THESES OF DOCTORAL DISSERTATION

INVESTIGATION OF THE RELATIONSHIP BETWEEN LIGHT AND FOREST UNDERSTORY VEGETATION IN ŐRSÉG, WESTERN HUNGARY

FLÓRA TINYA

Consultant:
Dr. Péter Ódor, scientific fellow

PhD. School of Biology
Head of School: Dr. Anna Erdei, Professor, Member of the Hungarian Academy of Sciences

PhD. Program of Ecology, Conservation Biology and Systematics
Head of Program: Dr. János Podani, Professor, Member of the Hungarian Academy of Sciences

Loránd Eötvös University
Department of Plant Taxonomy and Ecology

Budapest, 2011

1. Introduction and aim of the study

Forest communities keep a considerable part of the biodiversity of the Earth: They contain 90 percent of terrestrial species. Beside their own existential value they contribute to the human welfare in many ways. Thus their conservation, the preservation of their diversity is very important from practical aspects as well. However, most of the forests around the world – and also in Hungary – are under silvicultural management, so forest communities must be maintained in managed forests. This needs forestry practices which consider the environmental requirements of the different forest organism groups. However, little evidence-based information is available for the foresters about these questions.

This thesis is part of a larger project investigating the relationships between characteristics of forest stand structure, environmental variables determined by stand structure, and diversity and species composition of different organism groups. The results of our project can answer on the one hand questions of basic research. They also give predictions about the kind of stand structure that should be developed in order to maintain high diversity of different organism groups. So the regression models can be used in practical forestry. The investigated background-variables in the project are species composition of stands, stand structure, light conditions, microclimate, proportion of different substrate types, soil and litter conditions, surrounding landscape, and historical data. The studied organism groups are ground-floor and epiphytic bryophytes, herbs, seedlings, saplings, soil and wood inhabiting fungi, epiphytic lichens, saproxylic beetles, spiders, and birds.

In the understory vegetation light is one of the most important factors influencing species abundance, composition and diversity, therefore within the above mentioned questions this dissertation investigates the relationships between light as the background variable and forest understory (herbs, bryophytes and seedlings) as the organism group in deciduous-coniferous mixed forests. Our study contributes to the scientific cognition of light requirements of forest understory, and hereby it makes possible to design management methods favourable for the forest vegetation. Moreover we would like to refine the knowledge about the use of different light estimating methods in forests.

The questions were as follows:

1) Which are the most useful indirect methods for the description of light conditions in forests?

   - ♦ How are the light values estimated by different methods related to each other?
   - ♦ How similar are the relationships to an understory variable between three different light estimating methods?

2) How do the light conditions influence the understory vegetation (herbs, bryophytes and seedlings) in many stands with different stand structure?

   - ♦ To what extent can the variation in species composition be explained by light? To what extent is light intensity correlated with species richness and cover of different plant groups?
   - ♦ To what extent is light intensity correlated with cover of individual species?
   - ♦ How are these correlations related to the Ellenberg light indicator values of the species?

3) How do the light conditions influence the understory vegetation (herbs, bryophytes and seedlings) within one stand with heterogeneous canopy layer? Is there any relationship between the spatial pattern of light and the understory?

   - ♦ How are the cover and spatial pattern of understory plant groups related to light conditions?
   - ♦ How are the cover and spatial pattern of plant species related to light conditions?

The project is carried out in the Őrség National Park, in Western Hungary, therefore the relationships we get are mainly valid for the Őrség landscape. The silvicultural management and nature conservation of this region can apply them best. But our study also asks some general questions, so some of our result can be interpreted also in a broader spectrum.

2. Methods

Data collection

The study was carried out in 34 forest stands in the Őrség National Park, Western Hungary. The stands were composed by different combinations of tree species typical for the region (*Quercus robur et petraea* – pedunculate and sessile oak, *Fagus sylvatica* – beech, *Carpinus betulus* – hornbeam, *Pinus sylvestris* – Scotch pine, *Picea abies* – Norway spruce) under similar site conditions. Cover of herbs, bryophytes and seedlings and the amount of light were estimated in 30x30 m^2 blocks divided to 36 contiguous plots of 5x5 m^2. Ground floor and epiphytic bryophytes of vertical stems were recorded separately.

To answer our methodological questions we estimated light in 23 stands by three different methods. First, with a spherical densiometer, which consists of a convex mirror with a grid engraved on the surface and can be used to estimate the percentage of canopy openness. Second, with a spatially explicit light model (tRAYci), which calculates light intensity according to measured variables of trees and geographical position of the stand. The third method was the use of the LAI-2000 Plant Canopy Analyzer, which measures relative diffuse light.

To investigate the relationships between light and understory in many stands, data were used from 34 forests. In this case, we described the light conditions with LAI-2000.

The effect of light on the fine-scale pattern of understory within one stand was studied in the "Szalafői Őserdő" forest reserve, which has heterogeneous tree species composition and light conditions. Here the size of the block was 55x55 m^2 and it was also divided to plots of 5x5 m^2. The cover of 11 *a priori* selected herbs and all seedlings were estimated. Total cover of the understory (herbs and seedlings) and the bryophyte layer were also registered. The intensity of relative diffuse light in the understory was estimated by LAI-2000 Plant Canopy Analyzer.

Data analysis

During the methodological study first Spearman rank-correlations were calculated between light values measured by the three different methods. It was carried out both in case of mean light values and in case of variation coefficients representing the heterogeneity of light. In the second part of the analysis we assumed that blackberry (*Rubus fruticosus agg.)* as a light-flexible plant is a potentially sensitive response variable for the amount of light, and we calculated rank-correlation between light estimated by the individual methods and cover of blackberry. Both analyses were carried out at more spatial scales from 5x5 m^2 to 30x30 m^2.

To investigate the relationships between light and understory (herbs, bryophytes, seedlings) in 34 stands both univariate and multivariate analyses were performed. Redundancy analyses were carried out to study the effect of light on the species composition of the different plant groups. Spearman rank-correlations were calculated between the amount of relative diffuse light and some community characteristics of the groups (species richness and cover) and the cover of individual species. The analysis of the individual species was performed at five different spatial scales, similarly to the methodological study.

In case of the data from "Szalafői Őserdő", the pattern of the variables (light, total understory cover and cover of species) was investigated with the method of "four term local quadrat variance" (4TLQV). Relationship between the pattern of light and understory cover was evaluated by the method of "four term local quadrat covariance" (4TLQC).

3. New scientific results

1. According to our results, under closed canopy both tRAYci and LAI-2000 give reliable estimates of relative diffuse light, but their usefulness depends on our actual questions and the sampling design. Spherical densiometer does not give so accurate estimations.

2. Spatial heterogeneity of light shows much stronger correlations than mean values both between the methods and between light intensity and *Rubus* cover.

3. In the investigated stands, in case of herbs species richness, in case of bryophytes cover, while in case of seedlings both variables correlate positively with understory light.

4. On species level, within herbs it is possible to separate species the cover of which does not correlate with light, and species with correlations to light at finer and coarser scales. Within bryophytes, the cover of terricolous species correlates more with light intensity than the cover of epiphytic and epixylic ones. Seedlings can be divided into shade-tolerant and light-demanding species based on their response to light.

5. Within a stand, the pattern of both vascular and bryophyte cover fits well the pattern of light. The pattern of species correlating with light between stands corresponds to light pattern within one stand. However, it is not true for shade-tolerant ones. The spatial scale of maximal correspondence with light is finer for herbs (10x10 m^2) than for seedlings (25x25 m^2).

6. Herb species correlating with light at a coarser scale usually have high, while non-correlating species have low light indicator values. However, species correlating with light at finer scales have low indicator values, although they are not independent from light intensity. The correlation of bryophyte and seedling species cover with light is less supported by light indicator values than in case of herbs.

4. Conclusions

1. The use of the model tRAYci is suggested in case of intensive sampling of one or few stands. The data collection for the model is quite labor-intensive, but it is possible to get versatile information, in more different resolutions. On the contrary, LAI-2000 is appropriate for fast, extensive sampling.

2. In certain cases – depending on the structure and composition of the investigated stand, and on the studied understory variables – not only the effect of the amount of light on the understory, but also that of the heterogeneity can be worth evaluating.

3. The total cover of herbs can be limited by another environmental variable (e.g. soil acidity), that is why they can not reach a large cover even if the light intensity is high. Contrary to this, bryophyte species are determined mainly by the available substrate types (e.g. living or dead wood, open soil surface). In absence of these we can not expect high species richness at the bright places, either. However, some opportunistic species, which are not sensitive to the substrate type, can achieve high cover at these sites.

4. Herbaceous species can be divided into three distinct functional groups according to their response to light. Shade plants (many dicotyledons and ferns) occur only under closed canopy. Light-flexible plants are considered in the literature to be closed-forest species, and they are present also under shady circumstances. However, at brighter places they are able to reach a higher cover. Sun species, which are mainly monocotyledons, are not typically forest

species, they live in wet meadows or clearcuts. Because of the characteristics of the region (the most acidic stands are open, bright Scotch pine forests) this group contains many species preferring acidic forests.

Forest bryophytes are traditionally considered as shade-tolerant plants, but according to our results, terricolous species are largely determined by light. On the contrary, epiphytic and epixylic species are limited by the amount of the appropriate substrate.

Among the seedlings, tree species can be well divided to light-demanding and shade-tolerant species. In case of shrub species the separation of the groups is not so pronounced, presumably some other environmental factors are also important in their occurrence.

5. In older stands with natural stand dynamic, the overstory becomes more heterogeneous, and this causes variable light conditions and spatially heterogeneous understory layer. In case of most understory variables, pattern analysis within one stand confirms the relationships with light gained from the study of many stands. The occurrence of herbs fits primarily to the finer scale of light pattern, which is formed by the position of individual trees. Contrary to this, pattern of seedlings is related to light pattern at a coarser spatial scale, which is determined by the patches of saplings.

6. The response of sun and shade plants to light can be well described with one number, so in these cases Ellenberg indicator values are well applicable. At the same time light-flexible species have a more complex behavior, so for these plants the indicator values are less reliable.

For bryophytes, the indicator values do not give good information about the light demand of the species, either. It can be on the one hand because bryophytes are mainly determined by microhabitats, and so they can tolerate a wider range of light conditions. On the other hand their indicator values are not so elaborated and well established.

The exploration of these light–understory interactions in forests is important not only from the scientific aspect, but also for the forestry and nature conservation practices.

4. Publications forming the base of the dissertation

Articles published in peer-reviewed journals with impact factors

Tinya, F., Márialigeti, S., Király, I., Németh, B. és Ódor, P. (2009): The effect of light conditions on herbs, bryophytes and seedlings of temperate mixed forests in Őrség, Western Hungary. *Plant Ecology*, 204: 69-81. IF (2009): 1,567.

Tinya, F., Mihók, B., Márialigeti, S., Mag, Zs. és Ódor, P. (2009): A comparison of three indirect methods for estimating understory light at different spatial scales in temperate mixed forests. *Community Ecology* 10: 81-90. IF (2009): 0,792.

Conference proceedings

Tinya, F. (2007): The effect of light on understory vegetation in temperate mixed forests in Őrség, Western Hungary. In: Zupan, E., Vinko, D. és Creegen, S. J. J. (szerk.): International Life Sciences Students' Conference – Life with Science: Book of abstracts, Ljubljana, 70.

Tinya, F., Mihók, B., Márialigeti, S., Németh, B., Mazál, I., Mag, Zs. és Ódor, P. (2006): Indirekt fénymérési módszerek vizsgálata őrségi erdőkben. In: Szentesi, Á., Szövényi, G. és Török, J. (szerk.): 7. Magyar Ökológus Kongresszus – Előadások és poszterek összefoglalói, Budapest, 205.

Tinya, F. és Ódor, P. (2009): A fény és az aljnövényzet mintázatának összefüggése a Szalafői Őserdőben. In: Körmöczi, L. (szerk.): 8. Magyar Ökológus Kongresszus – Előadások és Poszterek Összefoglalói, Szeged, 219.

Tinya, F. és Ódor, P. (2009): The effect of light on forest understory in deciduous-coniferous mixed forests in Western Hungary. In: 2nd European Congress of Conservation Biology "Conservation biology and beyond: from science to practice" Book of abstracts, Czech University of Life Sciences, Faculty of Environmental Sciences, Prague, 217.

Tinya, F., Ódor, P., Németh, B., Márialigeti, S., Mazál, I. és Mag, Zs. (2008): Fényviszonyok hatása az erdei aljnövényzetre őrségi erdőkben. *Kitaibelia*, Különszám az Aktuális Flóra- és Vegetációkutatás a Kárpát-medencében VIII. című konferenciára, Gödöllő, 13: 194.

5. Further publications related to the dissertation

Mag, Zs., Mazál, I., Márialigeti, S., Németh, B., Tinya, F. és Ódor, P. (2006): A faállomány hatása a madárközösségekre az őrségi erdőkben. In: Szentesi, Á., Szövényi, G. és Török, J. (szerk.): 7. Magyar Ökológus Kongresszus – Előadások és poszterek összefoglalói, Budapest, 136.

Márialigeti, S., Németh, B., Tinya, F. és Ódor, P. (2009): The effects of stand structure on ground-floor bryophyte assemblages in temperate mixed forests. *Biodiversity and Conservation*, 18: 2223-2241. IF (2009): 2,066.

Márialigeti, S., Ódor, P., Németh, B. és Tinya, F. (2008): Erdei mohaközösségek és a faállomány összefüggései az Őrség erdeiben. *Kitaibelia*, Különszám az Aktuális Flóra- és Vegetációkutatás a Kárpát-medencében VIII. című konferenciára, Gödöllő, 13: 176.

Ódor, P., Király, I., Mag, Zs., Márialigeti, S. és Tinya, F. (2009): A faállomány hatása különböző élőlénycsoportok összetételére és diverzitására az őrségi erdőkben. In: Körmöczi L. (szerk.): 8. Magyar Ökológus Kongresszus – Előadások és Poszterek Összefoglalói, Szeged, 166.

Ódor, P., Mag, Zs., Márialigeti, S., Tinya, F., Németh, B. és Mazál, I. (2007): Effect of stand structure and tree species composition on different organism groups. In: Natural hazards and natural disturbances in mountain forests. Book of abstracts, Trento, Italy.

Ódor, P., Márialigeti, S., Mag, Zs., Király, I., és Tinya, F. (2008): A faállomány és különböző erdei élőlénycsoportok kapcsolata az őrségi erdőkben. In: Lengyel, Sz., Mihók, B., Lendvai, Á. Z. és Sólymos, P. (szerk.): Molekuláktól a globális folyamatokig. V. Magyar Természetvédelmi Biológiai Konferencia, 2008. november 6-9. Program és absztrakt-kötet. 137.

Ódor, P., Márialigeti, S., Mag, Zs., Lengyel-Király, I. és Tinya, F. (2009): The effect of stand structure on different organism groups in mixed deciduous-coniferous forests in Hungary. In: 2nd European Congress of Conservation Biology "Conservation biology and beyond: from science to practice" Book of abstracts. Czech University of Life Sciences, Faculty of Environmental Sciences, Prague, 97.

Ódor, P., Tinya, F., Márialigeti, S., Mag, Zs. és Király, I. (2008): A faállomány és különböző erdei élőlénycsoportok kapcsolata az őrségi erdőkben. In: Sólymos, P. (szerk.): KÖSzi 2008 – „Életre keltett adatok”. A 3. Kvantitatív Ökológiai Szimpózium program és absztrakt kötet, Budapest, 22.

Ódor, P., Tinya, F., Márialigeti, S., Mag, Zs. és Király, I. (2011): A faállomány és különböző erdei élőlénycsoportok kapcsolata az őrségi erdőkben. *Erdészeti Lapok*, 146: 23-26.