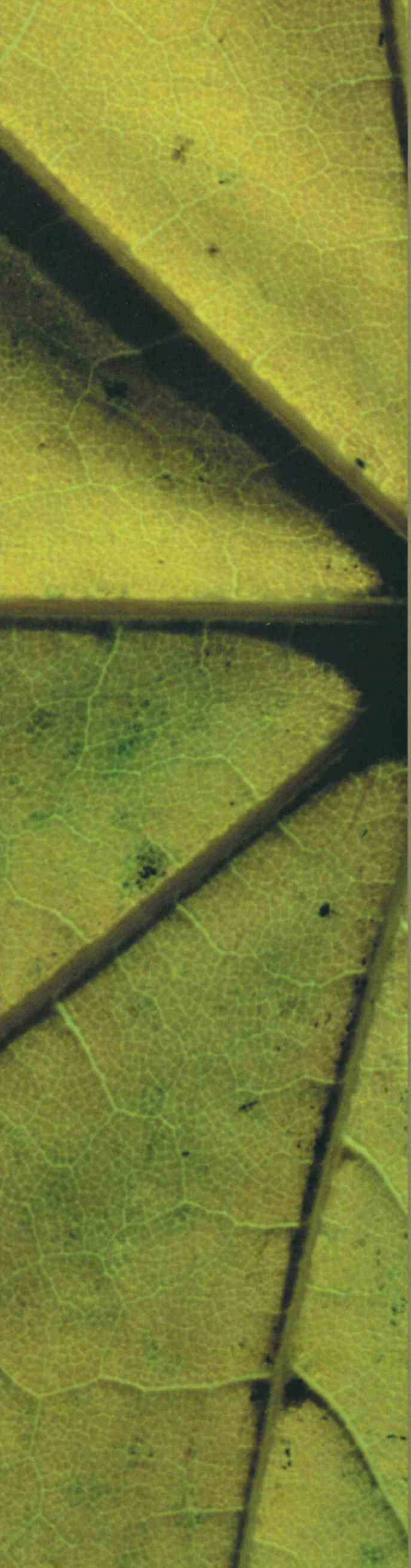

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ACTA SILVATICA ET LIGNARIA HUNGARICA

Vol. 14, Nr. 2

Contents

ACTA SILVATICA ET LIGNARIA HUNGARICA

Vol. 14, Nr. 2

Tartalomjegyzék

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Economic and Labor Sizes from the Brazilian Timber Housing Production Sector

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Abstract – Brazilian timber housing producers were evaluated through a survey, which was based on face-to-face interviewing supported by a semi-structured questionnaire. Derived from expansive research, this paper aimed to identify labor size and to characterize economic size from this production sector. The sampling process evaluated 50.95% (n = 107) of all producers (n = 210) whose performance was considered close to ideal. This sector is mostly concentrated in micro and small-scale companies, though a small portion of medium-sized companies owned by sole proprietors, families, or small groups of entrepreneurs does exist. Due to compact sizing, no producer was classified as an industry or a large corporation. The main contrast was indicated by the number of direct jobs, whose estimation was about 3,700 workers for the whole studied sector, representing 1% of the overall Brazilian timber industry. Around 95% of timber housing producers are considered micro or small from a labor perspective. Unprecedented information could support discussions for the creation of assertive public policies.

economic size / employment / wooden construction / personal interviewing / sectoral research

Kivonat – A brazil faház termelő ágazat gazdasági és munkapiaci súlya. A brazíliai faház-termelőket félig strukturált kérdőív segítségével végzett személyes interjú alapján értékeltük. A kiterjedt kutatásokból kiindulva a jelen tanulmány célja e termelési ágazat munkapiaci helyzetének meghatározása és gazdasági súlyának jellemzése. A mintavételi eljárás során az összes gyártó (n = 210) 50,95%-át (n = 107) értékeltük, akiknek a teljesítményét az ideálishoz közelinek tekintettük. Ez a szektor leginkább a mikro- és kisvállalkozásokra koncentrálódik, de létezik néhány olyan közepes méretű vállalkozás, amely az egyéni vállalkozók, családok vagy kisvállalkozói csoportok tulajdonában van. Az egyezményes méretkategóriák szerinti osztályozás miatt egyetlen termelő sem minősül iparinak vagy nagyvállalatnak. A fő különbséget a közvetlen munkahelyek száma mutatta, amely a becslések szerint az egész tanulmányozott ágazatra vonatkozóan körülbelül 3700 munkavállalót jelent, ami a teljes brazil faipari ágazat 1%-át teszi ki. A faház-termelők mintegy 95%-át munkaerő szempontjából mikro-, vagy kisvállalkozásnak tekintik. A példa nélküli információk alkalmasak az érdekérvényesítő állami politikák létrehozására irányuló megbeszélések támogatására.

gazdasági méret / foglalkoztatottság / fa szerkezet / személyes interjú / ágazati kutatás

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1 INTRODUCTION

Most timber operations in the southern Mediterranean area of Italy are considered to be in an early stage of mechanization (Proto et al. 2018). Forest-based industries, especially the primary processing industries, have low yield and generate large amounts of waste (Barbosa et al. 2014). Several Brazilian sawmills share low levels of reliability due to the absence of dependable technology (Scanavaca Junior – Garcia 2004). Formerly, self-built housing production in Brazil was based on simple and immediate solutions that adhered to carpentry principles and knowledge (Zani 1997, 2013). Compared to the local forestry and sawing industries, Brazilian timber housing producers possess relatively new machines, which are visibly composed of compact solutions such as hand tools, portable equipment, and medium-sized machinery (De Araujo et al. 2018a). Though some large enterprises exist, small businesses form the bulk of the forest and civil construction industry due to the basic and/or rudimentary activities, specific operational focuses, and vast number of companies in the sector. These facts suggest most companies in the industry will remain small over time.

The volume of research focusing on large companies is greater than the research focusing on small companies. Nevertheless, several authors have discussed the strategic management peculiarities of micro and small companies, but unlike research into large companies, little action has been taken in empirical terms on the quantitive side (Santos et al. 2007). This scenario has been repeated in several Brazilian production sectors. This creates a demand for new studies focusing primarily on more elementary organizational characteristics. Small-scale forestry-based activities mean different things in different countries (Harrison et al. 2002). From economic and social perspectives, several timber production activities such as woodworking and sawmilling as well as some timber house production and furniture production could be classified as small scale.

This paper aims to characterize economic size as determined by the Brazilian government, and to quantify direct employees from the local timber housing sector. Thereby, two hypotheses were listed: many producers are economically self-declared as micro or small sized; and, compared to the whole timber industry, the studied sector has an almost imperceptible labor force comprising of only a few jobs per company.

1.1 Theoretical background

According to Lakatos (1990), every company can be classified as an economic activity complex developed under the control of a legal entity such as a natural person, a mercantile society, a cooperative, a non-profit private institution, or a public organization. Small and medium-sized companies could act as a maturation mean to large companies as well as executive and entrepreneurial laboratories, and opportunity and/or job generator (Kassai 1997). By means of a combination of economic indicators of the political and social character, the association of quantitative and qualitative criteria seems to allow for a more appropriate analysis for company categorization purposes (Pinheiro 1996).

According to Antonik – Muller (2016), there are two ways to classify a business, be it a commercial, service or industrial enterprise: annual gross income *(Table 1)* or labor force size *(Table 2)*. The authors also indicated that a combination of these criteria could be applied; company listing on a stock exchange is a good example of this. Brazil (1976) proclaimed law 6404, which summarizes those share-holding companies that could possess open or closed capital. Open society democratizes its capital by accepting a minimum number of shareholders appointed by the National Monetary Council from the Central Bank of Brazil (Requião 1968).

In contrast, closed-end companies do not access the capital market through stock listings, or through securities on the stock exchange, or over-the-counter market since the focus of closed-end companies concentrates on aspects such as size, societal and legal compositions, maturity, etc. (IBGC 2014).

Table 1. Business classification according to annual gross income

Size	Revenue (US$ million)*
Individual entrepreneur	< 0.015
Micro company	< 0.6
Small company	0.6 − 4.0
Medium company	4.0 − 22.5
Medium-to-large company	22.5 − 75.0
Large company	> 75.0

* Exchange rate: US$1.00 to R$4.00; Sources: Antonik – Muller (2016), Brazil (2006, 2016), BNDES (2015).

Table 2. Business classification according to the amount of direct employees

Size	Industrial (people)	Commercial and Services (people)
Micro company	< 19	< 9
Small company	20 − 99	10 − 49
Medium company	100 − 499	50 − 99
Large company	> 500	> 100

Sources: SEBRAE (2013), Antonik – Muller (2016).

Obtaining actual and updated annual gross income value from any company is a complex stage in the survey data collection process due to possible entrepreneur constraint in this disclosure. Conversely, analyzing company size through the number of employees provides a more accurate and interesting alternative that eliminates the delicate issue of disclosing income.

Furthermore, labor is currently considered the main organizational capital, especially considering that it is a basic unit of work, production, and development (Valizadeh – Ghahremani 2012) as well as a successful organization's main asset (Siqueira – Kurcgant 2012).

2 MATERIALS AND METHODS

2.1 Materials

According to De Araujo (2017) and De Araujo et al. (2018a,b), the indispensable materials utilized for this study were the timber housing producers themselves, bibliographic materials about relative topics, and a standard questionnaire. Though the outlay cost on displacements for personal interviewing was high, the overall cost for the research materials was low.

2.2 Survey method

Surveys are the best way to collect actual and real information to define and characterize any population through delimited samples. Roos et al. (2010), Kuzman – Grošelj (2012), Dobsinska – Sarvasova (2016), De Araujo (2017), Koppelhuber et al. (2017), De Araujo et al. (2018a,b) and other studies are good examples for the application of surveys on forest and timber industries.

The visible lack of information about the timber housing sector and its respective producers was verified, which was justified by few studies and the absence of associations (De Araujo 2017). Producer association is a controversial topic worldwide. Hrib et al. (2017) revealed a timely example of small-scale forest owners in the Czech Republic who are reluctant to join associations or form associations. In contrast, associative initiatives are available for timber housing producers in Lithuania (Medinių Namų Gamintojų Asociacija 2007), Estonia (Eesti Puitmajaliit 2009) and Spain (Asociación de Fabricantes y Constructores de Casas de Madera 2009), and include mostly small-scale companies. A discordance regarding Brazilian sectoral populations was noted in two singular studies. Sobral et al. (2002) listed about 15 timber housing producers from São Paulo State in 2001. However, in 2014, Punhagui (2014) estimated the prefabricated housing sector in Brazil consisted of 50 timber companies. Such inconsistencies reinforce the need for new sectoral analyses.

Thus, this present paper was specially produced from an unprecedented wide-scoped survey study by De Araujo (2017) with a focus on the analysis of timber housing production sector. Targeting of the timber housing sector was based on an overall comprehension of the current situation, and the characterization of its aspects and hindrances was used to generate updated information that could be applied for to new public policies that have been created to support sectoral demands and, consequently, the development of timber housing sector itself.

2.3 Questionnaire preparation for data collection

The general manager of this project (first author) and his advisor (last author) developed a standardized questionnaire to collect data for this study. In addition, several timber-forest chain professionals contributed by assisting with the query pre-test, refining, and validation processes. The third version of the questionnaire was approved; the general survey manager was the sole interviewer (De Araujo 2017).

The design of this paper focused on determining the economic and labor sizes of Brazilian timber housing producers in the studied sector. Two queries were prepared to investigate the real scenario. Closed answering was the applied strategy in both analyzed queries. The first question considered four responses according to main economic standards prescribed by Brazil (2006) and BNDES (2015). On the other hand, a second investigation included seven categories for employee number *(Table 3)*.

Table 3. Questionnaire for this approach on economic and labor sizing

Query	Response
How is your company characterized regarding economic size?	Micro company; small company; medium company; and large company
In total, how many employees does your company possess as direct hired job?	< 5; 6 − 9; 10 − 19; 20 − 29; 30 – 39; 40 − 49; > 50

Three direct employee estimates (minimum, average, and maximum) were also obtained for this studied sector from a second query, which was supported by the declared amounts from these ranges through the proportionality principle. According to Silva – Guerra (2011), this method consisted of linear functions to establish correlations for percentage dimensions and financial mathematics among other mathematical and related disciplines.

2.4. Result analysis of collected data

For a comparison of the obtained results in each query (Table 3), all qualitative responses were converted into percentages, whose mechanism, according to Gil (2008), offers a stringent sampling. Therefore, as prescribed by Miles and Huberman (1994), three triangulation modes were considered: analyses by distinct places, a wide population sampling, and a qualitative view through literature.

Margin of error was obtained from percentages whose calculation was supported by the statistical software "Raosoft Sample Size Calculator" available from Raosoft (2004).

Raosoft (2004) considered the establishment of two variables to an efficient approach; that is, a 95% confidence level and a 50% response distribution. If the sampling process is not poor in terms of data collection, then the survey research could be classified as ideal or acceptable by the obtained margin of error according to Pinheiro et al. (2011). If the obtained margin is within these two acceptable levels, the survey performance can be validated as suggested by De Araujo et al. (2018a,b).

3 RESULTS

3.1 Sectoral estimation and survey

Table 4 shows the total estimated population of the timber housing sector in Brazil, which was obtained through this research study and through De Araujo et al. (2018a, b) as well as the sampling performed here; the obtained margin of error of ±3.325% was calculated by Raosoft's online software. In addition, two efficient situations were pointed out from the sample amount based on Pinheiro et al. (2011); more specifically, ideal and acceptable levels of sampling.

Table 4. Analysis of sectoral population and survey sampling results

Result	Company (Unit)	Margin of Error (%)
Overall Sectoral Population*	210	–
Prescribed Acceptable Sampling**	66	10.00
Prescribed Ideal Sampling**	136	5.00
Interviewees' Sampling*	107	6.65

* Values from this study and De Araujo et al. (2018a,b); **Obtained values according to Pinheiro et al. (2011)

3.2 Economic sizing in the Brazilian timber housing sector

In the identification of the economic sizes of enterprises from the Brazilian timber housing production sector, about 80% (86 producers) of the studied samples are currently formed by micro and small producers whose margin of error ranged ±3.325%. In contrast, medium companies represented a fifth of the whole sampling. No large-sized company was identified in the sector *(Figure 1)*.

This fact proved the first mentioned hypothesis concerning a panorama broadly based on micro or small-sized producers *(Figure 1)*. Thereby, all studied samples were revealed to be compact businesses that were family-owned, sole proprietorships, or owned by a small group of entrepreneurs or microentrepreneurs.

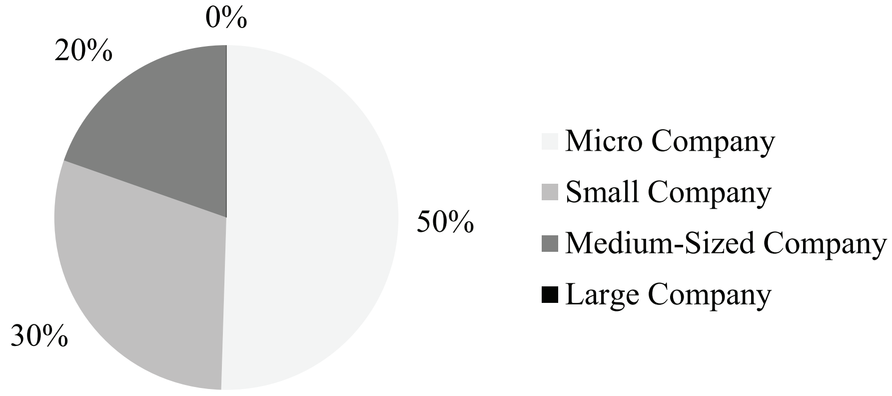

Figure 1. Economic size of Brazilian timber housing producers

3.3 Labor sizing in the Brazilian timber housing sector

Figure 2 shows the size categories according to direct jobs for the timber housing production sector in Brazil. Seven ranges were evaluated, and the results indicated that three-quarters of companies have hired fewer than 20 direct workers. Only one of the six companies that exceeded the limit of 50 direct workers had more than 100 workers. The remaining five producers hired fewer than 100 workers. This revealed that compact companies form the majority from the job perspective.

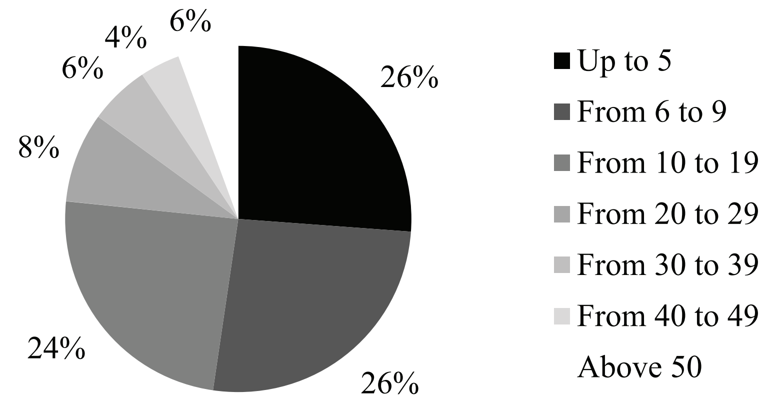

Figure 2. Direct job size of Brazilian timber housing producers

From the data in *Figure 2*, *Figure 3* identifies three population scenarios (maximum, average, and minimum) estimated for studied producer sampling (n = 107) and similar respective projections for the whole sector focused on timber housing production (n = 210).

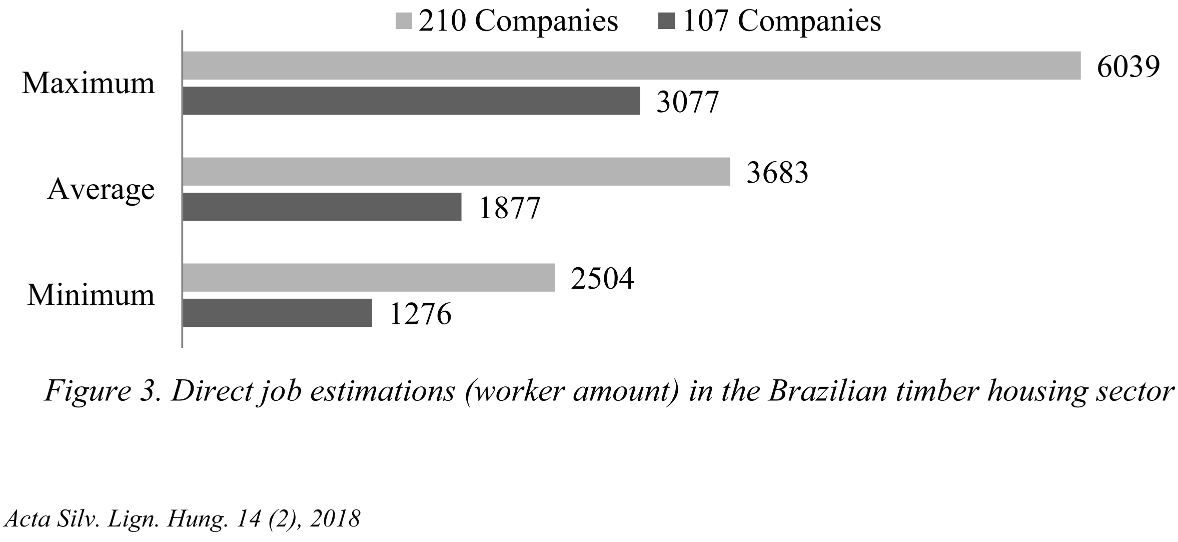

Figure 3. Direct job estimations (worker amount) in the Brazilian timber housing sector

4 DISCUSSION

4.1 Sectoral estimation and survey

Formerly, only a few studies focusing on the timber housing sector described the population of this sector – which was formed by 15 producers in São Paulo State (Sobral et al. 2002), and 50 producers in Brazil (Punhagui 2014). From the obtained overall estimated population for this sector *(Table 4)*, the current situation regarding producer listing differs extensively. Punhagui's study is both important and novel, but sectoral evaluation is not its main objective. In light of this, the present study challenges her initial listing by including 50 Brazilian companies. From statements made in De Araujo et al. (2018a,b), this refutation occurred because Punhagui's producer listing was visibly different from the one used in the present study; more to the point, Punhagui's listing was four times smaller than the overall estimated population and two times smaller than the sampling executed here.

Nearly 51% of the entire production sector – 107 of 210 companies – were evaluated in the data collection of the present study – *(Table 4)*. Six states – Santa Catarina, Rio Grande do Sul, Paraná, São Paulo, Minas Gerais, and Distrito Federal – from three Brazilian regions were considered in this survey. These facts successfully reinforced the obtained sampling in this study through triangulations that took different places and a wide population into consideration. Due to high performance costs, triangulation by the evaluation method was not possible, neither for other simultaneous interviewers, nor for the methodological analyses (De Araujo et al. 2018a,b).

According to Pinheiro et al. (2011), the margin of error obtained in this study revealed that the survey process *(Table 4)* was within the acceptable level of 10% and closer to the ideal of 5%. This performed sampling conforms to the literature as it is between two cited levels and is strictly closer than ideal. Therefore, this research can be efficiently statistically tested and validated.

4.2 Economic sizing in the Brazilian timber housing sector

The predominance of smaller enterprises in the civil construction industry has become the most widespread production mode in Brazil. Production simplification has ensured greater popularity of these smaller companies in Brazil, whereas according to Batista – Ghavami (2005), a large portion of houses are still built in conventional systems that are traditionally produced on the construction site.

This scenario is due to intrinsic factors within the Brazilian construction industry and its respective timber housing sector; these factors include unskilled and untrained labor, compact work teams, low investment, low industrialization levels, and rudimentary machines and tools (Ponce 1995, Lanier – Herman 1997, Shimbo – Ino 1997, Batista – Ghavami 2005, Thallon 2008, Alves 2012). As a result, these micro and small-sized producers contribute a considerable part of the income and employment generation throughout the country, which is the reason why the Brazilian government is working on implementing public policies to support and encourage the development of these small companies (Cunha et al. 2014). Such stimuluses have occurred even in those countries that are traditionally recognized for their timber utilization. Kuzman – Sandberg (2017) stated that promotion strategies to stimulate the increased use of timber in construction have been successfully applied in Sweden and Slovenia in an effort to develop sustainable housing, this despite the advanced stage of the industry in both respective countries. Luo et al. (2018) mentioned that Japan is also experiencing similar industrial development and government policy initiatives.

If compact companies continue to be the main timber house producers in Brazil *(Figure 1)*, the sector they occupy will be dissonant regarding the traditional construction industry, which is strongly based on masonry. The situation of small timber house producing companies is a direct contrast to the current civil construction scenario in which large corporations that monopolize and deteriorate the housing market are dominant. This fact is a result of the more inclusive and sustainable corporate view of the timber housing sector. Kuzman – Sandberg (2017) stated that high prefabrication, partnerships, and other factors could contribute to development of sustainable timber construction. In addition to such statements, the production efficiency and standardized quality provided by prefabricated timber houses will also guide strategies for timber house sectoral consolidation in the face of artisanal masonry.

4.3 Labor sizing in the Brazilian timber housing sector

The plural presence of small businesses could be observed from the perspective of direct job creation. About 95% of sampled companies individually self-declared a concentration of fewer than 50 jobs *(Figure 2)*. By means of classification from SEBRAE (2013) and Antonik – Muller (2016) *(Table 2)*, the studied producers were considered, for the most part, as micro- or small-sized examples.

Pulp and paper activities are present in 18 Brazilian states and provide around 115,000 direct jobs. From these, 68,000 jobs are industrial while 47,000 jobs are forest based (CNI 2012). In 2015, the segments of the Brazilian timber industry concentrating on panel, sawn wood, and pulp and paper directly employed around 540,000 workers (IBÁ 2016). Despite this highly visible job amount, the timber housing production sector was not declared nor counted in this projection. For this, simultaneous projections could be performed by local agencies to characterize this studied sector. Therefore, from average results *(Figure 3)*, there are 1,800 and 3,700 direct workers for sampled amount (n = 107 producers) and the whole sector (n = 210), respectively. The Brazilian timber housing sector can be considered small from a labor perspective since this sector maintains less than 1% of direct jobs in relation to the whole timber industry, which is about 150 times greater. This fact supports the veracity of last hypothesis. From the afformentioned results, the investigation of social and economics situations obtained by this survey, particularly about economic and labor sizes, became necessary, and revealed findings to support the entire wood chain of production in Brazil.

This focus is justified by Thomas-Seale et al. (2018), which verified the existence of the potential to economically target industrial and engineering context-specific development strategies. This survey could be applied for other countries' panoramas and industrial contexts such as studies from Bui et al. (2005), Hrib et al. (2017), Sekot (2017), etc.

5 CONCLUSIONS

Similar to the Brazilian civil construction industry, most business activities within the local timber housing sector is concentrated in micro or small companies despite a noticeable presence of medium-sized organizations. The main difference is the absence of large-sized producers in this studied sector. Maintenance of such a scenario could be very beneficial for this sector if more compact company sizes are maintained, which could allow greater production control and presence in smaller cities.

The establishment of partnerships between the compact organizations, through the possibility of greater production efficiency compared to conventional processes based on traditional artisanal masonry house production, can provide a consistent number of locally-produced timber houses. This strategy could be reached through social orientation to mitigate the current Brazilian housing deficit – about 6.2 million dwellings according to FIESP (2016) – without the dependence of large and monopolistic corporations focused on timber techniques, that is, contractors and/or constructors despite the non-existence of these, as was verified in this study for timber housing production.

With respect to labor size, the contrast is intensified, especially compared to the overall timber industry whose job amounts analyzed from projections is almost 150 times less than that of the whole timber chain, which includes a massive presence of pulp and paper, panels, and other timber companies.

Unprecedented sectoral information shared here could also serve as an effective instrument to support discussions for the creation of assertive public policies and inclusive to compact-size companies, aiming the development of this promising sector from Brazilian civil construction.

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Tending Cutting and Target Diameter Tables for Northern Red Oak (*Quercus rubra* L.) Stands in Hungary

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Abstract – In addition to black locust (*Robinia pseudoacacia* L.) and hybrid poplars, northern red oak (*Quercus rubra* L.) can be considered the third most important exotic stand-forming tree species in Hungary. Due to its advantageous silvicultural and growth characteristics, as well as its wood utilization possibilities, the present area northern red oak stands occupy in the country amount to 15 thousand hectares. This study presents a new, simplified tending cutting table for northern red oak stands as well as an age-target diameter table suitable for quality log production within a rotation period of generally 80–85 years. The simplicity of the practice-oriented tables based on a relevant yield table may further the qualitative development of northern red oak management and wood utilization.

Northern red oak / silviculture / management guideline / Hungary

Kivonat – Erdőnevelési és célátmérő táblák a magyarországi vörös tölgy (*Quercus rubra* L.) állományokra. A fehér akác (*Robinia pseudoacacia* L.) és a nemes nyárak mellett, Magyarországon a harmadik legjelentősebb exóta fafajnak tekinthetjük a vörös tölgyet (*Quercus rubra* L.). Köszönhetően előnyös erdőművelési és növekedési tulajdonságainak, valamint fahasznosítási lehetőségeinek, jelenleg az országban a vörös tölgy által elfoglalt terület nagysága 15 ezer hektárra tehető. Jelen tanulmány a vörös tölgy állományok új, egyszerűsített faállomány nevelési, valamint kor-célátmérő táblázatait közli a minőségi rönktermesztés figyelembe vételével, 80 – 85 éves átlagos vágásfordulóval. A releváns fatermési táblán alapuló, gyakorlat-orientált táblázatok egyszerűsége elősegítheti a vörös tölgy gazdálkodás és fahasznosítás minőségi fejlesztését.

vörös tölgy / erdőgazdálkodás / gazdálkodási irányelv / Magyarország

1 INTRODUCTION

Northern red oak (*Quercus rubra* L.) was introduced from North America to Europe in 1691 and currently covers over 350 thousand ha (Nicolescu et al. 2018). It appeared in Hungary in the middle of the 19th century and has adapted in large measure to site conditions in the country. Due to its advantageous silvicultural and yield characteristics, it now occupies an area of approximately 15 thousand hectares. The most important growing areas are in Baranya, Vas, Zala, Somogy and Szabolcs-Szatmár-Bereg counties (Járó 1957, Rédei et al. 2007).

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Northern red oak is a fast-growing species, and its seedlings and saplings emerge quickly from weed competition. During northern red oak tending operations, it is important to consider that its populations consist of varied genetic value specimens (genotypic), ranging from early to late flushing, and from more light-demanding to more shade-tolerant.

Northern red oak produces a well closings and favourably differentiated stand structures due to the great genetic diversity of individual trees (Szappanos – Nagy 1978, Rédei et al. 2010). Northern red oak utilizes the leaks of thinnings well. The individual selective method can be combined with frequent stem number reductions. Integrated systems of northern red oak silvicultural treatments have been not completely elaborated yet because very few northern red oak stands at final rotation age (at about 80-90 years) presently exist.

Advances in both research and practical experience have helped develop tending techniques for northern red oak. A grouping of forest silvicultural treatments to form a tending model can be made based on the results of long-term stand structure and forest yield trails. This greatly aids in the measuring, prescribing, and controlling of tending cuttings.

2 MATERIALS AND METHODS

The models we developed are based on our yield table for northern red oak of seed origin (Rédei et al. 2007). The table was created from data gathered from 100 experimental plots. The stands sampled were located from N 20°33' and E 48°00'. The main ecological characteristics of the sample plots region are the following: forest-steppe climate where the relative air humidity is between 50 and 55%; hydrology: free draining; dominant soil type: humus sand soil; annual precipitation varies between 500 and 550 mm. Stand ages varies from 5 to 70 years. Distribution of the measured stands by yield (site) class:

Yield class	Number of stands	Age group (years)	Number of stands
I.	35	5–10	12
II.	26	11–20	25
III.	12	21–30	28
IV.	11	31–40	13
V.	8	41–50	10
VI.	8	51–60	6
		61–	6

The key stand characteristics were measured during the tree stand surveys; major stand structure features such as average height, breast height diameter, volume, basal area, and stem number – given separately for the main, secondary and total crops per hectare – were all calculated based on the data collected (Laar – Akca 2007, Pretzsch 2009). A computer-based statistical programme (SPSS 2005) calculated the regression analyses.

The expected height values of the stands at the reference age (50 years) according to six yield classes are the following: 27.0 m, 24.6 m, 22.2 m, 19.8 m, 17.4 m, and 15.0 m. Based on the guide curve and the reference age (100%), a percentage value was calculated at any age and for any yield class. The yield table was constructed using the following formulae and coefficients (Rédei et al. 2007):

1. Stand age (A)
2. H_m = average height of stand (main crop) in m:
   $H_m = 1.19619 \times (1 - e^{-0.038963 \times A})^{1.16495}$
3. D_m = average stand DBH in cm:
   $D_m = 1.44498 + 0.47232 \times H_m + 0.02017 \times H_m^2$
   with $R^2 = 0.886$
4. V_m = stand volume in m^3 ha^{-1}
   $V_m = BA_m \times HF_m$, where
   HF_m = form-height quotient
   $HF_m = 2.27002 + 0.43222 \times H_m$
   with $R^2 = 0.923$
5. BA_m = stand basal area in m^2 ha^{-1}:
   $$BA_m = \frac{D_m^2 \times \pi}{4 \times 10000} \times N_m$$
6. N_m = stem number ha^{-1}
   $N_m = e^{9.80220 - 1.12607 \times \ln D_m}$
   with $R^2 = 0.826$

3 RESULTS

3.1 Simplified tending cutting table for northern red oak stands

Table 1 contains a tending cutting model for northern red oak stands. The table was compiled using data obtained from 100 long-term yield plots, of which 95 have had experimental interventions as well. The table presents the data in six yield classes. Tree height is an important factor because it determines the timing of a particular cleaning/thinning. The stem number quoted in the table is another basic parameter in the course of planning the interventions.

The optimum time to apply release treatments in young northern red oak stands is when the canopy begins to close, and to continue the treatments for about 10 years after canopy closure. The stand age at canopy closure varies with site quality. On higher quality sites, where relatively abundant resources accelerate stand development, canopy closure can occur at about 8 to 10 years. On poorer sites, where stand development is slower, canopy closure can occur somewhat later.

As northern red oak is a fast-growing species, *cleaning-respacing* (normally two interventions) in dense stands starts relatively early in order to preserve large canopies, but also to help the natural pruning of red oak trees. Stocking at the completion of cleaning-respacing (meandiameter ca. 9-12 cm) should not exceed 1,200-1,600 trees ha^{-1}. In general, a *negative selection* that removes undesired individuals, such as supressed and forked trees, from very dense areas is performed.

Commercial thinnings in northern red oak stands are *selective* all over Europe, and they should start before dominant height reaches 13-14 m (Nicolescu et al. 2018). The task of achieving high diameter growth rates for northern red oak trees can be fulfilled by the application of an intensive crop-tree silviculture utilizing positive selection that targets the free-growth state of final crop trees at the crown level. The final crop trees are selected based on the same vigour-quality-distribution criteria mentioned for cleaning. The crop tree number varies from 350 to 550 trees per hectare in the first four yield classes.

Table 1. Tending regimes for northern red oak stands

Timing of performed interventions (yrs)	Stand parameters after interventions were performed				
	Height (m)	DBH (cm)	Volume (m^3ha^{-1})	Stem number (ha)	Basal area (m^2ha^{-1})
Yield class I					
10	9	7	50	2000	4.3
20	16	14	140	930	9.3
35	23	22	280	530	16.3
50	27	29	370	400	21.7
65	29	34	405	350	24.7
80 (final cutting)	31	37	505	340	25.5
Yield class II					
10	8	6	40	2200	3.9
20	14	12	105	1100	7.9
35	21	19	215	620	14.0
50	25	26	315	480	18.0
65	27	30	350	420	20.6
80 (final cutting)	29	33	445	400	21.7
Yield class III					
10	7	6	40	2500	3.5
20	13	11	90	1200	7.2
30	17	16	160	820	10.6
45	21	21	240	600	14.4
60	24	24	260	510	17.0
75 (final cutting)	26	26	330	460	18.8
Yield class IV					
10	6	5	30	2800	3.1
20	12	10	80	1400	6.2
30	15	14	120	970	8.9
45	19	18	190	710	12.2
60	21	20	200	610	14.2
75 (final cutting)	23	22	260	560	15.5
Yield class V.					
10	6	5	30	3100	2.8
20	10	8	55	1600	5.4
35	15	13	115	1000	8.7
50	17	16	135	800	10.8
65 (final cutting)	19	18	190	720	12.0
Yield class VI					
10	5	5	30	3600	2.4
25	10	9	65	1600	5.4
40	14	12	105	1100	7.9
60 (final cutting)	16	15	135	920	9.4

Remarks: Data over 70 years are extrapolated.

3.2 Age, growing space, and target diameter table for northern red oak stands

As partly mentioned earlier, the timing for the expansion of the available growing space by maintaining the near optimal stem number and basal area per hectare is vital to attain the target assortments. Ecological site factors also essentially define the target assortments (Savill et al. 1997).

The data in *Table 2* show that an opportunity for the production of quality, sizeable logs is possible in northern red oak stands in yield classes I-III (DBH > 25 cm). In yield class IV, the 20 cm-target diameter can only be expected when the stand reaches the age of 60 years. Depending on the yield class, the sustainable stem number varies from 390 to 620 stems per hectare.

Table 2 also illustrates that stands of yield classes V and VI are suitable for the production of mass assortments (cutting, pallet, box basic material, pulp, fibre, chippings, and basic wooden board materials). However, the stands characterised by these two lowest yield classes are usually loss producing, and are thus unsuitable for plantation forest management.

Table 2. Age-target diameter table for northern red oak stands

Planned target diameter (DBH) (cm)	Factors			
	Yield class	Years required to each target diameter	Crop trees number (ha^{-1})	Basal area (m^2ha^{-1})
30	I	55	390 ± 5%	28 ± 5%
30	II	70		
25	I	40	480 ± 5%	24±5%
25	II	50		
25	III	70		
20	I	30	620 ± 5%	19 ± 5%
20	II	35		
20	III	45		
20	IV	60		
15	I	22	860 ± 5%	15 ± 5%
15	II	25		
15	III	29		
15	IV	35		
15	V	45		
15	VI	70		

4 CONCLUSIONS

Q. rubra was first brought to Europe in the 17th century primarily for ornamental purposes and out of botanical curiosity. Northern oak is quite common as it was planted in numerous botanical and residential gardens and was used as a roadside tree. Towards the end of the 18^{th} century, European foresters recognized the successful acclimatisation, large ecological amplitude, fast growth, and suitable wood properties of this tree species, all of which initiated its widespread introduction into timber forests. At present, *Q. rubra* is a commercially important tree and one of the most frequent deciduous species of foreign origin found in European forests. *Q. rubra* is an important source of hardwood timber for the wood industry. Northern red oak produces a close-grained, heavy, and hard wood that can be used in a broad range of applications, while its high fuel value makes it an excellent firewood as well.

As the present study demonstrates, the number of crop trees released within northern red oak stands varies depending on site quality, species composition, stand age, and management objectives. Total volume production per unit area between thinned and unthinned stands does not differ greatly.

In recent decades, growth models for different tree species based on stand level data have gradually been replaced by stand growth models predicated on stem number frequencies and individual tree growth models (Pretzsch 2009). Nevertheless, traditional silvicultural models will remain very useful tools for forest management and forest inventory. The published tables can be widely used in northern red oak management and inventory tasks including harvest scheduling, growth analysis, and volume estimates. The tables can also serve the further development of silvicultural (thinnings) models and the development of guidelines for local policies promoting plantation forestry.

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Carbon Footprint of Different Harvesting Work Systems in Short Rotation Energy Plantations

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Abstract – Almost half of the total area of Hungary is arable land. Nearly one-third of this area is poor-quality arable land where agriculture would be uneconomical. Energy plantations can be grown extremely well on poor-quality land. Currently, the carbon neutrality of wood as a raw material must also be justified, considering several factors. Environmental life cycle assessment (LCA) was developed as a tool for sustainable, decision-supporting, environmental management, which is an outstanding tool for the well-established analysis of environmental impacts, although the application of it in forestry remained a challenge for the LCA community. No sector specific LCA and life cycle inventory methodology has been developed in forestry; thus, implementing such a methodology remains a big challenge. Calculated on a common functional unit (100 m^3/ha wood chips, 100% energy purpose), we have performed a comparative environmental life cycle assessment for harvesting technologies of short rotation energy plantations (technology related to stands of 3 ha of poplar, 5–10 ha of willow, 20 ha of willow), specifically for the third year harvesting work system. Research results on global warming potential show the carbon footprint of harvesting work systems, the knowledge of which has a strong influence on the environmental consideration of raw material (wood chips) and also on the more precise definition of carbon sequestration capacity. The typical values of carbon balance ratio (1.37–1.46) indicate a positive carbon sequestration potential and a magnitude well within the system boundaries of the third year harvesting work system submodule. The results obtained enable the estimation and prediction of environmental impacts for the whole lifecycle of the plantation.

environmental life cycle assessment / carbon footprint / harvesting technologies / global warming potential

Kivonat – Rövid vágásfordulójú energia ültetvények betakarítási munkarendszer változatainak szénlábnyoma. Az ország összterületének közel fele szántóföld, melynek közel harmada rossz minőségű szántó, ahol a mezőgazdasági művelés gazdaságtalan. Az energetikai ültetvények a rossz minőségű szántókon kiválóan nevelhetők. A fa, mint nyersanyag szénsemlegessége napjainkban is igazolásra szorul, megannyi tényező figyelembe vételével. A környezeti életciklus-elemzést (LCA) fenntarthatósági, döntéstámogató környezetmenedzsment eszköznek fejlesztették ki, mely kiváló eszköze a környezeti hatások megalapozott vizsgálatának, azonban az erdészeti alkalmazása máig kihívást jelent az LCA közösség számára. Az erdészeti szektorban nincs ágazatspecifikusan kifejlesztett LCA és leltáradat gyűjtési módszertan, melynek megalkotása a legnagyobb kihívások egyike. Kutatásunkban közös funkcionális egységre vetítve (100 m^3/ha apríték, 100%-ban energetikai cél), a rövid vágásfordulójú energiaültetvény betakarítási technológiák (3 ha nyár, 5-10 ha fűz, 20 ha fűz állományhoz tartozó technológia) összehasonlító életciklus-elemzésére vállalkoztunk, kifejezetten a 3. éves betakarítási munkarendszer esetén. A globális felmelegedési potenciál eredmények

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rávilágítanak a betakarítási munkarendszerek szénlábnyomára, mely ismerete nagyban befolyásolja a nyersanyag (faapríték) környezeti megítélését, valamint a szénmegkötési potenciál pontosabb meghatározását. A szénmérleg viszonyszámának egyes értékei (1,37–1,46) jól mutatják, a 3. éves betakarítási munkarendszer szubmodul rendszerhatárain belül tapasztalt pozitív szénmegkötési potenciált és a nagyságrendet. A kapott eredményekből becsülhetők és előrevetíthetők az ültetvény teljes élettartamának környezeti hatásai.

életciklus-elemzés / szénlábnyom / betakarítási technológia / globális felmelegedési potenciál

1 INTRODUCTION

1.1 Life cycle assessment as a decision support tool

There is broad consensus that we must explore and implement methods to minimize resource use in economic and industrial processes while simultaneously reducing the environmental impacts of emissions and waste to near zero. Environmentally sound technologies were identified as a key element to achieving this long-term goal (Heinimann 2012).

In addition to other methods, the environmental life cycle approach, developed from the beginning of the 1990s, is an approach that is able to consider environmental impacts in the whole life cycle of a product or product system from "the cradle to the grave" rather than in one stage only. The bases of this modelling are process approach, environmental inventory, and the application of a specifically developed indicator system. Environmental life cycle assessment (LCA) was developed as a tool for sustainable, decision-supporting, environmental management (ISO 2006a), which is an outstanding tool for the well-established analysis of environmental impacts.

According to Erkman (1997), the concept of industrial ecology encompasses these assessment methods. This aspect scrutinizes industrial systems the same way that ecologists scrutinize ecosystems. The key issues are to model industrial metabolism, map the material and energy flows, and continuously develop environmental performance (Heinimann 2012).

An increasing number of databases and information systems to describe the state of the environment and to trace the environmental impact of individual companies have continuously been created to achieve set environmental protection objectives (Elekné Fodor – Pájer 2017).

Due to their differing intensities, the economic sphere and its open technological processes have dissimilar environmental impacts. Consequently, global environmental problems may occur in different ways due to their corresponding material and energy withdrawals and emissions. An environmental analysis of the technologies through the process and life cycle approach allows for both a detailed analysis and the defining of the contribution to climate change. Changes in the characteristics of environmental elements and systems caused by human activities is called environmental impact. In addition to the changes in growing conditions caused by cultivation techniques and the effects of land cover, the specific environmental aspects of each technology in land uses have to be taken into account. We believe the environmental analysis of technological aspects related to forest use may be an important supplement to current climate research (Polgár et al. 2014). The evaluation of environmental impacts aims to express the significance of the change and, concurrently, prepare development actions and decisions (Polgár – Pájer 2014).

1.2 Life cycle assessment in the forestry sector

Rumpf et al. (2016) states that recognizing the importance of atmospheric carbon sequestration puts forestry in a favourable position. In addition to being nearly carbon neutral, forest management is the only economic activity that allows for the sustained removal of significant amounts of carbon from the atmosphere.

Currently, the carbon neutrality of wood as a raw material must also be justified, taking several factors into account (Klein et al. 2015).

The application of life cycle assessment in forestry has remained a challenge for the LCA community.

Heinimann (2012) and Klein et al. (2015) fully review over twenty years of LCA forestry practice in their work.

The concept of industrial ecology can be traced back to outstanding scholars. The work of Robert Ayres (Ayres – Kneese 1969), Charles Hall (Hall et al. 1979) and Howard T. Odum (Odum et al. 1977) encouraged Professor Ulf Sundberg to carry out preliminary energy analyses regarding forest operations (Sundberg – Svanqvist 1987).

Sundberg (1982) suggests that fuel consumption costs are a key factor in the determination of forest machine operations. Forestry has become completely mechanized, with truck roads, forwarders, and skidders replacing horse-drawn hauling. Berg (1995) stated that the bulk of environmental impacts from forestry operations originates from the significant amounts of fossil fuel required to operate machinery.

Long distance transportation and forest road infrastructure account for about two-thirds of the total impact for typical forest productivity systems (Heinimann – Maeda-Inaba 2004).

Based on the calculations of greenhouse gas (GHG) emissions and energy cycles in the life cycle of wood products, Frühwald – Wegener (1993) concluded that wood could substitute more energy intensive materials possessing higher GHG-burdened footprints during their production and end-of-life stages. Additionally, emissions from fossil resources could be avoided when wood is burned at the end of its life cycle (Frühwald – Wegener 1993).

According to Frühwald (1995), no sector specific LCA and life cycle inventory (LCI) methodology has been developed in the forestry sphere; thus, implementing such a methodology remains a big challenge. According to Heinimann (2012) and Klein et al. (2015), there are currently no significant changes.

Applying sector-LCA in order to achieve both internal (comparative) and external (efficiency enhancing) benefits is a priority according to Frühwald (1995).

Thoroe – Schweinle (1995) developed a proposal for a standard forestry life cycle model that could serve as a basis for LCA application in forestry.

Based on the review of several LCA studies, Klein et al. (2015) established that great differences existed in the methodological assumptions and their subsequent results. These studies focused on the values of global warming potential (GWP). The term "carbon neutral" is often affixed to raw wood; we propose this term be refined to "low-emission raw material" based on the observed values of GWP (excluding cases where the long-term in situ carbon loss caused by the negative impact of changes in forestry or in the direct or indirect land use).

The surveys examined by the authors focused on spruce, pine, and Douglas fir. Beech, which is an important hardwood in Central Europe, has not yet appeared in European studies.

Due to the favourable ecological environment, "ligneous" biomass has great potential in Hungary. White willow *(Salix alba)* and hybrid poplar *(Populus x euramericana)* can attain higher production, but harvesting technologies have a significant impact on the efficiency of plantations (Dobos et al. 2006).

The model of Klein et al. (2015) represents the basis of life cycle assessment in forest production and creates a proposal for the raw wood process chain.

Raw wood products commonly serve as the base material for other final products; thus, the ecological impacts of raw wood in the forest production system are recognised as only a portion of the total impact. A Belgian study confirmed that despite the relatively low yields, the investigated system on degraded land reached a positive energy balance and can produce 7.9 times more energy than it consumed during rotation (Dillen et al. 2013).

Kim et al. (2016) examined the impact of thinning on the carbon storage of dead organic matter in larch and oak stands. Tellnes et al. (2017) conducted examinations according to carbon footprint calculations of wooden products.

After studying the relevant literature, we can highlight the necessity of a comparative LCA study to fill research gaps, thereby enabling a deeper understanding of the environmental impacts of the harvesting work systems in short rotation energy plantations.

Our goal was to answer the following main research question: what are the typical environmental impacts in short rotation energy plantations of a specific cutting age? Our study objective was to perform a comparative environmental life cycle assessment for the harvesting technologies of short rotation energy plantations (technology related to stands of 3 ha of poplar, 5-10 ha of willow, 20 ha of willow), specifically for the third year (first harvest period) harvesting work system, calculated on a common functional unit (100 m^3/ha wood chips, 100% energy purpose). Global warming potential (GWP) should show the carbon footprint of harvesting work systems, the knowledge of which has a strong influence on the environmental consideration of raw material (wood chips) and on the more precise definition of carbon sequestration capacity. The results obtained in the third year enable the estimation and prediction of environmental impacts for the whole lifecycle of the typical plantation.

2 MATERIALS AND METHODS

We carried out our fieldwork in short rotation hybrid poplar and willow energy plantations in Hungary, which were planted in single or twin rows. We separated the harvesting work systems of plantations based on the categories of the area, which are the following: large (above 20 ha), medium (5 to 10 ha) and small (below 3 ha).

The plantations are harvested 3 to 5 times by a return period of 3 to 5 years depending on site conditions and tree species. The goal of our study was to determine the common resulting environmental impacts of the harvesting work system in the cutting age of 3 years by using the life cycle assessment method.

In our study, we analysed the most ideal conditions of mechanisation. A wide range of other applicable solutions besides the work systems described below exists for the three area categories.

Short rotation energy plantation of 20 ha or more:
In the case of large plantation areas, the application of high performance machines is more favourable economically. A single machine, the so-called self-propelled walking chipper, executes the felling of individual trees of the plantation (felling), places the felled trees into a chipping chamber, chips the felled trees, and loads the wood chips onto the forwarder. Delivery equipment, more specifically tractors and trailers, forward the wood chips onto the loader and complete the unloading (dumping). A front loader then loads the wood chips onto the transporting truck (tractor with semi-trailer) *(Figure 1-2)*.

Figure 1-2. Large-plantation harvesting technology for a plantation of 20 ha or more (Photo: Vinkovics, S., Horváth, A. L.)

Short rotation energy plantation of 5-10 ha

Self-propelled walking chippers are not economically viable for the harvesting of medium plantations. In this case, it is better to apply a walking chipper that can be connected to a power tool as an adapter. In this way, the basic machine can also be used for other functions in addition to harvesting operations. The felling, chipping, and loading onto the forwarder all occur within a single operation in this case. As mentioned in the previous category, a tractor-trailer combination also completes the forwarding here, while a crane truck loads and transports the wood chips. *(Figure 3-4)*.

Figure 3-4. Medium-plantation harvesting technology for a plantation of 5-10 ha (Photo: Vinkovics, S., Horváth, A. L.)

Short rotation energy plantation below 3 ha

In the case of small energy plantations, manual power tools and low-power machines are optimal. A motor chainsaw or clearing saw is appropriate to fell individual trees. A mobile chipper operated by a crane power tool can carry out wood chipping for trees felled in the same direction. Once again, a tractor with a trailer is the most suitable machine to forward wood chips. A crane truck is the most effective equipment for loading and transport *(Figure 5-6)*.

Figure 5-6. Small-plantation harvesting technology for a plantation below 3 ha (Photo: Röchricht, H., Horváth, A. L.)

The methodology applied corresponds to the requirements of the ISO 14040:2006 (ISO 2006a) and ISO 14044:2006 (ISO 2006b) standards. The analysis was completed using GaBi thinkstep software (GaBi thinkstep 2018). We focused on the carbon footprint (GWP 100 years) from impact assessment results. Describing the climate change contribution by analysing the technological carbon footprint (GWP) helps to understand the environmental impact of raw wood products (wood chips).

Interpretation of carbon footprint

The carbon footprint (considered greenhouse gas emissions to air only) resulting from harvesting technologies should be interpreted as an absolute value in our studies (hereinafter referred to as carbon footprint) because of the contained fossil CO_2 emissions and also the amount of biotic-origin (neutral) CO_2 emissions resulting from the firing of typical amounts of wood chips (absolute dry).

This explanation of this carbon footprint is justified because the first commitment period of the Kyoto Protocol had not yet permitted the consideration of harvesting for industrial use as carbon capture; instead, all types of harvesting needed to be considered collectively as carbon emissions (Führer – Mátyás 2005). However, progress was made in the second commitment period of the protocol, and the carbon storage function of wood products can now be included in calculations (Frieden et al. 2012). In our case, the timber is 100% utilized as wood chips for energy purposes; therefore, the above interpretation and the carbon storage function of wood products are irrelevant.

In addition, the burning of firewood has a solid ash output as well, which must be considered as a carbon pool in our system.

Breeding and selection for SRC (Short Rotation Coppice) are complex; exceeding the fast growth rates is not the only aim. The main goal of the current study is to quantify the amount of CO_2 emitted for a certain amount of energy generated. The next step is to compare the amount of CO_2 emitted to generate the same amount of energy from a non-renewable source. The final step is the calculation of a whole LCA for harvesting

3 STEPS OF THE LCA

Corresponding to the ISO 14040:2006 standard (ISO 2006a), we followed the main steps of LCA: goal and scope definition; life cycle inventory analysis; impact assessment and interpretation.

3.1 Goal and scope definition

We conducted assessments in one-row or twin-row planting short rotation energy plantations (willow and poplar).

Goal

We performed the comparative life cycle assessment (LCA) for the studied harvesting work system technologies at the cutting age of 3 years in order to rank them based on carbon footprint (CF-carbon footprint/carbon profile). By the LCA method, we have performed the environmental impact assessment concerning the studied technologies.

System boundaries

The system boundaries determined in technologies: work in felling area – forest and road transport - firing of wood chips (energy goal).

We considered the environmental impacts of fuel and lubricating oil production in our model. The total amount of harvested wood will be used as wood chips for energy goals.

Further use of wood is not included in the studies. In addition, the environmental parameters in the production of machines and tools necessary in the technologies, the impacts of building forest roads, and changes in land use are also not included in the analysis.

Processes involved

In the case of short rotation energy plantations (willow and poplar stands): felling (in 3 ha poplar stand only); chipping with chipper (in 3 ha poplar stand only)/mobile chipper; forwarding, loading with crane truck / with front loader (in 20 ha poplar or willow stand only) + transport with crane truck / with trailer truck (in 20 ha poplar or willow stand only) + unloading with crane truck; firing of wood chips (absolute dry, energy goal.

The transport distance was considered uniformly as 40 tonne kilometre [tkm].

Functional unit and reference flow

As a functional unit, 1 ha of stand affected by technology was considered by the harvesting life cycle. As reference flow 100 m^3 of standing wood before cutting (100% energy goal) per 1 ha was considered.

3.2 Life cycle inventory analysis

We established an environmental inventory database (input- output, elementary flow) for the examined optimum technologies. We also worked with standard data, which often contains errors; nevertheless, their application was indispensable for the analysis.

The data reference period was the winter of 2015/2016. The geographical validity of the data is national. The data sources stem from our own data, expert estimations, and published data.

We have established the typical ecobalance for each stand (based on data from verified experts). Thereafter, we prepared the life cycle model of the examined technologies.

3.3 Impact assessment and interpretation

The methodology steps of the impact assessment are described in the ISO 14044:2006 (ISO 2006b) standard.

According to Simon (2012), the CML 2001 (Guinée et al. 2002) characterization factor for the major emissions of "GWP 100 years" is well suited to the IPCC 2007 study. The method is suitable for carbon footprint (CF) calculations.

We verified the results of life cycle inventory and impact assessment in the last phase of the LCA; furthermore, we established our conclusions. We focused on the carbon footprint.

We displayed the percent values of life cycle contribution of each impact category. Based on the values obtained, we set up the increasing environmental ranking of technologies. This resulted in the carbon footprint environmental impact assessment related to the technologies.

In order to normalize the carbon footprint values for the carbon sequestration of timber, we set up stand-specific ratios.

4 RESULTS

4.1 Inventory analysis

According to the processes, we have summarized the data of both the input and output sides in tabular form *(Table 1)*.

Table 1. Total input and output environmental inventory data of harvesting work systems per 1 ha of short rotation energy plantations in 2015-2016, winter in the third-year stand age per 100 m^3 standing wood for cutting (Hungary)

Parameter	Unit	Harvesting work system		
		3 ha > hybrid poplar stand	5–10 ha hybrid poplar or willow stand	20 ha < hybrid poplar or willow stand
Input				
Fuel	kg	592	558	225
Lubricating oil	kg	55	31	18
Output				
CO_2 emission from fuel	kg	1,870	1,740	697
CO_2 emission from firewood and slash burning	kg	58,903	59,800	59,800
Total CO_2 emission	kg	60,773	61,541	60,497
Waste oil (recycled)	kg	46	31	17

We considered the data in the reference period of 2015–2016, winter in the third-year stand age per 100 m^3 standing wood for cutting (Hungary).

On the input side, fuel need and the use of lubricating oil for the machines are significant, while on the output side, the emission of CO_2 and waste sump oil (recycled) turned out to be significant. In our case, the timber is 100% utilized as wood chips for energy purposes. We considered the CO_2 emissions from fuel and from firewood and slash burning as well. The amount of CO_2 emissions from firewood and slash burning is nearly three times higher than the amount of CO_2 emission from fuel.

4.2 Impact assessment

In the following *(Table 2)*, we focused exclusively on the results of the CML 2001 (April 2015) method being sufficient for characterization.

Table 2. Profile of environmental impacts of work systems by impact categories of CML 2001 (April 2015)

CML2001 (April 2015) Impact Categories	Harvesting work system		
	3 ha > hybrid poplar stand	5–10 ha hybrid poplar or willow stand	20 ha < hybrid poplar or willow stand
Abiotic Depletion (ADP elements) [kg Sb-Equiv.]	1.15E-04	1.05E-04	4.32E-05
Abiotic Depletion (ADP fossil) [MJ]	30,853.98	28,031.50	11,568.25
Acidification Potential (AP) [kg SO_2-Equiv.]	1.96	1.78	0.74
Eutrophication Potential (EP) [kg Phosphate-Equiv.]	0.58	0.54	0.22
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB-Equiv.]	20.14	18.58	7.59
Global Warming Potential (GWP 100 years) [kg CO_2-Equiv.]	61,003.29	61,735.45	60,581.02
Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO_2-Equiv.]	61,145.29	61,869.36	60,635.01
Human Toxicity Potential (HTP inf.) [kg DCB-Equiv.]	86.71	79.77	32.66
Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB-Equiv.]	37,045.95	33,506.34	13,867.13
Ozone Layer Depletion Potential (ODP, steady state) [kg R11-Equiv.]	3.23E-09	2.78E-09	1.19E-09
Photochem. Ozone Creation Potential (POCP) [kg Ethene-Equiv.]	0.23	0.22	0.09
Terrestrial Ecotoxicity Potential (TETP inf.) [kg DCB-Equiv.]	28.29	26.66	10.75

Work systems had the greatest impact on global warming (GWP 100 years) throughout their life cycle. This can be explained by the amount of carbon dioxide the technologies released into the atmosphere from the fuel used. Significant impact categories emerged, namely the abiotic depletion potential (ADP foss) as well as the marine aquatic ecotoxicity potential (MAETP). These categories can be explained by the contribution of fuel and lubricant inputs.

According to the system boundaries, we did not get any significant effects in the impact categories of acidification potential (AP), eutrophication potential (EP), freshwater aquatic ecotoxicity potential (FAETP inf.), human toxicity potential (HTP inf.), photochemical ozone creation potential (POCP) and terrestrial ecotoxicity potential (TETP inf.).

4.3 Impact interpretation. Carbon footprint calculation. Technology ranking, impact rating of technologies

Based on the carbon footprint impact category, we set up a technology ranking to attain the environmental impact rating of technologies based on absolute carbon footprint. The ranking is presented in the below table *(Table 3)*.

Among the examined system boundaries, we demonstrate the carbon footprint development according to the CML2001 method.

Table 3. Life cycle contribution (%) and carbon footprint-based (absolute, incl. biotic CO_2) ranking of the certain harvesting technologies. Life cycle contribution of certain harvesting work systems according to the carbon footprint (absolute, incl. biotic CO_2) of the wood fired and the technological processes (per 100 m^3/ha stand in Hungary)

Carbon footprint (CF)	Harvesting work system		Whole technology rotation carbon footprint		Burning of wood chips (incl biological) carbon footprint		Technological processes carbon footprint	
		%	[kg CO_2-Equiv.], biotic+fossil	%	[kg CO_2-Equiv.], biotic	%	[kg CO_2-Equiv.], fossil	%
CML2001 - Apr. 2015,	20 ha< poplar or willow	33	60,581	100	59,800	99	781	1
Global Warming Potential	3 ha> poplar	33	61,003	100	58,903	97	2,100	3
(GWP 100 years) [kg CO_2-Equiv.]	5-10 ha poplar or willow	34	61,735	100	59,800	97	1,935	3

In the final result, short rotation energy plantations presented almost equal absolute carbon footprint values, regardless of the different technologies applied in the typical stands.

Carbon footprint-based ranking of harvesting work systems:

- On the basis of absolute carbon footprint (considered fossil and biotic origin together), the ranking of harvesting work systems is the following: “20 ha < poplar or willow (33%) – 3 ha > poplar (33 %) – 5-10 ha poplar or willow (34%)”.
- Based on absolute carbon footprint, the ranking of technologies in the whole technology rotation is the following: “20 ha < poplar or willow (60,581) – 3 ha > poplar (61,003) – 5-10 ha poplar or willow (61,735)” (in the values of GWP 100 years [kg CO_2-Equiv.]).
- When considering the clearly fossil carbon footprint of technological processes, the ranking of “20 ha < poplar or willow (781) – 5-10 ha poplar or willow (1,935) – 3 ha > poplar (2,100)” (in the values of GWP 100 years [kg CO_2-Equiv.]) resulted.

CO_2 emissions of biotic origin resulting from wood firing has a major influence on the carbon footprint of total life cycle (97-99%), and the same ranking of stands can be observed in every case.

The following figure illustrates the contribution of processes to CO_2 emissions in fossil dimension *(Figure 7)*.

In the 3 ha> poplar and in the 5-10 ha poplar or willow stands we found that 20-30% of fossil CO_2 emissions are caused by the work in the felling area, while 70-80% are due to the loading, transport, and unloading of wood. In the technology processes of the 20 ha< poplar stand the distribution is 50-50%.

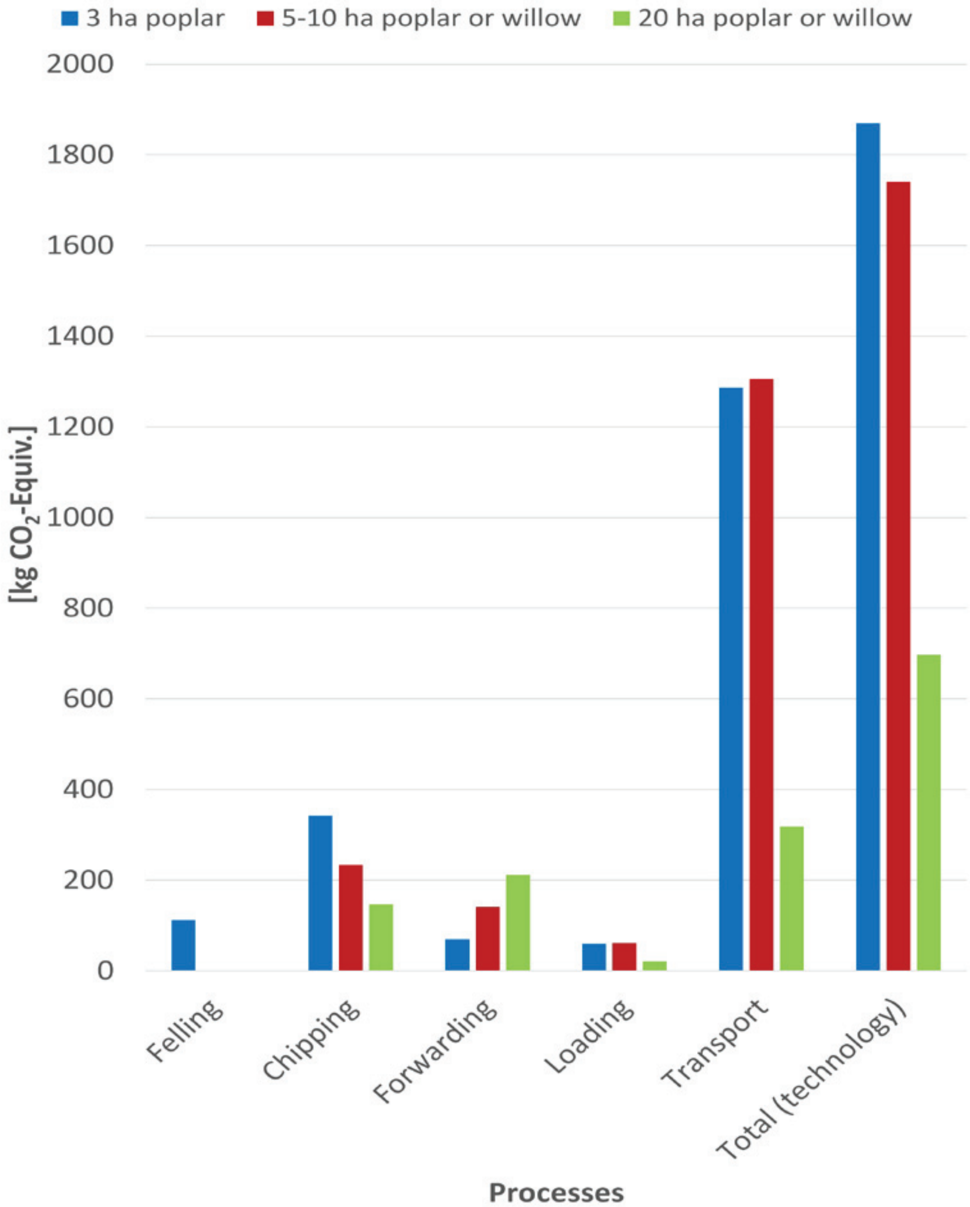

Figure 7. Contribution of processes to CO_2 emissions in fossil dimension of carbon footprint

In order to normalize the carbon footprint values *(Table 3)* for the carbon sequestration of timber, we set up stand-specific ratios *(Table 4)*. Based on the amount of cut wood at the cutting age of 3 years, the appropriate carbon footprint values [kg CO_2-Equiv.] were related to the carbon-dioxide need sequestered from the atmosphere [kg CO_2/ha] (Buzás 2005) according to the carbon storage of this wood amount typical for the different tree species (Vadász 1924, Ákos 1964). By these means, we have given the carbon sequestration potential.

Table 4. Life cycle contribution of certain harvesting work systems according to the carbon footprint (absolute, incl. biotic CO_2) of the wood chips fired and the technological processes vs. carbon sequestration of cut wood according to the whole technological rotation

Carbon footprint (CF)	Harvesting work system	Standing wood for cutting in the whole technology rotation [m^3/ha]	A	A/B	A/C	A/D
CML2001 - Apr. 2015, Global Warming Potential (GWP 100 years) [kg CO_2-Equiv.]	20 ha< poplar or willow	100	88,476	1.46	1.48	113.28
	3 ha> poplar	100	83,743	1.37	1.42	39.87
	5-10 ha poplar or willow	100	88,476	1.43	1.48	45.71

Abbrev.: A-CO_2 need from the atmosphere sequestered by the stand (cut wood) (Buzás 2005) necessary for the carbon storage of the given tree species (Vadász 1924, Ákos 1964) [kg CO_2/ha]; B-Whole technology rotation carbon footprint *(Table 3)* [kg CO_2-Equiv.]; C-Burning and biological burning of firewood and slash carbon footprint *(Table 3)* [kg CO_2-Equiv.]; D-Technological processes carbon footprint *(Table 3)* [kg CO_2-Equiv.]

The development of the ratio is between 1.37-1.48 for the carbon footprint for all of the technology (absolute carbon footprint) and the burning of wood chips (biotic dimension): "3 ha > poplar (1.37) – 5-10 ha poplar or willow (1.43) – 20 ha< poplar or willow (1.46)".

This ratio was 39.87-113.28 for the carbon footprint of technological processes (fossil dimension): „3 ha > poplar (39.87) – 5-10 ha poplar or willow (45.71) – 20 ha < poplar or willow (113.28)".

In the system boundaries of the harvesting life cycle stage at the cutting age of 3 years, the ratio values indicate the positive carbon sequestration potential and magnitude well, experienced both in absolute value and by dimension.

It should be emphasized that the burning of firewood has a solid ash output as well, which must be considered as a carbon pool of the system. Ash is largely responsible for the above-mentioned positive characteristic of the carbon sequestration of the system.

At the forest production stage of the raw wood process chain, our estimate verifies the statement of Klein et al. (2015), according to which wood is a low-emission raw material. Based on the environmental impacts studied at this harvesting stage, the positive carbon sequestration potential of the whole life cycle can be premised relative to the ratios.

Within the examined system boundaries, the environmental indicators are more favourable in the case of harvesting work systems related to the larger area category than to work systems related to the small area category.

5 DISCUSSION AND CONCLUSIONS

Applying sector-LCA in order to achieve both internal (comparative) and external (efficiency enhancing) benefits is a priority. After studying the relevant literature, we can highlight the necessity of a comparative LCA study to fill research gaps, thereby enabling a deeper understanding of the environmental impacts on short rotation energy plantations. Calculated on a common functional unit (1 ha), we have performed a comparative environmental life cycle assessment for harvesting work systems at the cutting age of 3 years in plantations: large: 20 ha< poplar or willow; medium: 5-10 ha poplar or willow; small: 3 ha> poplar.

We compared and ranked the optimum harvesting technologies at the cutting age of 3 years in the different area-based categories from an environmental perspective based on their carbon footprints.

We created an optimum environmental inventory database typical for the stands according to harvesting work system at the cutting age of 3 years life cycle stage. On the input side, fuel need and the use of lubricating oil for the machines are considerable, while on the output side, the emission of CO_2 and waste sump oil (recycled) turned out to be significant.

We found that felling area work causes 30-40% of fossil CO_2 emissions, while the remaining 60-70% are due to the loading, transport, and unloading of wood.

We built up the life cycle models of technologies using GaBi thinkstep software and, subsequently, we performed impact assessments. The technologies used in forestry had the largest contribution to the impact category of global warming (GWP). Significant impact categories emerged, namely the abiotic depletion potential (ADP foss) as well as the marine aquatic ecotoxicity potential (MAETP).

Based on their carbon footprint, we compared and ranked the typical harvesting technologies in terms of environmental impact, according to the whole technology.

When the values of carbon footprint contribution in the harvesting work systems are expressed in percentage terms, an increasing technological ranking of "20 ha< poplar or willow (33%) – 3 ha> poplar (33 %) – 5-10 ha poplar or willow (34%)" emerged. Based on absolute carbon footprint, the ranking of stands in the whole life cycle is the following: "20 ha< poplar or willow (60,581) – 3 ha> poplar (61,003) – 5-10 ha poplar or willow (61,735)" (in the values of GWP 100 years [kg CO_2-Equiv.]). When considering the clearly fossil carbon footprint of technological processes, the ranking of "20 ha< poplar or willow (781) – 5-10 ha poplar or willow (1,935) – 3 ha> poplar (2,100)" (in the values of GWP 100 years [kg CO_2-Equiv.]) resulted in the whole life cycle.

In order to illustrate the extent of the carbon footprint, we used the estimated carbon sequestration of stands. We set up stand-specific ratios whose values (1.37-1.48) are good indicators of the positive balance: „3 ha > poplar (1.37) – 5-10 ha poplar or willow (1.43) – 20 ha < poplar or willow (1.46)". The solid output of firewood burning, wood ash, as a carbon pool, is largely responsible for the above-mentioned positive character of carbon sequestration of the system.

The study results (GWP) highlight the carbon footprint of harvesting processes. Knowledge of these has a strong influence on the consideration of raw wood products (wood chips) as low-emission raw materials, and on the more exact definition of carbon sequestration capacity. This information will also help to better assess climate risks and climate change. The results obtained enable the estimation and prediction of environmental impacts for the whole lifecycle of the plantation.

Results are based on optimum environmental inventory data and should be interpreted in the domestic context. Following the introduced steps, this methodology can be adapted for other countries, applying region specific data. Outcome of the research are comparable with other LCA studies only in the case of the same functional unit and system boundaries. A better understanding of environmental impacts can be improved by the extension of system boundaries and inventories and the involvement of further primary and secondary processes.

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Waterborne *Phytophthora* Species Occurrence and Diversity in the Valley of the Rák Brook

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Abstract – This paper reports on a two-year monitoring of *Phytophthora* species occurring in the catchment area of the Rák Brook near Sopron. *P. gonapodyides, P. lacustris, P. plurivora and P. pseudosyringae* were found in the course of surveys completed in the vegetation period of 2011 and 2012. Diversity profiles and cluster analysis were calculated in order to compare the *Phytophthora* communities detected at different sites and times. Seasonal differences were observed in the species compositions. Temperature data and basic hydrological parameters were found to determine the presence or absence of waterborne *Phytophthora* species in the catchment area of the Rák Brook. Pathogenicity of the Phytophthora species discovered was confirmed and evaluated against sessile oak seedlings.

waterborne Phytophthora / monitoring / plant pathogen / catchment area

Kivonat – *Phytophthora* fajok előfordulása és diverzitása a Rák-patak vízgyűjtőjén. A tanulmány egy Sopron környékén, a Rák-patak vízgyűjtőjén kivitelezett két éves monitoring eredményeiről tudósít. A monitoring célja a vízben élő *Phytophthora* fajok felmérése volt. A 2011 és 2012 vegetációs időszakban kivitelezett felmérések során négy fajt sikerült kimutatnunk: *P. gonapodyides-t*, *P. lacustris-t*, *P. plurivora-t* és *P. pseudosyringae-t*. Az egyes mintavételi időszakokban talált *Phytophthora* közösségeket diverzitásrendezés és klaszteranalízis segítségével hasonlítottuk össze. Az egyes időszakok során tapasztalt fajkészletekben szezonális változásokat figyeltünk meg. Megállapítottuk, hogy a fajok előfordulását leginkább a hőmérsékleti viszonyok és alapvető hidrológiai paraméterek befolyásolták. A talált *Phytophthora* fajok kocsánytalan tölgy csemetékkel szembeni patogenitását igazoltuk és a fajok aggresszivitását értékeltük.

vízi Phytophthora / monitoring / kórokozó / vízgyűjtő terület

1 INTRODUCTION

The rapidly growing number of invasive species is an important ecological and economic problem. The greatest number of invasive plant pathogen species in Europe currently belongs to the *Oomycetes* followed by the Ascomycetes (Santini et al. 2012). The number of species in these two groups is three times higher than in the 1980s. The invasive species of the genus *Phytophthora* (phylum *Oomycota*) endanger the ecological and economic sustainability of forests around the world (Hansen 2008), including Europe (Jung al. 2015), and Hungary (Szabó et al. 2013). These species require water to reproduce and spread. Watercourses play a key role in the spread of Phytophthoras (Ghimire et al. 2009, Erwin – Ribeiro 1996). New infections may occur during flood events (Strnadová et al. 2010).

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European and North-American studies show that *Phytophthora* species are abundant in forest streams and rivers (Hansen – Delatour 1999; Reeser et al. 2011). Watercourse monitoring can help track the spread of invasive Phytophthoras and improve the early detection of these pathogens (Reeser et al. 2011). Early detection could enable timely plant protection actions, which may help prevent enhanced habitat loss. Stream baiting or water filtering methods are monitoring techniques that are frequently used to detect *Phytophthora* species worldwide (Hansen – Delatour 1999; Tjosvold et al. 2008; Hulvey – Gobena 2010; Reeser et al. 2011; Hüberli et al. 2013). However, inoculum dilutes in streams and rivers, which poses a challenge for detection methods. In the case of water filtering, the higher amount of water used may lead to more accurate results, while in the case of stream baiting, the plant species used as bait and baiting duration can help to improve accuracy.

Though North American studies have shown that water filtration may capture a greater number of taxa (Hulvey et al. 2010, Brazee et al. 2016), baiting is a cheaper and more frequently used method to investigate streams. Monitoring selected watercourses may reflect the occurrence of *Phytophthora* species over the watershed (Hwang et al. 2007). Furthermore, rivers might serve as a dispersal source for *Phytophthora* species, putting ecosystems at risk through flooding (Brazee et al. 2016).

During the study period, our main goals were to obtain information about the occurring *Phytophthora* species, investigate the health condition of forest stands along the Rák Brook near Sopron – with special emphasis on the symptoms of potential *Phytophthora* infection – and test the stream baiting method for forest protection purposes.

Forests potentially cover the entire Sopron Mountains area. Beech (*Fagus sylvatica*) forests cover the higher regions, and sessile oak (*Quercus petraea*) forests mixed with hornbeam (*Carpinus betulus*) exist in the eastern part. Planted coniferous forests currently cover more than 50% of the entire Sopron Mountains area. (Király 2008) Common alder (*Alnus glutinosa*) is the dominant tree species in the bottom part of the catchment area (Gribovszki et al. 2006). *A. glutinosa* is the dominant tree species in the riparian alder galleries, but the stands are mixed with common ash (*Fraxinus excelsior*) (Szmorad 2011). Walnut (*Juglans regia*) occurs in the lower valley sections (Szmorad 2011).

With a total length of 14.8 km, of which 10 km winds through forested area, the Rák Brook is one of the largest watercourses in the Sopron Mountains. Its water catchment area is approximately 36.8 km^2 in the northern part of the Sopron Mountains (Dövényi 2010). *Table 1* summarizes the main tree species of the catchment area according to the National Forest Database (National Food Chain Safety Office, Forestry Directorate).

Earlier, *P. quercina, P. cactorum*, *P. plurivora*, *P. europaea*, *P. uliginosa*, *P. psychrophila*, *P. citricola*, *P. gonapodyides*, *P. syringae*, *P. megasperma* were the *Phytophthora* species most frequently isolated from Central European sessile oak and pedunculate oak (*Quercus robur*) stands (Jung et al. 2000, 2002, Balci – Halmschlager 2003, Tkaczyk et al. 2017). According to Bavarian and Polish data, the main *Phytophthora* species causing decline in Central European beech stands are *P. cambivora*, *P. syringae*, *P. pseudosyringae* and *P. citricola (P. plurivora*,Orlikowski et al. 2016). In Rohrbach, near the Austrian-Hungarian border next to Sopron, *P. quercina* was observed in the rhizosphere of declining sessile oaks in 2000 (Balci – Halmschlager 2003). A few years later, in 2003, 2005 and 2009, *P. gonapodyides*, *P. multivora* and *P. plurivora* were isolated from the rhizosphere of declining pedunculate oak, sessile oak, and Turkey oak (*Quercus cerris*) trees (Szabó et al. 2013) on the Hungarian side of the Sopron Mountains. Szabó et al. (2013) isolated *P. plurivora* and *P. gonapodyides* from the rhizosphere soil of declining riparian alder trees near Sopron in 2002 and 2003. There is no available data about *Phytophthora* species occurring in Hungarian or Austrian beech stands. It was also important to know the pathogenicity of collected species against sessile oak (*Quercus petraea*).

Table 1. Tree species on the sampled water catchment area (abundance in percentage of the area).

Tree species	Abundance (%)	Tree species	Abundance (%)
Beech *(Fagus sylvatica)*	34.82	Sweet chestnut (*Castanea sativa)*	0.40
Sessile oak *(Quercus petraea)*	22.08	Black locust (*Robinia pseudoacacia)*	0.30
Norway spruce *(Picea abies)*	10.07		
Larch *(Larix decidua)*	9.50	Pedunculate oak (*Quercus robur)*	0.25
Hornbeam (*Carpinus betulus)*	6.90	Northern red oak (*Quercus rubra)*	0.23
Scotch pine (*Pinus sylvestris)*	6.27	Turkey oak (*Quercus cerris)*	0.16
Silver birch (*Betula pendula)*	2.59	European aspen (*Populus tremula)*	0.16
Common alder (*Alnus glutinosa)*	2.07	Douglas fir *(Pseudotsuga menziesii var. viridis)*	0.14
Fir *(Abies alba)*	1.37		
Great maple (*Acer pseudoplatanus)*	0.68	Goat willow (*Salix caprea)*	0.13
European black pine (*Pinus nigra)*	0.63	Wild cherry (*Prunus avium)*	0.03
Common ash (*Fraxinus excelsior)*	0.62	Wych elm *(Ulmus glabra)*	single individuals
Small-leaved lime *(Tilia cordata)*	0.60		

Source: National Forest Database, National Food Chain Safety Office Forestry Directorate

Weather condition and water quality data were also collected to secure information about the ecological parameters affecting the occurrence of different *Phytophthora* species.

This paper aims to interpret data collected during a two-year monitoring in an approximately 3,680 ha large catchment area covered by various tree species along the Rák Brook near Sopron in western Hungary. We assessed the ecological impact of *Phytophthora* species in this location, highlighting a potential threat to sessile oak, beech, and common alder stands.

Interest in estimating forest biomass for practical and scientific purposes is currently increasing. There are different approaches to calculate biomass and carbon stocks in forests, with most based on forest inventory information as well as on biomass equations, which transform diameter, height or volume data into biomass estimates (Somogyi et al. 2006). Biomass calculations can be obtained by direct and indirect methods. The direct method involves destructive biomass weighing, whereas in the indirect method, regression modelling is used to estimate biomass and carbon stocks from more easily measured tree and stand variables such as diameter at breast height (DBH), tree height (H) and tree age (A). Tree-level variables facilitate the development of biomass equations that are applicable to a wider range of sites and stands and can be used to examine the effects of various factors on stand growth and biomass stocking. The ability of allometric equations to predict aboveground biomass and carbon stocking is not only a matter of statistical tools. The errors made throughout the process of formulating these equations – from the fieldwork and modelling to biomass prediction – should be considered (Picard et al. 2012).

Chave et al. (2005) and Brown et al. (1989) pointed out that errors are caused by various sources such as tree measurement, plot sampling, insufficient number of big trees sampled, diameter intervals, selection of average sample trees in each diameter class, and application of unsuitable models. In addition, accuracy and reliability of biomass models should be assessed not only for individual trees, but also for forest stands taking into account the distribution of trees by diameter classes (Ketterings et al. 2001).

In Albania, information on aboveground biomass and carbon stocking is scarce and relevant estimation methods are not very well known. In contrast, information regarding biomass estimation is more plentiful in other Mediterranean countries. From the review of the studies conducted in Albania, we found one study that provides data on biomass and carbon stocking at national level (Agrotec 2004) and two other studies focused on aboveground biomass estimation for some species growing in natural (Omuri 2006) and artificial stands (Toromani et al. 2011). The first study regarding biomass estimation at the country level was conducted in the framework of National Forest Inventory (Agrotec 2004). Biomass was calculated from the inventoried stand volume per hectare where this value was expanded into aboveground components using biomass expansion factor (BEFs). Due to the lack of information on specific BEFs for Albanian forests, data from other studies was used (Louitat et al. 2000, Lowe et al. 2000, Schulze 2000). Omuri (2006) executed the second research study on forest biomass and BEFs and developed several models to estimate biomass. He determined the BEFs for Austrian pine (*P. nigra* Arn.), Beech (*F. sylvatica* L.) and Birch (*B. pendula* L.) and pointed out that BEFs values vary due to species and age. Thus, in the case of birch, the BEF was 2.1 for the 10 to 20-year age range, 1.4 for Austrian pine in the 20 to 30-year age range and, and 2.3 for beech in 10 to 20-year age range. The third study was conducted by Toromani et al. (2011) in some poplar plantations situated in eastern and central Albania where several allometric equations using tree variables (DBH; squared DBH; H; A) as predictors were developed.

Despite the limited number of published equations, many other forest species growing in Albania are not well represented. Turkey oak (*Quercus cerris*) is one of the species lacking biomass-related information. Undoubtedly one of Albania's most important forest species, covering more than 30.8% of the total forest area, Turkey oak grows in Haplic and Chromic Luvisol soil here, in a typical, hilly, Mediterranean climate with a considerable summer drought period (FAO2015). The species is widely distributed all over Albania, from hilly lands along the coastal area to the interior of country. *Q. cerris* is a significant firewood source and is also a fundamental fodder source for wildlife and livestock (mostly sheep and goats). The species also provides habitat for small game species such as Brown hare (*Lepus europaeus*), Common blackbird (*Turdus merula*), and Grey partridge (*Perdix perdix*). No information on the aboveground biomass for Albanian *Q. cerris* forest stands exists, but other Mediterranean countries possess abundant data. Therefore, the aims of this study were: (1) to estimate aboveground biomass of investigated stands, (2) to define the appropriate allometric models for estimation of aboveground biomass using tree variables, and (3) to estimate biomass expansion factors (BEFs) and their dependency. The present study will contribute quantitative data to the current, generally scarce knowledge of this species.

2 MATERIALS AND METHODS

2.1 Sampling, isolation and species identification

Stream baiting was performed at 18 sampling points (*Figure 1*). Almost the entire 10-km-long forested part of the brook and a further six small waterways joining the brook were sampled. Sampled waterways were adjacent to mature deciduous forest stands.

Sampling points were selected near the estuary. We aimed to choose easily accessible sampling points that allowed us to sample areas with diverse tree species composition. Four healthy cherry laurel (*Prunus laurocerasus*) leaves in a plastic mesh bag were placed onto the water surface as baits. The baits were fixed on the bank and were afloat on the water surface for two days.

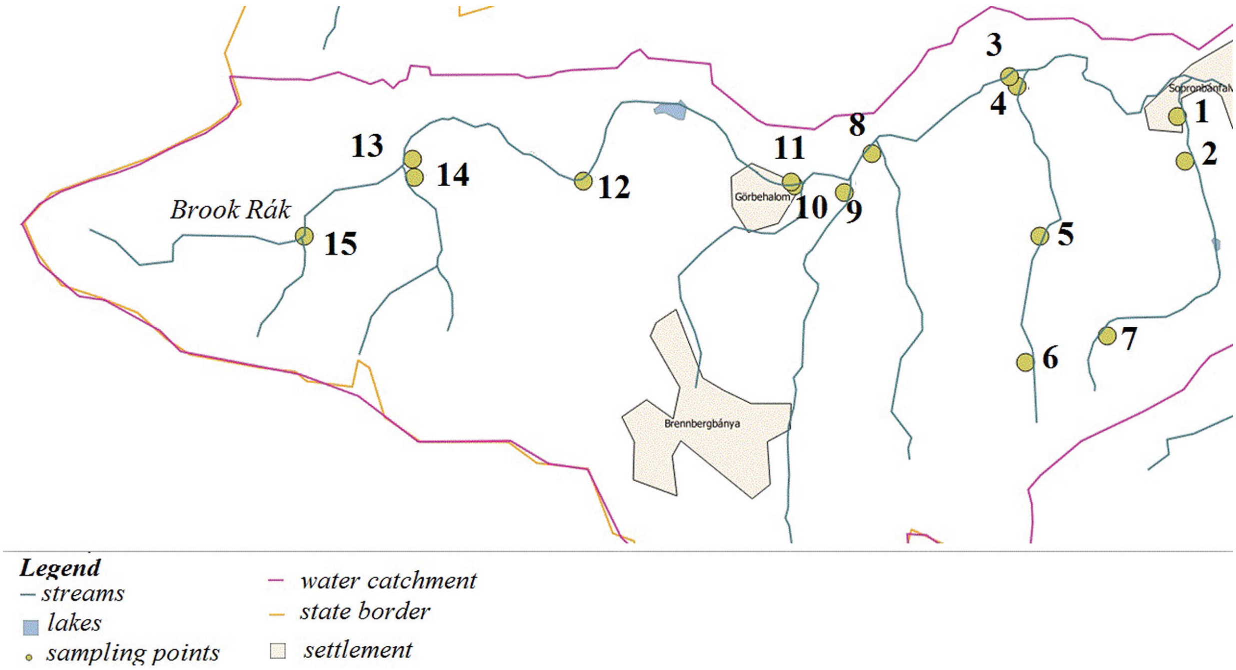

Figure 1. The selected sampling points

Sampling was performed five times in 2011 (April, May, July, September, October) and seven times in 2012 (April, May, June, July, August, September, October). We could not do baiting at every sampling point on every sampling date because several water flows ran dry, mainly in summer and autumn, but also in spring 2012. Sometimes baits disappeared or drifted to the bank and dried out. In these cases, baiting was repeated if water depths were adequate for the experiment. Leaf baits were rinsed with distilled water before isolation. A 5x5 mm piece was cut from the infected leaf sections and put on the surface of *Phytophthora* selective agar plates. The medium used contained 1.5% malt extract and 2% bacteriological agar. Ampicillin (250 mg/l), benomyl (15 mg/l) and hymexazol (50 mg/l) were added to the medium before use (Kovács et al. 2013).

Basic hydrological parameters (depth soundings, water pH, and water temperature) were measured at each sampling time in 2012.

2.2 Pathogenicity tests

Pathogenicity tests were completed using one *P. plurivora*, *P. gonapodyides* and *P. lacustris* strain, each of which were collected during the monitoring. Colonies were grown on potato-dextrose agar at 20°C in darkness. The two-year old sessile oak saplings used for the test originated from the local forest nursery. They were planted into plastic containers containing soil tested for *Phytophthora* species with the leaf baiting method. The soil proved to be free of *Phytophthora* species before we infected it in May, 2013.

Stem inoculation (seven saplings per strain plus seven uninfected control saplings, altogether 28 saplings) and soil infection (another seven saplings per strain plus seven uninfected control saplings, altogether 28 saplings) tests were carried out. The saplings for the stem inoculation test were planted into a nursery field. Saplings for the soil infection test were planted into 2.5-litre plastic containers. All of the seedlings were watered with tap water as necessary, but were otherwise maintained under natural conditions. Stem inoculation, soil infection, and evaluation of the experiment were completed as earlier described (Sárándi-Kovács et al. 2015). The health condition of the stem-inoculated sapling shoots was evaluated based on a similar five-point scale: 1. Symptomless sapling; 2. Some leaves are smaller than usual, occasionally with yellowish discolouration; 3. 30–50% of the potential crown is dead; 4. More than 50% of the potential crown is dead; 5. Completely dead saplings (Sárándi-Kovács et al. 2015). Stem diameter and two diameters of the necrosis on the lower stem were measured [mm]. The necrosis area was calculated with the area of ellipse formula [mm^2]. With the soil infection test, the health condition of the root system was evaluated based on a five-point scale: 1. Healthy root system; 2. Root loss is below 30%; 3. 30–50% of the root system is lost; 4. Root loss is more than 50%; 5.Completely dead saplings (Sárándi-Kovács et al. 2015). The main root length and the root system diameter was measured. The health condition of the shoots was evaluated based on the five-point scale mentioned above. The re-isolation of *Phytophthora* species used from the stem lesions and the necrotic root tissues was successful.

2.3 Map constructing and data analysis

Maps were constructed using QGIS 2.18.18 Software (www.qgis.org), based on Google Maps (Google Terrain).

Rarefaction curve and diversity profiles were drawn using PAST 3.19 (Hammer et al. 2001). These profiles were created using 2,000 bootstrap by 95% confidence interval. Populations were compared with cluster analysis based on the Euclidean similarity index, with the neighbour joining method, and with 10,000 bootstrap.

Data collected in 2012 were used to evaluate the effect of environmental factors on *Phytophthora* species composition. Meteorological data (*Table 2*) are from the Institute of Environmental and Earth Sciences database (University of Sopron, Hungary); basic hydrological parameters (*Table 2*) were measured during the sampling times in 2012.

Table 2. Meteorological data of the sampling times in 2012. Source: Institute of Environmental and Earth Sciences (University of Sopron)

	April	May	June	July	August	September	October
T_{av}	10.7	16.7	20.7	20.9	20.8	16.7	10.1
T_{min}	–1.6	1.2	6.3	12.2	11.4	5.3	–3.1
T_{max}	30.1	30.5	34.5	31.6	29.3	31.4	25.0
P	43.9	64.3	62.5	249.1	13.2	61.8	66.7
T_{avp}	8.4	10.7	16.7	20.7	20.9	20.8	16.7
P_p	9	43.9	64.3	62.5	249.1	13.2	61.8

T_{av}: Average temperature [°C], T_{min}: minimum temperature [°C],
T_{max}: maximum temperature [°C], T_{avp}: average temperature of the previous month [°C],
P: precipitation [mm], P_p: precipitation of the previous month [mm]

The following data were used for Spearman's rs nonparametric correlation in PAST 3.19: collected *Phytophthora* species, average monthly temperature, minimum monthly temperature, maximum monthly temperature, average temperature of the previous month, monthly amount of precipitation, monthly amount of precipitation in the previous month, water temperature, soundings, and stream water pH. As described earlier, the data from the pathogenicity tests were evaluated with the STATISTICA Ver. 11 software (Sárándi-Kovács et al. 2015).

3 RESULTS

3.1 Observed symptoms, isolation success and collected species

Tree decline suggesting the presence of *Phytophthora* species was not observed in the Sopron Mountains during the two-year monitoring period. The number of samplings proved enough to acquire accurate knowledge of the *Phytophthora* species living in the catchment area based on the rarefaction curve (*Figure 2*).

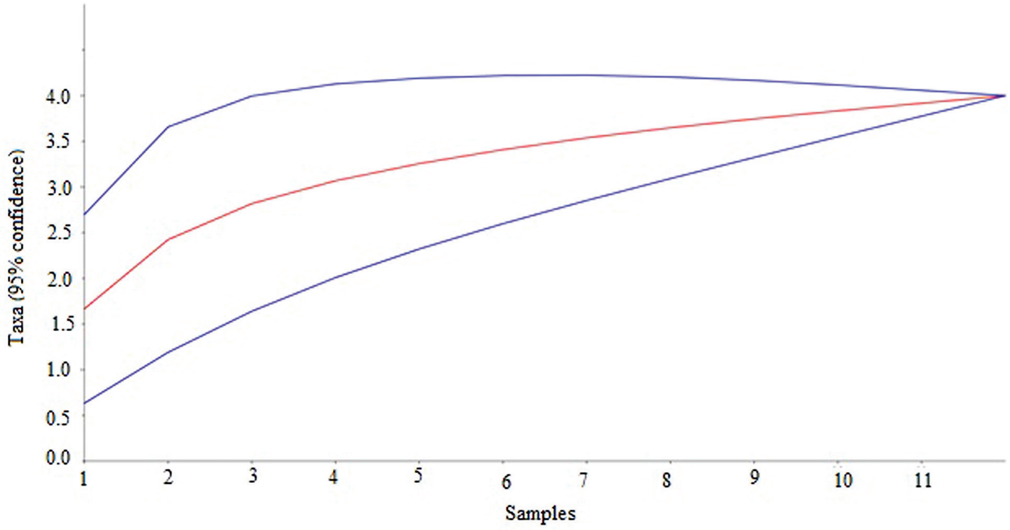

Figure 2. Sample rarefaction curve

Altogether 111 isolates were collected, but of these, 11 isolates died before identification. Three isolates belonged to the genus *Pythium*, 97 to the genus *Phytophthora*. Seven *Phytophthora* isolates were unidentifiable at the species level. The remaining 90 isolates belonged to four *Phytophthora* species: *P. gonapodyides*, *P. lacustris*, *P. plurivora*, and *P. pseudosyringae*. *P. gonapodyides* was abundant (48.89% of the total number of identified *Phytophthora* isolates), especially in spring and early summer. Furthermore, *P. lacustris* was also abundant (37.78%), while *P. plurivora* (12.22%) and *P. pseudosyringae* (1.11%) were isolated only occasionally in the catchment area of the Rák Brook. *Table 3* lists the numbers of successful baitings and isolations.

Table 3. Total number of successful baiting and collected isolates

	Total number of leaf baits set up	Total number of leaf baits collected	Number of collected isolates	Identified *Phytophthora* isolates
Apr 2011	20	14	12	12
May 2011	21	8	13	12
July 2011	18	12	19	15
Sept 2011	15	8	2	1
Oct 2011	15	4	4	4
Apr 2012	13	8	7	7
May 2012	13	8	9	8
June 2012	13	8	13	11
July 2012	14	12	10	8
August 2012	13	11	11	7
Sept 2012	14	11	11	5
Oct 2012	12	12	0	0
Total	**181**	**116**	**111**	**90**

Identification of the collected isolates was based on morphological characteristics and specific molecular markers as described earlier (Kovács et al. 2013). *Figure 3* shows the changes of the identified *Phytophthora* species composition during the two years of the survey.

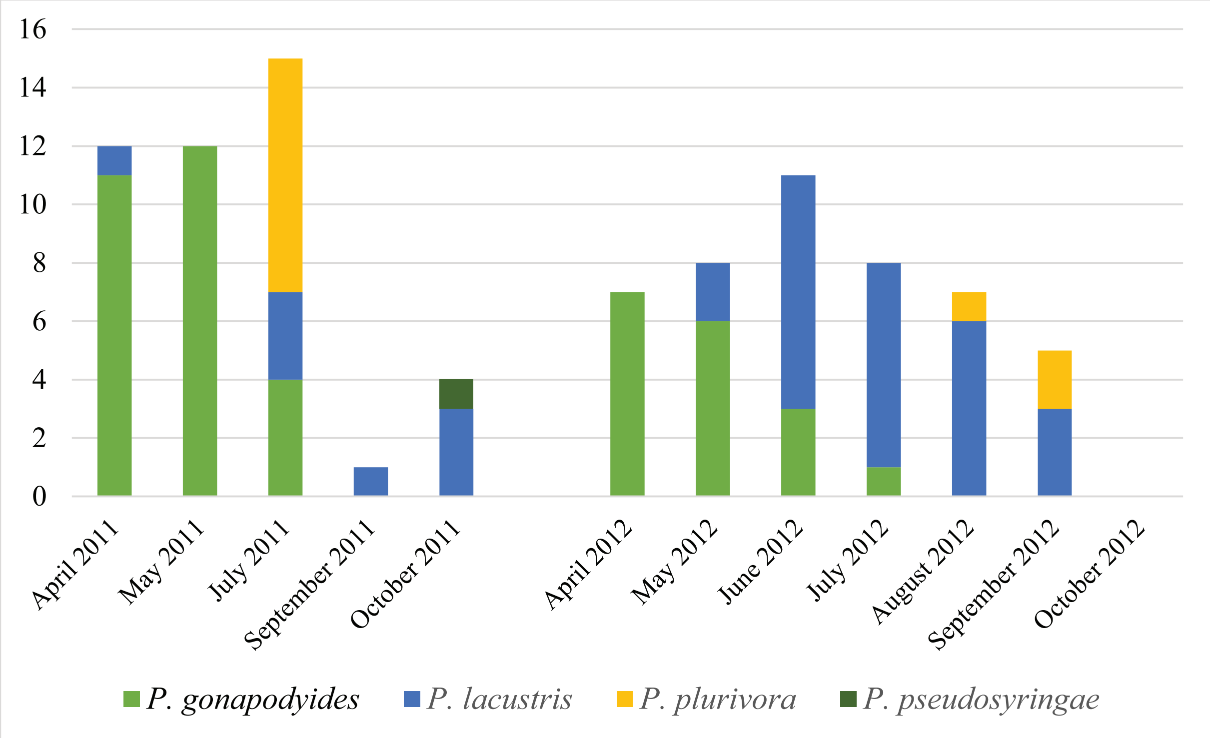

Figure 3. Number of detected Phytophthora species

Figure 4 shows the spatial distribution of identified *Phytophthora* species in 2011, 2012, and the complete database respectively. *P. gonapodyides* was the most widely distributed species in 2011 at 11 out of 15 sampling points. We could not isolate any Phytophthoras at sampling points 2 and 5. In 2012, *P. gonapodyides* was dominant only at three out of fifteen sampling points, while *P. lacustris* was dominant at seven sampling points. At two sampling points, these to *Phytophthora* species occurred in 50–50%, respectively. We could not isolate any Phytophthoras at sampling points 5 and 15. Altogether, we did not collect *Phytophthora* isolates from sampling point 5 during the two years of the survey. However, we had baits back from these sampling points. Only *P. gonapodyides* could be isolated at sampling points 3, 4, 13, and 15. At nine out of fifteen sampling points, *P. gonapodyides*, *P. lacustris* and *P. plurivora* occurred together, with the dominance of *P. gonapo*dyides or *P. lacustris*. We could isolate *P. pseudosyringae* only one time at only one sampling point (October 6, 2011.).

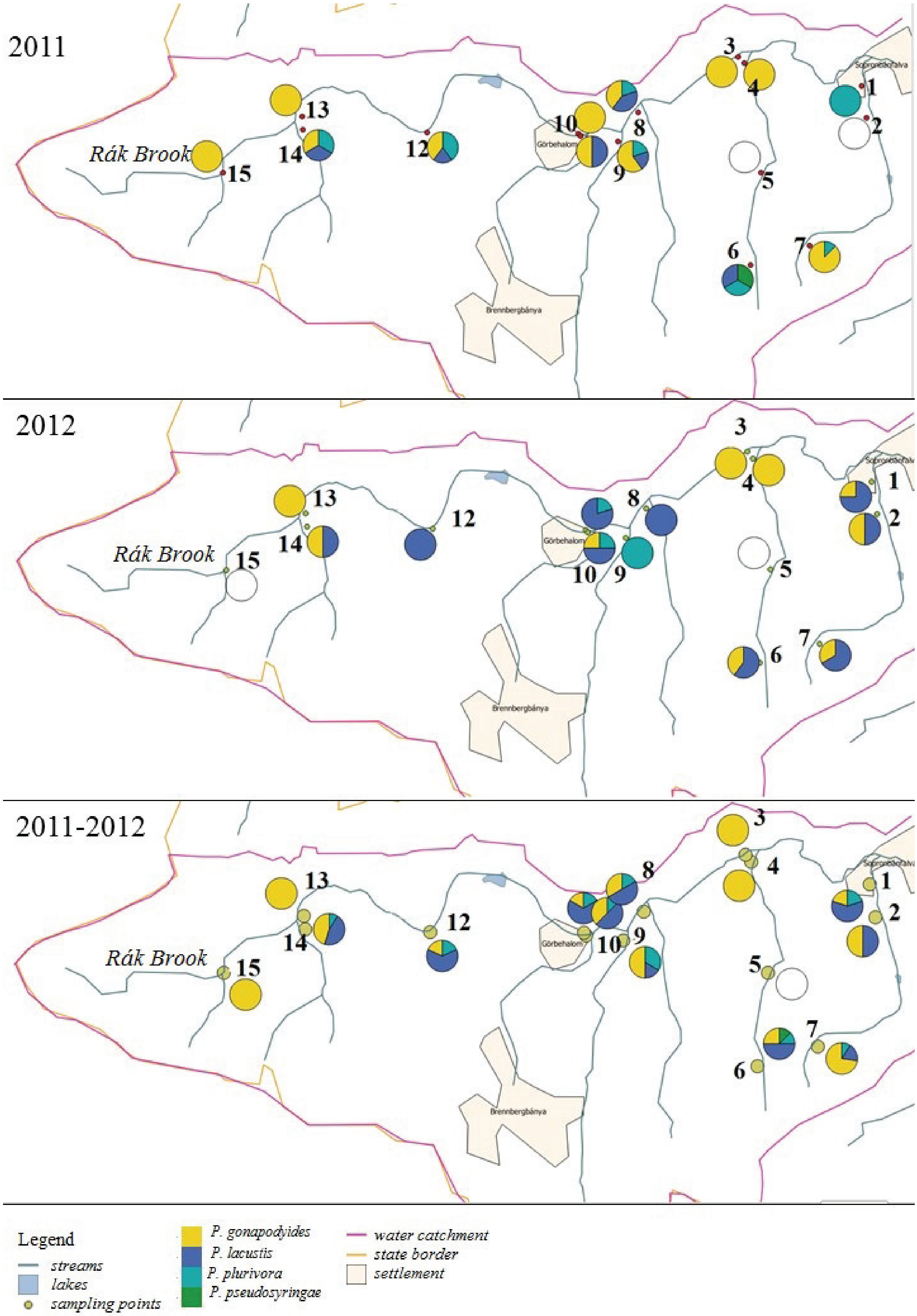

Figure 4. Observed species composition at the selected sampling points

3.2 Seasonal changes in the *Phytophthora* species composition

While *P. gonapodyides* was abundant in the samples collected in spring and early summer, the samples collected in summer and autumn contained mostly *P. lacustris* and *P. plurivora*, and only a few isolates of *P. gonapodyides* in July each year (*Figure 3*). The population found in July 2011 proved to be the most diverse based on the diversity curves. Based on the diversity profiles, there are no significant differences between the *Phytophthora* communities belonging to different sampling times.

There are two main groups based on the cluster analysis (*Figure 5*). The three successful autumn sampling times (September and October 2011 and September 2012) are on a separate branch. The *Phytophthora* communities collected in spring (April and May in 2011 and in 2012) are in a separate group, while the summer dissevers two groups: a group containing samples collected in spring, and another containing communities collected in summer. This result suggests seasonal changes in the species composition.

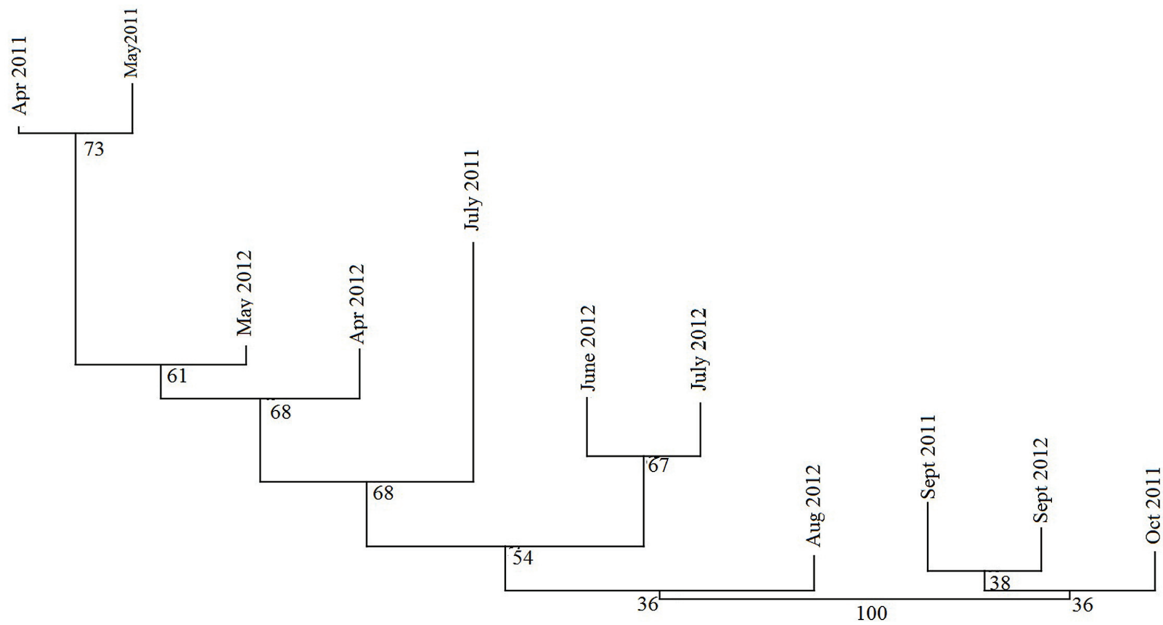

Figure 5. Cluster analysis based on the Euclidean index with neighbour joining method, using 10,000 bootstrap.

3.3 Environmental factors affecting the occurrence of *Phytophthora* species

Table 4 shows the values of measured environmental parameters. Stream water pH was slightly acidic during the survey (pH 5.2–6.8). The water temperature fluctuated between 9 and 18 °C, while the watercourse soundings also fluctuated at each sampling time (*Table 5*).

Table 4. Measured water parameters in 2012

ID	April			May			June			July			August			Sept.			October		
	R	S	T	R	S	T	R	S	T	R	S	T	R	S	T	R	S	T	R	S	T
1	6.4	3	5	5.2	3	17	6.4	3	15	6.6	15	17	6.1	3	18	6.1	3	13	6.1	2	15
2	6.6	17	10	6.1	10	13.5	6.4	5	15	6.4	15	15	5.8	12	14	6.1	5	13	6.1	10	13
3	6.8	<1	10	6.1	1	13.5	<6.4	1	13	6.6	1	13	5.2	0.2	14		dried up		6.1	<1	13
4	6.1	6	9	5.5	3	14	6.4	3	15	6.4	12	10	5.8	10	16	5.8	3	13	5.8	3	15
5	6.1	6	9	5.5	3	14	6.4	3	15	6.4	12	10	5.8	10	16	5.8	3	13	5.8	3	15
6	6.1	6	9	5.5	3	14	6.4	3	15	6.4	12	10	5.8	10	16	5.8	3	13	5.8	3	15
7		dried up			dried up		6.4	1	15.5		dried up			dried up			dried up			dried up	
8		dried up			dried up			dried up		6.6	8	15	5.8	4	17		dried up			dried up	
9	6.6	5	11		dried up			dried up		<6.4	5	16		dried up		5.8	<1	13		dried up	
10	6.6	5.7	10	6.7	5	16	6.4	2	17	6.8	15	16	6.1	3	17	5.8	4	13	6.4	10	14
11	6.6	5.7	10	6.7	5	16	6.4	2	17	6.8	15	16	6.1	6	17	5.8	4	13	6.4	10	14
12	6.7	17	10	5.5	10	15	6.4	5	16	6.4	15	15	6.1	12	16	5.8	6	13	6.1	10	13
13	6.8	17	11	5.5	10	16	6.4	5	15	6.4	15	15	6.4	13	17	5.8	7	13	5.8	10	13
14	6.8	17	11	5.5	10	16	6.4	5	15	6.4	15	15	6.4	13	17	5.8	7	13	5.8	10	13
15	6.6	8	11	5.5	7	18	6.4	3	18	6.4	<1	15	6.1	4	17	6.4	3	13	6.1	7	13

R: reaction; S: soundings [cm]; T: temperature [°C]

Table 5. Results of the Spearman's rs nonparametric correlation based on the survey in 2012, without data of unsuccessful isolation, rs values in Italic show weak correlation, rs values in bold suggest moderate correlation

r_s\ p(uncorr)	ST	Sp	T_{av}	T_{min}	T_{max}	P	T_{av_pr}	P_{pr}	pH	S	T_w
ST		0.001	<0.001	<0.001	0.369	0.526	<0.001	0.010	0.093	0.040	0.856
Sp	**0.422**		<0.001	<0.001	0.926	0.450	<0.001	0.005	0.260	0.006	<0.001
T_{av}	0.555	**0.493**		<0.001	0.004	0.002	<0.001	<0.001	0.386	<0.001	0.002
T_{min}	0.655	**0.495**	0.988		0.002	0.010	<0.001	<0.001	0.421	<0.001	0.009
T_{max}	0.125	0.013	0.385	0.404		<0.001	0.737	0.012	0.311	0.032	0.037
P	–0.088	0.105	0.413	0.346	0.499		0.337	0.948	0.272	0.196	0.006
T_{av_pr}	0.978	**0.474**	0.641	0.723	0.047	–0.133		<0.001	0.105	0.007	0.529
P_{pr}	0.347	*0.375*	0.748	0.716	0.338	0.009	0.482		0.516	0.230	<0.001
pH	–0.231	0.156	0.120	0.112	0.140	0.152	–0.223	–0.090		0.153	0.373
S	0.281	*0.367*	0.509	0.490	–0.292	0.179	0.364	0.166	0.197		0.199
T_w	0.025	**0.461**	0.419	0.353	0.285	0.367	0.088	0.519	0.124	0.178	

Abbreviations: ST: sampling time, Sp: species, Tav: monthly average temperature, Tav_pr: average temperature of the previous month, Tmin: monthly minimum temperature, Tmax: monthly maximum temperature, P: monthly precipitation, Ppr: monthly precipitation of the previous month. rs values in Italic show weak correlation, rs values in bold suggest moderate correlation.

3.4 Pathogenicity tests

Stem inoculation experiment

Two saplings died (out of 28) during the five months of incubation. Both saplings were infected with *P. plurivora*. *P. plurivora* caused the most severe symptoms (average health condition based on crown symptoms: *P. plurivora*: 2.14; *P. lacustris*: 1.42; *P. gonapodyides*: 1.13; control: 1.00).

Observed symptoms were yellowish discolouration and smaller sized leaves or shrivelling of some leaves.

There were significant differences between the lesion sizes (*Figure 6*) measured in the various treatment groups based on the Kruskal-Wallis test (*p=0.0038*). All tested *Phytophthora* species caused considerably bigger lesions than observed in the non-infected controls. *P. plurivora* caused the biggest lesions (min.: 15.71 mm^2; mean: 161.68 mm^2; max.: 592.18 mm^2; *p=0.0061*). Smaller lesions were caused by the *P. lacustris* strain (min.:7.07 mm^2; mean: 31.30 mm^2; max.: 82.47 mm^2; *p=0.0061*) and the *P. gonapodyides* strain (min.:3.93 mm^2; mean: 22.78 mm^2; max.: 50.27 mm^2; *p=0.0040*). *P. plurivora* caused substantially bigger lesions than *P. gonapodyides* did (*p=0.0401*).

Mean lesion size on host species ranged between 15.71 and 592.18 mm for *P. plurivora*, 7.07 and 82.47 mm for *P. lacustris*, and 3.93 and 50.27 mm for *P. gonapodyides*.

There were no significant dissimilarities in the different treatment groups based on the health condition of the saplings.

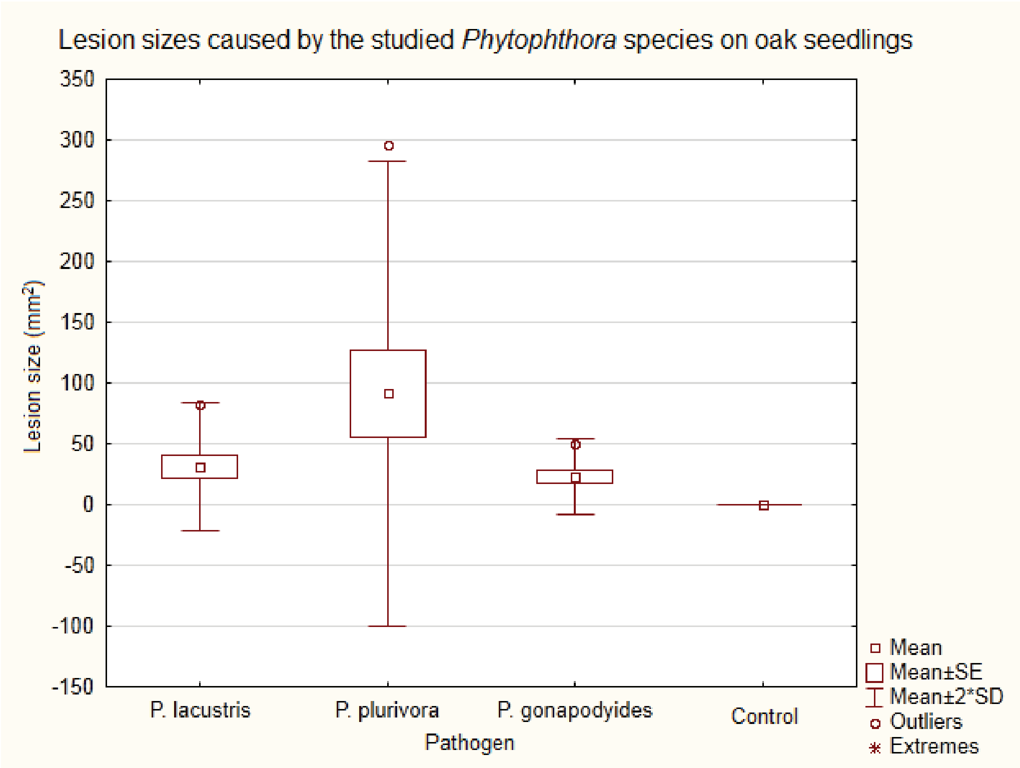

Figure 6. Mean lesion size for each of the four species following treatment with I.) *P. lacustris*, II.) *P. plurivora*, III.) *P. gonapodyides*, and IV.) PDA (control).

Soil infection experiment

Only one sapling out of 28 died during the five months of the experiment. This sapling was infected with *P. plurivora*. No crown symptoms were visible on the living saplings. Average sapling health condition based on the root symptoms is presented in *Figure 7B*. *P. plurivora* and *P. gonapodyides* were the most aggressive while *P. lacustris* caused less severe symptoms. There were significant differences in the root width between the different treatment groups based on the result of the One-way ANOVA (*p=0.4156*). *P. lacustris* (min.:10.00 mm, mean: 43.30 mm, max.: 100.00 mm; *p=0.0444*) and *P. gonapodyides* (min.: 5.00 mm; mean: 35.59 mm; max.: 50.00 mm; *p=0.0039*) caused substantial loss of roots according to the control saplings (min.: 45.00 mm; mean: 76.90 mm; max.: 110.00 mm) based on the results of the t-tests. *P. plurivora* also caused decrease in the root width but the difference is not significant (min.: 0.00 mm, mean: 47.50 mm, max.: 100.00 mm; *p=0.0696*). There are no notable differences between the impact of the different *Phytophthora* species (*Figure 7A*).

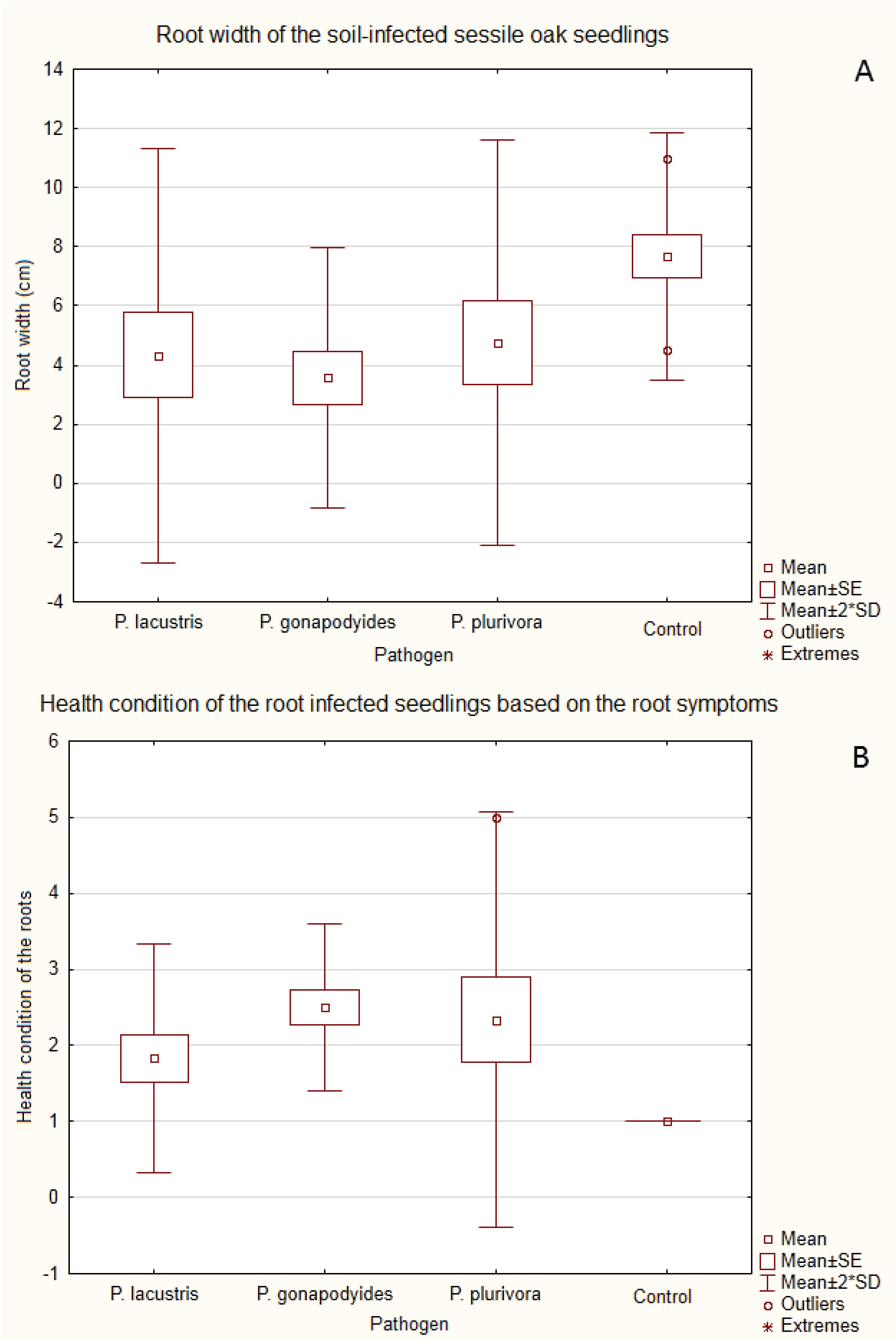

Figure 7. A.: Mean root width of the different treatment groups in case of soil infected seedlings. B.: Average health condition of the saplings in different treatment groups based on the root symptoms in case of soil infected seedlings.

There were also major dissimilarities between the root condition of the different treatment groups based on the result of the Kruskal-Wallis non-parametric test (*p=0.0019*). All of the tested *Phytophthora* species decreased root health conditions based on the results of the Mann-Whitney U-test (*P. plurivora*-control: *p=0.0080*; *P. gonapodyides*-control: *p=0.0007*;

P. lacustris- control: *p=0.0426*). There were no noteworthy differences in the impact of the varying *Phytophthora* species.

4 DISCUSSION

4.1. Observed symptoms, isolation success and identified species composition

Using the stream-baiting method, the number of isolated species would be larger if the sampling site were bigger and contained other vegetation types.

The *Phytophthora* species found earlier in oak stands and riparian alder gallery forests of the Hungarian part of the Sopron Mountains (Szabó et al. 2013), were re-isolated by the stream baiting method. This confirms that the baiting method used would be convenient for the goals of our survey. Two additional *Phytophthora* species (*P. lacustris* and *P. pseudosyringae*) were found by using the new method. *P. lacustris* is common in watersheds worldwide, and is a pathogen of common alder stands (Szabó et al. 2013, Sárándi-Kovács et al. 2015), while *P. pseudosyringae* is a pathogen of common beech stands in Central Europe (Orlikowski et al. 2006) that can infect common alder, too (Marcais – Husson 2014). The third most abundant species we found is *P. plurivora*. This species most likely originates from eastern Asia, and was distributed through Europe and North America in the twentieth century via infected nursery stock (Brazee et al. 2016). *P. plurivora* has a wide host range containing ecologically and economically important tree species and is involved in epidemics worldwide (Brazee et al. 2016). However, *P. quercina* is a frequently isolated *Phytophthora* species in Central European oak stands, but was not detected in the Sopron Mountains either during the survey of Szabó et al. in 2002–2009, or during the stream baiting experiments in 2011 and 2012.

Clade 6 species, especially *P. gonapodyides*, abound in streams and rivers worldwide. Hansen and Delatour (1999) detected abundant *P. gonapodyides*, occasional *P. citricola* and *P. megasperma* as well as two *Phytophthora* species that were unknown at the time during a nine-month monitoring in French oak forests. Reeser et al. (2011) detected many more *Phytophthora* species than we did in the rivers of Alaska and Oregon. However, they also observed abundant amounts of *P. gonapodyides* and *P. lacustris*. They collected *P. plurivora*, *P. taxon PgChlamydo*, *P. pseudosyringae* and *P. cambivora* with a lower number from the rivers. Among other species, *P. citricola*, *P. gonapodyides* and *P. pseudosyringae* were present and profuse in North Carolina watersheds (Hwang et al. 2007). Brazee et al. (2016) isolated altogether 457 isolates of 18 *Phytophthora* species during a two-year survey in Massachusets, USA. *P. gonapodyides* and *P. lacustris* were copious in their dataset, too. We can assume that the collected *Phytophthora* species of our investigation (*P. gonapodyides*, *P. lacustris*, *P. plurivora* and *P. pseudosyringae*) are cosmopolitan plant pathogens that they are also present in the rivers of other countries and continents. Even though most waterborne *Phytophthora* species seem to have a partially saprotrophic lifestyle, all four isolated species are involved in declines or epidemics of woody plants. Their presence in Sopron Highland watersheds could pose a possible hazard to deciduous forest stands. It might also mean that these *Phytopthora* species are already present in the forest soil of the catchment area.

4.2 Diversity and seasonal changes

While diversity profiles do not significantly distinguish the *Phytophthora* communities belonging to different sampling times, the cluster analysis suggests seasonal changes in the diversity of *Phytophthora*. Reeser et al. (2011) also found seasonal changes in the amount of *Phytophthora* inoculum; the study's results show the amount of *Phytophthora* inocula is the highest in summer and in autumn, while much lower in winter and in spring. The isolation success was also the highest in the summer in our case. However, due to different climatic conditions, isolation success was much higher in spring than in autumn. Hwang et al. (2007) found the greatest *Phytophthora* diversity in July in North Carolina streams, while they could isolate only *P. gonapodyides* in February (Hwang et al. 2007). The most diverse sampling times were also in July and in September in our dataset, while in spring (April and May) *P. gonapodyides* was abundant and only a few *P. lacustris* strains could be isolated. Seasonality as a finding of our study may require further investigation due to the different weather conditions over the two years and the short interval of the experiment.

4.3 The effect of environmental parameters

Temperature data and water quality data (pH, soundings, and water temperature) had a moderate correlation with the observed *Phytophthora* species composition in 2012. The amount of monthly precipitation before the baiting and the soundings at the baiting time had only a weak correlation with the *Phytophthora* species composition, and only when the unsuccessful baitings were excluded.

According Jung et al. (1996), *P. gonapodyides* requires at least 2–3°C for sporangia formation and zoospore release under artificial conditions, while this value for *P. quercina* is 5°C, and 5–8°C for *P. citricola*. These circumstances were fulfilled at every sampling time during our survey. Brazee et al. (2016) showed that Clade 6 species are most plentiful in water at 15–20°C. The above-mentioned findings may explain our results. *P. lacustris* was the most abundant species at every sampling time between May 2012 and August 2012 (*Figure 4*) when water temperature was above 15 °C. At the low water temperature values in April, only *P. gonapodyides* was isolated, while in September, the most diverse month of 2012, *P. plurivora* and *P. gonapodyides* were isolated with the same frequency (28.57% each), and *P. lacusrtis* was the most abundant species (42.86% of the collected isolates).

Phytopthora species of oak ecosystems occur in a wide range of pH values (3.4–7.1) according to the studies of Balcí – Halmschlager (2003). Jung et al (2000) detected similar, with slightly lower values (3.3–6.63 pH [$CaCl_2$]). They found that *P. gonapodyides* was the most abundant at pH 3.62–6.02, while *P. citricola* occurred mostly at pH 3.53–6.63 (Jung et al. 2000). The pH values measured during our survey overlap or are a bit higher in April and May during when *P. gonapodyides* was the most abundant species in our collection. However, higher pH values favour *Phytophthora* species (Erwin – Ribeiro 1996). The reaction of the streams concurred with both ranges published by Jung et al. (2000). In spite of this, *P. gonapodyides* only occurred in October, and *P. plurivora* and *P. lacustris* occurred in both months.

Based on field observations, precipitation amounts also greatly affect the success of isolation. This is not surprising because *Phytophthora* species need water for sporangia formation and transportation.

4.4 Pathogenicity

The tested *P. gonapodyides*, *P. lacustris* and *P. plurivora* strains proved to be aggressive against sessile oak seedlings in both the stem inoculation and soil infection experiments. Forest streams deliver the inoculum of soil borne pathogens, which may cause a decline in oak forests under favourable conditions. The tolerance of oak species against Phytophthoras decreases in later years (Brasier 1996). The trees cannot recover the fine roots they have lost and for this reason weaken. Furthermore, in the case of unfavourable abiotic environmental factors, they become susceptible to secondary pathogens and pests (Hansen – Delatour 1999, Jung et al. 2000). Among other *Phytophthora* species, *P. gonapodyides* is present in European penduculate oak and sessile oak stands and can infect oak root systems (Jung et al. 2000).

The abundantly isolated species, *P. lacustris* and *P. gonapodyides* are both aggressive to common alder (*Alnus glutinosa*). According to our previous studies, *P. lacustris* is slightly less aggressive to alder seedlings than *P. alni* (Sárándi-Kovács et al. 2015). *P. gonapodyides* is moderately aggressive to oak and alder seedlings. It causes bigger lesions on common alder seedlings (with an average of 45.61 mm^2) than on oak seedlings (average lesion size: 22.78 mm^2) (Sárándi-Kovács et al. 2015). Although *Phytophthora* species like *P. gonapodyides*, *P. pseudosyringae* or *P. lacustris* that we isolated are not responsible for epidemic devastation of common alder stands (Marcais-Husson 2014), they might cause forest stand decline (Szabó et al. 2013). The *Phytophthora* inoculum transported in the watercourses may also pose a potential threat to riparian alder gallery forests.

5 CONCLUSION

Four *Phytophthora* species were detected from the studied forest streams during the two-year monitoring period. These species are *P. gonapodyides*, *P. lacustris*, *P. plurivora* and *P. pseudosyringae*.

Seasonal changes in the diversity of waterborne *Phytophthora* populations seem to exist. The most diverse populations occurred in June 2011 and September 2012. The less diverse populations dissever into a spring-early summer and into a summer-autumn period. The changes of meteorological and hydrological conditions offer a partial explanation for this. While soundings and the quantity of precipitation had a substantial impact on the success of isolation, the monthly maximum of air temperature, the water pH, and the monthly amount of precipitation may have a great effect on the occurrence of different species.

The pathogenicity of *P. lacustris*, *P. gonapodyides* and *P. plurivora* isolates collected during the survey were tested through the inoculation of sessile oak saplings. They all proved to be moderately aggressive against the two-year-old saplings in soil infection and stem inoculation experiments. Earlier results showed that *P. lacustris* and *P. gonapodyides* are pathogenic against common alder saplings as well (Sárándi-Kovács et al. 2015). These results warn us of a potential threat: sessile oak trees might be infected by *Phytophthora* species transported in the water of forest streams.

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Contents and Abstracts of the Bulletin of Forest Science

Bulletin of Forest Science (Erdészettudományi Közlemények) is a journal supported by the Hungarian Forest Research Institute and by the Faculty of Forestry of the University of Sopron. The papers are in Hungarian, with English summaries. The recent issue (Vol. 8, 2018) contains the following papers (with page numbers). The full papers can be found and downloaded in *pdf* format from the journal's webpage (www.erdtudkoz.hu).

Vol. 8, Nr. 1, 2018

Anikó HIRKA, Zoltán PÖDÖR, BALÁZS GARAMSZEGI, and György CSÓKA:

50 Years trends of the forest drought damage in Hungary…11–25

Abstract – The frequency of droughts increased in Hungary between 1962 and 2011. On top of this increasing trend, the extreme droughts had become more and more frequent. As a response for this, forest drought damage also showed an increasing trend. The yearly values of the forest drought damage showed a significant response for the yearly values of two drought indices (Pálfai and Forest Aridity index). Drought damage is reported not only from younger lowland stands, but also from older native stands of montane regions. It is proven that droughts play a decisive role in the health of sessile oak and beech stands. On top of their direct impacts, droughts have major indirect effects on forest health, manifesting in "damage chains". Droughts regularly have positive effects on outbreaks of many forest insects. The trees and stands weakened by drought stress can successfully be attacked by pathogens which are less aggressive amid better weather conditions. If the frequency and severity of droughts (and other weather extremes) increase (as it is predicted), our forests will suffer from an even higher damage pressure, so further negative health trends can be predicted in Hungarian forests. Therefore the forest management/sylviculture should aim at increasing forest resistance/resilience. The reactive forest protection should be changed for a long term proactive approach.

Ernő FÜHRER:

Forestry aspects of climate evaluation…27–42

Abstract – In contrast to the other site factors, climate has shown a relative fast changes in the last decades. This emphasised the need of the rethink of the existing forest climate classification based on a more scientific, ecophysiological approach. For the more exact assessment of the climate, a new indicator (Forestry Aridity Index; FAI) has been developed that characterizes the forest climate categories with meteorological variables, thus the area of these categories and its observed and expected changes can be captured. FAI enables the more accurate climate categorization of the forest regions in the forest inventory, which is one of

the most important innovation in the forestry sector. Revision of the climate classification of the inventory is important, since the categories have also general forest management contexts, i.e. ecological, management and economic conditions are associated with them. In-depth understanding of these relationships allows the renewal of forestry site typology. Based on this, it is possible to develop a Decision Support System for forestry that can be applied to adapt to climate change its impacts.

Abstract – Tree species selection and decision support in forestry require long term climate projections. Our study is focusing on the future temperature and precipitation conditions for the months that are determining and limiting the distribution, vitality, growth and production of forests. For the 21st century, results of 12 regional climate model simulations were analyzed assuming the A1B emission scenario of the lPCC. Forest climate categories as well as the droughts were defined based on the forestry aridity index (FAI). Increase of temperature and decrease of precipitation are expected to be the largest in the critical period (July-August), but they are also significant in the main growing period (May-August). In the Hungarian lowland the drier conditions (Forest steppe climate category) are expected to expand (replacing the former Oak climate category) and cover more than 35% of the total forest area. This will result also in novel combinations of site factors that have not existed in Hungary before. Based on the mean estimations, these so called 'Steppe climate category' can reach more than 10% of the country until the middle of the century. In absence of surplus water, these climate conditions will not be suitable for managed forests any more. Additionally to the changes of the climatic means, the total number of droughts and extremely droughts can be doubled for the period 2021-2050 relative to 1981-2010. Water scarcity and extremely high temperatures can enhance the drought risk thus can lead to severe impact on the vitality, growth and organic matter production of the trees. Based on the expected climate conditions the Agroclimate Decision Support System defines the forestry climate category for the selected region and makes suggestion for the tree species composition.

Abstract – Climate change will have a significant impact on forest cover of Hungary. Climate is one of the most important site factors therefore, it has a direct influence on forests. On the other hand, the climate has an indirect impact on the change of other site factors, such as hydrological and soil conditions. Some changes occur relatively fast, thus a significant change may happen during a single vegetation period. Some other factors need longer periods or hundred of years for transformation. During our research, we estimated the impact of climate change on soils. Soils not only create the foundations of human, animal and plant life but also have a very important role in regulation and production. Significant changes in soil-forming processes may emerge as a result of climate change. Along with the change in soil-forming processes, we also evaluated possible changes in the nutrient cycle of forest stands. The appearance of changing site factors and the emergence of a new climate category – steppe – will determine new site type variants. To summarize, we described what kind of site type variants can be expected in the future and what kind of criteria are needed for a tree species proposal. It provides a good basis for a Decision Supporting System (DTR) which will facilitate the selection of tree species in the future.

Abstract – The global temperature increase is expected to cause severe impacts on the water balance. The objective of this paper was to develop a new monthly step model based on a Thornthwaite-type monthly water balance estimation and calibrate the model parameters using remote sensing-based evapotranspiration dataset. The calibrated model was also used for projection based on the simulation results of 4 regional climate models applying the IPCC SRES A1B emission scenario. The 3 periods of projection were: 2010-2040, 2040-2070, and 2070-2100 compared to the reference period (1980/2010). The benefit of our method is its robust structure; therefore it can be applied if temperature and precipitation time series are accessible. The key parameter is the water storage capacity of the soil (SOILMAX), which can be calibrated using the actual available evapotranspiration data as well. If the soil's physical properties are available, the maximal rooting depth is also projectable. The model can be used at the catchment level or for areas without additional water amounts from below. We have determined parameters (REW; SWD) to evaluate the water stress during the 21st century. The model has been successfully calibrated for a mixed parcel and for a small forest covered catchment in Northwest Hungary.

Abstract – In this article, we would like to present a machine learning algorithm that processes the data of Járó's target stands and their growth for each forest site variation. The method is able to propose stand types and growths on the basis of existing data for new variations due to climate change and for a newly entering forest climate zone. The essence of this process is to place the entries of the Járó's table in a five-dimensional space, and use distance kernels to select the closest target stand types and weight their growth rate. It defines for a specific forest site, which target stands are likely to be in the area and what kind of growth can be characterized. The results will be incorporated into the decision support system of the Agrárklima project after proper validation.

Abstract – Growth of forest stands is a central question in the field of forest research. Climate change impact assessment also assigns significance to this question. The growing conditions of forests are changing in Central Europe and the impacts of changes are generally considered to be disadvantageous. Increasing frequencies and duration of heat waves and droughts constrain the growing potential of industrially important species. For this reason a statistical evaluation of growth of sessile oak (*Quercus petraea*, Liebl) was conducted using site (bioclimate and soil) describing predictor variables. The study involved 4594 geo-referenced species records from the National Forestry Database. We focused on practically monoculture stands of seed origin. Climate variables were represented by the Climate EU database. The period of 1961-1990 was considered as climatic baseline. The future, altered climate conditions were represented by the RCP 4.5 scenario based climate models for the period of 2041-2070. Soil and non-climate site data were added from the most recent spatial soil database of Hungary. The statistical random forest package of R was used to build classifiers for yield class predictions based on soil and bioclimatic variables for the reference period. The results of the model series were tested on test sites taken from the permanent yield monitoring plots and forestry database. It was found that predictions reached a relatively high 62-83% correct classification rates by yield classes performing on 77% as an average. Models were run using future climate datasets for the period of 2041-2070 in order to assess changes in future yield classes of forests. Results showed that the extent of the area of best yield classes will decrease, and the most suitable areas show a slight shift to west and to north. In the Pre-Alps region, in the South-Transdanubian region, and in the Transdanubian Mountainous region the well growing sessile oak areas will probably turn into medium or even poorly growing ones. In the same time in the Northern Mountainous region models did not predict significant changes in yield potentials. Overall growing conditions of sessile oak seem to be slightly worsening in the next decades.

Imre BERKI, Norbert MÓRICZ, Ervin RASZTOVITS, Krisztina GULYÁS, Balázs GARAMSZEGI, Adrienn HORVÁTH, Pál BALÁZS and Bence LAKATOS:

Abstract – The drought-induced vitality loss of sessile oak (*Quercus petraea* (Matt.) Liebl.) has been continuously observed in Hungary for more than three decades. On the other hand there are some publications about the accelerated and decelerating growth of this tree species in Hungary. The changing height growth was studied on dry sessile oak sites to decide the presence or absence of the accelerated growth of young stands neighbouring older one with mass mortality in the last decades. Results showed a significant accelerated height growth of young stands in dry landscapes. The mass mortality and the accelerated growth of sessile oak stands in the dry landscapes are not contradictory.

Csaba MÁTYÁS, Anikó HORVÁTH-KÓCZÁN, Antoine KREMER and Cuauhtémoc SAENZ-ROMERO:

Abstract – The report presents the analysis of phenotypic response (reaction norm) of selected sessile oak populations to simulated climate change, based on 10-year height data from an international provenance experiment network initiated by INRA (France). Reaction norms were calculated for assessing tolerance of populations to (simulated) warmer and dryer conditions than at origin. The unilateral responses to waming and drying climatic conditions have been linear. The maximum growth potential of populations was shifted toward more favorable conditions than the original ones. Phenotypic plasticity of populations of various provenance, interpreted as an indicator of climate sensitivity, was found significantly different. The provenances from the Carpathian Basin have shown average performance compared to other European populations. The better phenotypic plasticity of populations originating closer to the xeric (trailing, lower) limit is the most important result of the analysis, in terms of reproductive material use. The results corroborate the concept of "assisted migration" for sessile oak and may support the development of a strategy for adaptive forest management

György CSÓKA, Anikó HIRKA, Mariann CSEPELÉNYI, Levente SZŐCS, Miklós MOLNÁR, Katalin TUBA, Rudolf HILLEBRAND and Ferenc LAKATOS:

Response of forest insects to the climate change (case studies)…149–162

Abstract – There is a very tight relationship between insects and their environment, therefore if there is even the slightest change – due to climate change for instance, they react sensitively. This reaction can be very diverse. Their area can expand, their development time can change and consequently their number of generations can alter as well. Effect of factors influencing the size of the populations (natural enemies, mortality) can differ too. It should also be mentioned the sensitive interaction between herbivore insects and host plants in particular, where the insects can react very fast to the changes in the host plant (e.g. drought, stress caused by heat). Ultimately new species can appear, previously rare species can have mass outbreaks or their damage area can expand. We are demonstrating the changes of the last decades in six sample examples: oak lace bug (*Corythucha arcuata*), cockchafer (*Melolontha melolontha*), oak processionary moth (*Thaumetopoea processionea*), cotton bollworm (Helicoverpa armigera), gypsy moth (*Lymantria dispar*), in addition to the bark beetle damage in spruce stands.

Dénes BARTHA, Imre BERKI, Attila LENGYEL, Ervin RASZTOVITS, Viktor TIBORCZ and Gergely ZAGYVAI:

Estimated shifts of forest communities and tree species during changing climate…163–195

Abstract – Our study reflects a multiple approach. On the basis of native tree species estimated response we analyzed the probable rearrangement of our native forest communities. Theoretical estimations were synthetize with result of field work tree mortality and regrowth examination. From the point of view of potential invasion biology, low risk tree species were chose for possible substitution of our native species. In case of native and invasive species country scale databases, in case of substitute tree species european scale were used for predict future potential distribution. On the basis of National Forestry Database potential natural forest community database of forests were created for the present and future prediction also. According to our results, case of forest and forest steppe habitats high species and structural diversity (fragmented forest stands with grasslands and shrubs) can report higher adaptation. Usage of non native tree species only be possible if new circumstances are not suitable in any case for native habitats and taxa.

Gergely ZAGYVAI, Attila EREDICS, Ágnes CSISZÁR, Márton KORDA, Attila LENGYEL, Viktor TIBORCZ and Dénes BARTHA:

Studies on factors influencing forest gap vegetation with special attention to the microclimate…197–210

Abstract – Based on data from 12 microclimate measurement networks placed in different gaps of various forest stands in Hungary, linear correlation was found between the gap size and certain daily meteorological parameters. The comparison of the forest and gap data to the nearest state meteorological observatory also revealed systematic differences. These provide opportunity to estimate certain climatic parameters, e.g. daily maxima or minima in various sized gaps and the surrounding forest stand, based on standard meteorological observations. Relationship between attributes of 109 gaps and species diversity were analysed as well as indication of microclimatic gradient by regrowth species. Effect of gap age and size are different by social behaviour type. The shape of gaps affects the species richness of regrowth. Positive correlation was detected between Forest Aridity Index and diversity variables. The total number of species, individuals and effective numbers of regrowth species are highest in the centre of the gaps. Shady, moist areas of gaps are indicated by regrowth of typical mesophilous tree species.

Abstract – Changes in the forest carbon cycle are among the projected risks of climate change. In this study, these changes were estimated for three important Hungarian tree species for two regional climate change scenarios and three wood harvesting scenarios using the carbon accounting model CASMOFOR. The effects of changing local climate type on species composition and tree growth were studied under ceteris paribus conditions using appropriate site-related forest inventory information. The effect of projected droughts on mortality was modelled using empirical results of a previous study, while conservative assumptions were applied for the effect of climate change on several less important model parameters. Results demonstrate dramatically increasing mortality, considerably changing species composition and significant drop of tree growth as the risk of drought increases. As a combined effect of all these processes, country-level emissions from forests are projected to reach the order of magnitude of the current total economy-wide greenhouse gas emissions by the second half of the century. By providing positive feedback, these emissions can considerably offset mitigation efforts in non-forestry sectors.

Abstract – Forest management is the only economic activity which also permits the prolonged extraction of significant amounts of atmospheric carbon. The purpose of our research is to deteminate the carbon footprint of forest loggings during utilization within the entire life cycle of raw wood products. In addition, the environmental impact assessment of forest logging technologies also can be an important factor in climate change adaption. Shortwood forestry work systems has been assessed by environmental impact assessment using the Life Cycle Analysis (LCA) method. Based on a common functional unit (1 ha), a comparative environmental LCA for intermediate and final cutting was performed in stands of beech, oak, spruce, acacia, hybrid poplar. Based on results, a carbon footprint order (GWP) were calculated for utilization life cycle phases and for the entire tree utilization life cycle. Final cutting had the most significant impact based on the analysis of the absolute carbon footprint (ABF) per hectare (considered fossile and biotic origin together). The distribution of ABF by final cutting showed the following order: hybrid poplar (8%) – beech (9%) – spruce (11%) – acacia (35%) – oak (37%). For the whole technological life cycle, the ranking of ABF was "hybrid poplar (77109,06) - spruce (120868,7) - beech (165050,7) - acacia (354843,2) - oak (439544,1) (GWP 100 years: [kg CO_2-Equiv.]). For the carbon footprint of fossil origin, the ranking was „beech (2326,0) – oak (7679,89) – hybrid poplar (9063,94) – spruce (11109,85) – acacia (11206,34) (GWP 100 years: [kg CO_2-Equiv.]. Based on the contribution of each climate change process, an ecological risk assessment has been added. With regard to the determination of carbon storage potential, raw wood products can be considered as low-emission raw materials

Abstract – This study utilizes a national questionnaire sample and interviews to examine attitudes to climate change as well as perceptions and adaptation activities among Hungarian forestry managers. The results show the respondents addressing climatic changes are concerned mostly by the decrease in the number of snow-covered days, but differences of opinion can be attributed to geographical location and the forest areas managed. Hungarian forest management is still in the preparation phase with only 16% of respondents reporting the implementation of climate change adaptation measures; however, many foresters claim this is often hindered by legislative constraints. Those who have implemented adaptation measures show an increased concern toward climate change on average; they have been aware of climate change for a longer time and regard it as a serious problem affecting their management activities. The study has evidence that state forest managers do not adapt better than private foresters do, high level of concern and nature conservation factors do not hinder adaptation. However, during the interviews respondents reported that nature conservation factors do, in fact, hinder adaptation processes.

Vol. 8, Nr. 2, 2018

Balázs GARAMSZEGI, Melinda NAGY-KHELL, Máté FARKAS and László NAGY:

Impact of weather conditions on the interannual growth characteristics of alder and oak stands with improved groundwater-management…9–16

Abstract – Tree ring analysis in common alder (Alnus glutinosa) and pedunculate oak (Quercus robur) stands were carried out as a part of the monitoring tasks related to the KASZÓ-LIFE project, which targeted to improve the groundwater supply of the project area. Aims of the research were to identify benefits of the increased groundwater level and its more balanced 10 Garamszegi Balázs, Nagy-Khell Melinda, Farkas Máté és Nagy László interannual course due to the technical interventions in the growth of the sample trees. A specific focal point was to assess the sensitivity of the annual increments to the severe weather events like droughts under the changed conditions. The preliminary results reveal a much stronger relationship of alder growth with climate (first of all, with summer rainfall and mean relative humidity) than in case of oak, even when considering the generally higher groundwater level of alder stands. Regarding the benefits of the technical interventions, a series of severe drought years after 2000, selected by the 6-month SPEI drought index and decrease in alder increments indicate that following the actions, growth decrease of alder stands were significantly lower than the rate at the control site in 2017, though a reverse tendency was common during all the previous drought periods. However, the average increment decline of all investigated stands was much stronger in this year, than it could be predicted by the weather conditions based on the growth-climate relationships dating back to the previous decades, giving a possible evidence of unfavorable climatic trends and recurrent drought periods, even parallel with the mitigating actions.

Csaba Béla EÖTVÖS and László HORVÁTH:

Changes of groundwater levels in Szenta-forest as result of Kaszó-Life project…17–23

Abstract – Monitoring of groundwater wells can give us a reliable method to the long-term analysis of the groundwater levels. With this method we have been able to follow the effects of different interventions to the groundwater recharge. During our experiments the groundwater level changes at 18 sample sites was investigated. The area was characterized by decrease of the groundwater level in the last decades caused by anthropogenic influences such as water management or drainage and by uneven precipitation distribution. We intended to increase the groundwater level by water wales disposed perpendicular to the direction of the flow of the periodic watercourses that encircle the area and by heightening the dams of reservoirs, furthermore by building new reservoirs. In the frame of KASZÓ-LIFE project, according to our results the implemented water retention works did slow down the speed by half of the decrease of the groundwater levels; meanwhile the precipitation have been still not enough to stop the decreasing tendency of groundwater levels.

Abstract – The effect of simulated climate change was studied on populations of different beech (Fagus sylvatica L.) provenances. The climatic adaptation of six selected beech provenances (Farchau, Pidkamin, Torup, Gråsten, Bánokszentgyörgy, Magyaregregy), growing at the site of the beech provenance test of Bucsuta (H) were compared by the assessment of their enzymatic and non-enzymatic antioxidant system. The total protein content, peroxidase (POD) and polyphenol oxidase (PPO) enzyme activities as well as ABTS (2,2'-azino-bis-(3-etylbenzothiazoline)-6-sulfonic acid) antioxidant capacity were measured from the leaves of selected trees. The identification and quantitative determination of major leaf polyphenols was also determined from the same samples. By the comparative analysis of the enzymatic and non-enzymatic antioxidant systems 26 Visiné Rajczi Eszter, Hofmann Tamás, Albert Levente és Mátyás Csaba of the provenances it was concluded that the selected chemical variables were suitable for the assessment of the climatic stress, simulated by the translocation of the investigated provenances. POD enzyme activity as well as total protein content and the concentrations of certian polyphenols could be potential chemical indicators of the adaptation process and could be used in the forecasting of the future effects of climate change and in the selection of propagation material in the future.

Abstract – The aim of this paper to show how hydrological measurements in forests and grasslands can contribute to the treatment of different areas. The study was carried out in three different forest stands and their surrounding grasslands of the area of the Kiskunság Sandridge, between 2012 and 2015. Different methods were applied during the study of the water balance. The water balance shows that the values of the water uptake of the grasslands are lower than that of the surrounding foreststands. The hydrological measurements and results can be useful for the sylviculture in different sand forest types under the changing climate conditions.

Abstract – Nowadays forest plantations have a growing role in wood production. The area of SRF plantations is growing in Europe, but there is only little information about how traditional forestry interventions, like thinning affects yield in the first couple of years after establishment on short and midi rotation plantations. The aim of this paper is to see if spacing controls result in higher yields. In 2011 an experimental plantation was established in the Dejtár 4 CS forest compartment, where the same intensity spacing control was used but at a different age on 'AF2 to see how it affects the yield. For this purpose, dendrometrical measurements were completed for 6 continuous growing seasons. There is no difference in the aspect of dendromass inventory between the controlled and not controlled plots nor in the case of interventions at different ages during the examination period. Following the year of spacing control, increment was higher than in the last growing season and then in the control plots. Despite having no difference between the yields, the dimensions of trees show difference in spacing controlled plots and in the control ones. This means that the spacing control mostly affects the quality of wood.

Viktória NEMES, Ágnes CSISZÁR and Dénes BARTHA:

Studies on black cherry (*Prunus serotina* Ehrh.) occurrence in the area of comparative tree species examination, Nagylózs…61–70

Abstract – Coenological studies have been carried out in Nagylózs 5F experimental forest subcompartment (Győr-Moson-Sopron county) to examine the occurrence of invasive black cherry in different forest stands planted in 1969. According to our monitoring results, black cherry is present in all parcels of the forest subcompartment and shows considerable spreading in the surrounding areas. Among the 12 studied parcels, the species became dominant in the canopy layer of sweet chestnut, Norway spruces and Scots pine parcels; where the presence of the former planted trees had decreased considerably. It occurs only infinitesimally, mainly with seedlings in linden parcels with high canopy closure. Statistical analyses confirmed negative correlation between the canopy closure and black cherry dominance in shrub layer. According to our studies, we would like to draw the attention to the importance of canopy closure and shading effect of the second canopy layer during the control of black cherry.

Réka ANDRÉSI, Gergely JANIK, Ágnes FÜRJES-MIKÓ, Csaba Béla EÖTVÖS and Katalin TUBA:

Faunistical studies on Coleoptera of tinder conk [*Fomes fomentarius* (L. ex. Fr.) Kickx.] in Hungary…71–82

Abstract – Our present knowledge on beetle communities of tinder fungi is far from complete in Hungary. During our research (2010– 2013) 193 fruiting bodies of *Fomes fomentarius* (L. ex. Fr.) Kickx. were collected from vicinity of 27 Hungarian settlements. Our purpose was to gain new knowledge from the beetle communities related to Fomes fomentarius fruiting bodies in Hungary. A total of 4,726 beetles were reared out from the samples. 4,703 specimen of this, belonging to 27 species were identified for species level. Some beetle species typically associated with Fomes fomentarius (e.g. *Bolitophagus reticulatus*), but *Bitoma crenata* is a predator, so other species could attract it to the fruiting bodies. The largest individual was the *Rhopalodontus perforatus*, from the Ciidae family, followed by *B. reticulaus* and *Cis castaneus*. Nowadays, treating dead wood has an ever-increasing significance in forests, so the examination of decomposer fungi and their communities is necessary to get better knowledge from diversity and functions of the forest ecosystems.

István HARTA, Dániel WINKLER and György FÜLEKY:

Effect of reforestation on soil properties and mesofauna (Collembola) in a former long-term fertilization experimental area…83–97

Abstract – Reforestation with black locust (Robinia pseudoacacia) and sessile oak (Quercus petraea) has occurred on two former fertilization experimental areas of Szent István University in Gödöllő. The aim of this study was to investigate the soil parameters and the Collembola fauna in the previously highest fertilizer-treated parcels. Nerby control sites (black locust forest, sessile oak forest, relict forest, as well as cultivated and abandoned arable land) have been selected for comparative analyses. Based on the results, the reforested areas were most similar to the control forests. Their Collembola fauna are transitional, species typical for both open areas and forests have also been detected. While the abundance, species richness and diversity of the experimental areas are still lower than in the control forests, we observed significantly higher 84 Harta István, Winkler Dániel és Füleky György diversity when compared to the communities found in the cultivated arable fields. While Collembola were slightly more abundant in the black locust plantation, species richness, diversity and evenness values were higher in the sessile oak plantation. Based on the Bray-Curtis similarity measure, open and forest communities clearly separated, moreover, the studied plantations and control forests formed separate subgroups.

Mariann KOMLÓS and Csilla KISS:

Estimation of the fallen dead wood in the Sopron Mountains…99–111

Abstract – In this paper we have analyzed the quantitative and qualitative dispersion of lying dead wood in two streambeds of the Sopron Mountains, the Tolvaj-árok and the Vadkan-árok. The estimation of the lying dead wood was made with the line transect method by perpendicular transects at the two valleys. The amount of dead wood was higher (30,66 m^3 /ha) in the Tolvaj-árok compared to the Vadkan-árok (21,23 m^3 /ha). The distribution of dead wood showed strong heterogenity on the study area for the three studied parameters (decay stage, diameter and tree species). The amount of fallen dead wood increased with stand age. Concerning forest communities, the largest amount of dead wood has been found in the sessile oak-hornbeam forests.

Tamás MERTL and Endre SCHIBERNA:

Private forest owners in Hungary…113–126

Abstract – Based on the analysis of land registry data, it can be concluded that the land lots with forest area larger than 0.5 ha, classified as forest management area and not 100% state property is owned by 425 thousand individuals and 3 thousand organizations such as enterprises, municipalities, civil organizations and churches. This study is focusing on the analysis of individual owners and finds that the number of female and male owners is equal, but male owners own almost double the area than that of the female owners. More than half of the owners live in villages, one-fourth in small towns and one-fifth in large cities, while only a fraction of owners is living abroad or at unknown places. The average size of property is 1.85 ha, and the distribution of property sizes is strongly concentrated. On the one hand, one-third of the owners own less than 0.1 ha and their forests cover only 0.6% of the study area, while on the other hand, the owners with forest area larger than 10 ha have a 3.1% share in the number of owners and a 55.0% of the study area. Two-third of the owners owns forest only in one single land lot, and the same share of owners lives within a 10 km radius from their property.