plots and analysed for chemical and physical variables. Changes of the natural vegetation after the different treatments were recorded twice a year using 2 m × 2 m sized permanent quadrats inside and outside of the fenced sample plots. The abundance of tree seedlings was recorded in species and size categories separately. Forest herbs were characterized by evaluating the cover of the plant species. Ground beetle and spider assemblages were surveyed twice a year (in May and September) by soil traps. In each occasion four soil traps was installed in the treatments (outside the fenced areas), the trapping period was 21 days. All collected specimens were determined on species level. Enchytraeid worm assemblage as characteristic decomposer group of the soil fauna was explored from soil samples (three samples per plot) collected twice a year (in May and September). From 2017, the zoological survey was extended by Malaise trap sampling (in spring and autumn) focused mainly on Dipterans; the crane fly (*Tipulidea*) assemblage have been analysed based on this survey.

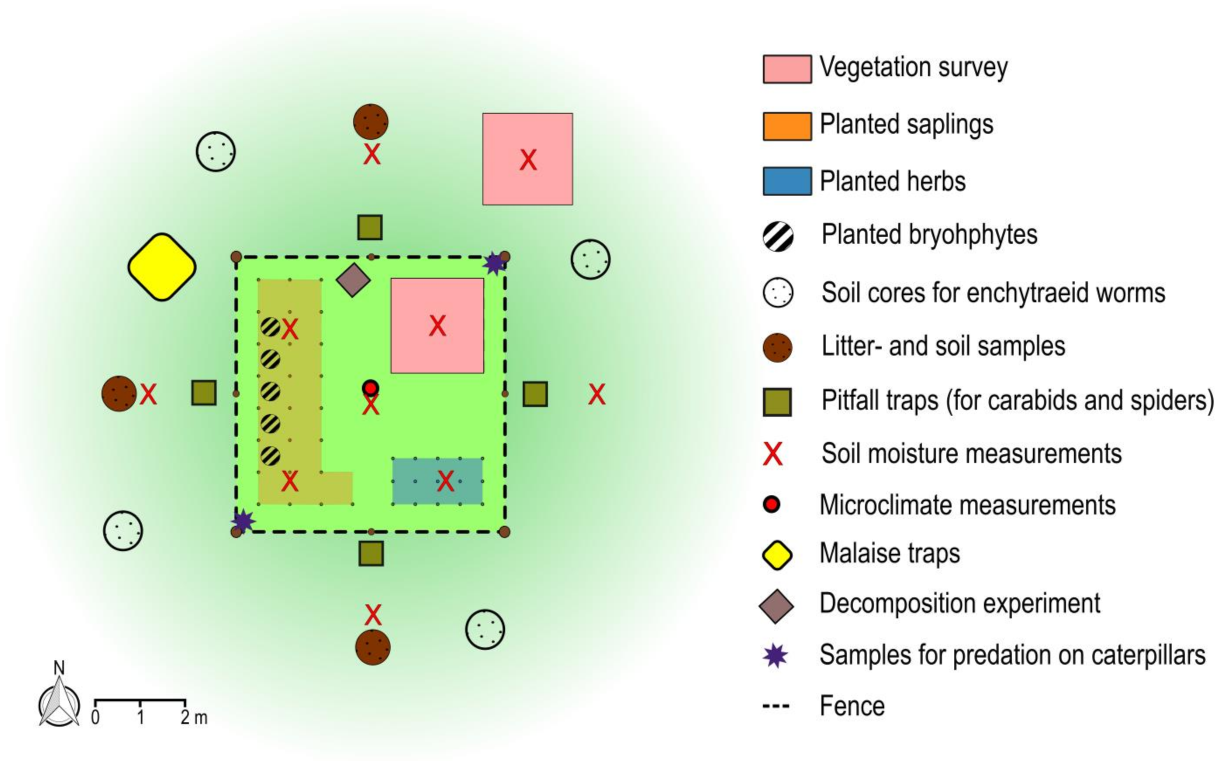


Fig. 2. The location of the sampling points within a plot.

The effect of treatments on the growth and survival of planted plants was studied in the fenced plots. Five individuals of five tree species (sessile oak, Turkey oak, beech, hornbeam, European ash) and two forest herbs (*Corydalis solida* and *Cardamine bulbifera*) were planted and recorded yearly during the project period. Five 20 cm × 20 cm sized blocks of an epixylic bryophyte (*Lophocolea heterophylla*) and a generalist bryophyte (*Hypnum cupressiforme*) were set on together with their substrates, and the survival of the patches was recorded in every month.

During the analyses, mainly the effect of treatments on the studied variables (organism groups and environmental variables)was explored, using general linear mixed models and multivariate ordinations (including block as random factor). It was also revealed, which environmental variables were the most important drivers of the studied organism groups. The abundance, richness, composition and functional (trait) composition of the organism groups were studied as response variables.

## Participants of the study

Most of the participant researchers worked in the main research unit (Centre for Ecological Research, Institute of Ecology and Botany), as Péter Ódor (principal investigator), Réka Aszalós (vegetation), Gergely Boros (enchytraeid worms), Bence Kovács (microclimate, employed by the project). In 2016, Flóra Tinya (regeneration) and in 2017, Zoltán Soltész (dipterans) joined to the project. Researchers of other institutes also participated in the study as András Bidló (University of Sopron, soil), Zoltán Elek (MTA-ELTE-MTM Ecological Research Group, ground beetles) and Ferenc Samu (Centre for Agricultural Research, Plant Protection Institute, spiders). Many students were involved to this study; one PhD (Bence Kovács), two MSc (Csenge Veronika Horváth, and Bence Tóth) and two BSc (Zsuzsa Gránitz, and Ákos Vadas) theses were defended directly related to the experiment.
The experiment was established as a collaboration between the research unit and the Pilis Park Forestry Company. The forestry company managed the experimental stand, implemented the treatments and maintained the basic infrastructure of the experiments (e.g., fences), but the foresters (Péter Csépányi, Viktor Farkas, Gábor Szenthe, László Simon) were also involved into the planning and evaluation of the study. This strong collaboration between researchers and practitioners provided the direct utilization of the results in forestry and conservation practice.

## Publications, dissemination of the results

The experiment started in the framework of the project, thus in the first three years we focused on the fieldwork, and we disseminated our study and preliminary results in conferences. 28 conference presentations were related to the study (including scientific conferences and local meetings for practitioners). The two papers of this period (Tinya and Ódor 2016, Kovács et al. 2017), were only indirectly related to this project (the topics were related to our project, the participants were employed by the project, but the analyzed data originated from an earlier study). The first scientific paper based on the data of the experiment was published in 2018 (Kovács et al. 2018), revealing the short-term changes of the microclimate and site conditions after the treatments. Later we published a multi-taxon study focusing on the short-term responses of plants, enchytraeid worms, ground beetles and spiders (Elek et al. 2018), and detailed studies of enchytraeid worms (Boros et al. 2019), understory (Tinya et al. 2019), tree regeneration (Tinya et al. 2020) and the four-year analysis of microclimate (Kovács et al. 2020). Because of the slow response of forest organisms to treatments, we asked for a one-year elongation of the project to fulfil our publication plans. All of our scientific results were published in high-standard international journal of ecology (D1: Agricultural and Forest Meteorology, Ecological Applications, European Journal of Forest Research, two papers in Forest Ecology and Management, Scientific Reports; Q1: Applied Soil Ecology, Forests). The experiment is continued in the framework of another NKFIA project (K128441); thus we plan to publish some results established in this project, as detailed analysis of ground beetles, spiders, bryophytes, and vegetation, in this year. We hope that this project supported the establishment of a long term forestry experiment that will produce many novel results for forest ecology and practice.
Because this study has a strong practical relevance for forestry and conservation, we emphasized the dissemination of our result to practitioners. Beside many oral presentations, we published a paper in 2015 in the journal of the Hungarian Forestry Association (Erdészeti

Lapok, in Hungarian, Ódor et al. 2015) about the aims and methods of the experiment, and another paper in 2020 the main results of the project (Ódor et al. 2020).
The media was very interested to our research, 17 media appearances (TV and radio interviews, publications in newspapers) were published during the grant period.
We established and maintain a homepage about this experiment (https://www.piliskiserlet.okologia.mta.hu) in that all documents of the research are available (including scientific papers, conference presentations, photos, descriptions for general public, and media publications).

**Summary of the scientific results**

*Microclimate, forest site conditions (papers: Kovács et al. 2018, Kovács et al. 2020; Fig. 3)*

- Microclimate conditions changed immediately after the interventions, and the circumstances remained relatively consistent during the first three years. The recovery of the original closed-forest microclimate can be expected only after longer time – even in the less drastic treatments.
- Temperature maxima and variance were the main determinants of the microclimatic differences between the treatments. In certain treatments, in summer days, these temperature variables can be quite high.
- The most drastic changes were observed in the clear-cuts. This treatment is characterized by extreme high amount of light, high air and soil temperature, increased soil moisture and low air humidity. The daily range of the microclimate is also the highest here, thus the animals and plants living in clear-cuts must adapt to very extreme conditions.
- In the gaps, the most important change was the increment of the soil moisture. Light also increased, compared to the closed forest, however, air and soil temperature and air humidity remained balanced, and similar to the conditions of the closed stand.
- Retention tree groups are able to compensate the extremities of the microclimate, compared to the clear-cuts (e.g. by the more moderated daily maxima), but the mean values of the most variables were similar to those in the cutting areas. However, the amount of light is lower here than in the clear-cuts, and the soil moisture remained similarly low as in the closed forest.
- Microclimatic conditions of the preparation cuts are similar to those of the closed stand. Light, air and soil temperature showed a slight increase, but the air humidity and soil moisture did not change.
- Differences in the microclimate of the treatments are the most pronounced in the summer period.
- Soil and litter conditions did not show remarkable changes in the first years after the interventions; we suppose that their alteration needs longer time.

*Understory vegetation (paper: Tinya et al. 2009, and MSc thesis: Horváth 2019)*

- Vegetation of the clear-cuts and gaps altered significantly: both the species richness and the abundance (cover and height) of the understory increased. Some new species established also in the retention tree groups, but the biomass of the species did not changed here.
- In the clear-cuts, due to the appearance of many non-forest (meadow and weed) species, the species composition of the understory changed remarkably.
- Contrary to this, in the gaps, however the biomass of the understory increased, the dominance of forest species was preserved.

- The cover of the annual herb species increased in the first two years in the clear-cuts and gaps, but for the fourth year it has fallen back.
- Retention tree groups are able to preserve the forest characteristics of the understory for some years, but later their vegetation also begin to alter.

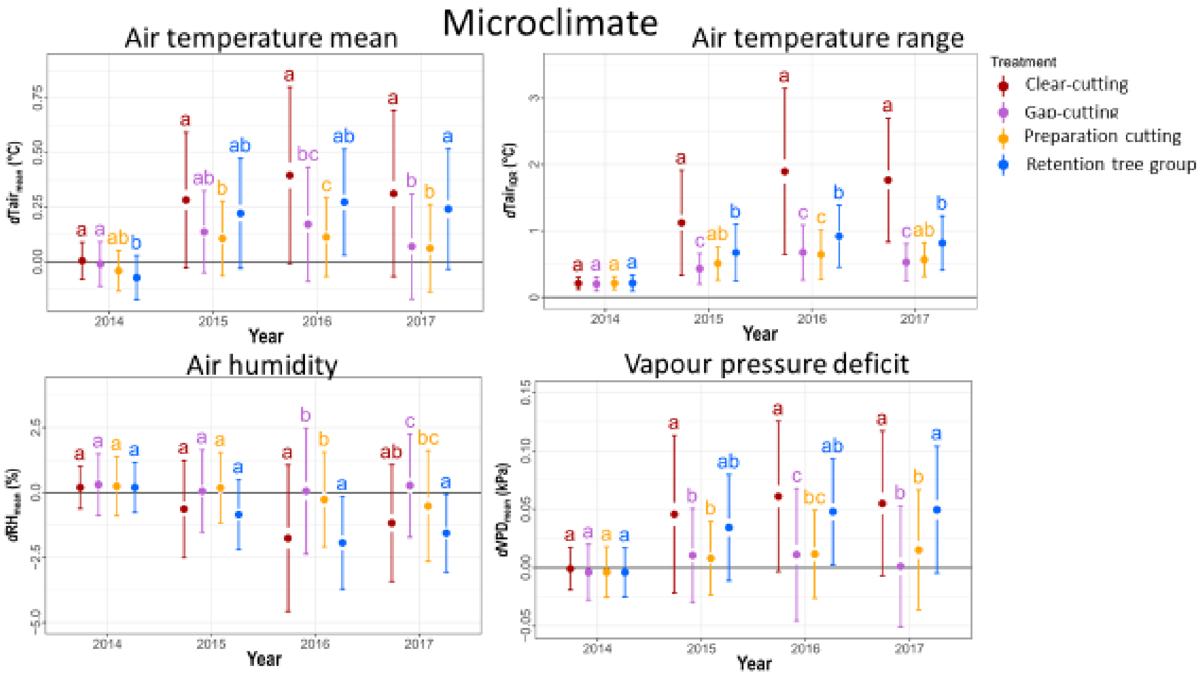

Fig. 3. Difference of microclimate variables from the control plots, in different treatments (Kovács et al. 2020).

*Bryophytes (conference presentations and BSc thesis: Vadas et al. 2017, Vadas 2018):*

- The response of bryophytes to the treatments depends considerably on the life strategy of the species.
- The generalist species survived in every treatment, but in the clear-cuts its cover decreased.
- The specialist deadwood-inhabiting species died off in the clear-cuts and in the retention tree groups, while in the preparation cuts and in the gaps – after an early relapse – it survived. We can conclude that shelterwood system cannot ensure the survival of specialist, humidity-demanding bryophyte species, while the continuous cover forestry may be able to preserve these species.

*Regeneration (paper: Tinya et al. 2020, Fig. 4):*

- Survival of the woody saplings was better in every treated site than in the closed stand.
- Based on the results of the first four years, regeneration is the most successful in the clear-cuts and gaps.
- In the retention tree groups many seedlings establish and survive, however, microclimatic conditions of this treatment (dry upper soil, low air humidity, little extra light) are not appropriate for their growth.
- The response of the different tree species to the treatments depend on the dispersal mechanism of the species.
- The establishment of new oak individuals in the gaps, and especially in the clear-cuts is strongly limited. However, individuals, which have been present there originally, showed here the most intensive growth. Oak seedlings cannot survive for long time in

the closed stand; in the preparation cut~~ting~~s and retention tree groups they survive, but they do not grow.

- Tree species of mesic forests (hornbeam, beech) respond to the increased light with an intensive growth in every treated sites, compared to closed stand. They showed the fastest growth in the gaps and cutting areas.
- Ash and animal-dispersed wild fruits germinated the best in the retention tree groups, but growth of the ash was the best in the gaps, and growth of the wild fruits was the most intensive in the clear-cuts.

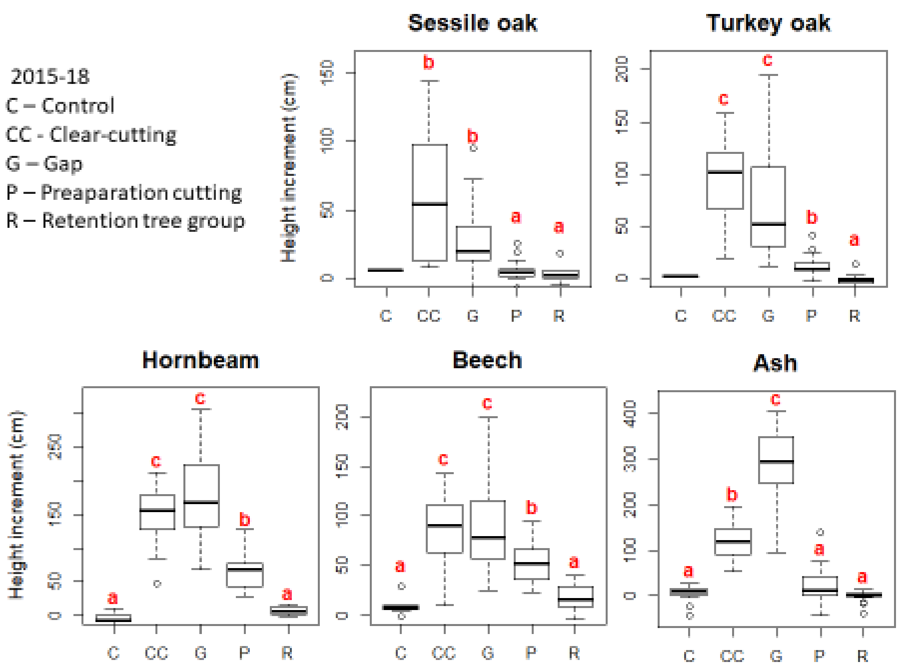


Fig. 4. Boxplot of height growth of the planted tree saplings, between the first and the fourth year, in the different treatments (Tinya et al. 2020).

*Browsing effect (conference presentations and MSc thesis: Tóth et al. 2017, Tóth 2019):*

- There was a significant difference in the rate of browsed saplings between the fenced and unfenced area. It was detectable even in the first year after the interventions, which shows an intensive browsing pressure in the region.
- All investigated woody species has grown better in the fenced areas.
- Browsing was more intensive on shrubs than on tree saplings, thus the preservation of shrubs in the stands can moderate the browsing pressure on the tree species.

*Ground beetles and spiders (paper: Elek et al. 2018):*

- Treatments did not have any effect on the species richness and abundance of these organism groups, but they altered the species composition of these communities, especially for spiders.

*Enchytraeid worms (paper: Boros et al. 2019):*

- Species richness and abundance of enchytraeid worms decreased drastically in the clear-cuts and in the retention tree groups. As they are soil-dwelling organisms with low dispersal ability, they are not able to tolerate the altered microclimatic conditions of the cutting areas. In their case, even the retention tree groups could not serve as a refuge.

- However, in the gaps and preparation cuts, the abundance and species composition of enchytraeid worms was similar to those in the closed forest. Thus we can conclude that continuous cover forestry may be more favourable for this important decomposer organism group than shelterwood forestry system.

*Crane flies (unpublished):*

- They showed the highest diversity and abundance in the gap, some species preferred only this treatment. Gaps kept the buffered air temperature and humidity conditions, but the increased soil moisture, light and understory cover made them favorable habitat for this group.

**Social utilization of the project**

Based on the short time processes after the treatments, we can conclude that the extreme abiotic conditions of clear-cuts have unfavorable effect on most organism groups. Retention tree groups can partially compensate the negative effects of clear-cutting (light, vegetation, temperature range), but for other aspects their conditions are unfavorable (soil moisture, soil organisms). However, more open stands (preparation cutting) and gaps can maintain the forest microclimate and biodiversity, and especially gaps have many favorable effects (more light, increased soil moisture) that increase biodiversity (soil organisms, plants). For natural regeneration of trees, gaps are similarly effective than large cutting areas. For the successful regeneration of oaks, foresters should consider the dispersal limitation of acorns (interventions should fit to masting years) and the higher competitive ability of hornbeam (hornbeam should be controlled during the regeneration).
The experiment supports that continuous cover forestry – producing uneven-aged, more open, heterogeneous stands – is much more favorable for maintaining forest ecosystems services (e.g. climate change mitigation) and forest biodiversity than rotation forestry. Small openings (gaps) in the canopy are ideal patches for natural regeneration, as well as could produce biodiversity hotspots within the stand for many organism groups. We hope that these evidences could contribute to the spread of this novel forestry system especially in the native and protected forests. However, incorporation of other conservational considerations is necessary also in this system, as maintenance of habitat trees, providing the existence of dead wood, excluding of small habitat patches (small wetlands and springs, rocky outcrops etc.) from timber production. While continuous cover forestry can be considered as a nature friendly way of timber production, and establish an ideal forest landscape for recreation, it cannot substitute the establishment of wilderness areas, where only conservation management could exist without timber production.

**References**

See the publication list of the project as well as the project webpage (https://www.piliskiserlet.okologia.mta.hu).