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In vitro and in vivo effect of poplar bud (*Populi gemma*) Extracts on late blight (*Phytophthora infestans*)

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Abstract: The effect of populin extract from black poplar (*Populus nigra*) on late blight was assessed under laboratory and field conditions. The growth rate of hyphae was found to be significantly lower after 1v/v% populin application, and no hyphae growth was detected under 3 and 6v/v% populin application. Populin also reduced the light blight severity on potato leaves under field conditions. From our results, we have concluded that populin extract can be considered as a new and environmentally-friendly alternative for the control of late blight under field conditions.

Keywords: potato, late blight, poplar bud extract, conventional treatment, field application, organic farming

1. Introduction

Late blight is one of the most severe diseases of the Solanaceae family [1]. It was responsible for the disastrous Irish potato famine in the 1850s, during which millions of people, especially children, starved and even died. Millions more were forced to emigrate [2]. Entire potato crops can be severely infested because of late blight infection [2,3].

Some management methods have been developed to control late blight. Because late blight can only survive on the living tissue of plants, transplants or imported potato tubers or tomatoes are the most significant source of early infestation. Therefore, one of the most effective management strategies is to avoid sources of early season inoculum (spores) [3]. Using conventionally (commercially available) fungicides is another approach to controlling late blight; however, several resistant strains against these fungicides have been reported [4–6]. Resistance to metalaxyl is already well known from The Netherlands [4]. Also the use of copper-containing formulations has precipitated an urgent need for alternative control methods all over in the EU [7].

Using different natural products, such as plant extracts, is considered an alternative method, and there is increased interest in developing treatment strategies based especially on natural plant products [8–10]. Under laboratory conditions, the effects of allicin (extracts from garlic) were tested and on the vegetative mycelial growth [11]. The allicin application significantly reduced the colonization of potato tuber. The inhibitory effects of allicin on the germination of sporangia and encysted zoospores, and the subsequent reduction in germ tube growth have also been reported [12]. Similar experiments under field conditions have been carried out directly against the pathogen, rather than via an induced resistance mechanism [11]. Other plant extracts may have similar effects, one potential compound being populin, an extract from black poplar (*Populus nigra*). The positive effects of populin in dealing with apple scab have been reported under both lab and field conditions [13,14]. Because potatoes represent one of the most economically important vegetables and because late blight resistance against conventional fungicides has already been demonstrated, we hypothesise that populin may have a similar effect on late blight in potatoes. We intend to offer a low-cost, accessible method for late blight control that may be useful in integrated pest control methods.

2. Material and methods

Laboratory survey

This study used the fungal strain *Phytophthora infestans* T2, which was obtained from József Bakonyi (Plant Protection Institute, Hungarian Academy of Sciences. Isolation source and date: potato leaf, Tordas village, Fejér County, Hungary, 9th September 2010) and maintained on Pea-broth agar (PBA) [15]. PBA test plates containing 1, 3 and 6 v/v% of the extract from black poplar (*Populus nigra*) buds (here termed *populin*) were prepared by the addition of the recommended amount of filter sterilized (0.45 µm pore-size mixed cellulose ester filter, Whatman GmbH, Germany), concentrated extract (20 v/v%) to the medium after autoclaving. Plates containing no extract were used as negative controls. First, PBA plates were inoculated with *P. infestans* and incubated for 14 days at 20°C. Round-shaped (8 mm diameter) agar blocks were excised from the plates that had

P. infestans mat on their surfaces, then the blocks were transferred both to the test plates containing the extract and to the control plates (10 plates of each type) (Fig. 1). The growth of *P. infestans* was measured daily over a 12-day period using a digital calliper. After two weeks, the whole experiment was repeated.

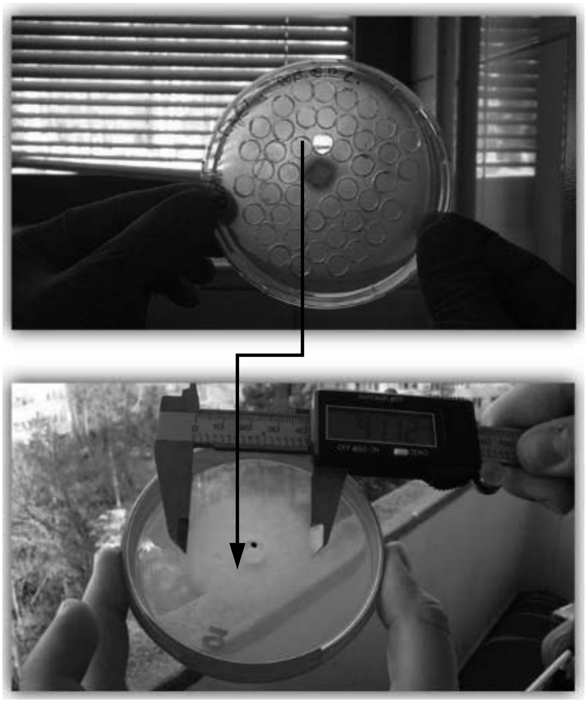

Fig. 1. Late blight strain growth rate experiment design under laboratory conditions

Field application of populin treatment

Field application of populin treatment was carried out during a complete vegetation period in Central Transylvania (46°1'22.01"N, 26°13'10.84"E). This area is dominated by potato fields on which traditional cultivating methods are applied. The experimental plot was established in a 1089 m^2 area representing 1.2 hectares. Altogether 12 experimental subplots were established from which four were populin treated, four were controls (without any pesticide application) and four were treated traditionally with commercially available pesticides in a normal regime (Table 1). Each experimental subplot contained 12 roves of plants with 75 cm between roves and 27 cm between plants. Populin treatment was applied in a 1% concentration (because 1% is easy to prepare for growers without any laboratory equipment). Populin application was carried out in a normal regime of a seven-day interval during the vegetation period. Pesticide application and populin application were synchronized and a total of 11 applications were performed during the whole field experiment.

Field assessment of late blight infestation

Field assessments of late blight were made two days after the final treatments for conventional, populin and control trees. To avoid interference from side effects, samples were taken from plants in the middle of each subplot. During the survey, the whole plant was extracted and the level of infestation determined on the leaves. 24 plants from each plot and a total number of 288 samples were acquired in this way. To assess severity, each leaf and fruit was classified as follows:

0 = healthy (0 foliar damage)
1 = slight infestation (1% to 25% damage)
2 = moderate infestation (26% to 50% damage)
3 = severe infestation (51% to 75% damage)
4 = high infestation (76% to 100% damage)

Tab. 1. Spraying programme of populin and conventionally used pesticides

No.	Date	Name	Active ingredient	Concentration %	Doses	Water (L)
1	6/20	Populus	*populin*	1	10 g/L	40
		Acrobat MZ WG	*mankozeb + dimethomorph*	-	2-2.5 kg/ha/600L	20
2	6/28	Populus	*populin*	1	10 g/L	40
		Antracol 70 WG	*propineb 70%*	-	2-2.5 kg/ha/600L	20
3	7/5	Populus	*populin*	1	10 g/L	40
		Infinito	*propamocarb + fluopicolide*	-	1.2-1.6 g/L	20
4	7/11	Populus	*populin*	1	10 g/L	40
		Galben M	*mankozeb, benalaxyl*	-	2.5-3 kg/ha/600L	20
5	7/18	Populus	*populin*	1	10 g/L	40
		Curzate R	*cymoxanil + copper oxychloride*	-	2.5-3 kg/ha/600L	20
6	7/25	Populus	*populin*	1	10 g/L	40
		Folpan 80 WDG	*folpet*	-	1.25-2 kg/ha/600L	20
7	8/2	Populus	*populin*	1	10 g/L	40
		Acrobat MZ WG	*mankozeb +dimethomorph*	-	2-2.5 kg/ha/600L	20
8	8/11	Populus	*populin*	1	10 g/L	40
		Antracol 70 WG	*propineb*	-	2-2.5 kg/ha/600L	20
9	8/16	Populus	*populin*	1	10 g/L	40
		Infinito	*propamocarb + fluopicolide*	-	1.2-1.6 g/L	20
10	8/29	Populus	*populin*	1	10 g/L	40
		Curzate R	*cymoxanil, copper oxychloride*	-	2.5-3 kg/ha/600L	20
11	9/5	Populus	*populin*	1	10 g/L	40
		Folpan 80 WDG	*folpet*	-	1.25-2 kg/ha/600L	20

Data analyses

The data from the lab-based experiments follow the assumption of normality; therefore, a paired t-test was used to assess differences between plant extracts at concentrations of 1v/v%. No analyses were performed to compare 3v/v% , 6v/v% and control because there was no development of fungal hyphae at any of these concentrations. Data from field experiment did not meet the assumption of normality. Therefore, the nonparametric Kruskal-Wallis test was used, followed by a Mann-Whitney test to compare the varieties of populin, conventional treatment and control.

3. Results

Considering the *average growth rate* of late blight under lab conditions, the 1v/v% populin significantly reduced the growth rate of late blight hyphae compared to the control ($t_{1\%} = 14.29$, $p < 0.001$). There was no change in diameter of late blight inoculums; thus, no hyphae development was detected with 3 and 6v/v% of populin application (Fig. 2).

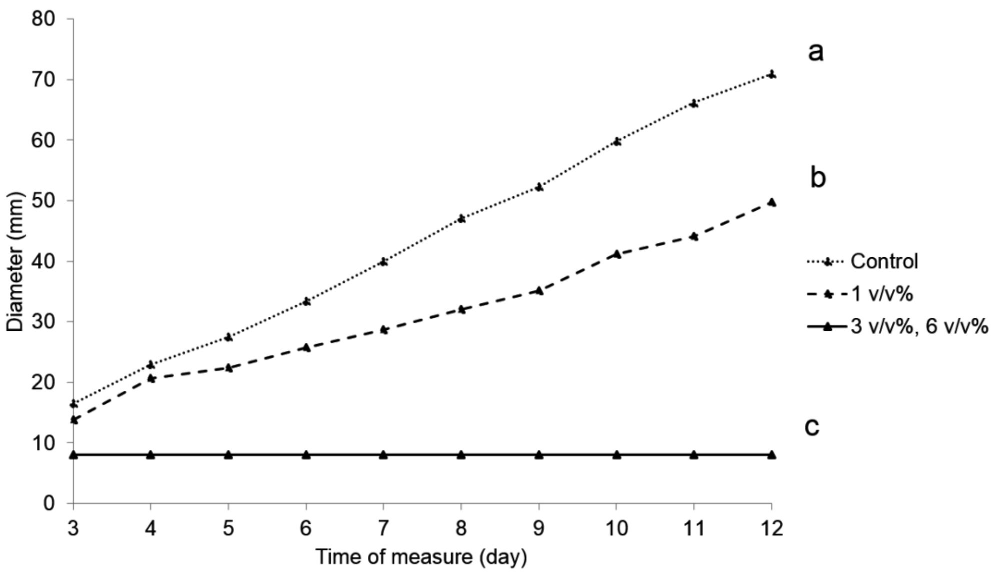

Fig. 2. The growth rate of late blight under laboratory conditions. Values were considered as the means of 10 replications. Different letters mean statistically significant differences (paired t-test).

The severity of late blight under field conditions was significantly reduced in both conventional and populin treatment ($z_{cont\text{-}conv} = -12.04$, $p < 0.001$, $z_{cont\text{-}pop} = -11.84$, $p < 0.001$). Comparing populin with conventional treatment, commercial fungicides showed a more noxious effect on late blight on potato leaves ($z_{conv\text{-}pop} = -3.145$, $p = 0.002$) (Fig. 3).

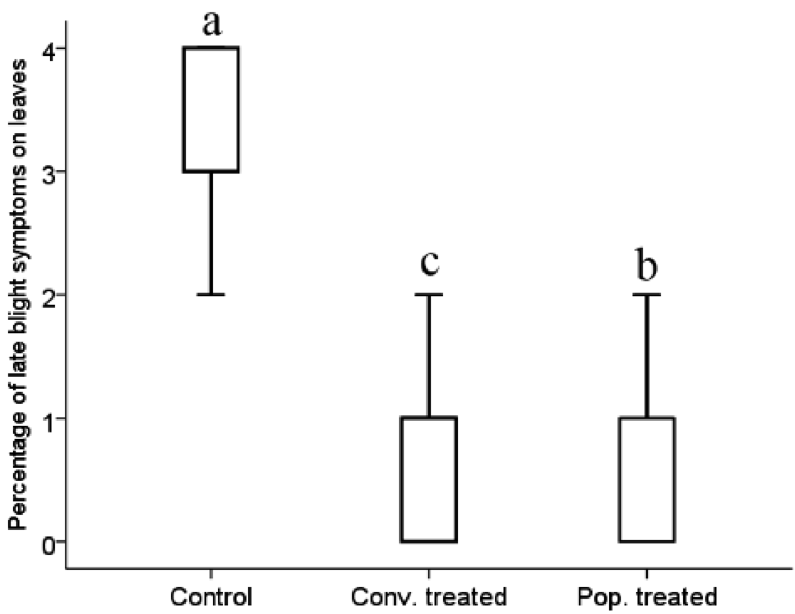

Fig. 3. Infestation level of potato leaves with late blight under filed conditions using conventional fungicides and populin. Values were considered as means of 96 samples. Different letters mean statistically significant differences (Mann-Whitney test).

4. Discussion and conclusions

Because of the traditional manner in which the potato fields from the study area are cultivated, it is less likely that the resistance of late blight to conventional fungicides exists. Based on our results, we have concluded that the severity of late blight infestation of potato crops can be significantly reduced by the use of populin plant extract. It is also a less expensive and readily available alternative method for reducing the growth rate of hyphae under laboratory conditions (Fig. 2).

For many growers, the repeated application of synthetic fungicides throughout the growing season has been the only available approach to managing late blight. Therefore, resistance against these fungicides now exists in many of the potato growing areas throughout the world [4–6].

According to our results, an application of 1v/v% populin, being one of the most accessible extracts, can therefore be easily prepared by growers at low cost. Its application considerably reduces late blight infestation on leaves during the whole growing season (Fig. 3). Populin extracts may have similar effects in reducing the growth rate of hyphae on leaves, although it may also reduce the germination rate of spores. Similar experiments in our previous study demonstrated that this extract considerably reduced the germination of apple scab (*Venturia inaequalis*) conidia and furthermore that infestation levels were similar or lower than those of conventional treatments [13]. Much more information however will be needed to test the long-term effects of populin extract on the development of late blight including the durability of the plant extract's effectiveness.

If late blight control using an integrated management programme receives attention in the future, populin extract seems to be a low-cost option for growers and the most environmentally-friendly approach for effective disease management. According to our results, including those of apple scab [13, 14], we conclude that controlling many severe fungal diseases with populin may enable partial elimination or at least the reduction of synthetic fungicide usage, thereby enabling efficient organic and / or integrated farming in regions of traditional agriculture.

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Changes of mycorrhizal colonization along moist gradient in a vineyard of Eger (Hungary)

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Abstract: The role of mycorrhizal fungi has special importance in the case of low soil moisture because the colonization of vine roots by mycorrhiza increases water and nutrient uptake and thus aids the avoidance of biotic and abiotic stresses of grape. Our aim was to investigate in the Eger wine region the changes of mycorrhizal colonization, water potential, and yield quality and quantity of grape roots at three altitudes, along a changing soil moist gradient. Our results show that the degree of mycorrhizal colonization is higher in drier areas, which supports the water and nutrient uptake of the host plant.

Keywords: mycorrhiza, grapevine, drought stress

1. Introduction

The changing climate can have adverse effects on agriculture. A quite serious effect is the increased length and frequency of extremely hot and dry periods during the summer, what may considerably alter the fruiting yield of the grape. Due to drought, the photosynthetic activity of the berries and the leaves is reduced [11, 14]. Poni et al. (1994) found that drought stress causes more serious damage to the youngest vines. Mycorrhizal colonization is really important for plants like grape for this plant species has fewer fine roots that cannot net the soil intensively on their own [12]. The fungal partner (mycobiont) supports the water and nutrient uptake of the host plant while the mycobiont gets the carbohydrate necessary for their metabolism from the plant [31]. In the case of grape, the fungus colonizes the roots intracellularly, and it forms dichotomously-branching invaginations (arbuscules), i.e. the roots bear arbuscular mycorrhizae (AM). The large surface area of the arbuscules ensures robust nutrient exchange between the plants and the fungus and vice versa [28]. The efficiency of the symbiosis can be described not only through the degree of colonization but also with the number of arbuscules on the colonized root stage [22, 28]. Mycorrhizal fungi are able to colonize different plants at the same time to form an interconnected physiological system, called common mycelia network [13, 30]. This develops a nutrient and water transport system between the several species of the vineyard [3, 7]. Typically, there is sufficient fungus already in the soil of the vineyards, but we can deliberately increase the level of colonization of the rootstocks used for the grafting. Consequently, artificial inoculation of grafting rootstock is suggested to increase adaptation to the plantation site, which results in stronger initial growth [2, 15, 21]. This is especially important in the first year of the vineyard development [10]. Mycorrhizal fungi are normally occurring in the soil [6], but inoculation can directly increase the number of mycorrhiza near plant roots [4]. Inoculation plays a significant role in the success of plantation development, especially under dry edaphic and climatic conditions, as water and nutrient uptake are increased for the young vines. If soil sterilization has occurred previously, inoculation of new rootstock may also be recommended [18]. Inoculation of older, already producing plantations is not necessary. If the soil contains inoculates of the native mycorrhiza fungi, the artificial inoculation is not worthwhile [19]. Native mycorrhiza species are more effective than the artificially available inoculants, presumably because the native species have adapted to the local circumstances. A successfully producing vine indicates sufficient mycorrhizal colonization [29]. In extreme weather conditions – especially in case of drought –, the role of mycorrhizal fungi is more important: mycorrhizal colonization changes the physiological nature of vines [9]. Mycorrhizal colonization is inversely related to soil moisture: as soil moisture increases, the incidence of arbuscules decreases [29]. With mycorrhizal colonization, grapes have a higher tolerance to drought [8, 16]. The effect on drought tolerance is related to the increased supply of soil moisture to the plants, osmotic regulation at the roots, and the altered hormone synthesis and transport [1]. In case of drought stress, the mycorrhizal colonization of the grapes increases [20, 25]. Where there are dry steep slopes and less fertile soils, there is a higher demand for mycorrhizal fungi to produce quality wines than in the case of more fertile or gently sloping soils having a more optimal retention of soil moisture [26, 32]. The aim of our experiment was to investigate the effect of inland water inundation – as a stress factor – of a two-year period (2011 and 2012) on the mycorrhiza colonization of grape roots, to study the effects of the inland water as stress factor, under field conditions.

2. Materials and methods

The Eger wine region is situated on 22,160 hectares in the northeast part of Hungary. The Eger wine region has almost 1,000 years of grape growing tradition. Our experiment was carried out in a plantation next to the city of Eger, which is the centre of the wine region. Three sets of experimental blocks were delineated at three different elevations along the slope of the sample vineyard (Fig. 1.). Samples were taken from the same plots in the spring and autumn. In addition to mycorrhizal colonization, yield and the stum quality were measured. The vine variety investigated was a Pinot Noir grafted on Teleki-Kober 125 AA rootstock, planted in 2001. The lowest part of the plantation had not been cultivated for decades before the vine establishment because the roughly 1000 m^2 area was often covered with standing water. The soil of the plantation is a Ramman brown soil, which is a clay type. Due to the high level of precipitation in 2010 (Tab. 1.), the low-lying area was covered with inland water until the end of 2012.

Tab. 1. Meteorological parameters

Monthly precipitate (mm)							**Yearly precipitate (mm)**	**Solar heat (Tmax ≥ 30°C)**
Year	March	April	May	June	July	August		
2010	10.2	53.5	167	98.9	166.4	62.5	924.6	24
2011	35.6	10.5	26.2	68.9	90.2	20.7	349.2	25
2012	0	40.1	38.8	75	107.6	5.4	493.5	42

Reference: www.metnet.hu

Block I was near the part of the vineyard covered with standing water. Blocks II and III were set progressively higher up the slope with the last one near the top of the vineyard, i.e. the crest of the slope. Each block contained four replications (4x25 vines in each block).

Fig. 1. The experimental blocks in the Eger wine-region

In 2011 and 2012, fine root samples were collected from 16 vine plants from each block after flowering and in the autumn (so, altogether 196 grapevines were sampled). The fine root segments were washed in distilled water, and stored in 70% ethanol. Before examination, the root sections were stained with aniline blue. Mycorrhizal colonization was determined on randomly selected root fragments using the method described by McGonigle et al. (1990) as modified by Schreiner (2003). The roots were mounted in parallel lines on the microscope slides. The proportion of colonization was determined under light microscope by assessing intersections between root fragments and the eyepiece micrometer at 2.5 mm increments. If the fragment contained hyphae and/or arbuscules, it was defined as colonized. Because the efficiency of the symbiosis can be described best by the number of arbuscules on the colonized root stage [22, 27], we also documented the number of arbuscules together with the colonization evaluation for the investigated root sections. For 2012, the water potential of the grapes was measured at the three different elevations [24]. We used the SPKM 4000 (Skye Instruments Ltd.) pressure chamber instrument, which can measure between 0 and 4 mPa. The measurement was carried out in the summer of 2012, on a hot, sunny midday. We collected eight leaves from each block.

The results were statistically analysed with the SPSS programme's One-Way Anova and Fisher's exact tests.

3. Results and discussion

However, the precipitation of 2010 (Tab. 1.) induced inland water till the end of 2012; the standing water and high water table destroyed all the grape plants in this area. The lowest lying block (Block I) was adjacent to this area so as to describe the significant differences regarding water potential of the plants between the three blocks (Tab. 2.). This is evident in the relief photo of the area.

Tab. 2. Water potential of the leaves (2012.08.19.)

Blocks	Water potential (mPa)		
I.	1.31		
II.	1.41		
III.	1.54		
Sign. [1]	I-II	I-III	II-III
	+	* *	*

[1]Difference between the averages investigated with Tukey-test ($p<0.05$)
n.s. = no significant difference; + = $p<0.1$; * = $p<0.05$; ** = $p<0.01$; *** = $p<0.005$

The results show that in the spring of 2011 there was difference in the number of arbuscules between blocks (Tab. 3). The mycorrhizal and arbuscular colonization did not differ significantly.

Tab. 3. Investigation of the root segments, 2011 spring

Blocks	Colonization (%)			Arbuscular colonization (%)			Number of arbuscules (pieces)		
I.	76			30			59		
II.	79			36			78		
III.	81			34			81		
Sign. [1]	I-II	I-III	II-III	I-II	I-III	II-III	I-II	I-III	II-III
	n.s.	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	+	+	*n.s.*

[1]Difference between the averages investigated with Tukey-test ($p<0.05$)
n.s. = no significant difference; + = $p<0.1$; * = $p<0.05$; ** = $p<0.01$; *** = $p<0.005$

During the investigation of the roots sampled in the autumn of 2011, we found significant difference in colonization between blocks I and II, I and III, and in the number of arbuscules we again found difference between blocks I and II and I and

III (Tab. 4*)*. The arbuscular colonization percentage did not show significant difference between the blocks.

Tab. 4. Investigation of the root segments, 2011 autumn

Blocks	Colonization (%)			Arbuscular colonization (%)			Number of arbuscules (pieces)		
I.	53			58			91		
II.	64			66			158		
III.	73			62			140		
Sign. [1]	I-II	I-III	II-III	I-II	I-III	II-III	I-II	I-III	II-III
	+	+	n.s.	n.s.	n.s.	n.s.	*	*	n.s.

[1]Difference between the averages investigated with Tukey-test (p<0.05)
n.s. = no significant difference; + = p<0.1; * =p<0.05; **=p<0.01; ***=p<0.005

We found differences between the blocks in the spring sampling of 2012 (Tab. 5). Our results show significantly higher rates of the mycorrhizal colonization and number of arbuscules in the higher altitude blocks than in the lowest lying block near the moist area of the vineyard.

Tab. 5. Investigation of the root segments, 2012 spring

Blocks	Colonization (%)			Arbuscular colonization (%)			Number of arbuscules (pieces)		
I.	46			31			48		
II.	62			37			97		
III.	64			38			105		
Sign. [1]	I-II	I-III	II-III	I-II	I-III	II-III	I-II	I-III	II-III
	*	**	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*	*	*n.s.*

[1]Difference between the averages investigated with Tukey-test (p<0.05)
n.s. = no significant difference; + = p<0.1; * =p<0.05; **=p<0.01; ***=p<0.005

Our results are in agreement with those of [26, 32]: the grape definitely needs the support of the mycorrhizal colonization on dry and sloped sites, as well as on those of low humus content. The results also confirm those [8, 16] who observed that drought periods with low precipitation can increase the amount of mycorrhizal colonization and therefore contribute to the vine tolerance of drought stress. Almost every investigation has found a higher number of arbuscules at higher elevations of the slopes. At the beginning of our work, the first block was adjacent to the inland-water-covered part of the vineyard, so, the soil water content was high and the soil gas content was low for the grapevines. These conditions have probably contributed to the low colonization level of these vine roots as well. Here, the vine plants may not need the help of the fungus to improve their water uptake. As soil moisture content is more available to the vines, the frequency of the arbuscules decreases [29]. Mycorrhizal colonization is less common in the case of irrigated vineyards where soil moisture is maintained near an optimal level [27]. Supporting water uptake is not the only function of the hyphae. The arbuscular-mycorrhizal fungus has an effect on the water storage capacity of the soil and the stability of soil aggregates by the ability of fungal hyphae to entwine the soil particles with the aid of a special compound, glomalin, produced by arbuscular mycorrhizal fungi [34]. 2012 was a dry year in Eger and the standing inland water evaporated from the lowest part of the vineyard. In the autumn of 2012, we did not measure significant difference in the number of arbuscules between the three blocks, but in terms of arbuscular colonization we saw significant differences in the favour of Block I. (Tab. 6).

Tab. 6. Investigation of the root segments, 2012 autumn

Blocks	Colonization (%)			Arbuscular colonization (%)			Number of arbuscules (pieces)		
I.	75			44			72		
II.	74			32			69		
III.	82			30			75		
Sign. [1]	I-II	I-III	II-III	I-II	I-III	II-III	I-II	I-III	II-III
	n.s.	*n.s.*	*n.s.*	+	*	*n.s.*	*n.s.*	*n.s.*	*n.s.*

[1]Difference between the averages investigated with Tukey-test ($p<0.05$)
n.s. = no significant difference; + = $p<0.1$; * =$p<0.05$; **=$p<0.01$; ***=$p<0.005$

Table 7 shows us the comparison of the initial and the last examined periods. The changes marked in bold numbers in the case of Block I are quite important in the context of the decrease of the inland water during the two-year period. In accordance with [25], the frequency of the arbuscules tends to indicate the efficiency of interaction between grape and fungus. Due to the mycorrhizal colonization, grapes have a higher tolerance to drought [8, 16]; so in the case of our open-field trial, the results are confirmed.

Tab. 7. Comparison of the investigated blocks

2011 spring and 2012 autumn						
Examined indices	2011 / spring I.	2012 / autumn I.	2011 / spring II.	2012 / autumn II.	2011 / spring III.	2012 / autumn III.
Mycorrhizal colonization (%)	76	75	79	74	81	82
Arbuscular colonization (%)	**30**	**44**	36	32	34	30
Number of arbuscules (pieces)	**59**	**72**	78	69	81	75

Most likely, the decrease of the soil moisture content contributed to the increased arbuscular colonization. Moreover, because of the previously unfavourable soil conditions, the nutrient uptake was limited in the first two years, and the increased AM colonization enabled the uptake of the previously unavailable nutrients (due to the saturated state of the soil) to nutrients available to the vines. Our results regarding the mycorrhizal colonization correlate with the measured yields. In 2011, the yield, the number of bunches and the average bunch weight was significantly lower in the case of Block I than the in the case of the others (*Tab. 7*). The differentiation of buds occurs in the previous year (Bényei et al. 1999), so the unfavourable circumstances in 2010 (lack of air in the soil, inland water inundation and less sunlight (due to overcast and cloudy skies)) had a negative effect on the number of bunches and yield in the following year.

Tab. 8. Yield, 2011

Blocks	Averaged weight of the bunches (g)			Number of bunches (bunch/vine)			Yield of 16 vines (kg)		
I.	106.4			11.4			19.4		
II.	138.3			18.4			40.9		
III.	148.3			15.6			37.1		
Sign. [1]	I-II	I-III	II-III	I-II	I-III	II-III	I-II	I-III	II-III
	*	**	*n.s.*	***	**	*n.s.*	**	**	*n.s.*

[1]Difference between the averages investigated with Tukey-test (p<0.05)
n.s. = no significant difference; + = p<0.1; * =p<0.05; **=p<0.01; ***=p<0.005

Tab. 9. Yield, 2012

Blocks	Averaged weight of the bunches (g)			Number of bunches (bunch/vine)			Yield of 16 vines (kg)		
I.	75			44			72		
II.	74			32			69		
III.	82			30			75		
Sign. [1]	I-II	I-III	II-III	I-II	I-III	II-III	I-II	I-III	II-III
	n.s.	*n.s.*	*n.s.*	+	*	*n.s.*	*n.s.*	*n.s.*	*n.s.*

[1] Difference between the averages investigated with Tukey-test (p<0.05)
n.s. = no significant difference; + = p<0.1; * =p<0.05; **=p<0.01 ; ***=p<0.005

Micorrhyza fungi help not only water uptake but nutrient uptake as well [25]; so, the low number of arbuscules correlates with the reduced differentiation of the buds. The drier weather of 2011 and the disappearance of the inland water had a positive effect on bud differentiation. Yet, more bunches were observed at higher altitudes than were counted on the inland-water-covered block, but the yield was not found to be significantly different (*Tab. 9*). The regeneration of the vine is indicated by increases in the number of bunches and so the increased activity of the mycorrhiza measured as the number of arbuscules.

4. Conclusion

The results of our experiment were confirmed by results from other experts, which had been carried out in most cases under greenhouse conditions. Our work was a field trial and its importance is that mycorrhizal colonization was investigated under the effect of more extreme conditions and predictions from controlled experiments were confirmed in the actual vineyard site and across its variable soil. The results show the relevance of the microorganisms (in this case, the mycorrhizal fungi) in the balanced life of the grapevine, especially under extreme weather and site conditions, and in the practice of the organic farming.

Acknowledgement

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Effect of the soil treated with biochar on the rye-grass in laboratory experiment

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Abstract: The application of biochars to improve soils and to mitigate global climate change is a popular research area all over the world, although it is not a new topic. In our study, wood chips char (BC) and animal bone char (ABC) were applied. The pot experiments were conducted under laboratory conditions. 2 grams of rye-grass (*Lolium perenne*) were seeded into each pot. The following various soil parameters were measured: pH (KCl), AL-P_2O_5, AL-K_2O, total water soluble salt content and organic matter content. The measured parameters from the plant samples were: total-P, total-K and micronutrients. Results show that the negative or positive effect of pyrolysis solids cannot be determined clearly, further experiments are needed.

Keywords: wood chips char, animal bone char, soil properties, nutrient uptake

1. Introduction

The application of different biochars to improve soils is a notable research area nowadays. Most of the biochar-application-related research has taken place in tropical environments [1]; so, the experiments on different climatic regions and different soil types are especially necessary.

Biochar as a material is defined as: "Biochar is a carbon-rich product of the pyrolysis process, intended to be used as a soil amendment to improve the physical and chemical characteristics of soils and to mitigate climate change by sequestering carbon. When applied to soil, biochar provides plant nutrients, increases surface area, CEC and water-holding capacity, and improves the soil as a microbial habitat” [4, 5].

The conditions of pyrolysis and feedstock types have a notable influence on the physical and chemical composition of the biochar. All these various properties determine its function, transport and fate in the environment, and, at last, the suitability for a given application. This heterogeneity renders the identification of the underlying mechanisms behind reported effects more difficult, but it also provides possibilities to engineer biochar with controlled properties [8].

The pH of biochars is usually neutral to basic; so, the biochar application has a liming effect on soils, which plays an important role in increasing plant productivity [8]. Biochar may also produce phytotoxic effects also due to the excessive soluble salts and the high pH [6]. Soluble salts are often present in the ash fraction of biochars, depending mostly on the mineral content of the feedstock [8].

Many studies have confirmed that biochar is a very efficient absorbent for nutrients [2, 3, 5]. The absorbance and slow release of plant nutrients of biochar provides a good feasibility to reduce the amount of fertilizers in agriculture.

Quilliama et al. found that biochar application benefits, e.g. improved soil nutrient levels or crop performance, seemed to be short-lived. The reapplication of biochar intensifies the short-term benefits rather than any lasting differences [7].

The goal of our experiment was to evaluate the effects of two types of pyrolysis solids as a potential soil amendment.

2. Materials and methods

The used soil samples were collected from the Ap horizon (0-30 cm) of an Arenosol from a research field plot of the Szent István University Crop Production and Biomass Utilization Centre, Gödöllő, Hungary. The air-dried samples were homogenized and were passed through a 2-mm sieve to the analysis. The basic properties of the soil are given in Tab. 1.

Tab. 1. The basic physical and chemical properties of the soil used in the study

Genetic horizon	**Depth**	**OC**	**$CaCO_3$**	**pH**	**pH**	**CEC**	**Total salt**	**AL-P_2O_5**	**AL-K_2O**	**hy**	**WHC**
	(cm)	%	%	H_2O	KCl	cmol kg^{-1}	%	mg kg^{-1}	mg kg^{-1}		%
Ap	0-30	0.49	-	5.54	4.24	12.19	0.028	111.12	119.86	0.08	21.5

Wood chips char (BC) and animal bone char (ABC) were produced in different Hungarian pyrolysis plants. Biochar properties are summarized in Tab. 2.

Tab. 2. Characteristics of the two applied biochars
(BC: wood chips char, ABC: animal bone char)

Parameters	**BC**	**ABC**
Bulk density g cm^{-3}	0.36	0.31
Dry matter %	93.87	99.95
Ignition residue (ash) of dry matter %	11.61	100
Total carbon %	79.8	9.9
Total nitrogen %	0.7	1.8
C/N ratio %	99.4	5.1
pH	8.32	7.58
CEC cmol kg^{-1}	14.7	n.d.
Calcium mg kg^{-1}	30 200	300 000
Chromium mg kg^{-1}	4	4
Copper mg kg^{-1}	9	5
Iron mg kg^{-1}	2 280	63
Potassium mg kg^{-1}	4 450	2 000
Magnesium mg kg^{-1}	1 200	6 000
Manganese mg kg^{-1}	1140	1
Sodium mg kg^{-1}	170	7000
Phosphorus mg kg^{-1}	780	133 000
Zinc mg kg^{-1}	41	152
Sum of PAH mg kg^{-1}	4.82	0.37
Sum of PCB	-	-
Nitrite (KCl) mg kg^{-1}	0.4	0.6
Nitrate (KCl) mg kg^{-1}	< 10	<10
Potassium (AL) mg kg^{-1}	1 450	1 500
Phosphorus (AL) mg kg^{-1}	214	24 600

In the pot experiment, two types of biochar were used. Predetermined amounts of biochars were added to the soil depending on the volume ratio contained (Tab. 3.). The four biochar application levels fitted to 1% (10 g), 2.5% (25 g), 5% (50 g) and 10% (100 g). The 1,000-g mixture was watered with 150 cm^3 kg deionized water equivalent to 60% of the soil's plasticity. These mixtures were divided into four plastic containers; each container was filled with 200 g of biochar-amended soils. 2 grams of rye-grass (*Lolium perenne*) were seeded in each pot. The pots were later watered to weight.

After the 4 weeks of the experiment, various soil parameters were measured: pH (KCl), AL-P_2O_5, AL-K_2O, total water soluble salt content and organic matter content according to Tyurin. The measured parameters for the plant samples were: total-P, total-K and micronutrients (Ca, Mg, Cu, Fe, Mn, Zn, Cr).

Tab. 3. Parameters of treatments

Treatments	**Soil**	**Added pyrolysis solids**
BC10	990g	10g wood chips char
BC25	975g	25g wood chips char
BC50	950g	50g wood chips char
BC100	900g	100g wood chips char
ABC10	990g	10g animal bone char
ABC25	975g	25g animal bone char
ABC50	950g	50g animal bone char
ABC100	900g	100g animal bone char
Control (C)	1000g	-

Differences in soil and plant properties between the treatments were statistically analysed using variance tests (Microsoft Excel. $P < 0.05$), while significant differences between individual treatments were determined by comparing the least significant difference (LSD) with the mean.

3. Results and discussions

The analysis of the soil after the reaping shows that both types of biochar (BC and ABC) had an effect and even the two types have had some differences. The $pH_{(KCl)}$ show that the treatments had an effect; the pH lift proportionately with the added products. This was expected from the related literature results, as biochar researches had shown a similar effect on soils as liming (Fig. 1).

As for the soluble salt concentration, it also got higher, especially in the case of the treatment noted as ABC (Fig. 2). The differences between the measurements are most possibly caused by the different raw material of the biochars.

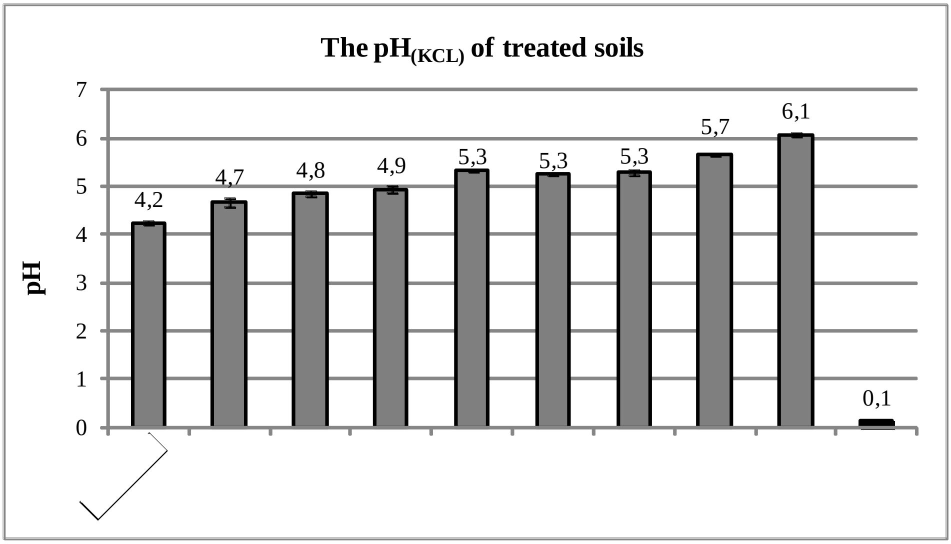

Fig. 1. Effect of different biochar treatments on the $pH_{(KCL)}$ of soils

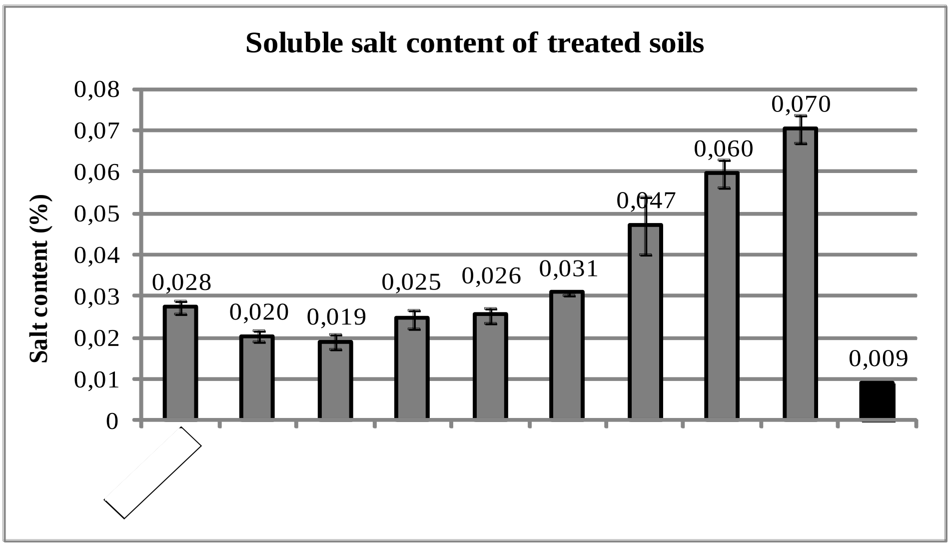

Fig. 2. Effect of different biochar treatments on the water soluble salt content of soils

As Fig. 3 shows, the bone char had great impact, proportionately with the added quantity. The differences between the measurements are expected and caused by the different raw materials of the biochars; the ones noted as ABC were made from animal bone, and so the material contained a much higher concentration of phosphorus.

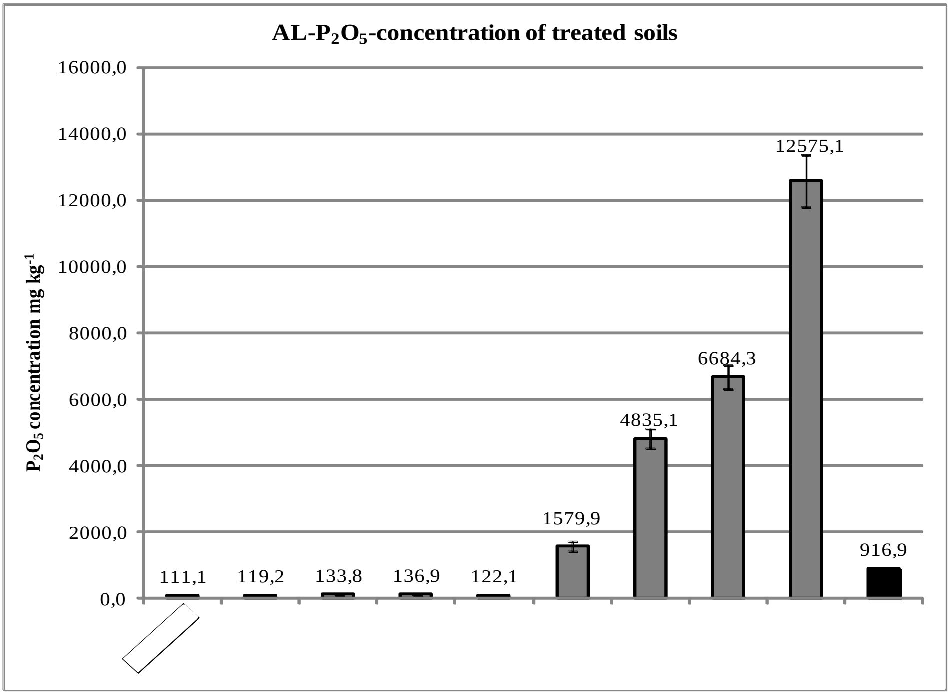

Fig. 3. Effect of different biochar treatments on the AL-P_2O_5 content of soils

The plant analysis shows that the biochar (wood chips char, animal bone char) application increased the air-dried mass of rye-grass in almost all cases, but this increase was not significant (Fig. 4).

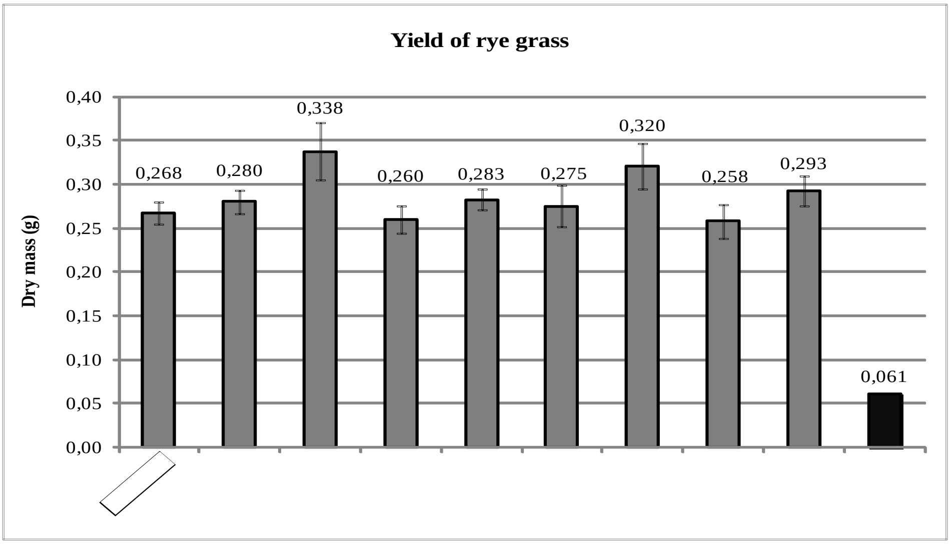

Fig. 4. Yield of test plants (Lolium perenne)

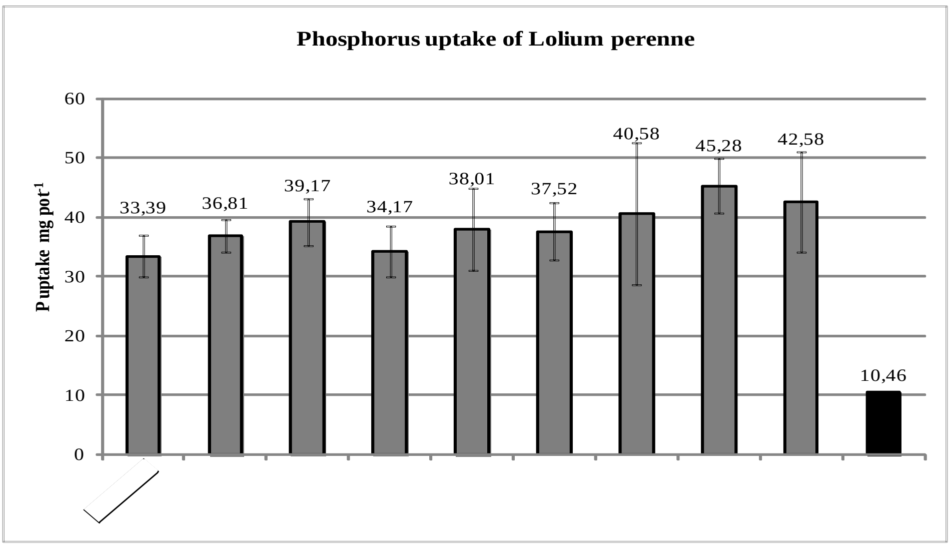

Fig. 5. Phosphorus uptake of test plants

Fig. 5 shows that the two types of biochar application increased the P-uptake (to one pot calculated); however, this increase did not show significant effect. The detected high P_2O_5 concentration in the soil due to the treatment, especially the bone char, had great amounts of phosphorus, but the test plants could not take up.

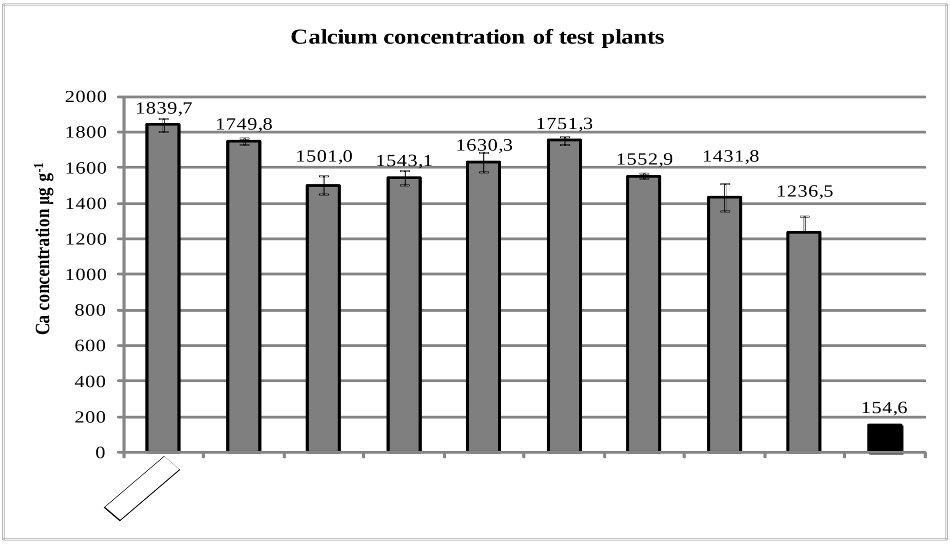

Fig. 6. Calcium concentration of test plants

The micronutrient analysis shows that the Ca concentration of test plants significantly decreased with the application rates of biochars (*Fig. 6*). This effect is very similar to the phosphorous content of rye-grass. Although the wood chips char and animal bone char have outstanding calcium content, this high amount is mainly unusable for plants.

4. Conclusion

We found the applied animal bone char (ABC) to be a good source of available phosphorous as it increased the easily soluble P_2O_5 content of the treated soil, but the plants could not take up such high amount in our short-term experiment.

The pH and water soluble salt content of the tread soil was increased significantly in the ABC treatments, while in the case of BC treatments the increase of pH was observed at all application rates and no effect on water soluble salt content was detected. The increase in pH and salt content did not cause very high alkalinity and/or salinity in neither treatment.

The application of pyrolysis products did not cause phytotoxic effects on test plants.

In our study, the high phosphorus content of ABC increased the easily soluble phosphorus content of soils. We suppose that the high Ca content of the applied biochars resulted in hardly soluble calcium phosphate forms and it prevented the uptake of the phosphate by the plants.

Decreasing Ca uptake was observed on test plants, possibly due to the high carbonate content of the applied biochars, which may form insoluble calcium carbonates under alkaline pH conditions.

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Examination of zinc adsorption capacity of soils treated with different pyrolysis products

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Abstract: Organic matter input into soils is essential regarding agricultural, environmental and soil science aspects as well. However, the application of the pyrolysed forms of biochars and materials with different organic matter content gained more attention in order to decrease the emission of the green house gases (CO_2, N_2O) from the soil. During pyrolysis, the materials containing high organic matter (biomass-originated organic matter) are heated in oxygen-free (or limited amount of oxygen) environment. As a result, the solid phase, which remains after eliminating the gases and liquid phase, is more stable compared to the original product, it cannot be mineralized easily in the soil and its utilization is more beneficial in terms of climatic aspects. Furthermore, it can improve soil structure and it can retain soil moisture and cations in the topsoil for long periods of time, which is very important for plants. In our experiment, the effects of biochar and bone char were examined on soils by zinc adsorption experiments. Based on our experiments, we concluded that the pyrolysis products can have significant Zn adsorption capacity compared to the soil. Bone ash can adsorb more Zn than the charcoal product. The Zn adsorption capacity of soils treated by pyrolysis products can be described by Langmuir adsorption isotherms. However, based on the amount of pyrolysis products, one or two term Langmuir isotherm fits well on the experiment data, which depends on the time the pyrolysis product has spent in the soil.

Keywords: biochar, bone char, Zn adsorption

1. Introduction

The pyrolysed biomass products have high carbon content and their chemical structures differ greatly. Thus, the weakly charred organic materials, such as the biochar and the soot, also belong to this group [1]. Depending on the temperature of the pyrolysis, different structural changes occur in the organic macromolecules. By the effect of the lower temperature, the chemically bound water will leave; then, as the temperature increases, the functional groups, the amount of oxygen and hydrogen will decrease, which might result in an aromatic and polyaromatic structure [2]. This type of organic matter can resist the mineralization processes in the soil for a long period of time (even for 100 years); thus, it decreases the amount of greenhouse gases (CO_2, N_2O), leaving the soil in the atmosphere. Their role is essential from climatic aspects, but they also improve soil structure, moisture and the nutrient holding capacity of soils.

In our experiments, we compared the Zn retention capacity of two types of pyrolysed organic substances (biochar, bone char), and we examined the effect of incubation on the Zn retention capacity in soil-biochar systems with different composition.

2. Materials and methods

Incubation

The soil that was used in our experiment (Tab. 1) was mixed with 0, 1, 2.5, 5 and 10% pyrolysed products (biochar, bone char). Soil moisture was adjusted by adding distilled water to 50% of field capacity; then it was incubated for two weeks. After this, the samples were dried and sieved (2 mm), and adsorption experiments were carried out.

Tab. 1. Parameters of the test soil (brown forest soil, Gödöllő)

K_A	pH (KCl)	pH (H_2O)	Humus %	Total C%	Total N%	AL-P_2O_5 mg/kg
25	4.9	5.2	1	0.58	0.58	33

Tab. 2. Parameters of the pyrolysed products

	pH	Bulk density kg/m^3	Total C%	TOC%	Total N%	Total P_2O_5 %	AL-P_2O_5 %	Zn(EDTA) mg/kg	Total PAH mg/kg
Biochar	8.3	360	80	70	0.7	0.2	0.05	73.8	4.8
Bone char	7.5	320	10	9	1.8	31	5.63	3.6	0.4

Adsorption Experiment

One gram of the above-mentioned treated soil samples and the pyrolysis products were placed in centrifuge tubes. They were mixed with Zn solution (shaking solution) with different concentrations (0, 25, 50, 75, 100, 200, 250, 500, 600, 750, 1000 mg dm^{-3}) in a ratio of 1 g to 10 cm^3 during 12 hours in rotary shaker at constant temperature (20±1°C). After completing the shaking, centrifugation (5,000 rpm, 5 minutes) and filtration were carried out; then, with proper dilution, the Zn concentrations of the filtrate (hereinafter: equilibrium solutions) were measured by Perkin Elmer 303 AA spectrophotometer. Knowing the concentration of the shaking and the equilibrium solution, we calculated the amount of adsorbed Zn on the solid phase. Then we illustrated the amount of adsorbed Zn (mg kg^{-1}) as a function of the concentration of the equilibrium solution. We fit the Langmuir adsorption isotherm onto the obtained experimental points, which mathematical form is the following:

$$q = \frac{A \cdot k \cdot c}{1 + k \cdot c} + b$$

q = the amount of Zn adsorbed by the soil (mg/kg)
A = maximum amount of Zn that can be adsorbed by the soil
k = equilibrium constant of adsorption (dm^3/mg)
c = Zn concentration of equilibrium solution (mg/dm^3)
b = constant (mg/kg)

3. Results and discussions

The bone char adsorbed a large amount of Zn (Fig. 1), which can be explained by the high phosphate content of the bone char (Tab. 2). In this case, the Zn is not adsorbed in an exchangeable form, but precipitation occurred, since poorly-soluble Zn-phosphates were produced.

This is also proved by the equilibrium constant (k) of the process and the steepness of the isotherm curve calculated in different points and the buffering capacity values as well (Tab. 3).

Thus, the bone char mixed into the soil significantly increased its Zn retention capacity; even when 5% bone char was mixed in, it doubled the maximum amount of Zn that can be retained.

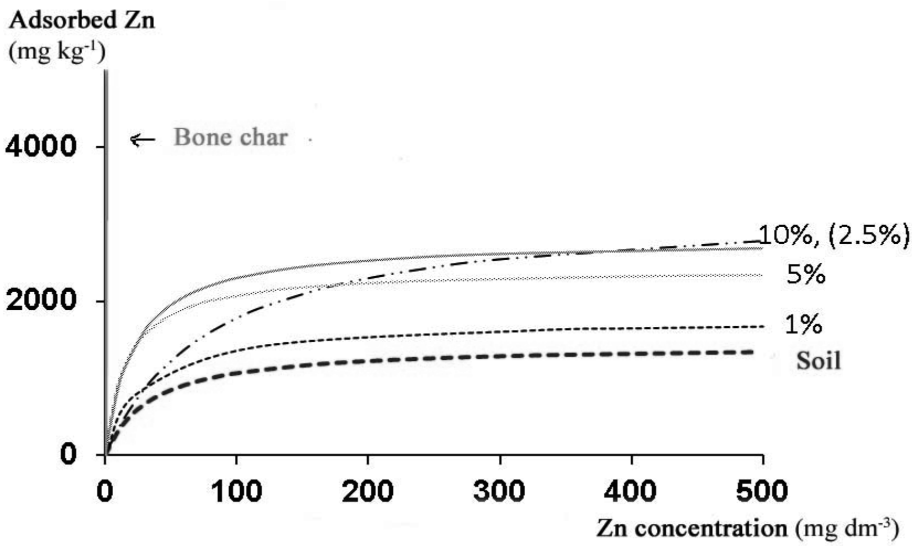

Fig. 1. Zn adsorption capacity of bone char and soils treated with bone char (Langmuir isotherms)

The Zn retention capacity of biochar and soils treated with biochar was significantly lower compared to the bone char. The maximum amount of Zn that the soil can retain is nearly seven times higher than the amount the biochar can retain. This is probably due to the fact that chemical changes occurred within the structure of the biochar during the pyrolysis, which destroyed its cation retention capacity.

Tab. 3. Parameters of the Langmuir isotherms of bone char and soils treated with bone char

	Langmuir isotherm parameters		**Buffering capacity** (dm^3/kg)			
	A **mg/kg**	**k** **dm^3/mg**	**0**	**0.1**	**1**	**10**
Bone char	20 193	0.7768	15 688	13 508	4 968.8	204.0
Soil	1 378	0.0290	41.7	41.4	39.3	25.0
1% bone char	1 768	0.0337	59.7	59.3	55.9	33.4
2,5% bone char	3 236	0.0120	39.6	39.5	38.7	31.4
5% bone char	2 416	0.0604	146.1	144.4	129.9	56.7
10% bone char	2 804	0.0460	129.2	128.0	118.06	60.5

Probably, hydrophobic, aromatic structures were formed which are able to adsorb only a few cations. It is interesting, however, that when this material was mixed into the soil and was shortly incubated, the Zn retention capacity increased.

When 5% was mixed, the maximum amount of Zn that can be retained doubled. This phenomenon is probably due to the activated biological processes in the soil in such a short time.

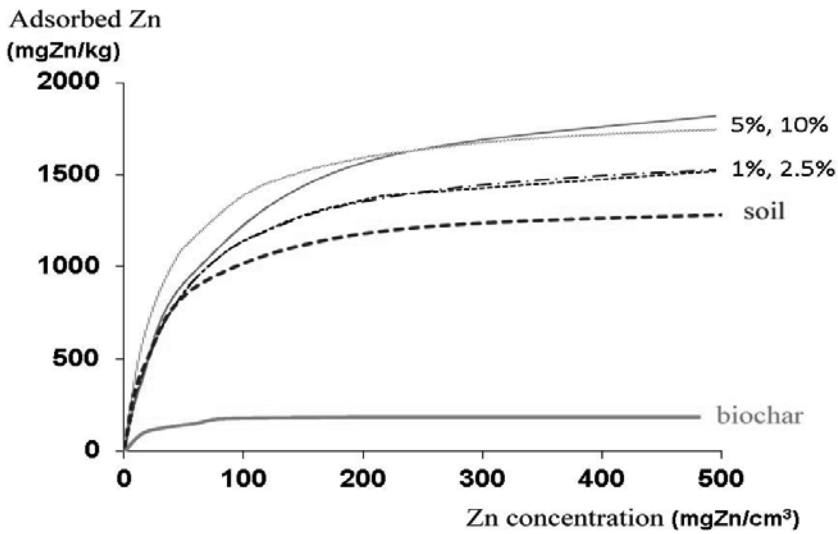

Fig. 2. Zn adsorption capacity of biochar and soils treated with biochar (Langmuir isotherms)

Tab. 4. Parameters of the Langmuir isotherms of biochar and soils treated with biochar

	Langmuir isotherm parameters		**Buffering capacity** (dm^3/kg)			
	A mg/kg	**k** dm^3/mg	**0**	**0,1**	**1**	**10**
Biochar	197.2	0.0601	11.9	11.7	10.5	4.6
Soil	1 378	0.0300	41.4	41.1	39	24.5
1% biochar	1 689	0.0208	35.2	35.0	33.8	24.1
2,5% biochar	1 668	0.0215	35.8	35.7	34.4	24.3
5% biochar	2 083	0.0150	31.3	31.2	30.4	23.7
10% biochar	1 867	0.0287	53.6	53.3	50.7	32.4

4. Conclusions

The soil microorganisms attach onto these organic substances that have very high surface area and they change their structure during their metabolism. Functional groups that are able to adsorb cations are formed especially on the edges, which are easily accessible.

This is the reason why the pyrolysed organic substances that are able to resist mineralization and sometimes contain toxic material (PAHs) can change into a harmless and useful soil component [3].

Acknowledgements

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Monitoring the degradation of partly decomposable plastic foils

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Abstract: We have monitored the behaviour of different polyethylene foils including virgin medium density polyethylene (MDPE), MDPE containing pro-oxydative additives (238, 242) and MDPE with pro-oxydative additives and thermoplastic starch (297) in the soil for a period of one year. A foil based on a blend of polyester and polylactic acid (BASF Ecovio) served as degradable control. The experiment was carried out by weekly measurements of conductivity and capacity of the soil, since the setup was analogous to a condenser, of which the insulating layer was the foil itself. The twelve replications allowed monthly sampling; the specimen taken out from the soil each month were tested visually for thickness, mechanical properties, morphological and structural changes, and molecular mass. Based on the obtained capacity values, we found that among the polyethylene foils, the one that contained thermoplastic starch extenuated the most. This foil had the greatest decrease in tensile strength and elongation at break due to the presence of thermoplastic starch. The starch can completely degrade in the soil; thus, the foil had cracks and pores. The polyethylene foils that contained pro-oxydant additives showed smaller external change compared to the virgin foil, since there was no available UV radiation and oxygen for their degradation. The smallest change occurred in the virgin polyethylene foil. Among the five examined samples, the commercially available BASF foil showed the largest extenuation and external change, and it deteriorated the most in the soil.

Keywords: polyethylene foil in soil, capacity, conductivity, tensile strength, elongation at break

1. Introduction

Since the upswing of the plastic industry, there have been debates about reducing plastic waste whether by recycling, elimination or environmental or biodegradation. The time needed for their degradation is unknown for most plastics. These materials can resist degradation for centuries on waste disposal sites without light and oxygen. This problem could be solved by using and producing biodegradable plastic foils. However, it is very important to know what "biodegradable plastic" means, which can be easily misunderstood by the non-professional public [1]. It is not known how much time is needed for the plastic foils to be degraded, to what extent they degrade and how they affect the environment.

In our research, we have monitored the behaviour of polyethylene-based foils in the soil for one year, based on capacity and conductivity measurements. We investigated monthly the changes in thickness, molecular mass, mechanical, structural and morphological properties of the foils.

2. Materials and methods

The list of the examined foils is given in Tab. 1. We prepared 6x10-cm bags from the plastic foils, in 12 repetitions.

Tab. 1. Composition of the examined plastic foils

Signs	Composition
340	MDPE (medium density polyethylene) (Tisza Chemical Works, TVK)
238	MDPE + pro-oxidative additives (salts of metals with different oxidation degree: Fe 0.072 %, Co 0.015 %, Zr 0.031 %, Mn 0.006 %, total metal content: 0.124 %) (BME-Qualchem Zrt)
242	MDPE + pro-oxidative additives: Fe 0.051 %, Co 0,025 %, Zr 0,024 %, Mn 0.044 % - total metal content: 0.144 %) (BME-Qualchem Zrt)
297	MDPE + pro-oxydative additives (Mn 0.0103 %, Co 0.0094 %, total metal content: 0.0197 %) + thermoplastic starch (8.75 %) (BME-Qualchem Zrt)
BASF	Mixture of thermoplastic polyester and polylactic acid (BASF, Ecovio)

The soil used in the experiment

The soil originated from Gödöllő-Szárítópuszta, from the experimental farm of Szent István University. It was a brown forest soil; its characteristics are listed in Tab. 2.

Tab. 2. Parameters of the examined brown forest soil

K_A	pH_{KCl}	pH_{H_2O}	Total C%	NO_3-N + NH_4-N mg/kg	Total N%	AL-P_2O_5 mg/kg	AL-K_2O mg/kg
25	4.9	5.7	0.58	5.5	0.08	33	135

The nutrient and moisture content of the soil was adjusted in order to prepare convenient circumstances for the degradation by the soil microorganisms. Thus, the carbon-to-nitrogen ratio was adjusted by NH_4NO_3 addition, and the proper moisture content was set by distilled water (60% of outdoor field capacity).

Setup of the experiments

The experimental setup is represented by Figure 1.

Fig. 1. The experimental design

The measuring cells

The plastic bags were filled with soil and placed in a beaker full of soil; thus, the plastic bags were surrounded by soil. Measuring electrodes were put into the soil that was in the plastic bag and into the soil that surrounded it. The beakers were kept in plastic boxes in which the moisture content had previously been set, and it was aerated at certain times.

Capacity and conductivity measurements

The basic principle of the capacity measurement is that the plastic foil, along with the soil, behaves as a condenser, its armature is the soil, and the insulating layer is the plastic foil. The capacity correlation of this system is the following:

$$C = \frac{\varepsilon_0 \cdot \varepsilon_r \cdot A}{d}$$

C = capacity of the condenser (F)
A = surface (m^2)
d = distance (m)
ε_0= dielectric constant of the vacuum (As/Vm)
ε_r= relative dielectric constant of the insulating material

The capacity is directly proportional to the area of the armature (soil layers) and inversely proportional to the distance between them. Thus, the increase of the capacity values can be expected as the insulating layers (foils) become thinner.

The electrical conductivity is produced in the electric field by the movement of the charge carriers (electrons and ions); thus, in this case, we consider the soil as a conductor in which the conductivity depends on the soil moisture content and the insulating layer is the foil. Thus, we assume the phenomenon of the electrical conductivity when a crack occurs on the insulator.

As a reference, measuring cells were set in three repetitions, which only contained the prepared soil.

The measuring circumstances of thickness, molecular mass, mechanical, structural and morphological properties of the foils and the results are written in detail in Heffner, 2013 and Vargha, 2014 [2, 3].

3. Results and discussions

It can be seen in Figure 2 that the capacity was measured in all measuring cells. The soil sample that did not have foil can also behave as a condenser; its capacity can be several times higher than that of the measuring cells that contained foils.

During the measurements, we found that the soil moisture content decreased; thus, we had to rewet them twice in order to help degradation. It can be seen in the figure that as water was added on the 81st and the 177th day there was a sudden increase in capacity. The greatest capacity increase was found in the BASF and in the 297 foil. We assume that the soil microorganisms started to degrade the easily mobilizable organic polymers (polylactic acid, starch); thus, the structure of the foils changed, and microcracks were formed. The degradation of the above-mentioned foils was confirmed by the change in mechanical properties, molecular mass and in surface morphology. The virgin polyethylene foil and the foils containing polyethylene and pro-oxidants did not show significant change in capacity during the measurements.

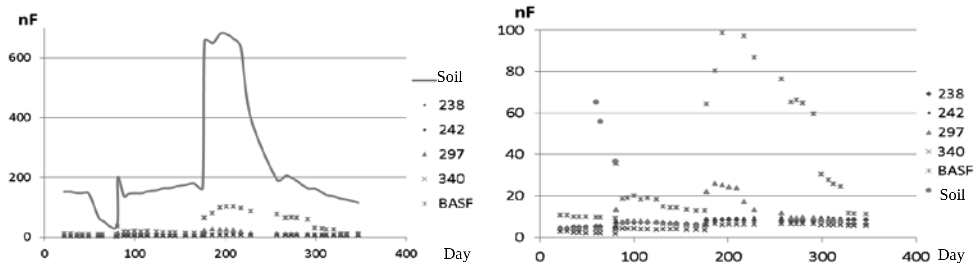

Fig. 2. Capacity change of the plastic foils in time

The changes in the conductivity values are shown in Figure 3. The conductivity values of the virgin polyethylene foil (340) showed a little change only after the addition of water, from which we can conclude that there was no significant degradation on this foil. Similarly, the polyethylene foils that contained pro-oxidative additives showed similar behaviour, i.e. their degradation was negligible, due to the lack of oxygen and UV radiation. However, the test results of the other properties of these foils (change in thickness, decrease in molecular mass and change in surface) suggest signs of initial degradation [2].

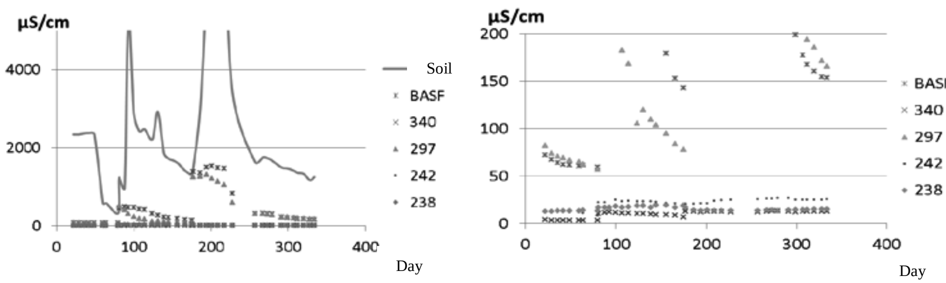

Fig. 3. Capacity changes of the plastic foils in time

The conductivity values were significantly higher in the case of the polyethylene foil with thermoplastic starch and of the polylactic acid-based BASF foil compared to the virgin and pro-oxidant-containing polyethylene foils. This also supports the possibility of the biological degradation that we mentioned at the capacity results. We have to point out, however, that after the decomposition of the easily mobilizable organic materials further degradation of the polyethylene can only occur when the long chains are broken to smaller units [4, 5, 6].

4. Conclusion

We found that the measurement of capacity and conductivity is suitable for the continuous monitoring of the degradation of the different plastic foils in soil. Within the one year of the experiment, only the polymers that have easily mobilizable organic material could be degraded; however, this does not mean that polyethylene-based foils are biologically degradable. Concerning the polyethylene foils with pro-oxidative additives, their degradation in soil is negligible due to the lack of required conditions (UV radiation, appropriate amount of oxygen).

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The establishment and significance of district/regional roof cadastres in the utilization of solar energy

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Abstract: After its establishment, the roof cadastre – solar cadastre I wish to introduce in this article will form a database, with the help of which we will be able to analyse solar radiation factors on the local level (street, house), and a map display will also be available. Through the implementation of the appropriate methods, we can establish roof/solar cadastres on the settlement/district/regional level and these can help to increase the rate of utilization of renewable energy sources.

Keywords: renewable energy, geoinformatics, solar energy potential, GIS, SEAP

1. Introduction

Due to the gaining ground of renewable energy sources in the 21st century and the development of the geographic information and remote sensing methods, there are several opportunities to create databases related to innovative, utilizable and alternative energy resources. These cadastres, digital databases – depending on the size of the examined area – can facilitate the calculation of the solar energy potential of the settlement or district. I would like to present the current state of the creation of such a roof cadastre and the significance/opportunities of its utilization.

2. Materials and methods

As of today, analogue cadastre maps are dominant in Hungary, and these show buildings in two dimensions. The 3D representation of buildings is possible, similarly to the floor-by-floor plan of the condominiums, but the use of codes and the display of a unique identifier are necessary on the map.
The permanent development in the geographic information system makes possible the creation of spatial maps, the visualization of buildings and 3D representation.

Digital maps must show the horizontal situation and the elevation, dimension and shape of underground and overground buildings. An important characteristic of spatial modelling is the level of detail (Level of Detail, LOD), in the case of which Europe distinguishes the following levels for city models and building models [1, 2]:

- LOD 0: regional model, 2.5D field model, with orthophoto texture;
- LOD 1: city/building model, 3D taking the model plan showing the block of building as starting point;
- LOD 2: city/building model, 3D building model including walls and roof shown with simplified texture;
- LOD 3: city/building model, 3D architecturally detailed model;
- LOD 4: interior model, which is the exterior and interior 3D model of the building with texture.

To establish the roof cadastre I wish to create, the LOD 2 level must be reached, as this level of detail makes possible the observance/calculation of the shape of the roof structure, the exposure and the extent of leaning, and further calculations can be made on the basis of the model. To establish roof surface models, we need to know the height data of the given buildings, which we can get through 3 different digital height measurement procedures: field measurement, photogrammetry/photo matching and the LiDAR measurement [5].

The basis of my research was served by the LIDAR measurement carried out with the help of the Remote Sensing and Rural Development Research Institution of Róbert Károly College of Gyöngyös in the spring of 2013. The LiDAR (Light Detection And Ranging) measurement is a laser scanning based on distance measurement with the help of laser light. When creating a roof surface model, the measurement is made by a laser distance gauge mounted on an airplane. The necessary data during the measurement are the spatial place of the instrument and the ray direction of the emitted laser; thus, we can calculate the height of a given point from which the laser ray is reflected. The point cloud created by the measurement can then be “cleared” to a set of points we are interested in: in the present case, to the set of points reflected by the roof surfaces [3]. A big advantage is that this procedure makes possible the measurement of thousands of points per second, and the height values we receive are very punctual [4]. With the help of appropriate software, it is then easier to calculate the size, exposure and leaning angle of the roof surfaces of the buildings. In order for the roof cadastre to be suitable for the estimation of the solar energy potential, we need to know the relatively exact amount of sunshine – incident sunshine in the given area, which we can get either by our own measurement (with the help of a pyranometer) or by the results measured by the measuring stations of the National Meteorology Institution (Országos Meteorológiai Szolgálat – OMSZ) (other options: values calculated by algorithms of geographic information software packages: ArcGIS, GRASS GIS, on-line databases – SOLEMI, SoDa, etc.) [6].

I am processing both the point cloud received from the LiDAR measurement and the data provided by the OMSZ with ESRI's ArcGIS 10.1 software. ArcGIS's version 10 can handle files with LAS extension coming from LiDAR measurements; so, they have been insertable and editable since 2010, plus the sunshine data can also be processed by the Solar Radiation that can be found in the SpatialAnalyst toolbar of the ArcGIS 10.1 software. The import of the own data gives an even more exact result, as if our research were based on the irradiation values automatically calculated by the programme. "Putting" the irradiation values calculated per m^2 we thus receive on the roof surfaces of the prepared 3D settlement models, the amount of irradiation falling on the given roof surfaces can be calculated in a daily, monthly or yearly breakdown.

3. Results and discussions

During the LiDAR measurement in the valley of the River Bódva in Northern Hungary, in Borsod-Abaúj-Zemplén County (see Figs. 1 and 2), approximately 618 million points got into the created point cloud on a 218 km flying route; so, the point density was 5 points/m^2. According to international specialist literature, such a point density is sufficient to exactly determine the size, exposure and leaning angle of particular surfaces (including roof surfaces).

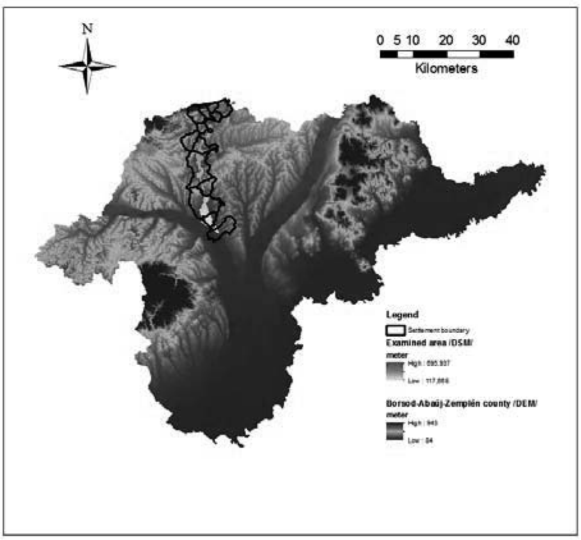

Fig. 1. The examined area in Borsod-Abaúj-Zemplén County.

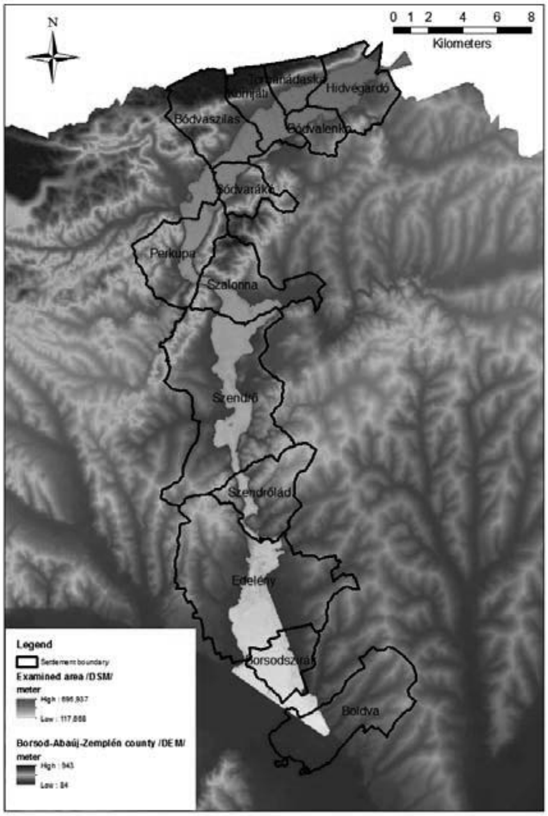

Fig. 2. Closer view of the examined area – Bódva Valley.

After clearing the received point cloud, we prepared – also with the help of Róbert Károly College of Gyöngyös – a digital surface model (DSM). An advantage of DSM is that it includes every object (tree, building, etc.) as opposed to DEM, which shows only the elevation above sea-level of the Earth's surface (see on Fig. 3). The further evaluation of the surface model we have thus received is still under way. This means selecting the buildings with the help of orthophotos and cadastre maps, thus increasing the exactness and reliability of subsequent results.

Fig. 3. Closer view of the DSM and cadastre (Edelény).

As for irradiation data, in the absence of own measurement/measuring equipment, I received exact data through acquiring the data sets recorded by the Edelény measuring station of OMSZ between 2008 and 2012. These show the amount of irradiation in J/cm^2 in a daily breakdown. By the import of these data, SolarRadiation fits on the digital surface model and shows the amount of irradiation collected on the surfaces [7].

I will continue my research by linking up the already established DSM and the irradiation values, and I will also take into account the shadiness of buildings and roof surfaces as a separate factor. This shadiness can be caused by the chimneys on the roofs, the trees and taller buildings in the surroundings of the examined buildings. I would also like to select the buildings owned by the local governments or the state, as the provision with devices utilizing solar energy of private and public buildings has to be treated separately.

4. Conclusion

As a consequence of the roof cadastres described in this study and the irradiation values linked to it, we can establish a so-called solar cadastre. Its utility lies in that on a website you can get a lot of information about the roof surface of any chosen property. Such data can be, for instance, the amount of producible electricity and heat, the amount of CO_2 saved, the investment cost and the period of return of the planned system, etc.

Their significance, apart from the information they provide, is that individuals and state institutions alike can more easily and cheaply implement investments related to solar energy and make decisions on the planning of a system connected with solar energy. They can also act as a sort of “supporting-incentive” service for the writing of tenders related to renewable energy sources, in the hope of increasing the willingness of writing tenders in the 2014–2020 programming period, in which – in all probability – the biggest ever sums will be allocated for renewable energy sources.

For the decision-makers of settlements and regions, the existence of a solar cadastre and the database provided by it can form a significant basis to write their own (settlement-region) SEAP (Sustainable Energy Action Plan), which is an essential document for joining the Covenant of Mayors (later it can be called Climate Protection Association), which can offer a settlement further opportunities for a European collaboration and the implementation of joint projects. The SEAP documents focus on the buildings, equipment/facilities and urban transport; furthermore, they could include actions related to local electricity production. The roof cadastres could take place in the planning stage (reading of the current situation – where are we?) and could give exact numbers for the solar potential of the examined area.

In Central and Western Europe (Austria, Germany and Great Britain) and in the United States of America, there already exist roof and solar cadastres with different quality and functions, both on the settlement and the province level. It is very likely that due to the knowledge transfer, by the end of the 2010s, these information sources will appear in several Central-Eastern European countries and regions, and help further increase the proportion of utilized renewable energy sources (solar energy).

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ACTA UNIVERSITATIS SAPIENTIAE
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Assessment of the environmental value of the Zichy Castle Park in Voivodeni, Romania – Brief description

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Abstract: The Zichy Castle from Vajdaszentivány (Voievodeni) is located in Mureş County, central Romania, south-west from the town of Reghin. Its construction in classical baroque style dates back to the beginning of the XVIII century. The archaeological findings from the area show that Vajdaszentivány was already populated in the Copper Age. The findings of gray dishes from the III and IV centuries were considered by Dr. Protase as indigenous Daco-Roman relics. The Roman presence here was demonstrated by residues of the hewn-stone road along the Maros River. After the Roman Age, several other populations (Goths, Slavonic peoples, Darghins and Huns) settled down here. The feudal Hungarian state occupied this area around the XI century. Several streams, terraces and old cemetery ruins demonstrate that the Hungarians used the region for protective purposes. The first written records of Vajdaszentivány date back to 1332, when the Papal documents (Sacerdos de Sancto Johanne) mention the settlement for the first time. In 1366, the name of the village was Márton-Szent-Iván, and during the centuries it belonged to several old and noble families and dynasties as szentiváni Székely, monoszlai Losonczi, Szakácsi, the Bánffy and Dezsőfi, the Szentiváni, Butkai, Balog, Kecseti, Kerelői, Szengyeli, Dengelegi, Fodor, vajdaszentiványi Földvári, Kóka, Piski, Járai or Járai Felsőjárai Abafája. During the first half of the 19th century, among former Hungarians noble owners of the village, the following can be mentioned: Count Sámuel Kemény, Albert Horváth, Budai, Szőcs (Károly és Mihály) and Duke Löwenthál. Later on, the village of Vajdaszentivány became famous because of its castle, later named the "Zichy Castle," but also because of its citizens as preservers of folk music, folk dance and folk tales.

Keywords: cultural value, castles, historical value, rehabilitation

1. The brief history of the castle

The single-storeyed building was originally owned by the Order of Friars Minor, after which the members of the Kemény Family became the owners of the estate. The foreign-educated Sámuel Kemény I, after his return, married Kata Bethlen, and became one of the political leaders of Transylvania in the XVI century. The first restoration works on the castle were made by Sámuel Kemény. Because one of his two sons died early, while the youngest never got married, the Klebelsberg Family became the owner of the castle in the 1890s [1, 2].

According to historical landowner surveys in 1896, Count William Klebelsberg's properties included 2,861 apple and 240 peach trees around the castle. Later on, the castle was owned by Melanie Georgina Antonia Josefa, also called "Baby Aunt," who owned the castle until 1949. After the Second World War, together with other similar castles, the Zichy Castle was also nationalized. After 1989, the legal owner retained it, and it actually serves as a cultural centre. The former Zichy Castle, as a double-deck building, was built by the former coast of the Maros River. The approximately 68-meter-long building is a beautiful example of the late 18th-century Transylvanian baroque (Fig. 1) [2, 3].

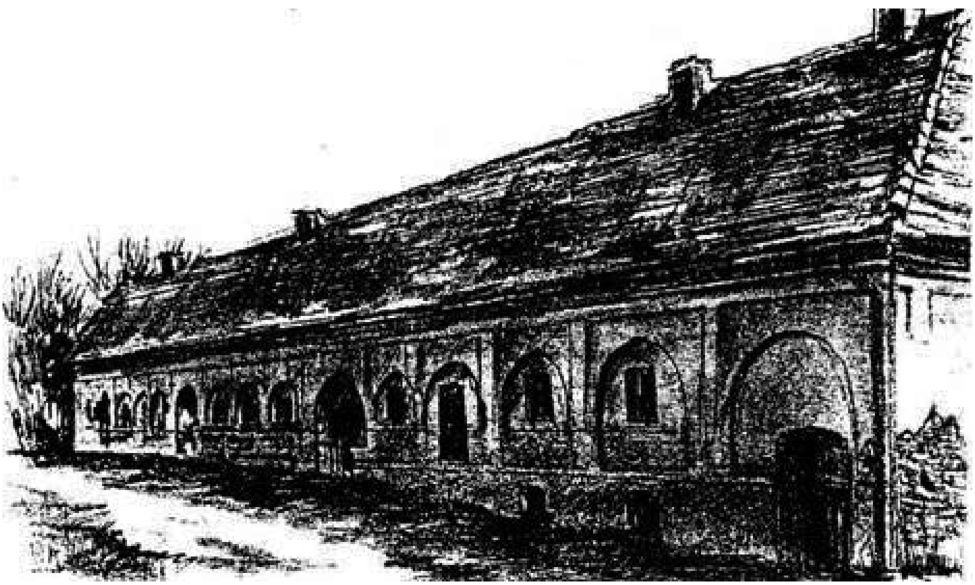

Fig. 1. The castle (By P. Zoltán)

After the nationalization of the former court, the whole surroundings have been altered, partly being used as farm directory building but also as ethnographic museum and warehouses (Fig. 2). Almost no official documents have remained on the castle and its garden, but a description of the former park has survived as part of the personal stories and written memoires of Jozefa "Baby Aunt" [1, 2, 3].

"In the first half of the 20th century, the castle garden, unlike the more similar gardens, was not a park. We simply called it garden. The estate itself was very extensive. That is why the properties of János Horváth and the Budai family were also owned by the Zichy Family. The inner squares were decorated by quadratic groups of red roses and pink geraniums. The evergreens were lined around the hedges. The garden did not have a built road, a dirt road between the buildings served as a connection. A grow was between Luc Creek and the River Maros. No typical garden elements were found in the garden. It had however a small lake and several water sources. The estate included a tennis court too. It was located on the north-eastern part of the main building."

Fig. 2. The façade of the castle (by P. Zoltán)

2. The actual condition of the castle

The main building is in a satisfactory stage; it has been recently renovated and equipped, serving as a cultural centre. The condition of the secondary building is critical, the roof structure is damaged. The old garden boundaries cannot be defined; so, no accurate assessment can be made about the former extent. The old garden elements can only be concluded from military maps and the geographical contours of the surrounding habitats. The place of the old lake can be identified. A complete change in plant compositions and structure is also clear; several old trees have been chopped down and several walnut trees planted. Major changes are also obvious if we compare the memoirs and old documents with the actual stages (Fig. 3) [4, 5, 6]. The view of the two churches from the village is probably the only remaining aesthetical image, as several new buildings break the view and create "visual conflicts".

Together with several other old Hungarian noble castles from this area, this castle represents one of the examples of the Transylvanian baroque style that has become an important and even historical element of the Transylvanian environment [4, 5, 6].

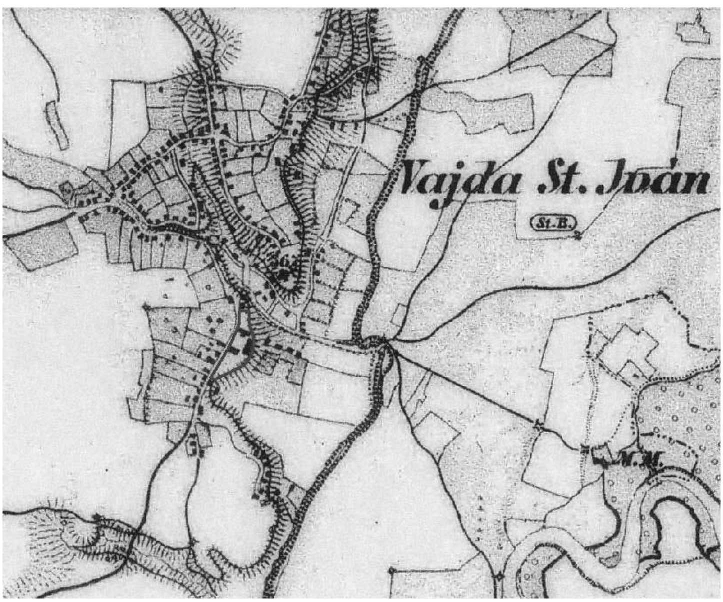

Fig. 3. The II. A map of military survey

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Landscape ecological and visual significance of dendrological gardens in the Carpathian Basin

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Abstract: This article presents and summarizes our observations based on historical research and site visits of 130 dendrological gardens in Hungary and 36 sites in Transylvania. The results favourably demonstrate the outstanding ecological and landscape values of these dendrological gardens in the Carpathian Basin. The research identifies the most typical exotic woody species that can be still found in those dendrological gardens that were developed in the Carpathian Basin during the era of creating landscape gardens, which is the 19th century in our region. We have defined about twenty exotic tree species, located in the researched dendrological gardens, of which presence highly affects the architectural and botanical composition, just as the landscape appearance or atmosphere of these gardens. Beyond all these effects, the article also highlights two other important points of the dendrological gardens: firstly, these gardens were breeding and acclimatization centres for spreading the new woody species, while, on the other hand, representatives of the spontaneous flora remained as veteran trees in these protected gardens, representing – mainly due to their age – outstanding ecological, dendrological and cultural values.

Keywords: landscape ecology, historical garden, dendrological garden, exotic tree, arboretum, Carpathian Basin, Transylvania

1. Introduction

In the course of landscape historical and horticultural history researches, the plant use of past ages is an important factor in the analysis of environmental interactions, i.e. the connection of humans and the landscape proper. The knowledge of this factor is indispensable not only for cultural history, but it also facilitates a better understanding of contemporary land use and future landscape ecological planning. Archaeobotanical investigations have a special significance in this respect. This discipline is focusing on the relation of mankind and the flora, providing an aspect of economic activity of past societies. Macrofossils recovered from archaeological excavations are especially valuable when we have no other evidence, written or iconographical, on the agricultural production. The Carpathian Basin is an ancestral home for one of the oldest cultures in Europe. Agricultural production looks back to a past of eight hundred years, the cultivation of vegetables is proven for more than five thousand years, while fruit production has a past of two thousand years in this region [1]. Cereals were introduced in the Neolithic period, leguminous plants mainly in the Bronze Age, while fruits and grape were acclimatized by the mediation of the Romans. These basic features were completed by the specific knowledge about crop plants of Eastern origins from the conquering Hungarians and later on, after conversion to Christianity, various crops of Western origin were naturalized together with their specific production technologies. Among the climatic and ecological features of the Carpathian Basin, the cultivated plants – introduced during centuries of cultivation and the inherent popular selection – complemented the naturally versatile vegetation and resulted in a high degree of biodiversity. According to our data on the development of the dendroflora, the beginning of the Neolithic period in the Carpathian Basin coincided with the beginning of the Atlantic climatic phase, i.e. a warm, humid and temperate climate of sub-Mediterranean character, started approx. 8,000 years ago. This phase brought about the formation of mixed oak forests dominated by oak, elm, linden and ash, and in the shrub level, hazelnut [2].

As a result of climatic changes, among the main species constituting the forests, the ratio of oak showed alternating and complementary tendencies in the Carpathian Basin. In the past thousand years, we consider the climatic deterioration period between the beginning of the 13th century and approx. 1450, the so-called 'little Ice Age,' as a significant change with essential influence on plant cultivation with obvious effects in the Carpathian Basin as well. Following the general amelioration of the climate, starting in the second half of the 15th century and peaking at the middle of the 16th century, another cool and wet period started with hard and cold winters. From the beginning of the 18th century, another general warming took place, influencing the climate and vegetation of the Carpathian Basin [3]. In this period, the large-scale planting of *Robinia pseudoacacia*, commonly known as the black locust, was started which is still the only arboreal species planted *en masse* in the Hungarian villages, apart from the fruit trees [4].

As opposed to this, in the Baroque gardens of the aristocracy, appearing in the Carpathian Basin in the first half of the 18th century, besides fruit trees and the native small-leaved linden (*Tilia cordata*), the plantation of some alien, exotic arboreal species was started to make use of – predominantly in the form of allées and raster-type plantations (quincunx) – the characteristics of the Baroque spatial organization. Moreover – although in the iconographical sources and ground-plans of the Baroque gardens, the arboreal species are typically depicted only as formal elements (allées, bosquets, etc.), without actually mentioning specific plant species –, the use of horse chestnut (*Aesculus hippocastanum*) is documented in the written sources [5, 6].[1]

In this respect, we can mention the garden of the Fáy-Ocskay Castle from Dédács (today, Piski-arboretum, Simeria, RO), mentioned by Zsuzsanna Ocskay in 1954. In a manuscript dated 1763, unfortunately lost in the socialization process in 1949, a horse chestnut alley is specifically mentioned, leading from the springs of the garden to the centre of the garden (Coanda et al. 2006).[2] Similarly, exotic plants are mentioned from the same period by Anton Huber (1757) from the Károlyi-Castle of Nagykároly, (Carei, RO), mentioning an extended and valuable park with various flowering species and exotic arboreal species [7].[3]

The 'planted dendroflora' of the Carpathian Basin started to unfold in the second half of the 18th century with the appearance of the Hungarian landscape gardens and became generally widespread during the 19th century with the appearance of arboreta and dendrological gardens as an important factor in landscape and landscape ecology. Typically, the aristocratic gardens represented certain, artificially formed, biotopes, where the conscious plantation of arboreal plants – often collected in a systematic (scientific) aspect – could become an important factor on the landscape-architectural level [8].[4]

As Attila Szabó T. mentioned, a castle garden was not a simple ornamental garden but rather an intrinsic part of the complex, cultural-historical, ecological and economic (estate) system. It is exactly due to this that the garden was operable and

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[1] Gyenis A. (1941): Régi magyar jezsuita rendházak, Budapest, qtd. in: Fatsar K. (2008): Magyarországi barokk kertművészet. Budapest, p. 78.

[2] „Pe baza unui manuscris din anul 1763 (pierdut în anul naționalizării - 1949), Suzana Ocskay menționează existența, în perioada respectiva, a unei alei de *Aesculus hippocastanum* L. de la izvoare (parcela 13) către centrul parcului (alee dispărută între timp)." In: Corina Coanda, Radu, S. (2006): Arboretumul Simeria, monografie, Bucureşti, 173, 21.

[3] Qtd. in: Fekete A. (2012): Az erdélyi kertművészet – Maros menti kastélykertek, Kolozsvár, 120, 51.

[4] One of the contemporary descriptions of the botanical garden in Kolozsvár (Cluj-Napoca, RO) – a 14-acre site developed in the 1870s around the summer residence of the Mikó family after being donated to the Transylvanian Museum Society (Erdélyi Múzeum Egyesület) – emphasizes that the "nature-like arranged arboretum fruticum also increases the landscape beauty of the small botanical garden."
In: Richter A. (1905): A Kolozsvári Magyar Királyi „Ferencz József" Tudomány-Egyetem Növénytani Intézete és Botanikus Kertje, Kolozsvár, 78.

sustainable. Thus, we are studying an ecological-technical system with significant historic and artistic content, which can only be interpreted in its entirety [9].[5]

The aftertaste of the Baroque style and the expansion of the notion of landscape gardens resulted in the introduction of new tree species in the aristocratic gardens that had been formerly unknown within the Carpathian Basin. Whereas arboreta and dendrological collective gardens were formed in the 19th century and reached their flourishing period in the second half of the century, some of the early landscape gardens were adorned with specific exotic plants planted in an artistic arrangement. The use of white ash (*Fraxinus americana*), weeping willow (*Salix babylonica*), common hackberry (*Celtis occidentalis*), red juniper (*Juniperius virginiana*), balsam poplar (*Populus balsamifera*), horse chestnut (*Aesculus hippocastanum*), staghorn sumac (*Rhus typhina*) and stone pine (*Pinus pinea*) mentioned in the garden of Hédervár also proves the early use of exotic tree species [10, 11].[6] The reference on horse chestnut is a good example on how the consistent use of a typical species used in Baroque gardens survives and remains popular in the early landscape gardens, mainly in the form of allées and groups of trees.

In the first half of the 19th century, Palatine Joseph and his son, Archduke Joseph (Hapsburg), planted about 320 species in the Alcsút Arboretum that had been formerly unknown in Hungary [12]. The picturesque array of the plants was curated by landscape architect Károly Tost who also attained everlasting merits as the first gardener of the Margaret Island.

In dendrological gardens, as a variant of landscape gardens, the notion of using the natural beauty of plant specimens as main decoration aspect was prevailing throughout the 19th century. Trees were consequently not only symbols of human emotions, much rather, the expression of their own beauty. Planting exotic species attained wide popularity and plant individuals formerly counted as rare sensations became widespread in the Hungarian dendrological gardens. In the second half of the 19th century, several public parks founded in the region used exotic arboreal species in large numbers, attaining, apart from their role in spatial composition, a decisive role in landscape and settlement architecture as well as settlement ecology. Such an example is the Orczy-garden in Pest, where Bernhard Petri used *Robinia pseudoacacia* for the plantation of the city's public park for stabilizing aeolian sand (Zádor, 1988). Various exotic species were used in the second half of the 19th century, among others, in the ornamental gardens of

[5] Qtd. in: Fekete A. (2007): Transylvanian garden art – Castle gardens along the Maros River, Kolozsvár

[6] Petri [Petri, Bernhard]: Beschreibung des Naturgartens des Herrn Grasen von Wizan zu Hedervar, auf der Insel Schütte in Ungarn. In: Becker, Wilhelm Gottlieb: *Taschenbuch für Garten Freunde*. Leipzig, 1798, 83.

Pozsony (Bratislava), in the City Park (Városliget) and the Margaret Island in Pest as well as numerous other Hungarian locations [13, 14, 15].

The appearance and overall distribution of arboreta and dendrological gardens in England and in Europe can also be connected to the popularity of evergreens. "*David Douglas has discovered a lot of beautiful American pines and they could show their beauty soon in acclimatisation gardens. […] striving at planting and naturalise groups of exotic pine trees were common. By this practice, one by one, the beautiful foreign pines started their conquest on the Continent as well.*" [16]. The fashion of evergreens was soon manifested in the Hungarian dendrological gardens as well. At the beginning of the 19th century, the irregular collective garden of the agricultural school *Georgikon* at Keszthely, apart from a variety of exotic deciduous tree species, was also ornated by several foreign pine types and served as a living study material for the students. At the same time, the plant groups of the garden – which were systematically registered in sections – served as living materials for the students, as well as decoration for the immediately connected park of the Festetics Castle.

The most important evergreen tree species of the plant list dated 1808 are: Cupressus sempervirens, Ginkgo biloba, Picea mariana, Pinus strobus, Taxodium distichum and Tsuga canadensis (MNL).[7] The Erdődy Castle Park at Vép had a leading role in the acclimatization of the pine varieties, possessing a considerable collection of evergreens by the 1850s. In the sixties-seventies of the 19th century at Nagycenk, Bogát (today: Szombathely-Szentkirály), Rátót and Nádasdladány, the Vép model was successfully followed, enriching the former local collections by valuable evergreen species. Rare variants of pine trees were to be found at Vácrátót and Gyöngyösapáti (today: Gencsapáti); the most striking example in this respect was Kámon, where István Saághy created the valuable pine collection of the Öregpark, forming the core of the current Arboretum. Botanical exchange connections are well known and documented among the aristocratic families. It was not by a mere chance that in Malonya (today: Mlyňany, SK) Garden of István Ambrózy-Migazzi, son of Countess Agáta Erdődy, we can find an exceptional collection of evergreens in landscape array, from the beginning of the 1890s till modern times [17]. The landscape-ecological and landscape-aesthetical aspects of the exotic arboreal species in the afore-mentioned garden are adequately reflected in the report of Gusztáv Moesz on Malonya Park [18]: *"He* [Ambrózy-Migazzi István] *did not consider important the number of species in the garden, much rather the abundance of species and forms already established positively. The eye-pleasing effect was achieved by the masses of the used species. He did not want to construct a botanical garden but a pleasure garden of Mediterranean character. Plants were only tools in his hands to form and colour the landscape."*… Moesz

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[7] MNL OL P 275. 356. XIV. No. 58–67. (Hungarian National Archives).

noted: *"I have been many times in Malonya Park. I have always been impressed by the knowledge transformed into art, by the help of which the Count could harmoniously insert the 50 acres of his park into the beautiful landscape of the Zsitva Valley bordered by distant mountains."*

The survey of the proprietor families is also important as they carry that conceptual and cultural background, which is essential for the formation of the *genius loci* and the identity of the site, as well as for the creation of the residence gardens. In several cases, the proprietors shaped or directly influenced the formation of the gardens according to their own ideas.

The owners of noble residences and gardens can be considered as landscape architects, as on several occasions they constructed and cultivated their own gardens, or even if they employed a gardener or an estate manager, they provided the ideas for development.

The main objectives of the current research are to determine the landscape-ecological and landscape-architectural factors that have been present till our days. Most probably, these aspects were appearing as a result of the creation of a large number of dendrological gardens constructed in the 19th century.

2. Material and methods

The following theoretical work plan was established for the methodical exploration of the dendrological garden remains: preparation of the list of all possible sites, identification of research priority sites, conducting the historic exploration, condition survey and assessment of these priority sites and compilation of their assessment documentation.

Preparation of a list of possible dendrological garden sites

Recently, data on existing dendrological gardens have been collected in a database for numerical evaluation. The selection of possible research locations was based on former garden history research reflected in technical literature.
The Central European Historic Garden Database (CEHGD; in Hungarian: Történeti Kertek Adattára) was used, which contains the most complete list on the historical gardens of the Carpathian Basin, enumerating more than 1,500 historic or historically significant gardens. Following the database, we can delimit the gardens to be surveyed personally to a reasonable number filtering on potential dendrological gardens.

Historical research

The remains must and can only be interpreted together with the surrounding settlement and site for the full comprehension of their former significance and current ecological value. According to this, the historical overview compiled based on archival and literary resources tries to give an accurate picture about the formation and development of the researched gardens. It deals with the garden's determining role in the creation of site character and settlement structure and investigates all those site-scale relationships which were considered as particularities during the creation of the castle garden, and which largely influenced the image of the small region that made up the castle's greater environment – especially the existence of characteristic or newly introduced tree species of that epoch. Evidently, the research pays close attention to family historical data, as in many cases they can be directly tied to the formation or remaking of the park, garden parts or elements.

Field survey

Part of the gardens was irrelevant for the present study: either having no landscape aspect, or having limited dendrological value, or it was of very recent establishment, or it has already perished to an extent that prevents current studies.
Accordingly, the most important aspects for the viability of analysis were:

- garden historical value
- photos and documentation reflecting current condition
- vegetation cover or its absence as shown on Google Earth.

The on-site assessment in all cases records the current conditions (drawings, manuals, GPS-coordinates, geodesic surveys, plant assessment, photos etc.) as well as the securable values found so that it could serve as a condition report and comparative basis for any possible future professional use.
Integration of current means and methods of analysis offered a great help in the work, mainly using facilities of the modern IT tools and the Internet. The feasibility of a given area was assessed on the basis of fresh aerial photography and photo images, and text-based descriptions if existing. Aerial photos offered data on vegetation cover and variability of the vegetation in the case of individual castle parks. The current garden descriptions were collected from the official web pages of the communities and institutions maintaining the castles, but we could also use blog-type communications of visitors or recent touristic descriptions or dedicated studies. These pieces of information have frequently allowed locating old and exotic arboreal plant individuals, offering a good argument on the necessity to personally visit the individual parks and gardens.

3. Results

The virtual survey delimited our sample set to 130 potential dendrological gardens in Hungary and 36 in Transylvania. On the basis of actual (physical) survey, in 90 gardens in Hungary and in 36 gardens in Transylvania, the old exotic tree specimens could still be located. We can define the concept of 'dendrological gardens' accordingly: the spatial composition of the park and the overall atmosphere of the garden are basically determined by exotic arboreal species. In view of the above definition, we could locate 75 dendrological gardens in Hungary and 14 in Transylvania (*Fig. 1*).[8]

Fig. 1. Geographical disposition of the investigated gardens

It is postulated that the landscape-ecological and landscape-architectural impact of the dendrological gardens of the Carpathian Basin can be primarily attributed to the variable species composition of the investigated gardens (75+14) and the extended application of exotic species.

As a first step of the analysis, the characteristic old exotic specimens determining the current species composition of the gardens, their spatial composition and landscape-architectural impact were identified. The number of such old exotic specimens was altogether 34 in the explored dendrological gardens and all of them were found in at least five different gardens. In the investigated dendrological gardens, 20 arboreal species were located in at least 24 gardens and, among them, 13 arboreal species were found in at least 30 gardens. The most frequently encountered 20 exotic arboreal species, located by field survey, are the following: *Platanus x acerifolia, Aesculus hippocastanum, Ginkgo biloba, Fagus sylvatica 'Atropunicea,' Pinus nigra, Liriodendron tulipifera, Sophora japonica, Abies spp., Juglans nigra, Quercus robur f. fastigiata, Magnolia spp., Quercus rubra, Sequoiadendron giganteum, Gymnocladus dioicus, Gleditsia spp., Catalpa*

[8] The number of dendrological gardens may change in the course of subsequent research with the accumulation of data. Some dendrological gardens are preserved only in the memory of the locals; so, the collection of local lore is absolutely important.

bignonioides, Taxodium distichum, Pinus strobus, Pinus sylvestris, Pseudotsuga menziesii. Table 1 shows the localization of tree species.

Tab. 1. Occurence of tree species

No.	Name of the arboreal species	Number of dendrological gardens
1	Platanus x acerifolia	69
2	Aesculus hippocastanum	56
3	Pinus nigra	44
4	Ginkgo biloba	43
5	Fagus sylvatica 'Atropunicea'	41
6	Liriodendron spp.	39
7	Sophora japonica	39
8	Abies spp.	37
9	Magnolia spp.	33
10	Quercus robur f. fastigiata	33
11	Quercus rubra	33
12	Juglans nigra	31
13	Gleditsia spp.	30
14	Pinus sylvestris	28
15	Sequoiadendron giganteum	28
16	Catalpa spp.	27
17	Gymnocladus dioicus	24
18	Pinus strobus	24
19	Pseudotsuga menziesii	24
20	Taxodium distichum	24

Most of the listed arboreal species appeared in the Carpathian Basin during the 19th century (sometimes in the second half of the 18th century) as imported or as a result of local breeding. They were reproducing and spreading successfully in the Hungarian historical gardens. These exotic species withstood the test of time, proved their successful applicability in the (Central) European region; therefore, their further utilization is adequately founded.

The dendrological gardens in the Carpathian Basin, by the help of the numerous exotic arboreal species, essentially contributed to the increase of biodiversity, as one of their landscape-ecological merit. In the case of dubious instances, the replacement of the arboreal species – due to its specific environmental demands – should be considered. For the sake of authenticity, however, the replacement should aim at similar aesthetical and landscape-architectural character: exotic or local elements with similar shape, colour, branch system etc.

There are certain instances known when plant species spontaneously growing or eventually planted in the garden proved to be aggressive, oppressing the valuable exotic plants and destroying significant dendrological assemblages.

The landscape-ecological significance of dendrological gardens can be supported by further considerations:

- Dendrological gardens represent a specific segment of green surface facilities, where – due to special status and protection – representatives of local arboreal species of Methuselah's can also be spotted.
  We can mention in this respect the following gardens from Hungary: Sárvár, Zsennye, Gencsapáti with centuries-old pedunculate oak forests, the chestnut forest of Szeleste, the beech forest surrounding the garden of Püspökszentlászló. From Transylvania, we can mention Marosvécs (Brâncoveneşti, RO) with the several centuries-old oak grove and Scots pine (*Pinus sylvestris*) grove, Bonchida (Bonțida, RO), Kendilóna (Luna de Jos, RO) and Hadad (Hodod, RO) with small-leaved linden and oak, Gernyeszeg (Gorneşti, RO) and Görgényszentimre (Gurghiu, RO) with tall ash trees and the riparian alder forests from Piski (Simeria, RO).
- Dendrological gardens can be considered as a basis for the spread of new species in the past and also in our days. Exotic tree species were imported, as a first step, into these gardens and the surplus of the progeny could be transferred to other nursery gardens, parks, arboreta or the nature proper.
  Our survey corroborated a number of contemporary descriptions. We could identify the sycamore trees from Alcsút planted by Palatine Joseph, the ginkgo planted by József Teleki at Gernyeszeg and the gingko trees planted by the Festetics family in the botanical garden of the ELTE University, Budapest. In the park of the Festetics Castle, we could find the almost two-hundred-year-old *Ginkgo biloba*, presented to the Count by the famous botanist Pál Kitaibel. Moreover, we can still locate the individual specimens of *Juglans nigra* (unfortunately in dry state) brought to Keszthely by the son of György Festetics, László [19].
- Dendrological gardens were strongholds of Hungarian plant breeding during the 19th and the 20th centuries; therefore, we can consider them as the cradle of new arboreal species and different variants. For example, István Saághy performed considerable scientific activities in respect of pine species, their naturalization, the observation of the limits of their tolerance and their applicability for various purposes. He could select two, formerly unknown

variants, i.e. *Chamaecyparis nootkatensis ‘Ericoides’* and *Picea abies ‘Araucarioides’*. He also had considerable results in the cross-breeding of pines, crossing for the first time the species *Picea glauca* and *Picea jezoensis* in 1917. The new hybrid was named by Gyula Gayer *Picea saághy* (Saághy-spruce) [20]. The Saághy-spruce was located in other Western Hungarian gardens as well; the last specimen died off in the garden of the Sigray Castle at the beginning of the 1990s. The subspecies *Thuja occidentalis ‘Malonyana’* T was selected by Count István Ambrózi-Migazzi on his Malonya estates [21, 22]. This thuya type of columnar growth can be found recently in several Hungarian dendrological gardens like Kámon or Vép.

- Due to the large number of significant exotic woody plants, frequently planted in mass, the dendrological gardens have remotely striking appearance. By the means of their visual connections remaining to present times, they enrich the landscape character, appearing as spots or characteristic elements in the landscape and represent a serious value to landscape aesthetics.

4. Discussion and Conclusions

The comprehensive analysis and systematic researches regarding the ecological significance and landscape values of the dendrological gardens in the Carpathian Basin have not yet been accomplished. The actuality of the topic is supported by the fact that most of the exotic tree species planted in the 19th century have now reached the final stage of their life; therefore, these days are the last option to analyse the dendrological plant material, their ecological effects and the way they had been arranged in a spatial composition.

Our research is trying to fill a gap in historical and ecological garden studies by means of the broadest possible range of field exploration combined with the identification of the dominant tree species influencing the spatial composition and the landscape appearance of the dendrological gardens.

The main value of the dendrological gardens in the 19th century has been manifested by means of the rare plant species. Nowadays, this dendrologic value can be defined by the veteran age and developed habit of the formerly planted and still living woody species, while landscape-ecological and visual values have been formed owing to the acclimatization and wide spreading of the new species.

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Improving the urban green system and green network through the rehabilitation of railway rust areas

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Abstract: The Industrial Revolution had a negative impact on both the city and the environment. By the second half of the 19th century, the urban erosion of industrial cities cried for direct intervention and curing. The methods developed either along an urban or an anti-urban philosophy: they resulted in the new models of green belt systems aimed at solving all the main urban problems with restructuring the urban fabric, controlling the urban spread into the rural landscape, the lack of green areas and open spaces for recreation and social life, and the lack of green spaces for ventilation. Nowadays, the major cities and capitals around the globe are competing for titles such as healthier, more liveable or even greener city. Given the unfortunate attributes of the urban structure in the historical cities, the development of new transportation sites or green areas is an extremely difficult issue. On the other hand, in the big cities, the brownfield sites are considered as reserve areas for sustainable urban development. Reusing the brownfields and rust areas is already a land saving urban development approach and in case of a complex and ecological urban rehabilitation it can underlie the development of an efficient urban green system and green network.

Keywords: brownfield development, urban green system, green network, railway rust belt rehabilitation

1. Introduction

The aim of our research was to identify those rust areas that hold potentials for green surface development following the principles of sustainable and ecological urban development. The linear structural elements of the railway network can replace the missing elements of the ring-radial urban green system. Therefore, among the various brownfield rehabilitation possibilities, we were focusing on the formal railway sites. After reviewing the literature on the urban green system of Budapest and its railway rust areas, we established the following research hypothesis: *How can brownfield rehabilitations improve the urban green system and the green network connections?*

To answer this question, our first step was to prepare the cadastre map of the railway rust areas by comparing orthophotos with the development plans (realignment plans for the railway network, selected areas to be vacated) of the Hungarian State Railway (MÁV Zrt.). Among the current railway areas in Budapest, the following sites could be recommended to be reused:

1. *the underutilized, almost functionless, or abandoned sites;*
2. *sites that are not involved in the future development plans of MÁV;*
3. *sites that can be integrated into the urban structure due to their adequate size or location.*

Having prepared the first cadastre map, we compared the two networks and studied the relations between the green network and the railway rust areas. After further ground truthing and analysis of the land use maps, we determined the development potential based on a 4th criterion:

4. *which railway rust areas are valuable due to their size or location and hold significant green surface potentials?*

Finally, we conducted an analysis from an ecological perspective so we could identify those rust areas that have good attributes for green surface development. Based on the vegetation index assessment, near-infrared orthophotos and multiple ground truthing, we can determine:

5. *the proportion of biologically active green surfaces in the railway rust areas and the ecological value of the established vegetation*

The detailed analysis of the vegetations will be presented on a selected, representative area. Due to its diversity and complexity, it will provide an insight into the degraded habitats and green surfaces established on the rust areas.

Based on the above described criterions, we will make suggestions for the possible land use categories and new functions for potential railway rust areas. Making an example of Budapest, we will demonstrate on a schematic map how the rehabilitated rust areas can support a well-established ring-radial green network, the development of a well-functioning green network, and broaden the urban recreational facilities.

The role of green system in urban ecology

The first comprehensive urban green system plan in Hungary was prepared in the 1960s. It reviewed the various elements of the green surface of the capital and the agglomeration, with the prospect of joining them together in a more united and coherent system. The so-called MÉM Green Belt Concept Plan was mainly focusing on agricultural production, having carried out a significant afforestation programme. However, though it resulted in a well-structured optimal – from the landscape architectural, urban structural and urban ecological aspects – ring-radial green system, there were several new green-space developments based on this plan in the next two decades, mainly in connection with the afforestation programme on the Pest-side. After all, by the end of the 1980s, it was obvious that the once realistic urban development objective would not be feasible, and the urban green system had become mosaic [1]. The green surface policy in the 1970s included the 60% guideline. We intend to achieve that within the urban inner area the green surface proportion would reach 60% [2]. Perhaps this planning principle was not so idealistic back in the 1970s. The first green surface balance of Budapest was prepared for the Environmental Protection Concept in 1982. In the early 1980s, within the administrative boundary of the capital (and not only within the inner area), this green surface proportion still reached the 60%. As a consequence of the urban developments in the last decades, it has been constantly decreasing. The last survey was conducted in reference to the Pro Verde Budapest (the development concept and programme for the green system of Budapest), when they analysed satellite images taken in 1990 and 2005 [3]. The speculative green surface proportion in 1990 was recorded as 51% and by 2005 it reduced to 48.7%.[1] From this tendency, we assume that today the overall green surface is unfortunately even below 50%. Considering the overall green surface decrease, it seems a rather drastic diminution: 11% in 27 years.[2]

Nevertheless, the urban heat island phenomenon has been intensified in the past decades. Regarding the urban climate of Budapest, we can see minor changes in the last 100 years, but in the last three decades the warming tendency has been stronger.[3] This change is obviously not only the consequence of the decreasing green surface area, but there are several other factors including:

- changes in the macro-climate and, as a result, the intensification of the continental character in the climate of Hungary;
- changes in the urban energy import, mainly an increasing road traffic.

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1 To examine the condition of the green surfaces of Budapest, we used the satellite images taken on 23 July 1990 and 1 August 2005 by the Landsat 5-satellite. The assessment was based on the NDVI values obtained from red and near-infrared layers.

2 Undoubtedly, the accuracy of the general balance based on the average green surface index and the NVDI values obtained through digital assessment could not be compared. If we compare the green surface proportions obtained from the same assays (51% in 1990, 48.7% in 2005) with the urban development, it is probable that the balances prepared back in the 80s presented slightly better proportions since the expansion of the city was not so intensive that it would have resulted in a 9% decrease in 10 years, especially if we compare it to the 2.3% decrease occurring in the 15 years from 1990.

3 Changes in the annual average temperature between the 1900 and the 2000 OMSZ report.

- decreasing the biologically active green surface proportion of the city, as a quantitative alteration;
- changes in the quality of the biologically active green surfaces, deterioration of the conditioning effect of the green surface network caused by the decreasing green surface intensity, the decaying vegetation and the over-fragmented system.

Brownfields and rust areas in the urban structure

Various rust areas are considered as valuable sites in our crowded, overbuilt cities with a mosaic structure. After the political changes of the 90s, the expanded industrial areas with their belongings, such as public utilities and transport area, have lost their original functions. Nowadays, these occupy large and valuable areas and cut off important urban linkages.[4] The reuse of these underutilized areas aids the land-saving urban-development and the green space development projects.

More than 13% (68 km^2) of the administrative boundary of Budapest is considered a brown zone, while if we compare it to the built-up area it is 30%. Within a few areas, the rehabilitation process has already started, or it has already been completed; so, the real problem remains the so-called rust belt.

The brownfield sites are not always abandoned, ruinous areas that have lost their functions. In some cases, there is still business activity, new companies and ventures open or close and there are ongoing changes along with the reminiscence of the former enterprises that have gone bankrupt and closed long ago. Still, this area plays a vital part in the economy of Budapest, but maintaining an updated cadastre map of the extensive and large rust areas is difficult and it demands a tremendous work. Based on their location, we can divide them into three main regions: 1-northern, 2-eastern and 3-southern (Fig.1) [4].

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[4] The term brownfield was first mentioned in the American terminology and, firstly, it only referred to the abandoned industrial areas. Since then, it has gained new meanings and several different definitions have been published. There are certain publications that merely focus on the terminology itself but without giving any final classification. Having said that, in this article, we will use the following definitions based on the common terminology of the Hungarian research studies: brownfield area: usually classified as an area that has fully or partly lost its function, underutilized and abandoned; former industrial or military areas with their transportation facilities that might have real or perceived contamination problems; unsettled proprietary relations and legal regulation, and the numerous small real estates. The above specified brown areas together form a brown zone. Rust belt: consists of the unused and abandoned industrial sites – with the former facilities or transport areas – that have fully lost their functions and are unlikely to be restored (Barta 2004).

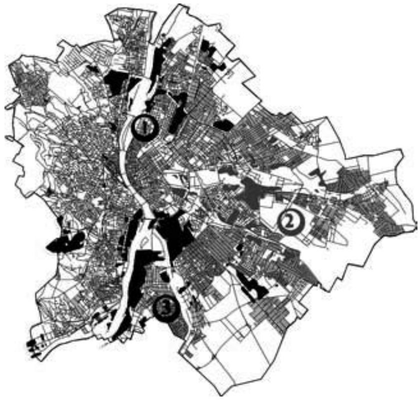

Fig. 1. The 3 major regions of the Budapest brownfield zone
(Beluszky, Győri 2004)

Transport, as any other element of the infrastructure, generates development in a city. It provides public transport, logistics, and creates military and communicational possibilities, resulting in an increasing population and in an expanding urban area. From the second half of the XIX century, one of the most dominating impacts on the urban structure was the railway itself. There is a strong relation between the expanding industrial sites and the developing railway network. As a result, the current brownfield areas are located along the railway network.

Relations between the railway system and the green network

Speaking of either a railway network or an urban green system, in a well-functioning network, the nodes consist of smaller-larger areal elements and are connected by lineal segments. The resulting coherent system is built up from such elements that each serves unique functions. A good example is the railway network that could be characterized with the following components: (Tab.1)

Correspondingly, the green system and the green network[5] consist of linear and areal elements (Tab. 2).

5 'Green network: is the network of open spaces with characteristic vegetations that are – with or without minor restrictions – open for the public' [5].

Tab. 1. The components of the railway network

RAILWAY SYSTEM	
linear elements	areal elements
industrial trails	railway crossing, delta areas
loading platform	transfer trails, storage trails
public transport trails	transfer station
railway platform	train station, stopping-place
buffer zone along the railway	
railway bridge	terminal buildings, train shed, repair workhouse, other railway buildings
elevated railroad	
railway embankment	railway industrial zone
railway cutting	railway 'fallow'
access road network	
mosaic brownfield areas along the railway	
linear elements	areal elements
access industrial railway	transformational, developing brownfield areas
access road network	functioning industrial areas
	included residential areas
	industrial rust belt

Tab. 2. The components of the green system and green network

GREEN SYSTEM		**GREEN NETWORK**	
linear elements	areal elements	linear elements	areal elements
green corridor (ecological corridor)	forest	green corridor	forest for recreation
forest belt (buffer forest belt)	public park	greenway	public park, public garden
roadside green surfaces	public garden		public open space with tree canopy
	public open space with tree canopy	bicycle way	open space of housing estates
	green surface of housing estates		public or semi-public institution gardens
	residential garden	promenade	private garden with public access
tree alley	private garden		
water management area	sports field, open-air bath	waterfronts	specific non-built-up areas
	cemetery, memorial garden, hospital garden, other institutional	path in rural landscape	waterfronts
	rural landscape		(open spaces of city centre)
	water management area		(open space of commercial and service
	specific non-built-up areas		

Through transforming the abandoned sites of the railway network (making use of their original structural features), we can improve the urban green system by replacing the missing linear elements or nodes. National and international examples prove that theme parks, institutional gardens, public parks or other linear green elements developed from brownfields draw attraction and hold increasing tourist potentials due to the fresh and modern design approach that exploits the unique features of such particular sites. As a new recreational area, green network element or just as a conditioning surface, they can become valuable elements of the settlement's recreational green network and its complex green system.

A brownfield rehabilitation project can bring urban ecological benefits even if the objective of the particular investment is not to create a new green area or green elements. Through any complex brownfield development – in addition to the renewal of buildings – the development also improves the environment and revitalizes the open spaces. Thus, it provides better environmental quality. The rehabilitation would also improve the climatic characteristics of the site and it would at least minimally increase the biologically active surface proportion and improve the quality of the green surface. All in all, such rehabilitation is beneficial from the urban ecological perspective. The new land use, the type and density of the buildings will determine the foreseeable beneficial impacts on the ecological attributes.

International overview

In the past decades, the revitalization of the abandoned industrial and transportation sites has been one of the most significant elements in the urban development programmes of any major city, especially in those where the economic transformation resulted in the degradation of the valuable elements in the urban structure and where sustainability and liveability are among the top priority issues. "In Europe, the greening movement has been playing a central role in the sustainable urban development process. Between 1988 and 1993, more than 19% of brownfield and derelict sites in Britain were converted into green spaces" [6, 7]. The renewal of the obsolete or abandoned railway lines as open space or linear green element was first realized in Paris back in the 1990s. The unique and notable rehabilitation of the former line that runs through the city centre provides an intensely planted, biologically active green promenade (*Promenade Plantée*) [8]. The green path runs through the crowded city, mostly in a cutting, planted with extensive species and sometimes even several meters above the ground, disengaging the individual from the urban environment [9]. However, the most famous and spectacular rehabilitation project today is the Highline in New York. The former industrial area and the 10-m-high, 2.3-km-long elevated railway track have been transformed into a greenway. In the USA, with state fund and urban co-operation, the former area in downtown Los Angeles was also revitalized.

Including almost 40 acres, the new park recreated a "riparian habitat in the heart of the bustling metropolis, complete with playgrounds, outdoor classroom facilities and picnic facilities" [10]. These international examples of landscape architecture are inspiring previews for future developments of urban green structure and green network with comparable attributes.

2. Materials and methods

The aim of our research was to present those railway rust areas that are potential for rehabilitations from an urban ecological perspective. Our methodology was based on two parallel examinations. We analysed various urban plans and maps comparing them with near-infrared orthophotos.[6] This enabled us to prepare cadastre maps, study the relations between the networks and define the potential development directions. Further on, we conducted multiple ground truthing and attended various professional exhibitions (conferences, forums), and prepared a more accurate computer analysis.

Preparing the cadastre map of the railway rust areas

Analysing the development of the Budapest railway system, its part in the urban structure and its decreasing importance, we can recommend the following areas for rehabilitation:

1. *that are underutilized or totally abandoned*
2. ***that are not involved in the future development plan of MÁV** (Hungarian State Railways)*
3. *that can be integrated into the urban structure due to their size or location*

On Fig. 2, we marked out these areas and the entire brownfield zone, the frame of which is provided by the railway network. Our mapping was based on our three primary criterions. It provided the ground for further research on the possibilities to improve the urban green system. Overlaying the important elements of the green network, we can observe their relations to the urban structure.

[6] Regulation map of Budapest, Settlement development Concept of districts, Urban Planning Concept of districts, Realignment plans for the railway network, Brownfield zone of Budapest [11], Bicycle route map of Budapest, 2009.

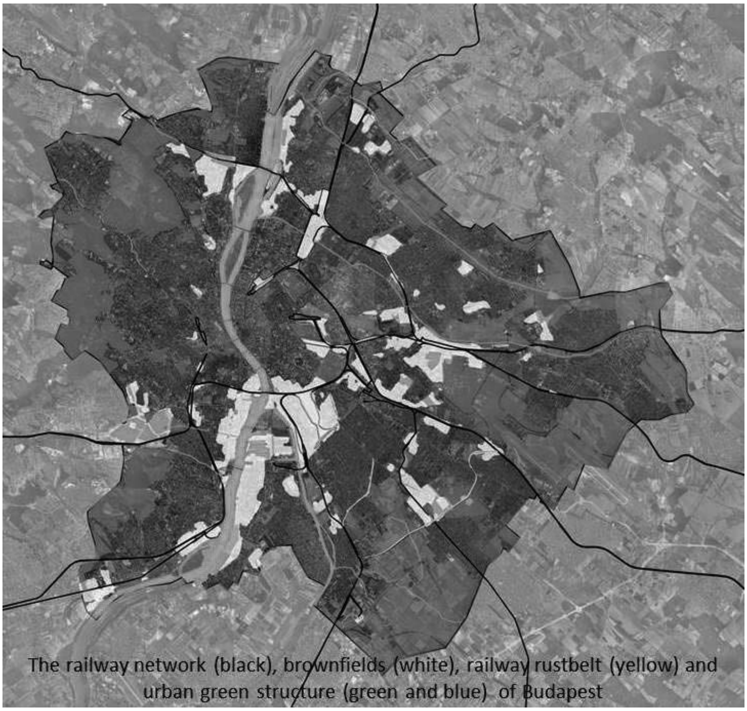

Fig. 2. Railway network, brownfields together with the green system of Budapest (source: Hutter 2012)

Nature reclaims the abandoned and derelict sites through spontaneous occurrence. Mostly adventive, urbanophil species find habitat on the disturbed, usually contaminated sites. The biological activity of the 'urban fallow' is still better and even shows an increasing tendency comparing to the former industrial sites or service areas. On the urban scale, in the context of green network, the "greening rehabilitation" of the rust areas – and specifically the railway rust areas – can create new, ecologically balancing open spaces and linear/aerial green elements that are suitable for recreation. These are created exactly in those urban zones where structural elements or other local features are missing. Based on sustainability and liveability principles and overlaying the rust areas and the urban green system, we can investigate:

which railway rust areas hold potentials for significant green surface development due to their size or location?

We selected more than 20 potential areas with diverse characteristics. We analysed their ecological and green surface values to identify those that hold the most potentials from urban ecological perspective (see Fig. 3).

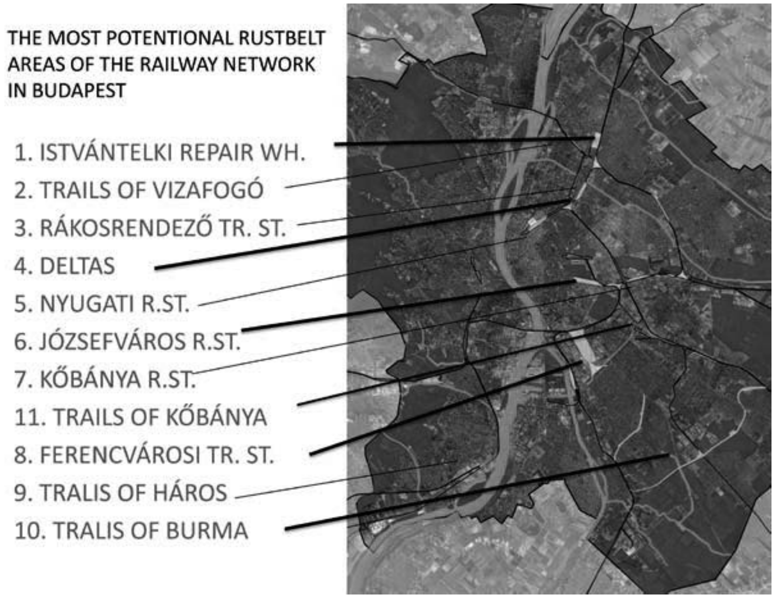

Fig. 3. The potential railway rust areas of Budapest (Hutter)

In the present study, the northern sector will serve as a representative area where a comprehensive assessment was conducted. Focusing merely on the northern sector, we also indicated the industrial rust areas along the railway network. We have studied the extremely detailed previously prepared cadastre maps [11, 12], which we updated using aerial photos and reviewing urban development plans. Figure 4 clearly demonstrates the mosaic distribution of the brownfields, the most significant green surface and green network elements, and the relations between the two networks.

Along the fundamental Northern railway line (Bp. Nyugati pályaudvar – Vác) and the crossing Circle lines, ongoing developments and constructions are altering the urban structure. The transformation of the industrial sector has resulted in underutilized, abandoned and derelict rust areas. There are several former brownfield sites with good transportation facilities and optimal location that have already been rehabilitated, transformed (or taken over by industrial use). In the representative area, we can find both linear and areal elements among the abandoned railway areas. We have thoroughly analysed the nearby industrial rust areas and those blocks that are already under transformation or reconstruction. Afterwards, we compared the underutilized sites with the elements of the urban green system and the green network. The occasional inclusions of various green surface elements in the surrounding brownfield zone hold particular potentials. The most valuable ecological network elements in our representative area are: the

Danube shore and islands, FOKA Bay, Rákos-creek, Szilas creek, Városliget (City Park), Hungarian Railway Museum (Vasúttörténeti Park), the various neighbourhood parks, public gardens, sports fields and the forests located on the urban boundary. The lack of essential linear elements that would provide optimal connections can be clearly observed. Therefore, it would be important to make use of the various features provided by the structure of the railway network. The aim to improve the green network is supported by the fact that the waterfronts in Budapest hold even more potentials regarding the urban green system and the green network.

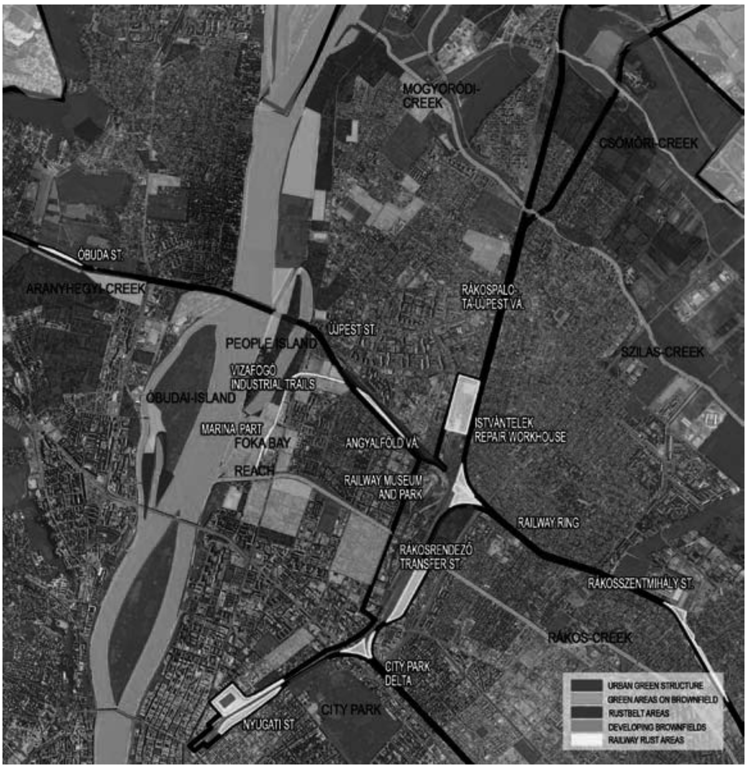

Fig. 4. The railway network and the green system along the northern trails (Hutter)

Subsequently, we also need to consider the ecological attributes and values of the sites, and include them into our criteria, while also analysing the previously selected areas from this aspect. We need to evaluate where we can find an established vegetation; which site could preserve its local green surface characteristics, or where we can detect valuable vegetation cover or significant tree canopy.

Vegetation assessment along the railway rust areas

Redeveloping or reusing the rust areas is an important mean of urban development, which generally improves the environmental quality. The various rehabilitation objectives and principles in Hungary unfortunately hardly consider the ecology, urban ecology or green surface. Our research study, therefore, aimed at making an evaluation and recommendations based on these ecological principles.

Thus, our next step was to analyse near-infrared orthophotos and the vegetation index of the areas and try to determine the changes occurred since 1990. Analysing various maps and databases [3, 13, 14] and conducting multiple ground truthing, we have updated and improved the inventory (see Fig. 5). Finally, we formulated the following research thesis:

What are the biologically active green surface proportion and the ecological value of the established vegetation in the railway rust areas?

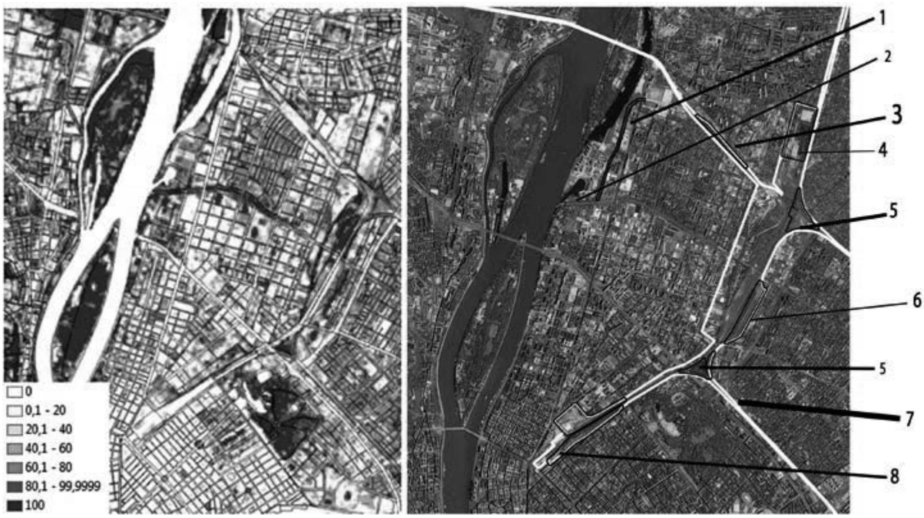

Fig. 5. Vegetation Intensity Map, 2013[7] (Jombach 2012); Near-infrared orthophoto, 2010 (FÖMI – Institute of Geodesy, Cartography and Remote Sensing, Hungary)

The representative area in the northern region introduces various characteristics and shows a great diversity of vegetation. We have chosen 8 sites with different characteristics that are connected by the railway network and we studied the established local vegetation (see Fig. 6).

[7] We have used the following satellite images: 19/05/2013; 22/07/2013; 07/08/2013 made by the Landsat 8 satellite.

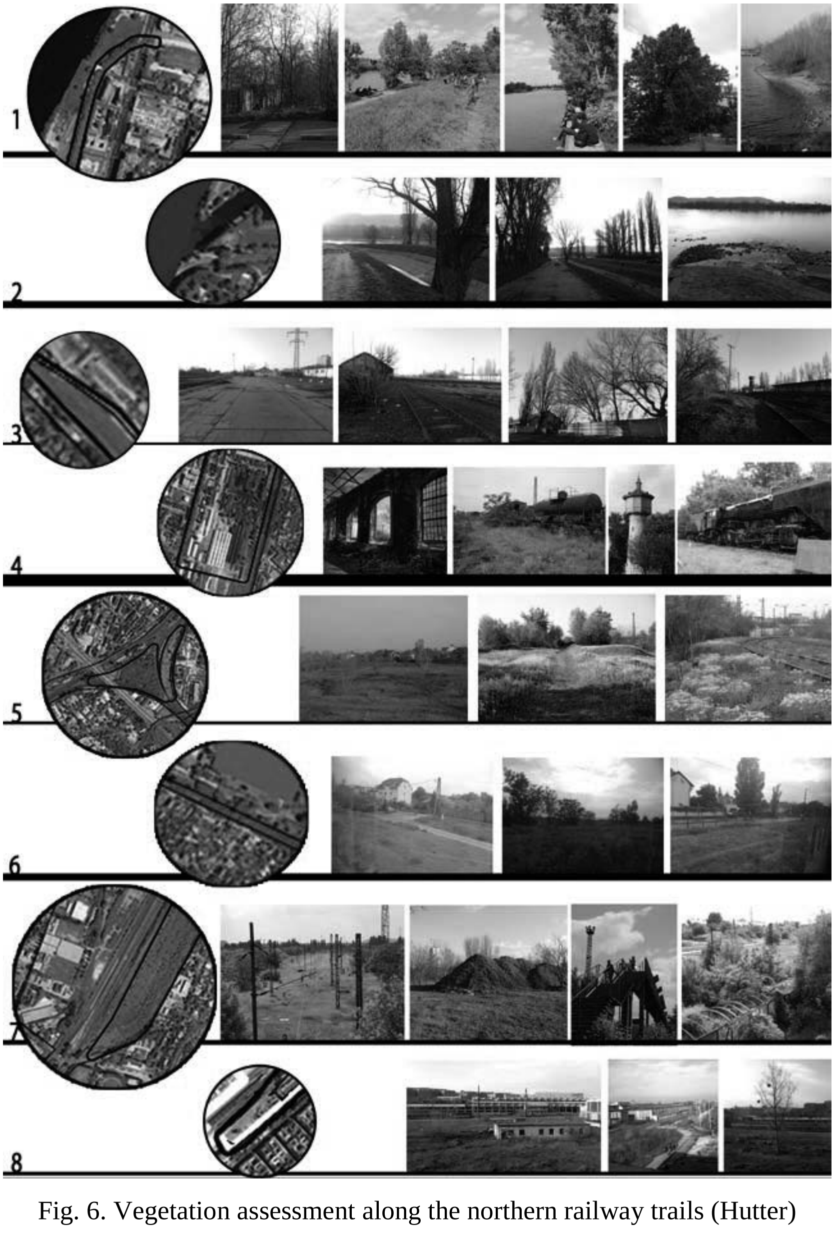

Fig. 6. Vegetation assessment along the northern railway trails (Hutter)

In general, we can conclude that on a slowly abandoned railway fallow, which is still under temporary use, a ruderal weed community is most likely to be established, while on those sites that have been completely abandoned (even if the former service facilities have remained behind), pioneering species would emerge.

1. Vizafogó – abandoned railway line and former shipyard

The abandoned industrial trail remained undisturbed during the past decades allowing a wood vegetation to develop among the old tracks. From the mouth of Rákos Creek, along the slightly elevated creek bank and up to the overpass, a dense and occasional shrubbery vegetation follows the trail. Between the trail and the shore, a more diverse vegetation appears. Various patterns of large continuous grassland communities, smaller shrubberies and valuable solitaire trees are formed. The flood-plain grove by the Danube and the established wood vegetation on the massive concrete walls of the former shipyard have special significance. These two latter habitats and the tall railway 'alley' have unique characteristics and even recreational values.

2. Vizafogó – Rákos Creek and the surroundings of FOKA Bay

The Rákos Creek and its surroundings are one of the most significant linear green elements of the city. Even though the discharge of the creek is not substantial, the drainage basin covers most of the transitional and outer zones of the city. In the outer districts, it flows in the original riverbed in shorter-longer sections, but typically a concrete river bed is applied. This dominant, linear element "cuts into the urban fabric". Various green surfaces appear on both sides of the creek. Occasional stairs emerge from the green slopes by the creek, but mostly we can hardly get close to the water as it flows so deep below. Even though the water is deep beyond the area, it has a calm, soothing atmosphere and provides opportunity to relax. The green corridor along the creek is also valuable from recreational aspects, and the idea to transform it into a long green corridor connecting the nearby districts has already been included in several development plans. Probably the most important section of the creek is the mouth, where it flows into the Danube, running through an artificial riffle. The spit offers a scenic view over the whirling water and is also a shelter for birds and wildlife. It is a natural value of our city. The unique microclimate, the adjacent water and the sparse trees create an optimal habitat for the rich grassland community. The old Lombardy poplar alley by the creek enhances the linear spatial pattern.

3. Angyalföld – railway station

The established ruderal vegetation on the former station is a common example of a less valuable green surface that is usually developed on slowly abandoned railway sites through spontaneous succession process. Mostly large paved surfaces (the former loading areas and platforms), disused rails and the herbaceous plants create the typical stripe pattern. In the dense urban structure, these "empty" brownfields facilitate the ventilation of the nearby areas. Through minor but determined interventions (breaking off pavements, removing the leftover objects), these areas could be soon integrated into the urban green system. Eventually, the wood vegetation established along the former fence could accompany a new road or recreational path.

4. Istvántelek – repair workhouse

The former vehicle repair workhouse can be compared to a ‘classical industrial rust area’ in many ways. It is a densely built area and is a so-called ‘train graveyard’ preserving old railway memories. Due to the once conscious planning, today we can see remarkable and mature wood vegetation. The flourishing flora emerging from the former gardens dominate the site and the young saplings and offshoots also try to find their way on the abandoned site.

5. Railway crossing, delta areas

The areas created by the crossing railways are not typical railway rust areas. From an industrial and urban design perspective, they are not ideal for new building constructions. We can hardly find buildings or other facilities and premises on these sites where nature dominates. The succession processes are more or less progressive: we can observe clearings, ruderal vegetations, grooves and even dense forests formed by pioneering species with a vegetation index rate occasionally above 80%.

6. The railway ring

The inter-station sections of the railway ring have resemblance to the abandoned site of Angyalföld Station. Its most valuable features are the kilometre-long sections and their unique morphology. Even though the mostly herbaceous vegetation among the rails is not significant, the green surfaces have evolved nicely on the empty sites during the past decades. By narrowing the former tracks and releasing rust areas, we could increase the green system and the urban green network. The different sections with various dimensions show different vegetation intensity. In case of a future railway corridor development, not only the demands for new road development should be considered but the idea of improving the green network. These sites should also be evaluated from the “greening” prospective based on their recreational values and their potential role in the green network.

7. Rákosrendező – railway transit station

This abandoned railway transit station is one of the largest and complex reserve areas in Budapest. Various urban development concepts were already presented on its rehabilitation or reuse. So far, none of the functional or image concepts have taken into consideration the spontaneous vegetation that is established on the site (still owned by MÁV). From the near-infrared satellite image, it can be clearly seen that the vegetation is more evolved on the external trails, which were abandoned first. In the surrounding areas, we can also find a three-level vegetation with mostly pioneering species with significant canopy. Both the satellite images and the ground truthing confirm that during rehabilitation we need to take into consideration the spontaneous vegetation.

8. Nyugati (Western) Railway Station

The head station of the northern line experienced various changes. The industrial railway areas slowly became vacant and lost their functions. This was a long and ongoing process; therefore, only rudiments of the still developing vegetation can be observed. As a result of the constant activities, mainly ruderal (weed) communities could become established. There are only a few ornamental trees in the former service areas. The main potential of the 'railway fallow' is its central location and its extensive surface. The rust areas of the Nyugati Railway station are crucial for improving and enhancing a green system that serves good ventilation, air circulation.

In general, the urban development concepts do not consider the aspects of improving or enhancing the green network during a rust area revitalization. Making an example of the Vizafogó area,[8] we will demonstrate how a general (or even “green-surface-improving”) urban development project can relate to potentials held by the brownfields (Fig. 7). We have also chosen this particular area because District XIII has already prepared a strategic green area development plan – uniquely in Budapest – [15, 16, 17, 18], and it is willing to create new green areas or renew the existing ones. However, in the case of the abovementioned railway corridor, it seems that when they prepared the long-term strategy they still did not try to exploit all the potentials of the brownfield areas. Budapest and District XIII recognize the importance of developing green corridors along the watercourses.

[8] Vizafogó is part of District XIII. After the demolition of the former Vizafogó Train Station, the old industrial tracks and the surrounding industrial sites mainly create residential areas (housing estates and new apartment houses) and transforming, redeveloping office buildings are erected.

They also highlight the urban ecological and recreational objectives; however, from the development plan, we can draw these conclusions:

- According to the plan for road development (GREY), a new road would go along the railway line, crossing it at the northern end; consequently, the railway bridge crossing will need to be demolished and the nearby trees will be cut down.

- A considerable building construction is planned in the former shipyard area by the Danube-shore, developing both residential (ORANGE) and institutional (BLUE) buildings. As a consequence, the nearby trees along the rail line are also in danger. There would not be enough space left for the proposed ecological corridor. Moreover, the ecological and cityscape-value of the flood-plain grove and its significance are not appreciated.

- The creek mouth will be even more loaded by the new, traverser road; the remaining green area is very small along the creek bed; notwithstanding the prominent value of the mouth (even on urban scale), the plan does not draw proper attention to it.

- The recreational route by the Danube is broken at FOKA Bay; the missing green network connection will be provided by the new roads in the new blocks (institutional and residential buildings).

Fig. 7. Vizafogó – Photos, 2014 (Hutter); Orthophoto, 2010 (FÖMI); Near-infrared orthophoto, 2010 (FÖMI); Regulation plan (District XIII, 2009)

3. Results and conclusions

The international overview also shows that the modern principles of sustainability and liveability would eventuate in land-saving, ecological means in urban development. Such a development will improve and enhance the urban green network and the urban green system. Unfortunately, the urban development concept of Budapest does not consider these aspects; it is rather influenced by economic or real estate development interests. Our research hypothesis is based on the finding that the urban structural and ecological features of the railway rust areas support the development of a well-structured green network and also improve the urban green system, thus ameliorating the environmental quality and the urban ecological conditions. This study presents the methodology of an ecologically-based assessment and investigation for rust area revitalization. We are aware of the fact that urban ecology is only one of the various development objectives. The previously described methodology could be applied for including this aspect into future development concepts. Although a successful revitalization is based on a complex assessment, in this study, we did not consider the aspects of investment, market or economic interests. Our aim of discussing merely the urban ecological aspect was to raise attention to the importance of this neglected field.

We have compiled a table (see Tab. 3) to introduce the potential land uses, new functions along the rust areas by the northern railway lines. We can demonstrate how the rehabilitated railway areas can function in the urban green system of Budapest.

Tab. 3. Suggested new functions in the rust belt

Num.	Name	Current function	Suggested function in the green system
1	VIZAFOGÓ	elevated industrial railway line	multilevel greenway, green corridor
		abandoned shipyard	public open space with tree canopy, public park, flood-basin forest, private garden with public access
2	RÁKOS CREEK	mouth	public park, greenway along waterfronts, public institutional garden, sports field
	FOKA BAY	water front	
3	ANGYALFÖLD	railway station: abandoned trails	greenway, bicycle way, buffer forest belt
4	ISTVÁNTELEK	repair workhouse	public institutional garden, public park
5	DELTA	areas of railway network	buffer forest, public park, sports field
6	RAILWAY RING	abandoned trails	greenway, bike way, buffer forest
7	RÁKOSRENDEZŐ	transfer station	green corridor, buffer forest, public park, public institutional garden
8	NYUGATI	railway station: empty areas	green corridor, public park, sports field

Finally, a schematic map (see Fig. 8) will demonstrate the network of the proposed optimal developmental directions: the new greenways and green corridors. The linear green elements – supporting the major nodes – complete the current urban green system.

Fig. 8. The schematic map represents the improvement of the green network through railway rust area rehabilitation (Hutter)

In the urban environment, it is rather difficult to create new greenways, but, as the schematic map illustrates, through conscious and long-term planning, we can improve the ring-radial urban green system and create recreational opportunities within the urban area.

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