Carbon content of the biomass of vineyards and orchards in Hungary

An assessment based on large-scale field measurements, case studies and expert judgement

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Introduction

The carbon cycle of vineyards and orchards differs from that of forest ecosystems in many ways. In forests, nearly 100 % of carbon dioxide is absorbed by the dendromass. In a study it was found that 57 % of the total carbon content is stored above- and 41 % belowground, whereas the remaining part gets into the soil through defoliation at the end of the vegetation period (FÜHRER and MOLNÁR, 2003). Wood is periodically removed from the forest through whole-tree cutting in thinnings and final cutting. In the case of orchard plantations and vineyards, a substantial amount of carbon is removed from the land by annual pruning and harvesting. Thus, carbon is stored permanently only in the perennial woody biomass, such as the root system, the trunk as well as the rootstock, lateral branches, branch leaders and central leaders.

The standing volume and perennial woody biomass of orchards and vineyards is highly influenced by the technology of crops and training techniques:

1. By the training of fruit trees, the height of trees, the length of trunks, the number, length, spacing and inclination angle of lateral branches, central leader and branch leaders are formed until the fruit bearing age.
2. The number and size of sublateral branches are controlled by annual prunings. That way the vast majority of these branches regrow annually.
3. Trunk characteristics vary along with training and cultivation methods in vineyards.
4. About 80-90 % of vine shoots and canes are cut and regrow annually.
5. Only a small part of the vineyard biomass is residual and woody, so the high proportion of the biomass is the primary unit of vine growth.
6. Growth intensity is influenced both by the stock and the scion in vineyards and orchards. The effect of the stock is stronger.
7. Perennial woody volume is not as strongly related to the age of plantation as in forests due to the intense regulation of the above-ground biomass.
8. The amount of the below-ground dendromass is determined mainly by the stock, plant density (number of trees per hectare) and soil conditions (available water and nutrient content).
9. Plant density is usually a function of mechanization of the cultivation technology and stock requirements.
10. The cut vine shoots and canes arising on the plantations are mainly burnt on site or transported elsewhere.

On account of the points listed above, the classical dendrometrical methods can be applied for the orchards and vineyards only to a limited extent.

The Hungarian horticultural science does not deal with the whole woody part or perennial woody biomass of orchards and vineyards. Estimates made several decades ago are outdated because of new varieties, stocks and training techniques. Although there are some studies on CO_2-absorption intensity of orchards and vineyards, they are not really suitable for biomass calculations because it would be very cumbersome and uncertain to assess the amount of biomass due to the annual harvesting and regrowth. Thus, it can be concluded that no practically useful estimation methodology of carbon content of the Hungarian orchards and vineyards has been developed yet.

The aim of this study is to estimate the perennial woody biomass and carbon content of the Hungarian orchards and vineyards. We largely relied on our practical experiences, but we incorporated the few results of some former studies with reservations. We had applied those data only if we could have confirmed its validity for the present situation. We also gave an uncertainty estimation of the results.

1. Methodology

1.1. Level of estimation

The chosen main level of estimation was the species-level. In the case of the orchards the expert judgement was carried out for those fruit species which are dominant in Hungary regarding their area, such as apple, pear, peach, apricot, plum, sour cherry and walnut (Hungarian Central Statistical Office, HCSO 2008). Both in the orchard plantations and in vineyards there are a huge number of scion-stock combinations, so we rejected the subspecies-level estimation as an impractical method.

Beyond the species-level, orchards were grouped according to technology of fruit crops and training (crown shape) techniques because this approach covers the variety of growth intensity. Technologies of crops and training techniques used for creating groups were chosen based on the literature and HCSO (2008) data.

In the case of vineyards, the estimation was carried out for those training techniques that are the most abundant traditionally, and those that are taking place in the intensively cultiveted plantations recently planted.

Due to lack of appropriate data, we have not undertaken to estimate the biomass as a function of age of orchards and vineyards. Our results are valid for relatively young (not older than 15-years-old) but fruiting orchards and vineyards, whose age has been derived from the age-distributions (HCSO, 2008). It makes the results somewhat uncertain, however, this type of uncertainty is also covered by our uncertainty estimation. The results must cover the nation-wide average on a middle- and long-term.

1.2. Estimation methods

1.2.1. Perennial woody biomass of orchards

The estimation was carried out in the following steps:

1. Calculation of perennial woody biomass volume (q) on individual-level based on the major sizes (i.e. tree height, trunk diameter, length, number and thickness of central leader, lateral branches and branch leaders).

In case of orchards only the trunk, the central leader, the lateral branches, the branch leaders are included in the standing volume as carbon pool. The parts of crown sizes were assessed following data of Soltész (2001) as well as our own results (e.g. the Experimental and Training Farm of Soroksár). Some Hungarian regulations (Ministerial Decree No. 35/2010) on the prescribed trunk girth of fruiting trees were also considered.

For volume calculations, branches and leaders were regarded as cones and trunks were regarded as cylinders.

2. Calculation of above-ground perennial woody biomass volume per unit area (Q, m^3/ha) from the individual-level volume (q, m^3) and the plant density (number of trees per hectare).

Plant density is determined by not only the requirements of mechanisation but also the applied training techniques and stock types. Each training techniques analyzed in this expert judgement was linked to a characteristic plant density.

3. Calculation of above-ground air-dry woody biomass per hectare (M_{ff}) from plant density (Q, m^3/ha) and wood density (kg/m^3).

Wood density values of fruit trees are not available yet for Hungarian conditions. Thus, for every species those were substituted with the average density of medium-heavy forest tree species (Somogyi, 2007) which amounts to 592 kg/m^3.

4. Estimation of below-ground biomass (M_{fa}, t/ha) from above-ground biomass (M_{ff}) and root-to-shoot ratios.

Root biomass of fruit trees is influenced by several factors: stock type, plant density as well as various soil conditions (water and nutrient supply). Due to lack of appropriate own measured data, root-to-shoot ratios were taken from Gyúró 1974.

1.2.2. Perennial biomass of vineyards

The estimation steps applied were the following:

1. Quantification of fresh perennial biomass on individual-level.

The Hungarian literature provides more data on fresh perennial biomass of vineyards than that of orchards. The below-ground biomass has been calculated based on the stand densities of the varying cultivation methods. The above-ground biomass derived from the literature by direct proportionality between vine stock heights.

2. Estimation of air-dry perennial woody biomass on individual-level.

Air-dry biomass was assessed applying the average moisture content values of the perennial woody biomass taken from Diófási 1968.

3. Calculation of air-dry perennial woody biomass on plantation level.

The air-dry perennial woody biomass values on stand level were gained by multiplication of the characteristic plant density value of the given cultivation method by the air-dry perennial woody biomass values on individual-level.

1.2.3. Estimation of biomass carbon content

A carbon fraction value of 50 % was supposed in general because carbon fraction of various species seems to be more or less constant (Führer and Molnár, 2003).

2. Results

2.1.1. Perennial woody biomass of orchards

According to a HCSO (2008) survey, the area of orchards of huge area and low plant density is decreasing for all species. Furthermore, the ratio and area of orchards older than 24 years old are also decreasing.

The above-stated characteristics apply to **apple** orchards, i.e. the orchards occupying the largest area, too. The area ratio of orchards older than 24 years is 37 %. As a result of the fewer and fewer number of planting after 2001, the ratio of orchards younger than 5 years-old has dropped from 20% to just above 5%. The area of orchards of low plant density (< 400 trees/ha) is decreasing (currently it amounts to 32 %), whereas the area of orchards of high plant density (> 1200 trees/ha) is increasing, currently amounting to 18 %. Traditional training system (wide central leader) represents 35 % of the area and area of "dwarfing central leader" system is 17 %.

Changes in age distribution of **pear** orchards are similar to those of apple orchards. The area of orchards older than 24 years old has been declining to 38 %. Planting has become more intensive since 2001 which yielded an increase of area of young orchards from 20 % to 29 %. Orchards of low plant density (< 400 trees/ha) have an area of 24 % and those of density higher than 1200 trees/ha represent 18 %. The most common (40 %) training system is the "traditional" system (wide central leader). The ratio of the "central leader" system is 22 %.

The area of **apricot** orchards older than 24 years is decreasing. Currently, their area ratio is 16.7 %. After 2001, planting intensity has decreased which has led to a drop in area of orchards younger than 5 years-old to 6.6 %. Orchards of low plant density (< 300 trees/ha) dominates with a proportion of 60 %. The "traditional" training system (combined) represents 50 % of the total area whereas ratio of the "vase" training system amounts to 25 %.

Regarding age distribution of the **peach** orchards similar processes are taking place as described above: orchards older than 24 years are declining. Their area ratio is 14.1 % currently. Orchards younger than 5 years-old have an area proportion of 7.7 %. Orchards of medium plant density (401-500 trees/ha) dominate with a ratio of 67.8 %. The most widespread (73.2 %) training technique is the "open vase". The "vase" method is applied on 13.2 % of the total area.

No statistical data are available on cultivation methods and age distributions of plum, sour cherry and walnut. The most common training techniques of plum orchards are the "vase" and the "central leader". In Hungary, crowns of sour cherry are shaped mainly by the "vase" method whereas in walnut orchards both the "vase" and the "sphere" are applied.

The area and training methods of the dominant orchard types are shown in Table 1. As area of some cultivation types is not known, mean values on country level were calculated based not only on the available statistical data but also on data of various published studies (Soltész, 2001).

Table 1: Area, the most common cultivation techniques and stand densities of the dominant Hungarian orchard types. Weights used for calculation of weighted average on country-level are shown in the last column.

Orchard species	**Area (ha)** (HCSO, 2008)	**Training method (proportions of area are shown in parentheses)** (HCSO, 2008)	**Plant density (trees/ha)** (Soltész, 2001)	**Weight (%)** (based on HCSO, 2008 and Soltész, 2001)
Apple	34906	wide central leader (35%)	367	35
		central leader	888	48
		dwarfing central leader (17%)	2222	17
Pear	2878	wide central leader (40%)	416	64.5
		central leader (22%)	476	35.5
Peach	5787	open vase (73.2%)	476	84.7
		bush, vase (13.2%)	370	15.3
Apricot	5216	combined (50%)	285	66.6
		bush, vase (25%)	341	33.4
Plum	around 24000	bush, vase	317	50
		central leader	500	50
Sour Cherry		bush, vase	333	100
Walnut	around 4200	globular	123	50
		bush, vase	158	50

The most frequent crown shapes and sizes are summarized in Table 2 following data of Soltész (2001) which were corrected according to our own data (e.g. the Experimental and Training Farm of Soroksár). Values of Table 2 show data of fruiting trees not older than 15 years old.

Root-to-shoot ratio of fruit trees is strongly depended on various soil conditions. For example, on soils rich in nutrient the ratio is between 1:4 and 1:5 whereas on nutrient-poor soils it is between 1:2 and 1:3 (Gyúró 1974). Furthermore, root biomass is also influenced by the plant density and the stock. It is not possible to cover all combinations of plant density, soil conditions and stock types when the mean values are calculated on country level. Considering published data, root-to-shoot ratios are given for each training techniques because well-known plant density and defined stock types with particular growth rate belong to each analyzed training types. Ratios of 1:2, 1:3 and 1:4 were used for low ("traditional" training systems), medium (semi-intensive training systems) and the highest plant density (intensive training), respectively (see Table 2).

Table 3 summarizes the perennial woody biomass volume, the above- and below-ground biomass calculation by training types.

In a mid-mature orchard – along with the elder woody parts – 1-5 t/ha lopping is arose annually, which have a moisture content of 50%. Usually, the trimming is pruned and transported away from the field.

Table 2 Root-to-shoot ratios and various crown attributes of fruiting orchards not older than 15 years-old. Values were assessed based on own unpublished data and Soltész (2001), as well as Gyúró (1974).

Orchard type	Cultivation method (stand ages are shown in parentheses)	Root-to-shoot ratio	Trunk height (m)	Central leader	No. of lateral branches /branch leaders	Tree height (m)	Crown diameter (m)	Length of lateral branches/ branch leaders (cm)	Largest diameter of the lateral branches/branch leaders (cm)	Trunk diameter (cm)
Apple	wide central leader (8-10)	1:2	0.6	yes	7	3.75	4	2	3.5	7
	central leader (5-10)	1:3	0.7	yes	7	3.25	3.5	1	3	6
	dwarfing central leader (5-8)	1:4	0.55	yes	4	2.25	1.6	0.7	2.5	5
Pear	wide central leader (8-10)	1:2	0.65	yes	7	4.5	4	2	3.5	7
	central leader (5-10)	1:2	0.65	yes	7	4.5	4	1.2	3.25	6.5
Peach	open vase (10-15)	1:2	0.5	no	4	3	4	3.2	8	14
	bush, vase (8-10)	1:2	0.5	no	4	4	3.5	4	5	10
Apricot	combined (8-10)	1:2	1	yes	7	6.5	6	4	7	14
	bush, vase (8-10)	1:2	1	no	4	4.5	4.5	3.5	5	10
Plum	bush, vase (5-10)	1:2	1	no	4	4.5	4	4	3.5	7
	central leader (5-10)	1:2	0.5	yes	7	4.5	4	1.2	3.5	7
Sour Cherry	bush, vase (5-10)	1:2	1	no	4	4.5	4	3.6	3.5	7
Walnut	globular (10-15)	1:2	1.7	yes	7	9	10	6.1	7.5	15
	bush, vase (10-15)	1:2	1.6	yes	5	9	7	4.9	6.5	13

Table 3 Various volume quantities and perennial woody biomass of the dominant orchard types. Values were assessed based on own unpublished data and Soltész (2001), as well as Gyúró (1974).

Orchard type	Cultivation method	Stand density (trees/ha)	Trunk volume (m^3)	Central leader volume (m^3)	Volume of lateral branches/branch leaders (m^3)	Standing volume on individual level (m^3/tree)	Standing volume (m^3/ha)	Above-ground biomass (t/ha)	Below-ground biomass Mfa (t/ha)	Total biomass Mff + Mfa (t/ha)
Apple	wide central leader	367	0.0007	0.0040	0.0045	0.0093	3.40	2.01	1.01	3.02
	central leader	888	0.0006	0.0024	0.0016	0.0047	4.16	2.46	0.82	3.28
	dwarfing central leader	2222	0.0003	0.0011	0.0005	0.0019	4.25	2.52	0.63	3.15
Pear	wide central leader	416	0.0008	0.0049	0.0045	0.0102	4.25	2.52	1.26	3.78
	central leader	476	0.0007	0.0043	0.0023	0.0073	3.46	2.05	1.02	3.07
Peach	open vase	476	0.0025	0.0128	0.0214	0.0367	17.47	10.34	5.17	15.51
	bush, vase	370	0.0013		0.0105	0.0117	4.34	2.57	1.28	3.85
Apricot	combined	285	0.0049	0.0282	0.0269	0.0600	17.11	10.13	5.06	15.19
	bush, vase	341	0.0025		0.0092	0.0117	3.98	2.35	1.18	3.53
Plum	bush, vase	317	0.0012		0.0051	0.0064	2.01	1.19	0.60	1.79
	central leader	500	0.0006	0.0051	0.0027	0.0084	4.22	2.50	1.25	3.75
Sour Cherry	bush, vase	333	0.0012		0.0046	0.0058	1.94	1.15	0.58	1.73
Walnut	globular	123	0.0096	0.0430	0.0628	0.1154	14.19	8.40	4.20	12.6
	bush, vase	158	0.0078	0.0380	0.0314	0.0772	12.20	7.22	3.61	10.83

2.2. Perennial woody biomass of vineyards

The area of vineyards was 83,555 ha in 2009 which is a value of 9 % lower than that of 2001 (HCSO, 2010). Most of the Hungarian vineyards are between 10 and 19 years old. The most common training type is the high cordon, though its area has been decreasing by 10 % since 2001. At the same time, the area of low cordon type increased dramatically (more than by 30 %) between 2001 and 2009. The area distribution of various training types is shown in Table 4.

Table 4 Area distribution of training methods in the Hungarian vineyards (HCSO, 2010).

Training method	(%)
traditional low training systems	11.9
low cordon	4.7
medium-high cordon	14.1
high cordon	21.1
curtain	8.0
single curtain	16.7
Other	23.5

The Hungarian Institute for Viticulture and Oneology made measurements on above- and belowground biomass of the Hungarian vineyards. Results by Diófási (1968) referring to 10-year-old vineyards of various training types are shown in Table 5. The root systems were excavated to the depth of 60 cm.

Table 5 Fresh biomass of 10-year-old vineyards during the dormant period (Diófási, 1968)

	Stems/ha	Root biomass 0-60 cm (dkg/stock)	Trunk biomass (dkg/stock)	Shoot and canes biomass (dkg/stock)
traditional low training systems	9615	94.9	41.5	41.8
low cordon	5128	124.2	81	79.5
high cordon	2564	145.8	174	126.5

Excavation data reported by Kozma (1967) refers to a depth of 125 cm (Table 6).

Table 6 Root biomass of vineyards of various plant densities (Kozma, 1967)

Stocks/ha	Root biomass 0-125 cm (dkg/stock)
4444	216.0
10000	192.0
20000	81.8

Root and trunk biomass values necessary for the current expert judgement were assessed by direct proportionality (Table 7) based on plant densities and trunk heights values respectively, taken from Bényei et al. 1999 and Csepregi 1997. Data concerning “buck” training can be used to describe traditional low training systems, because these two methods are very similar. Average trunk height is substantially different in vineyards of various training types.

Table 7 Fresh perennial biomass of 10-year-old vineyards of various training systems (Bényei et al., 1999 and Csepregi, 1997).

Training method	Stocks/ha	Trunk height (cm)	Trunk biomass (dkg/stock)	Root biomass (dkg/stock)	Total residual biomass (dkg/stock)
traditional low training systems	10000	-	41.5	192.0	233.5
low cordon	5128	50	81.0	214.7	295.7
medium-high cordon	5128	70	113.4	214.7	328.1
high cordon	3333	120	168.0	221.9	389.9
curtain	3333	140	196.0	221.9	417.9
single curtain	3333	175	245.0	221.9	466.9

Dry biomass values were calculated from fresh biomass and moisture content values published by Diófási (1968) (Table 8). Moisture content of trunks slightly varies between the traditional low training (37.6 %) and the cordon systems (40 %). Moisture content of the root biomass amounts to 50 %.

Table 8 Dry residual biomass of vineyards of various training systems (based on Diófási, 1968).

Training method	Stocks/ha	Trunk biomass (dkg/stock)	Root biomass (dkg/stock)	Total above-ground biomass (t/ha)	Total below-ground biomass (t/ha)	Total biomass (t/ha)
traditional low training systems	10000	25.90	99.84	2.59	9.98	12.57
low cordon	5128	48.60	111.64	2.49	5.72	8.22
medium-high cordon	5128	68.04	111.64	3.49	5.72	9.21
high cordon	3333	100.80	115.37	3.36	3.85	7.20
curtain	3333	117.60	115.37	3.92	3.85	7.76
single curtain	3333	147.00	115.37	4.90	3.85	8.74

It is obvious from data of Table 8 that ratio of the root biomass of vineyards is much higher than that of orchard types (see Table 3).

It is not really important from the piont of view of carbon storage, but we also note that biomass of shoots and canes removed annually is not included in biomass values of Table 7-8.

Usually, pruned shoots and canes are transported away from the field or burned on site, thus, the biomass fixed in these biomass components are taken as emissions in the same year, resulting in a zero carbon stock at the end of the year. Shoot fresh biomass amounts to 1-4 t/ha depending on the following factors:

- Site and weather conditions;
- Between-row distance, plant density, growth intensity;
- Age and health condition of the vineyard;
- Agrotechnique such as: soil tilling type, amount of fertilization;
- 'Fitotechnique' such as: pruning of shoots and canes.

Shoot moisture content is about 50 %.

2.3. Biomass carbon pool of the Hungarian orchards and vineyards

The area-specific above- and below-ground residual biomass carbon pool values, estimated using the data and calculation methods described above, are summarized by orchard and training types in Table 9., calculated with a carbon content of 50%.

Table 9 Above- (Cag) and below-ground (Cbg) carbon pool of perennial biomass of the Hungarian orchards and vineyards.

Species	training techniques	Cag (t/ha)	Cbg (t/ha)	Cag + Cbg (t/ha)
apple	wide central leader	1.01	0.50	1.51
	central leader	1.23	0.41	1.64
	dwarfing central leader	1.26	0.31	1.57
pear	wide central leader	1.26	0.63	1.89
	central leader	1.02	0.51	1.54
peach	open vase	5.17	2.59	7.76
	bush, vase	1.28	0.64	1.92
apricot	combined	5.06	2.53	7.60
	bush, vase	1.18	0.59	1.77
plum	bush, vase	0.60	0.30	0.89
	central leader	1.25	0.62	1.87
sour cherry	bush, vase	0.58	0.29	0.86
walnut	globular	4.20	2.10	6.30
	bush, vase	3.61	1.81	5.42
vineyard (10 years old)	traditional low training systems	1.29	4.99	6.29
	low cordon	1.25	2.86	4.11
	medium-high cordon	1.74	2.86	4.61
	high cordon	1.68	1.92	3.60
	curtain	1.96	1.92	3.88
	single curtain	2.45	1.92	4.37

It can be concluded that more carbon is stored in the residual biomass of vineyards than in that of orchards due to the higher root biomass and stand density values. The traditionally trained peach, apricot and walnut plantations store the highest amount of carbon among the orchards.

3. Conclusions and uncertainty estimation

In Hungary, fruiting orchards not older than 15 years-old store 0.9-7.7 t carbon per hectare in their above- and below-ground residual biomass depending on orchard and training type. The country-level average value weighted by areas of orchard types is 2.35 t C/ha. The carbon content of residual biomass of vineyards is between 3.6 and 6.3 t/ha. Averages of orchard types weighted by areas of training systems are shown in Table 10.

Table 10 Perennial biomass carbon pool of orchards not older than 15 years-old and vineyards (country-level weighted average)

Orchard type	C (t/ha)
apple	1.58
pear	1.76
peach	6.87
apricot	6.03
plum	1.38
sour cherry	0.86
walnut	5.86
vineyard	4.43

Due to lack of appropriate data, it is not possible to estimate statistical uncertainties to the above figures. Our expert judgement is that the uncertainty can be at the order of +/- 40% because of the high variability of training systems, crown shapes, site conditions, stand age etc. This uncertainty can be lowered only with additional measurements covering more site and training types, as well as age groups.

4. References

1. BÉNYEI F. – LŐRINCZ A. – SZ. NAGY L. (1999): Szőlőtermesztés. Mezőgazda Kiadó, Budapest [Viticultire. In Hungarian.]
2. CSEPREGI P. (1997): Szőlőtermesztési ismeretek. Mezőgazda Kiadó, Budapest. [Knowledge of Viticulture. In Hungarian.]
3. DIÓFÁSI L. (1968): Különböző művelésű szürkebarát tőkék egy- és többéves fás részeinek friss súlya és szénhidrát-tartalma nyugalmi időben. In: Katona J. (szerk.) Az Országos Szőlészeti és Borászati Kutatóintézet Évkönyve XIII. pp. 3-16. [Fresh Weight and Carbohydrate-content of Year-old and Older Parts of „Gray Friar" Vinegrapes in Dormant Stage, under Different Training Regimes. In Hungarian.]
4. FÜHRER E. – MOLNÁR S. (2003): A magyarországi erdők élőfakészletében tárolt szén mennyisége. Faipar LI. (2) pp. 16-19. [Carbon Content of the Woody Biomass of Hungarian Forests. In Hungarian.]
5. GYÚRÓ F. (1974): A gyümölcstermesztés alapjai. Mezőgazdasági Kiadó, Budapest. [Basics of Fruit production. In Hungarian.]
6. KOZMA P. (1967): Szőlőtermesztés 1. Mezőgazdasági Kiadó, Budapest. [Viticultire I. In Hungarian.]

7. KSH (2008): Alma-, körte-, őszibarack-, kajszibarack-ültetvények adatai, 2007 (Előzetes adatok). Statisztikai Tükör II. évf. 8. szám. [Data of Apple-, Pearl-, Peach-, Approcot-plantations, 2007, preliminary edition. In Hungarian.]
8. KSH (2010): Szőlőültetvények összeírása, 2009 (Előzetes adatok). Statisztikai Tükör IV. évf. 73. szám. [Catalogue of Vineyards, 2009 (preliminary data). In Hungarian.]
9. SOLTÉSZ M. (2001): Integrált gyümölcstermesztés. Mezőgazda Kiadó, Budapest. [Integrated Fruit Production. In Hungarian.]
10. SOMOGYI Z. (2007): A hazai erdők üvegház hatású gáz leltára az IPCC módszertana szerint. Erdészeti Kutatások 92. pp. 145-162. [Greenhouse-gas Inventory of Hungarian Forest Based on the IPCC-methodology. In Hungarian.]
11. 35/2010 (IV.9.) FVM rendelet az Európai Mezőgazdasági Vidékfejlesztési Alapból kertészeti ültetvények korszerűsítéséhez, korszerű ültetvények létesítéséhez nyújtandó támogatások részletes feltételeiről. [Statue of Ministry of Agriculture and Rural Development on Subsidies for Modernization of Horticultural Plantations from the European Agricultural Fund for Rural Development , Detailed Conditions. In Hungarian.]

5. Biographies and related publications

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1977 – 1983: University of Horticulture, Faculty of Culture, horticulutre engineer, graduate
1982 (10 days): Kalinin College of Agriculure, Szimferopol
1986 (7 days): Humboldt University, Berlin
1990 (2 months): Advanced course on irrigation and soil management, Israel, postgraduate

Academic title:

1984, dr. univ., Eötvös Loránd University
1998, CSc, earth science

Language skills:

Advanced in English and Russian

Work experience:

1977 – 1979: University of Horticulture and Food Industry, *research student*

1979 – 1984: University of Horticulture and Food Industry, *assistant lecturer*
1984 – 1999: University of Horticulture and Food Industry, *assistant professor*
1999 – University of Horticulture and Food Industry; from 1st January, 2000.: Szent István University, Faculty of Horticulture; from 1st September, 2003: University of Economic Science, Faculty of Horticulture; from 1st September, 2004: Corvinus University of Budapest, Faculty of Horticulture, *associate professor*

1991 – 1994: *head of department* (Department of Agrocultural Meteorology and Water Management)
1999 – head of department (Department of Soil Science and Water Management)
2004 – 2011: *vice dean*

Research area:

- Water shortage of habitats
- Phytoclimate in orchards
- Physical analysis of sap flow dynamics in trees and transpiration

Fellowship in scientific organizations/corporations:

1974: Hungarian Meteorological Society, member
1995: Hungarian Meteorological Society, member
1991: Hungarian Academy of Sciences, Committee on Meteorology, Subcommittee on Agicultural Meteorology, member
1994 – 1998: COST 711, representative of Hungary
2000: COST 711, representative of Hungary

Expert activities:

- 1981: *Examination of climate in biosphere reserves*. Institute for Air Protection
- 1988: *Climatic conditions in Zemplén landscape-protection area*. Ministry of Environmental Protection
- 1996: *Measurement of water shortage of habitats and description with a view to environmental protection*. Ministry of Environmental Protection
- 1999: *Climatic conditions in Budapest District II. (enclosed by Széna square–Retek street–Fény street–Ganz Electircity Works).* Institute of Urban Planning, Budapest.
- 1999: *Climatic aspects of urban planning in Győr*. Municipality of Győr.
- 2002: *Climate assessment on subregion level with a view to horticultural corps.* National Programme for Research and Development.

5.1.1. Related publications: Dr. László Tőkei

Tőkei L. - Sipos B. Z. (1998): *Application of the heat pulse method for determining water uptake of elderberry.* Lippay János - Vas Károly Scientific Meeting, 16-18 September 1998, Budapest, Hungary (In Hungarian).

Tőkei L. - Jung A. - Dunkel Z. (2003): *A new method for direct estimation on water uptake of cherry trees.* Lippay János - Ormos Imre - Vas Károly Scientific Meeting, 6 November 2003, Budapest, Hungary (In Hungarian).

Juhász Á. - **Tőkei L.** - Rácz Szabó R. - Nagy Z. - Pap Zs. (2007): *Measurements on sap flow of woody cultures.* Forestry Conference 11 December 2007, Sopron, Hungary (In Hungarian).

Juhász Á. - **Tőkei L.** (2007): *Measurements on sap flow of fruit trees.* Lippay János-Ormos Imre-Vas Károly Scientific Meeting, 7-8 November 2007, Budapest, Hungary (In Hungarian).

Juhász Á. - **Tőkei L.** - Nagy Z. - Gyeviki M. - Hrotkó K. (2008): *Measurements on water use of cherry trees.* 7th International Symposium "Prospects for the 3rd Milenium Agriculture". 2008, University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca.

Juhász Á. - **Tőkei L.** - Nagy Z. - Hrotkó K. (2008): *Estimating of water consumption of cherry trees.* International Journal of Horticultural Science 4., pp. 15-17.

Juhász Á. - **Tőkei L.** - Nagy Z. - Gyeviki M. - Hrotkó K. (2008): *Measurements on water use of cherry trees.* Bulletin UASVM Horticulture 1., pp. 237-241.

Tőkei L. - Juhász Á. - Begyik A. - Nagy Z. - Hrotkó K. (2010): *Factors affecting water consumption of high density sweet cherry orchard.* International Horticultural Congress, 22-27 August 2010., Lisbon, Portugal.

Juhász Á. - Tőkei L. - **Juhos K.** - Hrotkó K. (2010): *Estimating of water uptake of cherry trees based on sap flow measurement data.* International Conference on Horticulture Post-Graduate Study. 30-31 August 2010., Faculty of Horticulture in Lednice, Mendel University, Brno, Czech Republic.

Juhász Á. - **Tőkei L.** - Halász K. - Juhász A. - Hrotkó K. - Lukács N. (2011): *Water availability and eater use in high density cherry orchards on different rootstocks in sandy soils.* Columbia University Seminar Series. Columbia University, pp. 378-392.

Juhász Á. - **Tőkei L.** - Juhos K. - Hrotkó K. (2011): *Estiminating of water uptake of cherry trees based on sap flow measurment data.* 2nd International Conference on Horticulture Post-Graduate study. 30-31. August, 2011., Lednice, Check Republic.

Juhász Á. - Sepsi P. - **Tőkei L.** - Hrotkó K. (2011): *Night-time transpiration rate of sweet cherry trees.* Second Balkan Fruit Sysmposium. 5-7 September 2011, Pitesti, Romania.

Juhász Á. - Hrotkó K. - **Tőkei L.** (2011): *Sap flow response of cherry trees to weather condition.* Air and water Components of the Enviromen. 14-18 March 2011, Romania, Cluj Napoca.

Juhász Á. - Sepsi P. - Hrotkó K. - **Tőkei L.** (2011): *Transpiration of high density sweet cherry orchard.* 8th International Workshop on Sap Flow. 8-12 May 2011, Italy, Volterra.

Hrotkó K. - Nagy Z. - **Tőkei L.** (2011): *Water uptake of cherry trees related to weather conditions.* 46th Croatian and 6th International Symposium on Agriculture. 14-18 February 2011, Opatija, Croatia.

Juhász Á. - Sepsi P. - Aszalós I. - Hrotkó . - **Tőkei L.** (2012): *Sap transport of sweet cherry trees on heat wave days.* International Conference Plant Growth, Nutrition and Environmental Interactions. 18-21. February, 2012, Vienna, Austria.

5.2. **Katalin** Juhos

Personal data:

Year of birth: 1984
Postal address: H-1118 Budapest, Villányi Street 29-43.
E-mail: katalin.juhos@uni-corvinus.hu
Tel: +36-1-482-6468

Education and instructional trips:

2003 – 2008: University of Debrecen Faculty of Science and Technology, MSc in geography (spec. landscape protector)
2004 – 2009: Szent István University Faculty of Water and Environmental Management, BSc in agricultural engineering in environmental management (spec. settlement management)
2009 – 2012: Corvinus University of Budapest Doctoral (PhD) School of Horticultural Science
2012 – Szent István University Faculty of Water and Environmental Management, soil conservation engineering, postgraduate

Language skills:

Advanced in English and German

Work experience:

2008 – 2009: Corvinus University of Budapest Faculty of Horticultural Science Department of Soil Science and Water Management, *departmental engineer*
2009 – Corvinus University of Budapest Faculty of Horticultural Science Department of Soil Science and Water Management, *assistant lecturer*
2011 – Corvinus University of Budapest Faculty of Horticultural Science, Faculty Conuncil Experimental Farm Committee, *member*

Research area:

- Strategy for the local land use related to the soil conditions and tillage technology. Alternative soil usage proposals on unfavorable areas, specially for the energy forests (2009–, Corvinus University of Budapest)
- Impacts of the irrigation to the soil; salinization and sodification (2008 – 2009, Szent István University)
- Heavy metals pollution of floodplain areas (2006-2009 University of Debrecen)

Expert activities:

- 2012: *Land suitability assessment of Soroksár for short rotation willow plantation for energy*. Bionova Ltd., Budapest
- 2012: *Soil management and fertilization in energy farming*. Pannon-Biomassza Ltd., Pécs

- 2012: *Water conductivity and available water capacity assessment of soil mixtures and substrate*. Zöldtető Építő Ltd., Budapest
- 2011: *Problems in plant nutrition in ornamental nursery*. Radev Tree Nursery, limited joint-stock partnership, Szentendre
- 2010: *Assessment of growing media*. Planta Dekor limited joint-stock partnership, Budapest

5.2.1. Related publications: Katalin Juhos

Juhos K. - Nádosy F. - Juhász Á. - Sepsi P. - Magyar L. - Tőkei L. (2012): *Land suitability assessment in Soroksár for energy willow and poplar.* In: Sustainable development, livable region, livable urban landscapa 3., Corvinus University of Budapest, Budapest (In Hungarian).

Juhos K. - Nádosy F. - Juhász Á. - Sepsi P. - Magyar L. - Tőkei L. (2012): *Land suitability assessment for short rotation energy plantations*. Corvinus University of Budapest, Budapest (In Hungarian).

Juhos K. - Magyar L. - Gurály A. - Szabó V. - Búcsi A. - Nádosy F. (2011): *Questions about species and technology in short rotation forestry.* In: Szabó V. - Fazekas I. (eds.) Environmentally energy production and consumption. 2nd Conference Environment and Energy, 25-26 November 2011, Debrecen, Hungary (In Hungarian).

Juhász Á. - Tőkei L. - **Juhos K.** - Hrotkó K. (2011): *Estiminating of water uptake of cherry trees based on sap flow measurment data.* 2nd International Conference on Horticulture Post-Graduate study. 30-31. August, 2011., Lednice, Check Republic.

Juhász Á. - Tőkei L. - **Juhos K.** - Hrotkó K. (2010): *Estimating of water uptake of cherry trees based on sap flow measurement data.* International Conference on Horticulture Post-Graduate Study. 30-31 August 2010., Faculty of Horticulture in Lednice, Mendel University, Brno, Czech Republic.