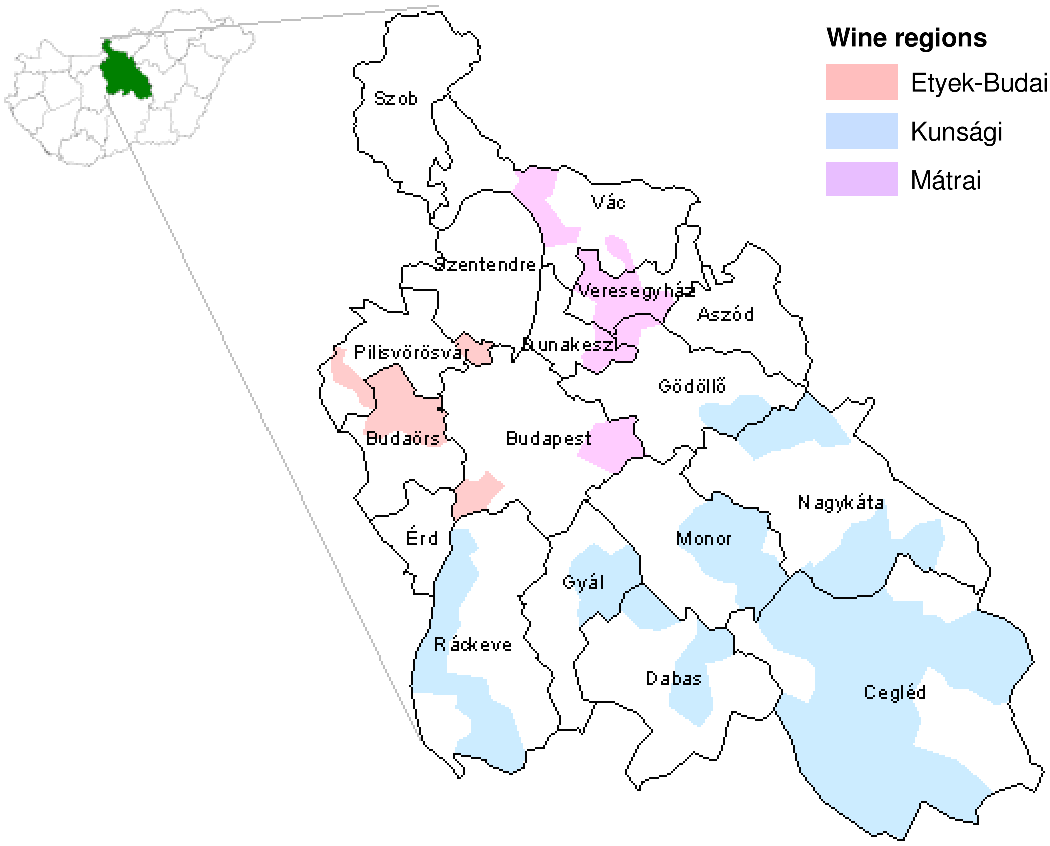
Applied Ecology and Environmental Research

International Scientific Journal



Thematic issue

TÁMOP-4.2.1/B-09/1/KMR-2010-0005 project
"Sustainable development – liveable region – liveable landscape" subproject

Corvinus University of Budapest, Hungary

VOLUME 10 * NUMBER 1 * 2012

http://www.ecology.uni-corvinus.hu
ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

TÁMOP-4.2.1/B-09/1/KMR-2010-0005 project

The project was realised through the assistance of the European Union, with the co-financing of the European Social Fund.

THE ROLE OF HOUSING ESTATES' GREEN SURFACES IN FORMING THE CITY CLIMATE OF BUDAPEST

BAKAY, E.

Corvinus University of Budapest, Department of Garden and Open Space Design
1118 Budapest, Villányi út 29-43., Hungary
(phone: +36-1-482-6512)

e-mail: eszter.bakay@uni-corvinus.hu

(Received 18th October 2011; accepted 25th November 2011)

Abstract. The concept of housing estates is closely connected to urban developments after World War II., most significantly in the residential developments of former Socialist countries. Since the 1950s many new public functions have appeared in housing estates, and a variety of different design styles and fashions have changed. The goal of our research is to clarify, how the green surfaces of these housing estates influence the present urban ecological system of Budapest and to determine principles and physical data, which might have an influence on today's open space- and green-system planning.
In our research, the sizes and proportions of green surfaces and tree canopy, the multi-leveled vegetation and the proportion of fragmented green surfaces are analyzed on different testing sites. These data are evaluated in the light of relevant building codes for residential developments effective in each period. Areal and spatial photos help to evaluate the present plant-coverage by the help of Vegetation Index.
The edification of our research is that these housing estates have developed an extremely high vegetation index by the present day. Thanks to their large open spaces, proper supply of green surfaces and significant index of tree canopy, these housing estates have a good urban ecological effect today.
Keywords: *green surface norms, city climate, multi-leveled vegetation, fragmented greens, tree canopy*

Introduction

Although the first housing estates appeared in Europe around the beginning of the 19th century, the concept of housing estates is closely connected to urban development after World War II. Within this timeframe, it is most significant in the residential developments of former Socialist countries. In this region the housing estates can be considered as the symbols of Socialist urban design. Within the history of housing estate developments certain periods can be distinguished according to architectural composition, applied building technology, design principles and their urban structural situation. The main types of housing estates are similar in the various Eastern Bloc countries.

The development pattern of the housing estates built in the 1950s during the era of social realism is different from those of the 1960s – when block technology was applied – and from the housing estates with the system-building technology of the 1970s. The other important impact causing significant differences were the new norms at the end of the '70s regarding green areas of housing estates. Housing estates built in the '80s and '90s are more ambitious regarding applied open space design solutions, in order to balance the declining prestige of the block-flats. The big housing estates developments ended after the change of regime, but the construction of planned high-density developments has survived in the form of residential park developments. The gated community residential developments of the last 15 years fulfil the new needs of a social class quite different from the population of the older housing estates. These new requirements affect the green surface and open space development in these new residential areas, as well.

Materials and methods

Since the 1950s many new public functions have appeared in housing estates, and a variety of different design styles and fashions have come and gone. In our research, the sizes and proportions of green surfaces and tree canopy, the multi-leveled vegetation and the proportion of fragmented green surfaces are analyzed on different testing sites. These data are evaluated in the light of relevant building codes for residential developments effective in each period. The goal is to clarify, how the green surfaces of these housing estates influence the urban ecological system of Budapest and to determine principles and physical data, which might have an influence on today's open space- and green-system planning.

Original physical plans, landscape development plans were used to determine the proportion of impervious (paved) and green surfaces, the composition of the vegetation and the amount and proportion of recreational open spaces. Areal and spatial photos help to evaluate the present plant-coverage (Bakay et al., 2011).

In order to study the design principles and methods of housing estate developments in the period from 1950 to 1990, we chose site layouts of two housing estates designed in each decade and analyzed them according to certain aspects. The site layouts of two housing estates built after the year 2000 were analyzed by the same aspects. Besides the site layouts construction drawings were necessary to detect the exact type of paving materials and plantations. The chosen sample sites represent building arrangement systems typical of that decade, and their available documentation is detailed enough. In the case of same-sized housing estates, like Bp. IX. József Attila housing estate and Bp. XVIII. Lakatos út housing estate, we analyzed only some building phases.

The comparison of green surfaces and green areas of different housing estates and the demonstration of differences were effectuated by comparison of some data measured on the plans and some values calculated from them.

The proportion of built areas determines the „density" of the housing estate and shows how much open-space is available. Analyzing the paved surfaces we have to differentiate between impervious and pervious surfaces. However both are inactive from a biological point of view, thanks to their drainage capacity, the pervious pavements are much favourable from an ecological point of view. The green surface proportion, which is determined in the building codes or master plans of today, is an extremely important value from a city-climate perspective. The approach of the regulations in the '50s, '60s, '70s and '80s was very different of today's. On one hand these regulations were normative and not surface proportion based, and on the other hand, instead of the minimum green surface, the minimum green area per resident was determined. The concept of green area contains the green surfaces, playgrounds and leisure areas and the walkway system leading to them.

When calculating the size of green surfaces in residential parks built after the millennium, we took into consideration green surfaces of roof gardens according to the regulation operative today. According to it only 40% of green roof can be considered as green surface in the case of a 30-40 cm soil layer, typical of the analyzed blocks of apartments.

Although nowadays when calculating green surface proportion we take into consideration even small, fragmented green areas, these green islands usually bounded by paved walkways are not equal with the same size portion of large, coherent green surfaces neither from an ecological point of view nor from usage. Therefore when evaluating the green surfaces of a housing estate the proportion of fragmented green related to the total green surface, is an important indicator. Fragmented green is a biologically active surface with a size less than 200 m^2, and linear green spaces under 300 m^2.

To calculate normative green surface we need to know the number of residents, which approximately can be calculated from the number of flats by using certain statistical indicators from the decade of the construction. The accurate number of planned flats is usually indicated on the site layout plan. If the number of flats was not available, we counted the flats on the spot. In certain cases statistics of the period (Preisich, 1998) show the number of flats in certain housing estates.

As multi-leveled vegetation is extremely valuable from an ecological point of view, we analyzed the proportion of areas covered by three-level vegetation (deciduous trees + shrubs + herbaceous plants) compared to the total green surface.

In the interpretation of recent regulations the value of tree canopy means the proportion of the total projection of deciduous tree crowns compared to the total lot-size (total lot size does not contain the lots of different institutions). Tree-density is determined by the number of trees on given area-units. Though the minimum required tree canopy proportion was not regulated before the '90s, we measure this from an ecological aspect extremely important indicator on housing estates built in different decades.

When calculating canopy we suppose that the crown projection size of a deciduous tree is approximately 30 m^2. The size of shaded area is calculated from the number of trees, and tree canopy value shows the proportion of shaded green surfaces related to the whole area.

After making some measurements on the original plans and calculating some values, by the help of aerial photos and satellite images we evaluate the present value of housing estate green surfaces built in different eras, referring to the conditions and the canopy of the vegetation.

Analyzing site layouts of different housing estates

Housing estates built in the 1950s

The developments with framed built-up areas are typical at the beginning of the 1950s (before 1956), whose enclosed or semi-closed courtyards made a rather pleasant and intimate garden use possible (e.g. Bp. XX. Gubacsi hídfő housing estate, *Fig 1*). Even primary childcare facilities were placed in bigger courtyards. Besides this typical built-up area more and more housing estates were built with detached houses in a strip-like arrangement, like Bp. XI. Villányi út 55-65. (*Fig. 2*), where the buildings are placed in a strict geometrical order in a strong axial symmetry, accentuated by some decorative garden-features like ornamental pool, arbor, statue, etc. The proportion of flower beds is extremely high on both housing estates, but only few trees are planted, most of them scattered on the area singly or in small groups.

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

Indicator	Quantity	%
Total area (m^2)	56391	100
Built-in area (m^2)	16609	29.5
Solid pavements (m^2)	5854	10.4
Pervious pavements (m^2)	12670	22.5
Water surface (m^2)	0	0
Green surface (m^2)	22053	39.1
Green+pervious surface (m^2)	34723	61.6
Multi- level vegetation (m^2)	1116	
Fragmented green surface (m^2)	7090	
Deciduous trees (pc.)	493	
Number of residents	2432	
Green surface/resident (m^2/res.)	9	
Green+pervious surface /res. (m^2/res.)	14	
Proport. of multi-leveled greens		5
Proport. of fragmented greens		32
Tree canopy (30m^2/tree)		26.2

***Figure 1.** Bp. XX. Gubacsi hídfő housing estate – layout and data*

As practically no one owned a car in those years, there were no parking stalls on the lot, and the approach of the buildings was provided through roads with mixed traffic. In the year of planning according to the regulations of the period (Norms of Urbanism) 10 m^2/resident public garden was to be provided either in the immediate surroundings of the building or in the neighbourhood unit at a maximum walking distance of 500 m (Ormos, 1967). These housing estates have a pleasant, airy atmosphere even today thanks partially to the strict urbanism norms and partially to the lack of investor's pressure to squeeze the most possible flats in housing estates. Generally high green surface proportions are typical in housing estates of the 1950s, especially if we consider green surface together with pervious pavements, like gravel, an often used pavement in the '50s.

Indicator	Quantity	%
Total area (m^2)	14903	100
Built-in area (m^2)	3103	20.8
Solid pavements (m^2)	3945	26.5
Pervious pavements (m^2)	0	
Water surface (m^2)	69	2.2
Green surface (m^2)	7855	52.7
Green+pervious surface (m^2)	7855	52.7
Multi- level vegetation (m^2)	392	
Fragmented green surface (m^2)	1608	
Deciduous trees (pc.)	92	
Number of residents	561	
Green surface/resident (m^2/res.)	14	
Green+pervious surface /res. (m^2/res.)	14	
Proport. of multi-leveled greens		5
Proport. of fragmented greens		20
Tree canopy (30m^2/tree)		18.5

***Figure 2.** Bp. XI. Villányi út 55-65. housing estate – layout and data*

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

Besides of the high green surface proportion the portion of the fragmented green is also rather high in these housing estates. In the case of Gubacsi hídfő housing estate the tree canopy value is extremely high as well.

Housing estates built in the 1960s

In the housing estates of the 1960s instead of framed and semi framed site layouts the more modern detached strip-like site layouts prevailed, more favourable from the industrialized building methods' point of view. The detached buildings were placed in a way that a semi-closed courtyard was formed among them (e.g. Budapest, IX. József Attila housing estate, *Fig. 3*). The car traffic was only outside the block; inside only pedestrian traffic was allowed. On these housing estates there were but sporadic parking places and only on the peripheries.

Indicator	Quantity	%
Total area (m^2)	176176	100
Built-in area (m^2)	36437	20.7
Solid pavements (m^2)	56945	32.3
Pervious pavements (m^2)	399	0.2
Water surface (m^2)	176	0.1
Green surface (m^2)	81820	46.4
Green+pervious surface (m^2)	82219	46.7
Multi- level vegetation (m^2)	8672	
Fragmented green surface (m^2)	9441	
Deciduous trees (pc.)	1322	
Number of residents	10806	
Green surface/resident (m^2/res.)	8	
Green+pervious surface /res. (m^2/res.)	8	
Proport. of multi-leveled greens		11
Proport. of fragmented greens		12
Tree canopy (30m^2/tree)		22.5

Figure 3. *Bp. IX. József Attila housing estate – layout and data*

At certain housing estates of the '60s, the buildings are organized in clusters, around cul-de-sacs. The traditional street system disappeared. This arrangement method was extremely successful at housing estates built in one phase (e.g. Bp. XVIII. Lakatos út housing estate, *Fig. 4.*). At housing estates built at the beginning of 1960s the size of green surface per resident is relatively high, but at those built in the second half of the decade it decreased significantly. The reason for this is partially the growing demand for many new and thrifty housing developments due to a great shortage of flats. The other reason is that the decrees regarding green surface planning haven't regulated the normative sizing of green surfaces in the newly built residential areas.

The fragmentation of green surfaces became a hot issue in the '60s in professional literature, because small size green units are less useable and their ecological value is also reduced. Regarding site layout plans, a new professional requirement, extremely important both from usage and aesthetical point of view, has been conceived. The goal was to create usable, coherent and solid shape green surfaces placed in a distance from the buildings, which were not fragmented by car traffic lanes, besides the necessary front- and side yards.

Indicator	Quantity	%
Total area (m^2)	59080	100
Built-in area (m^2)	8960	15.2
Solid pavements (m^2)	22983	38.9
Pervious pavements (m^2)	1526	2.6
Water surface (m^2)	0	0
Green surface (m^2)	25611	43.3
Green+pervious surface (m^2)	27137	45.9
Multi- level vegetation (m^2)	956	
Fragmented green surface (m^2)	2526	
Deciduous trees (pc.)	297	
Number of residents	1785	
Green surface/resident (m^2/res.)	14	
Green+pervious surface /res. (m^2/res.)	15	
Proport. of multi-leveled greens		4
Proport. of fragmented greens		10
Tree canopy (30m^2/tree)		15.1

Figure 4. *Bp. XVIII. Lakatos út housing estate – layout and data*

However, even in this decade, similarly to the '50s, we can read about a desired tree canopy of 50-70% on open spaces of housing estates (Greiner, 1966), which means approx. 1.7 trees on each 100 m^2 – in the analyzed housing estates we see much less dense tree plantations.

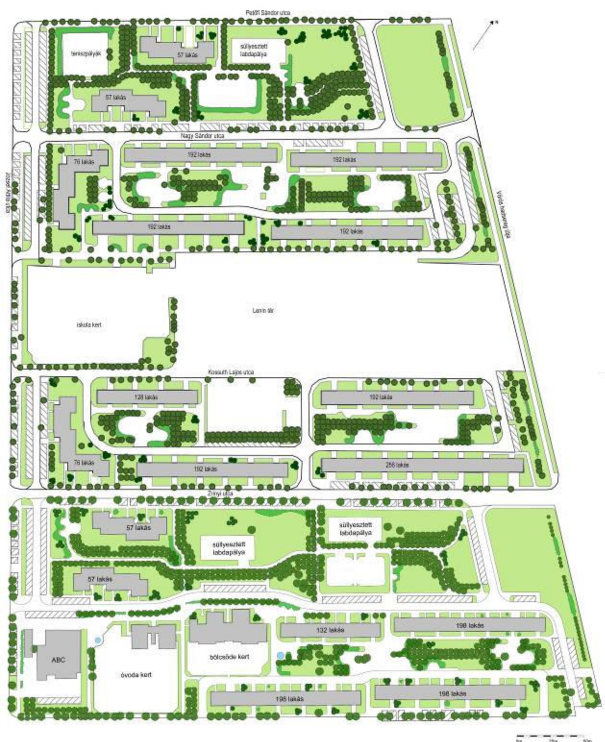
Housing estates in the 1970s

This is the decade of panel (prefabricated building elements) technology. Typical strip-houses of the 1970s are 10 stories high and a few hundred meter long giants. The easiest and cheapest building arrangement method required by building technology is the stripe-like building arrangement, when the huge buildings are placed parallel to each other in a distance, allowing to use just one crane position at the construction of two houses. In the case of a one-sided stripe-like site layout the buildings are placed in equal distance from each other. The other similar arrangement type, the so called fiber-like building arrangement, was popular at the beginning of the '70s, when parallel buildings were placed at uneven distance from each other. In the narrower courtyard between the buildings the service roads and parking lots were placed, while on the other side of the buildings a direct connection to green surfaces could be provided. In these arrangement methods car and pedestrian traffic were separated. The advantage of this arrangement is that it is easy to construct, but the placement of the parking lot, which results in streets filled with parking cars, is disadvantageous (e.g. Bp. X. Kőbánya Újhegy housing estate, *Fig 5).*

At the end of the '70s a new building arrangement method became increasingly popular, which placed huge residential buildings along one line, forcing residents to walk along this line, where commercial and service units were placed as well. This is the renaissance of the traditional „urban" street on housing estates. The primary public institutions were strung on this main street with mixed traffic (e.g. Bp. XX. Kispest Városközpont housing estate, *Fig. 6*).

Indicator	Quantity	%
Total area (m^2)	274370	100
Built-in area (m^2)	34104	12.4
Solid pavements (m^2)	134446	49.0
Pervious pavements (m^2)	364	0.13
Water surface (m^2)	0	0
Green surface (m^2)	105456	38.4
Green+pervious surface (m^2)	105820	38.6
Multi- level vegetation (m^2)	8576	
Fragmented green surface (m^2)	17624	
Deciduous trees (pc.)	2447	
Number of residents	20263	
Green surface/resident (m^2/res.)	5	
Green+pervious surface /res. (m^2/res.)	5	
Proport. of multi-leveled greens		8
Proport. of fragmented greens		17
Tree canopy (30m^2/tree)		27

Figure 5. *Bp. X. Kőbánya Újhegy housing estate – layout and data*



Indicator	Quantity	%
Total area (m^2)	154170	100
Built-in area (m^2)	22454	14.6
Solid pavements (m^2)	60776	39.4
Pervious pavements (m^2)	3272	2.1
Water surface (m^2)	30	0.02
Green surface (m^2)	67668	43.9
Green+pervious surface (m^2)	70940	46.0
Multi- level vegetation (m^2)	3160	
Fragmented green surface (m^2)	16290	
Deciduous trees (pc.)	1583	
Number of residents	7477	
Green surface/resident (m^2/res.)	9	
Green+pervious surface /res. (m^2/res.)	9	
Proport. of multi-leveled greens		5
Proport. of fragmented greens		24
Tree canopy (30m^2/tree)		30.8

Figure 6. *Bp. XIX. Kispest Városközpont housing estate – layout and data*

Although one of the buildings' main facades faced the street with car traffic, on the other side of the buildings an undisturbed use of the garden was provided. This arrangement method allowed the creation of large coherent green surfaces. The minimum amount of parking lots to be provided on housing estates was already regulated in the 1970s (1 car/flat), but only 50% of the required parking lots had to be placed next to the buildings, the other 50% could be provided on a parking palette at the brink of the development.

By this time it became obvious that mainly wooden vegetation has justification on open spaces of housing estates (Schmidt, 1988). There were professional discussions regarding the density of tree plantation and the degree of optimal canopy coverage. The goal was to reach an approx. 50-60% canopy coverage at a 15-20 years old plantation, which requires an approx. 1 tree/90 m^2 plantation density. Both analyzed housing estates of the '70s show an extremely high tree canopy.

The growing proportion of built-up areas and the reducing size of green surfaces made it necessary to tighten the norms regarding green surfaces inside the blocks of new housing estates. The first mandatory norms regarding the sizing of public gardens of housing estates appeared in the National Building Code (OÉSZ) in 1970, according to which a minimum of 5 m^2/resident has to be provided. This area contained paved playgrounds and leisure areas, the walkways leading to them, plus the green surfaces.

According to the new regulation in 1977 (11/1977 (Ép. Ért 31.) ÉVM-OTSH joint statement), 7-10 m^2/resident area had to be provided for sport- , play- and leisure areas in the public gardens of housing estates. Another open space of 7-10 m^2/resident was to be provided in the public park belonging to the housing estate for purposes of sport and leisure activities and a third open space of 7-10 m^2/resident in city-parks. This extremely progressive and even in European comparison modern regulation affected mostly open spaces of housing estates built in the '80s. Kispest Városközpont housing estates were designed at the end of the 1970s and show an impressive normative green surface value.

Housing estates built in the 1980s

In the '80s, due to the growing economical problems, much less housing estate flats were built and the size of housing estates shrank dramatically compared to their sizes in the '70s. However, the great-panel technology prevailed, the developments became more versatile. The proportion of 10 stories high strip-houses shrank, more and more four or three stories high buildings and two-level townhouses were built. Due to the decrease of building-height, the separation of car and pedestrian traffic became unnecessary, and the „streets" were considered as basic organizing elements.

Indicator	Quantity	%
Total area (m^2)	127179	100
Built-in area (m^2)	16560	13.0
Solid pavements (m^2)	54921	43.2
Pervious pavements (m^2)	2860	2.2
Water surface (m^2)	0	0
Green surface (m^2)	52837	41.5
Green+pervious surface (m^2)	55697	43.8
Multi- level vegetation (m^2)	2619	
Fragmented green surface (m^2)	15530	
Deciduous trees (pc.)	988	
Number of residents	12393	
Green surface/resident (m^2/res.)	4	
Green+pervious surface /res. (m^2/res.)	4	
Proport. of multi-leveled greens		5
Proport. of fragmented greens		29
Tree canopy (30m^2/tree)		23.3

Figure 7. *Bp. III. Pók utca housing estate – layout and data*

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

The traditional structured street-system was reintroduced, which drives the pedestrian and car traffic into the same „channel". Although the striped building arrangement was still dominant, the layout of the buildings became more versatile. The buildings with off-line layouts created open and closed courtyards (e.g. Bp. III. Pók utca housing estate, *Fig. 7*).

The other housing typology characteristic for the '80s is the multi-level courtyard housing, with protected inner courtyards used only by the residents of the block (e.g. Budapest XX. Szentlőrinci út housing estate, *Fig. 8*).

Indicator	Quantity	%
Total area (m^2)	426756	100
Built-in area (m^2)	88225	20.7
Solid pavements (m^2)	127623	29.9
Pervious pavements (m^2)	8264	1.9
Water surface (m^2)	461	0.1
Green surface (m^2)	193919	45.4
Green+pervious surface (m^2)	202183	47.4
Multi- level vegetation (m^2)	12033	
Fragmented green surface (m^2)	27254	
Deciduous trees (pc.)	2406	
Number of residents	8000	
Green surface/resident (m^2/res.)	24	
Green+pervious surface /res. (m^2/res.)	25	
Proport. of multi-leveled greens		6
Proport. of fragmented greens		14
Tree canopy (30m^2/tree)		16.9

***Figure 8.** Bp. XX. Szentlőrinci út housing estate – layout and data*

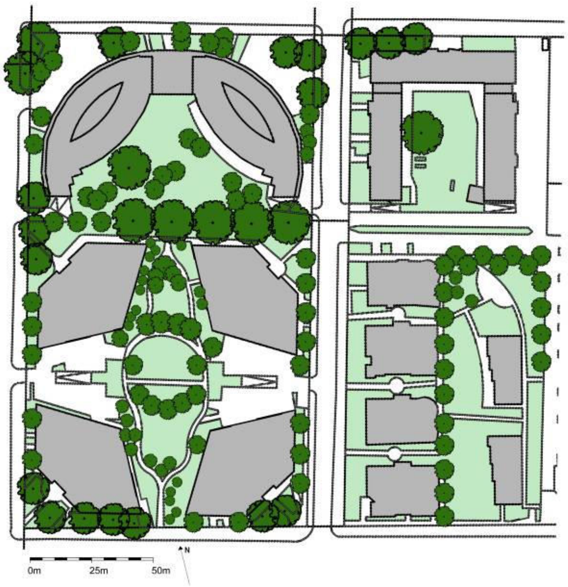
The trees planted in mass or in alleys articulated well the structure of the open space system. The fully developed, sometimes too dense vegetation of housing estates built in the '60s or '70s influenced the plantation methods of the '80s. It became increasingly important to consider leaving some sunny, open areas without trees between those mass plantations; the tree plantation became slightly less dense on the housing estates of the '80s. Thanks to the above mentioned decree (11/1977 (Ép. Ért 31.) ÉVM-OTSH joint order) the green surface proportion was usually relatively high in the blocks of housing estates built in this decade in spite of the growing number of parking lots. Besides the green areas within the residential blocks, some residential parks were built to make up for the loss of investments of the '70s.

Blocks of apartments built after the Millennium

The state-financed housing estate developments were terminated in the '90s. In a deregulation process the norms of minimum green surfaces disappeared, and only decrees of detailed development plans remained standard. However the blocks of apartments can be considered as the descendants of housing estates, there are many differences between them. The basic difference is that, while the state- financed housing investments between 1950 and 1990 took social political aspects into consideration, the

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

residential parks built recently as a private investment are guided only by quick return, which might have resulted in a sharp decline of green surface proportion. Extremely high density developments are typical, with high-rise buildings. But even in the cases of two extremely intensive housing developments, the green surface proportions and the normative green surface values are quite sufficient, only the significantly low proportion of multi-leveled green vegetation might be problematic. These green surfaces are generally high-quality and well maintained (e.g. Bp. XI. Nádorliget residential park, *Fig. 9*).



Indicator	Quantity	%
Total area (m^2)	34850	100
Built-in area (m^2)	14200	40.7
Solid pavements (m^2)	1481	4.3
Pervious pavements (m^2)	1237	3.5
Water surface (m^2)	0	0
Green surface (m^2)	14677	42.1
Green+pervious surface (m^2)	15914	45.7
Multi- level vegetation (m^2)	261	
Fragmented green surface (m^2)	2216	
Deciduous trees (pc.)	274	
Number of residents	1710	
Green surface/resident (m^2/res.)	9	
Green+pervious surface /res. (m^2/res.)	9	
Proport. of multi-leveled greens		2
Proport. of fragmented greens		15
Tree canopy ($30m^2$/tree)		23.6

Figure 9. *Bp. XI. Nádorliget residential park – layout and data*

Indicator	Quantity	%
Total area (m^2)	89809	100
Built-in area (m^2)	13266	14.8
Solid pavements (m^2)	31653	35.2
Pervious pavements (m^2)	723	0.8
Water surface (m^2)	1059	1.2
Roofgarden surface, soil 30-80 cm (m^2)	10261	11.4
Green surface netto (m^2)	39073	43.5
Total green surface with roofg. (m^2)*	43177	48.1
Green+pervious surface (m^2)	43900	48.9
Multi- level vegetation (m^2)	227	
Fragmented green surface (m^2)	2763	
Deciduous trees (pc.)	376	
Number of residents	2196	
Green surface/resident (m^2/res.)	20	
Green+pervious surface /res. (m^2/res.)	20	
Proport. of multi-leveled greens		0.5
Proport. of fragmented greens		6
Tree canopy ($30m^2$/tree)		12.6

* contains 40 % of the roofgarden's total size

Figure 10. *Bp. IV. Marinapart residential park – layout and data*

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

As car parking areas are usually placed on basement level or under green surfaces in these developments, all of these green areas are roof gardens (e.g. Bp. IV. Marinapart, *Fig. 10*). Therefore only few places are suitable for tree planting here, which might result on a long term in a low tree canopy index. But as in the case of Marinapart development, a big open space on the Danube shore is also part of the development which balances the reduced ecological value of a roof garden.

The role of housing estates' green surfaces in forming the city climate based on Normalized Difference Vegetation Index

Calculating Vegetation Index is a suitable method for evaluating the role of housing estate green surfaces built 20-60 years ago in today's city climate in Budapest. The NDVI (Normalized Difference Vegetation Index) is a simple numerical indicator. Its value is determined by the quotient of the difference and the amount of radiation-intensity reflected by plants in near-infrared (NIR) and visible red (RED) regions:

$$NDVI = (NIR-RED) / (NIR+RED).$$

Chlorophyll in plants is responsible for the light absorption and reflection in the visible red and near-infrared regions (Eredics, 2007). Therefore the quantity and quality (heat, levels, foliage) of the plants determine the Normalized Difference Vegetation Index, whose value is largely influenced by the healthiness of the vegetation, by the tree canopy and by the multi-leveled structure of the vegetation. Therefore it is a suitable indicator for evaluating the physical condition of the vegetation on a certain territory.

NDVI takes on values between -1.0 and +1.0. The vegetation is very poor near the 0.0 values, between -1.0 and 0.0 there is no plant life (only impervious surfaces: buildings, pavement or naked surface). Above 0.5 the vegetation is perfect (complex, prolific and rich).

We analyzed the present NDVI value of the housing estates, whose development plans were analyzed, too. There are three downtown parks shown on the map as reference areas: Bp. II. Ganz park (3.5 ha), Bp. II. Mechwart tér (1.8 ha), and Bp. V. Erzsébet tér (2 ha). An overview map shows the location of the analyzed sites (*Fig. 11).*

By monitoring the NDVI changes of the past 20 years and recent NDVI figures of analyzed housing estates, we were able to get numerical data of the urban ecological effects of block-like constructions.

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

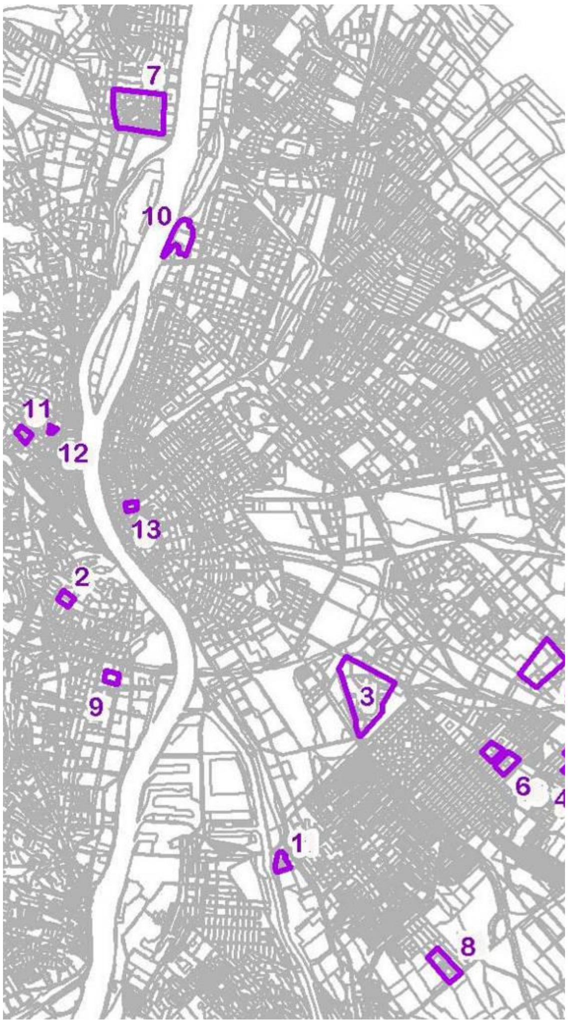


Figure 11. *Location of analyzed and reference sites on the map of Budapest*

The first maps show the vegetation status of the year 2005. Analyzed sites in the northern part of Budapest are shown on *Fig. 12,* while the sites in the southern part are on *Fig. 13*. The intensity of the green colour represents better vegetation (Gábor et al., 2006). In this map, the green colour is dominant. On housing estates built over 40 years ago, a complex green area has been developed by 2005. Three housing estates are in especially good condition: József Attila housing estate close to the city center, Pók utca housing estate close to river Danube and the center zone of Lakatos út housing estate. There is no green colour in the new residential park areas, as the vegetation has not yet been developed around the new building investments.

According to the comparative table (*Table 1*), the average Normalized Difference Vegetation Index of some housing estates built more than 40 years ago is almost as high as the index of the reference sites. It means that the ecological value of these older housing estates is almost the same as that of some new down-town parks.

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

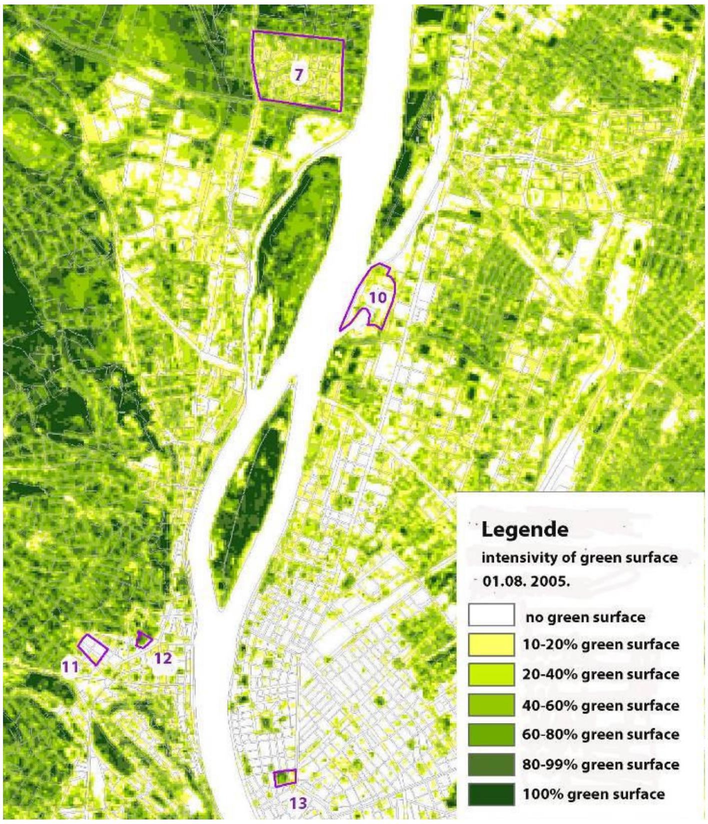


Figure 12. *NDVI of analyzed and reference sites in North Budapest in 2005*

Figure 13. *NDVI of analyzed and reference sites in South Budapest in 2005*

Table 1. *Comparative table of the NDVI values at analyzed and reference sites*

Area	Name	Minimum	Maximum	Average	St. deviation
1	XIX. Gubacsi hídfő housing estate	0.0000	0.3953	0.2495	0.0663
2	XI.Villányi út 55-65. housing estate	0.1136	0.4545	0.2815	0.0650
3	IX. József Attila housing estate	0.0000	0.5476	0.2321	0.1124
4	VIII. Lakatos út housing estate	0.0000	0.5000	0.2691	0.1126
5	X. Kőbánya Újhegy housing estate	0.0000	0.4595	0.1693	0.1020
6	XIX. Kispest Városközpont housing estate	0.0000	0.3864	0.1599	0.0862
7	III. Pók utca housing estate	0.0000	0.5402	0.2130	0.1030
8	XX. Szentlőrinci út housing estate	0.0000	0.4151	0.1294	0.0862
9	XI. Nádorliget residential park	0.0000	0.2121	0.0157	0.0360
10	IV. Marinapart residential park	0.0000	0.3165	0.0225	0.0547
11	II. Ganz park	0.0000	0.4500	0.1206	0.1214
12	II. Mechwart tér	0.0909	0.4375	0.3096	0.0774
13	V.Erzsébet tér	0.0000	0.4915	0.2244	0.1302

The next maps (*Fig. 14* for northern Budapest*, Fig. 15* for southern Budapest) show the changes in Normalized Difference Vegetation Indices between 1990 and 2005 (Gábor et al., 2007). The green pixel represents an increase, while the red shows a decrease of green surface intensity. Generally the values seem to be constant; the vegetation index has not changed in most cases, as housing estates built in the 1950s or 1960s and 1970s had a complex, well developed plantage by the 1990s.There are signs of construction marked by the red colour on the maps, which refers to some newly built parking areas or other facilities (for example a sport field, shop or playground). At newer housing estates of the 1980s, we can see dynamic growth in the green surface intensity, because the plantage developed considerably between 1990 and 2005.

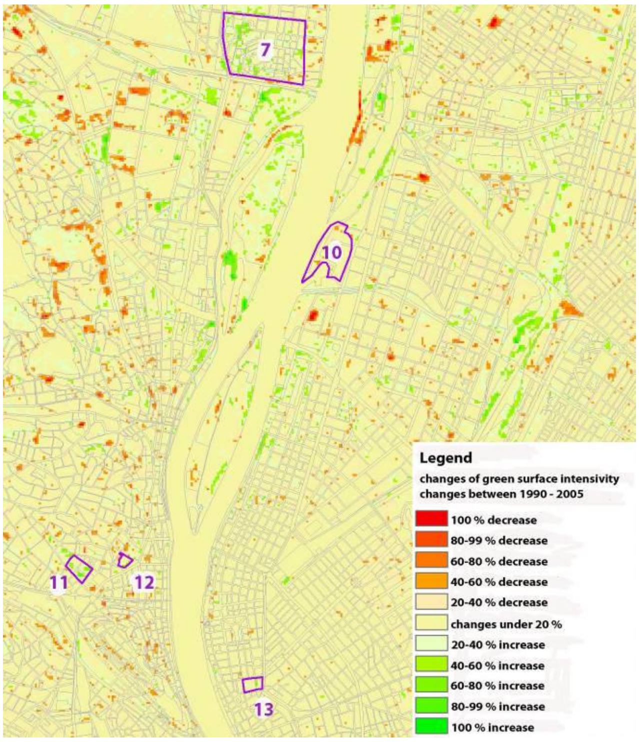


Figure 14. *Changes of NDVI between 1990 and 2005 at analyzed and reference sites in North Budapest*

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

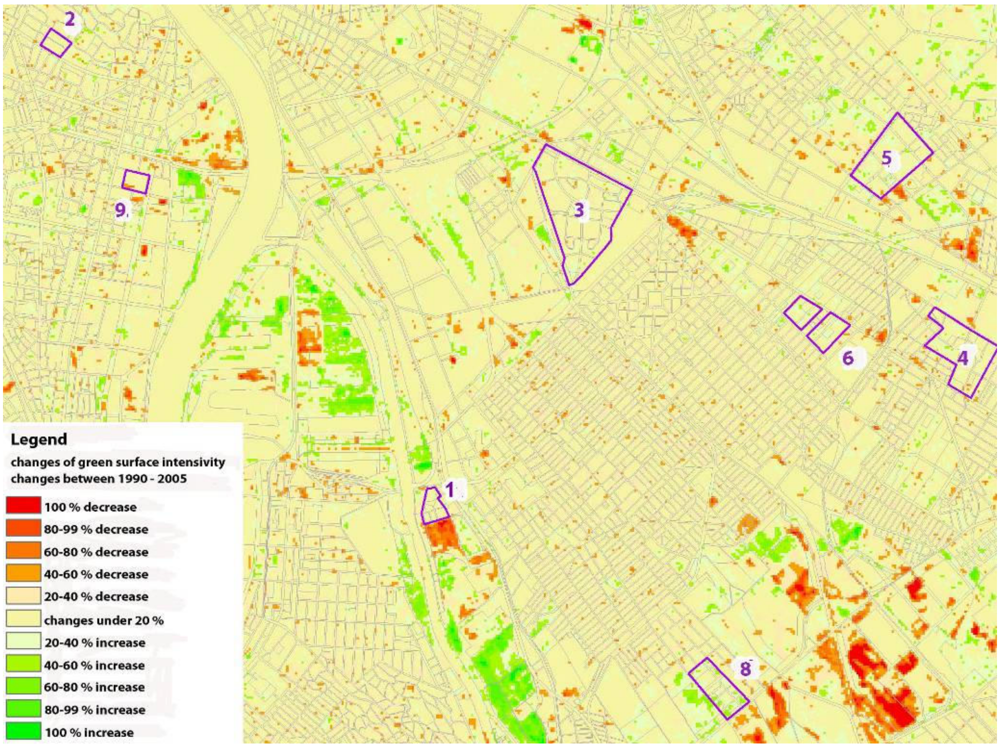


Figure 15. *Changes of NDVI between 1990 and 2005 at analyzed sites in South Budapest*

Conclusion

One of the greatest values of the housing estates built earlier is their well-established wooded vegetation, thanks to an open-space proportion provided by a detailed and high level green surface normative system that was more or less observed. The edification of our research is that these housing estates – so often criticized and viewed in a negative light – have developed an extremely high NDVI by the present day. Thanks to their large open spaces, proper supply of green surfaces and significant index of tree canopy, 20, 30, 50 years after plantation these housing estates have a good urban ecological effect. Nowadays the modernization of old housing estates takes place. When deciding about further developments or reconstruction of open spaces, it is necessary to take into consideration the role of housing estates' green surfaces in regulating the city climate of Budapest.

Besides of green surface proportion and tree canopy index, which have been well-known as important data from urban ecological point by professionals for long, some new indicators like proportion of multi-leveled greens and fragmented greens might be useful indicators in analyzing the ecological value of new developments.

Acknowledgements. I thank dr. Kinga Szilágyi and Dóra Hutter for constructive comments on earlier version of this research, and Sándor Jombach for technical assistance. The analyzed plans were provided by FŐKERT Zrt. The areal photos were provided by the Department of Landscape Planning and Regional Development, Corvinus University of Budapest. This paper has been supported by TÁMOP-4.2.1/B-09/1/KMR-2010-0005 project.

REFERENCES

[1] Bakay, E., Hutter D., M. Szilágyi, K. (2011): The evolution of openspaces and green surfaces on high density developments built by action – The evaluation of Hungarian high density developments built by action since 1950 from the aspect of green surfaces and openspaces. – Acta Universitatis Sapientiae Agriculture and Environment 3/2011 (accepted/in press)

[2] Eredics, A. (2007): Planning and development of Vegetations Indexmeter (NDVI) – Nyugat-Magyarországi Egyetem Erdőmérnöki Kar, Sopron

[3] Gábor, P., Jombach, S., Ongjerth, R. (2006): Budapest green surface status-survey by processing spatial photos. – 4D Tájépítészeti és Kertművészeti Journal 4: 15-22.

[4] Gábor, P., Jombach, S., Ongjerth,R. (2007.): Changes of biological activity in Budapest and in the suburbs between 1990-2005. – 4D Tájépítészeti és Kertművészeti Journal 5: 21-28.

[5] Greiner, J. (1966): Grünanlagen für mehrgeslossige Wohnbauten. – VEB Verlag für Bauwesen, Berlin

[6] Ormos, I. (1967): History and practice of landscape architecture. – Mezőgazd. Kiadó, Bp.

[7] Preisich, G. (1998): History of Budapest's urban development 1945-1990. – Műszaki Könyvkiadó, Bp.

[8] Schmidt, G. (1988): Living ornaments of the garden, the skill of plant use. – Mezőgazd. Kiadó, Bp.

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

EVALUATION OF RURAL LANDSCAPE FUNCTIONS BASED ON DOMESTIC CASE STUDY

FILEPNÉ KOVÁCS, K.* – NAGY, G.G. – KOLLÁNYI, L.

Corvinus University of Budapest, Dept. of Landscape Planning and Regional Development
1118 Budapest, Villányi út 29-43., Hungary
(phone: +36-1-482-6281; fax: +36-1-482-6338)

**Corresponding author*
e-mail: krisztina.kovacs@uni-corvinus.hu

(Received 18th October 2011; accepted 5th December 2011)

Abstract. Nowadays a new research field is the application of the so called landscape indicators which serve the description and evaluation of landscapes. In this study we analyze landscape functions and ecosystem services in rural landscapes. We summarize most of the services/functions of the landscapes and analyze its balanced functioning in the case of micro-region of Csorna situated in Western-Hungary. The micro-region is comprised of two major landscape units. One is the Hanság, Tóköz which still preserved the values of the former vast marshland. The analyzed indices show that the population can not really enjoy the benefits of natural values; the recreational and cultural-educational functions are inadequate in spite of the high rate of protected areas. The ratio of cultivated areas is very high Looking at the landscape aesthetics functions the protected areas are of high value but in the cultivated areas especially plough fields the planting of elements of mosaic like and the traditional landscape such as vegetation along canals, forest belts, trees and greater areas of pastures should be enhanced. The second part of the micro-regions is Rábaköz which can be characterized by high intensity of cultivation. Here we revealed that the habitat (and regulation) and information (aesthetics, recreation, education) services are inadequate.
Keywords: c*arrier function, ecosystem services, micro-region of Csorna, multifunctionality, sustainable development*

Introduction

Because of the increased pressure of population growth since the 1950s there is an increased need for the natural resources (e.g. food, water, wooden, fuel). These unfavourable processes loaded the ecosystems of the earth on an unprecedented scale. The most important driving factors are the conversion of habitats, climate change, biological invasion, overuse and pollution (Török, 2009). Evaluating the effects of the unfavourable processes more and more experts and civil recognized that the human welfare depends on the services and goods of nature summarized in ecosystem services (MEA, 2005) or natural capital (Costanza et al., 1997; de Groot et al., 2002).

The existence of the society is essentially based on landscapes, so the analysis of the ecosystem services shall cover the entirety of the services of natural and semi-natural systems of these landscapes. This logic leads us to the concept of landscape functions, which in case of rural landscapes with extensive, natural or semi-natural land cover almost entirely is identical to ecosystem services. The primary role of these tools is to support and substantiate decision making having impact on ecosystem functioning or their management, and therefore should be deeply considered by both local and global political decision makers. There are a number of options to group assets offered by nature, very often the next being an advanced version of the previous one, thus so much similar to one other (de Groot, 1992, 2006; Costanza et al., 1997; MEA, 2005). In case of three groups of services there is a consensus of opinion: provisioning services (food, timber, etc.), regulating services (climate control, water purification, etc.) and information services (recreation, education, etc.).

These services and landscape functions are provided by the biological and landscape diversity so it is inevitable to maintain the biodiversity and to turn back the unfavourable processes. It is particularly true for the rural landscapes which are the most important food production places of the humankind, which next to the production function fulfils important social/cultural and landscape/nature protection functions as well (EEC, 1992). Several studies reveal the fact that those landscapes will be competitive in the future which maintain such landscape management which is based on the natural resources following the concept of precaution and accept that the society is organic part of the nature (Glatz, 2010). So it is inevitable to relate the concept of competitiveness in case of rural areas with the ecosystem services/landscape functions of the landscape breaking with the traditional interpretation of the nowadays so fashionable concept of competitiveness. The nowadays so fashionable concept is mostly related to economic aspects incidentally considering social issues and environmental aspects. In case of rural areas we consider the competitiveness as the ability of rural areas to preserve their population, so it is important to fulfil the needs of society as well. But we can not rely on the economic issues and conditions. We highlight the balance of economic, social and environmental needs and aspects which spatially reflect in the land use system and land use functions of the landscapes. The landscape conditions especially the land use forms play an important role in maintaining proper life quality of rural population so in the competitiveness of rural settlements.

There have been used indicators for the description of regions and settlements for a long time. So, nowadays we can reach indicators quiet easily to present the economic and social conditions (Central Statistic Office, TEIR, etc.). Another popular field of indicators is the environmental monitoring. The growing environmental concern led to the application of wide range of environmental indices. Rather new research field is the application of the so called landscape indices which serve the description and evaluation of the landscapes. There is no accepted practice for developing landscape indicators. The majority of the indicators come from agri-environmental researches as the management, ecologic state or "state of health" of landscapes is mostly determined by agricultural practices. It is important to find simple, easily available indicators. There is a wide range of data sources available: former plans, study in the field, maps (maps with the present state – CORINE Land Cover, tourist and historic maps, etc.), data basis (Central Hungarian Statistic Office, TEIR, database of national monuments, database of landscape values – TÉKA, nature and environmental protection databases), guide books, monographs, Internet, etc.

But what are those indicators which bear importance and significance also for rural development, which give information how we could use the landscape conditions in a more rational and sustainable way enhancing life quality and improve income of rural population and in its entirety to enhance preservation ability of population of rural regions. In our approach a balanced system of the existing landscape functions (multifuncionality) serve in a better way the preservation ability of population of rural regions.

The entirety of landscape conditions offers wide range of possibilities of different activities for the public (Konkoly-Gyúró, 2003). It is an important aspect how can be served or fulfilled the growing demand and diverse expectations of the society meanwhile maintaining the environmental quality which is covered by the aspect of multifunctionality of landscape management**.** First of all the demand of multifunctionality was formed in case of agriculture (CAP reforms). The primary sector fulfils a main function – production and related joint productions including tangible and non-tangible goods and a mix of private and public goods (externalities).

The landscape is regarded a physical spatial unit that fulfil several purposes (several functions) for the society. In the 1990s increased attention was paid on the multifunctional character of the landscape, mostly because many environmental problems of the countryside were considered related to the segregation of functions and disappearance of other functions than production from the rural areas. In the landscape production is just one function among many others (Vejre et al., 2007).

In this paper we analyze some ecosystem services/landscape functions of landscapes and look for simple available indicators for description of landscape functions to highlight the imbalances. We apply the concept for the micro-region of Csorna situated in Western-Hungary (*Fig. 1*). Because of the differing landscape conditions we divided the administrative spatial unit into two groups: settlements of Hanság, Tóköz and Rábaköz.

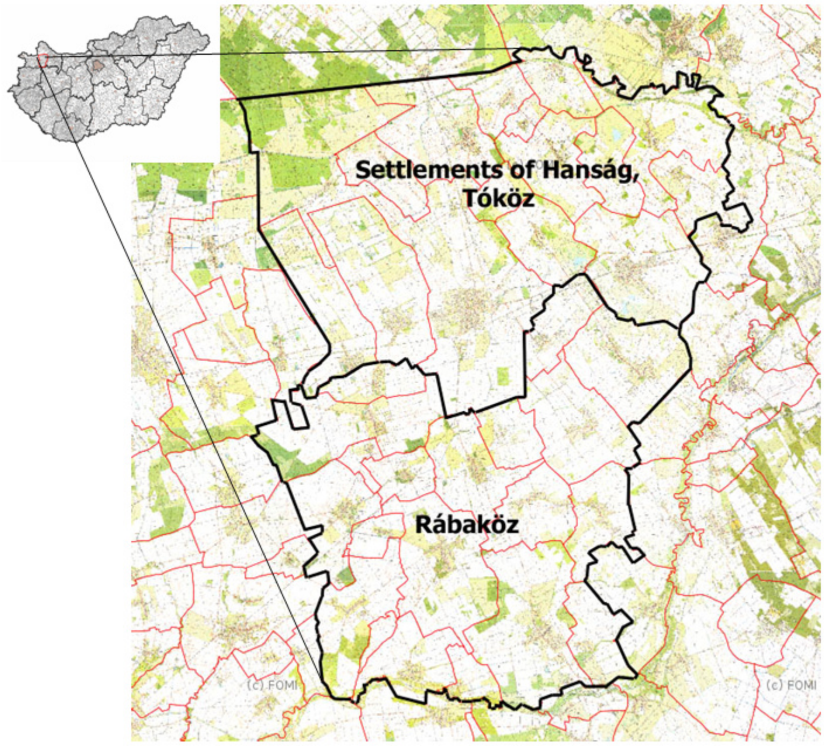


Figure 1. *Micro-region of Csorna with the two groups of settlements*

Materials and methods

In this paper we follow the classification system of de Groot (2006) emphasizing the services and functions of the landscape for the society. *Regulation functions* cover all the ecological processes and life support systems (geochemical cycles, biospheric processes) which are inevitable in the maintenance of "healthy ecosystems" at different scale levels. *Habitat functions* relate to the spatial conditions needed to maintain biotic (and genetic) diversity and evolutionary processes. These services can be described in

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

terms of carrying capacity and spatial needs (minimum critical ecosystem size) of the natural ecosystems which provide them. *Production functions* mean many resources of the nature for human use (food, raw material-fibre, timber, etc.). *Information functions* cover all the services related to recreation, reflection, cognitive development and aesthetic experience. Finally de Groot distinguishes *carrier functions* which include cultivation, habitation and transportation. This group of services includes all the human activities which converse the original ecosystem. Of course there are overlaps and interactions between the different functions, for example the carrier function offer other goods such as cultivated landscape maintain regulation services as well and have aesthetic qualities, etc. (de Groot, 2006). Applying the subdivision of de Groot we summarized the functions and landscape architecture requirements of the landscape functions in *Table 1*.

Table 1. *Landscape functions and ecologic services and aspects of landscape architecture (sources: Leader European Observatory (2001), Ghimessy (1984), de Groot (2006))*

Main groups of functions	Landscape functions	Examples	Requirements of landscape architecture
Carrier functions	**Agricultural cultivation**	– Permanent spatial production elements – Agricultural areas	– Agricultural production fitting landscape conditions (relief, soil, water resources, etc.)
	Forestry	– Forests	– Forests containing domestic species characteristic for the landscape
	Energy-conversion	– Areas for water management and water power plants – Wind energy parks, etc.	– Favouring renewable resources
	Mining	– Not renewable spatial production elements – Mining – Industrial sites	– Rehabilitation of devastated surfaces
	Connection-Transportation	– Areas serving roads, railways, water-, gas, electric lines	– Minimizing negative effects of infrastructure – Accessibility of markets – Efficient infrastructural network for economic activities
	Residential function	– Settlements and green spaces	– Satisfying social need and preserving architectural traditions and green spaces – Ensuring quality of life – Integration of settlers – Planning serving the needs of socialization and integration: community places, sport centres
	Waste disposal		– Recultivation, re-use of abandoned land fills

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

Table 1. *cont.*

Main groups of functions	Landscape functions	Examples	Requirements of landscape architecture
Regulation function	– Preservation of biodiversity – Gas regulation – Climate regulation – Water regulation – Water supply – Soil retention – Soil formation – Waste treatment	– Areas under nature protection – Areas for water protection – Protection zones of industrial areas – Protection zones of residential areas	– Spatial planning serving the protection of biodiversity: protection of biotope mosaic like landscapes, ecologic corridors
Habitat function	**Refugium function**	– Areas under nature protection	– Maintenance of biotopes, mosaic like landscapes, ecologic corridors
	Nursery function	– Habitats of agricultural fields: forest belts among agricultural fields etc.	– Environmental and nature-friendly agriculture
Information function	**Cultural and artistic function**	– Areas for national monument preservation – Archaeological sites – Unique landscape values – Historic landscapes	– Listing and preservation of values of regional identity – Community places presenting local heritage
	Recreational function – Satisfying the needs of urban society: leisure, recreation, sports – Harmonizing the needs of locals and tourists	– Thematic parks – Nature parks – Park forests	– Changing rural spaces for spaces of learning and discovery: thematic routes, study trails, visitor centre
	Scientific and educational function	– Thematic parks – Nature parks – Study trails – Unique landscape values	– Listing and preservation of landscape values
	Aesthetic information	– Attractive landscape features	– Preservation of the beauty and aesthetic value of the landscape – Decreasing the monotony of agricultural fields (forest belts)
Production function	**Food** (hunting, gathering of fish, game, fruits.)	– Small scale subsistence farming – Goods of nature protection areas	– Environmental requirements – Environmental education
	Raw materials – Building and manufacturing – Fuel and energy – Fodder and fertilizer		– Use for unique and local products
	Genetic resources		– Use of diverse, endemic plant material
	Medicinal resources		
	Ornamental resources		– Resources for fashion, jewellery, handicraft

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

Analyzing the range of economic, social and landscape indices there are countless possible indicators. We have strived to find simple, easily available indicators for all landscape functions giving meaningful interpretation of the services of landscape. In some cases we could rely descriptive indicators and experiences of the on the spot survey. In rural development mostly we can influence the carrier and information functions and because of sustainability and its additional services we consider the habitat function.

We analyzed the chosen functions through the following indicators:

- Habitat function (share of protected areas)
- Information functions
    - Cultural function including education (unique landscape values, study trails, exhibitions)
    - Recreational function (capacity of rural tourism and recreational possibilities).
    - Aesthetic information (attractive landscape features, characteristic landscape elements)
- Carrier function (cultivation – share of cultivated areas).

We have analyzed the above mentioned functions and aspects in the case of micro-region of Csorna situated in the Small-Plain between the great centers of the County Győr–Moson–Sopron. The micro-region of Csorna holds most of the settlements of Hanság and Rábaköz together. In spite of the fact that the micro-region is situated in one of the most developed region of the country it was always considered as an inner periphery. For centuries especially in Rábaköz agriculture was the most important economic basis of the region. From the point of view of tourism important landscape conditions is characterized the area in a shadow-situation, the Rábaköz does not have outstanding attractions but it is situated between the Szigetköz/Danube and Lake Fertő recreational areas of national importance, in the vicinity of the Austrian boarder. The micro-region can be characterized by rural small settlement structure. The wetlands, swamps and forests of Hanság and the banks and gallery forests of river Rába are of great ecological value. The landscapes of Rábaköz and Hanság dispose of such natural and folksiness values which have disappeared from Western-Europe. If we are talking about the Hanság it is inevitable to mention it is past as well because the structure of the landscape changed dramatically due to the drainage efforts of the society. According to *Fig. 1* still in the first part of the 19^{th} century the Hanság (the North-western part of the later micro-region area) was mostly a vast marshland. The drainage works of local scale started already in the 17^{th} century but the most intensive works were elaborated during the 18^{th} century when the main canals were built and Rábca, Kis-Rába was regulated. The most intensive and effective drainage works were elaborated in the second half of the 19^{th} century. With the drainage works vast areas of the former marshland were turned into grass fields (Takács and Pellinger, 2008). For information we have to turn to the historic maps as the KSH databases shows the rate of the different land use forms just since 1895. In the settlements of Hanság and Tóköz during the last century we witnessed an extremely drastic decrease of grasslands, moderate growth of plough lands and stronger expansion of forests. Unfortunately mostly forests were established just as poplar plantations during the socialist regime.

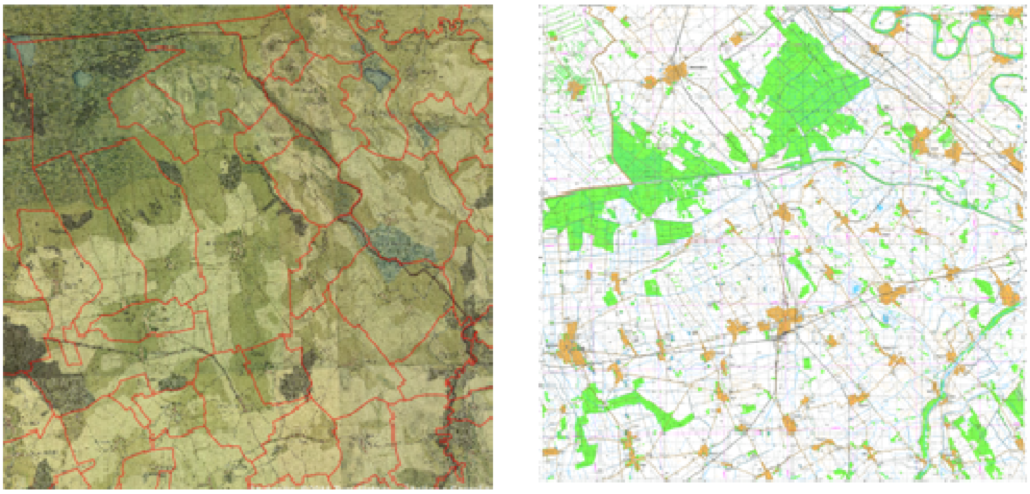


***Figure 2.** The area of Hanság–Rábaköz during the II. Military survey and nowadays (source: http://www.tajertektar.hu, RTA 50)*

Because of the constant decrease of marshlands, wetlands and pastures, low lying areas of poor quality were turned into plough fields, nowadays about 5-10% of the cultivated area is frequently waterlogged which means a financial loss for the farmers and in total loss in biodiversity as well. The historic maps show considerable land use changes in the micro-region (*Fig. 2*).

Results

Habitat function

Analyzing the habitat function, we used the data of the Fertő–Hanság National Park, and compared the share of protected areas and according to the importance and occurrence of protected species we evaluated the function. The share of protected areas in the region of Hanság and Tóköz is really high, here we can find areas of the National Park, National Ecologic Network, Natura 2000 areas, Ramsar sites and MAB biosphere reserve as well. According to *Fig. 3* in the settlements of Hanság, Tóköz the National Park and Natura 2000 areas dominate meanwhile in Rábaköz the areas of National Ecologic Network are in majority. It is important for the farmers because while in the area of Natura 2000 different support schemes are available for farming in the area of National Ecologic Network there are no such support available.

The Natura 2000 area of Southern-Hanság and Tóköz (Lake of Barbacs and Fehértó) covers all the remained natural habitats, which preserve just the fraction of the former vast marshland but in spite of the extensive drainage several natural values of community importance can we find in Hanság. Among the habitats of community importance in greatest extension we can find mesotrophic meadows and Molinia meadows. Thanks to the habitat-reconstruction works of the National Park Directorate there are again great water surfaces in Hanság. The Nyirkai–Hany became in the last five years significant waterfowl station. The alder and ash swamp woodlands, riverine ash-alder woodlands and riverine oak-elm-ash woodlands are of great importance in Hanság.

The Natura 2000 areas of Rábaköz are characterized by forests and watercourses. Unfortunately because of the intensive cultivation the natural forests of the region were shrinked (http://www.fhnp.nemzetipark.gov.hu).

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

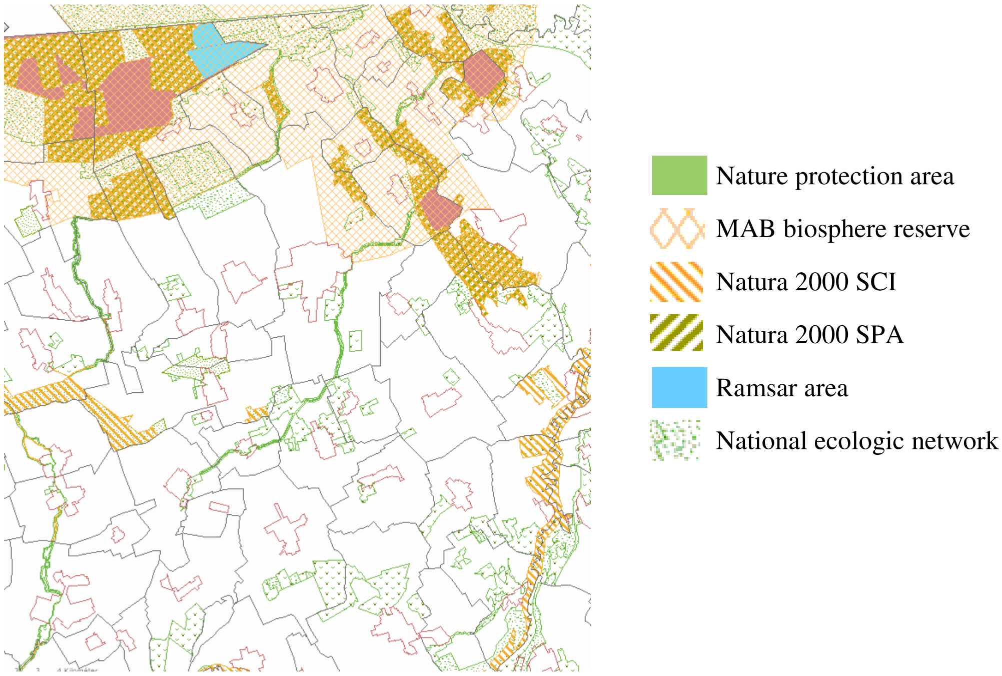


Figure 3. *System of protection areas in the micro-region*
(source: TEIR, http://arcgis.vati.hu:81/teirgis_termeszetvedelem)

If we look at the share of protected areas in the settlements of Hanság–Tóköz we can find really high values as these are parts of the national park area: for example in Barbacs, Csorna the nature protection areas cover more than 30% of the administrative areas of the settlements. Natura 2000 areas cover also large parts of the villages of Hanság as well (Fehértó 42%, Tárnokréti 56%). The National Ecologic Network category means restrictions in different land use forms and building activities enforced by the Local Building Code (*Fig. 4*).

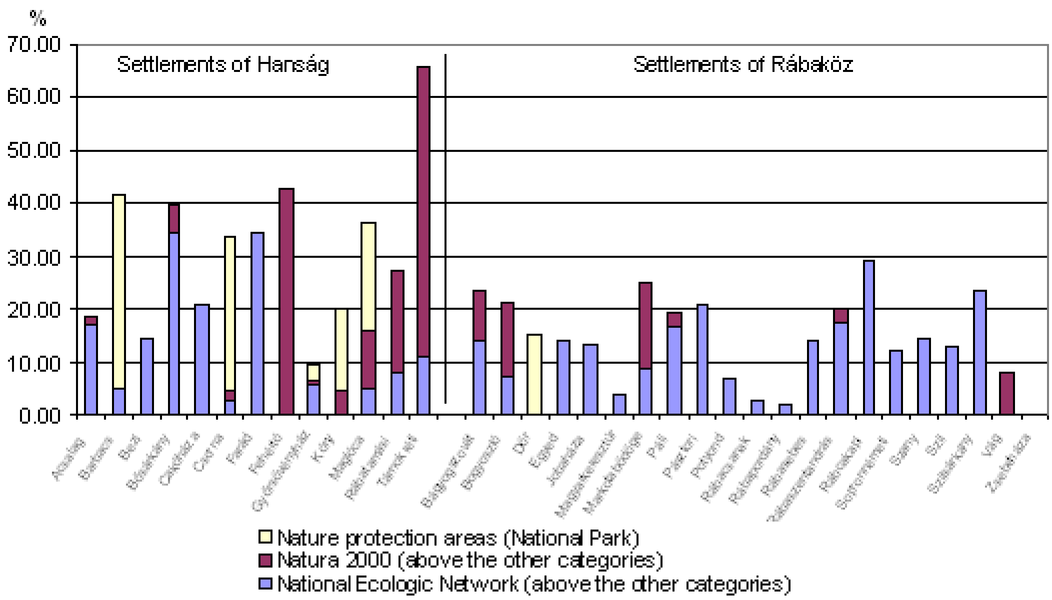


Figure 4. *Ratio of protected areas per settlements in Hanság and Rábaköz*
(source: https://teir.vati.hu)

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

Because of the high rate of protected areas (which means land use restrictions) and parallel to that the cultivated areas we considered it important to analyze the level of agri-environmental payments. The analysis revealed that in spite of the high rate of protected areas the agri-environmental payments are not extreme high with the exception of a few settlements (Fehértó, Maglóca), in case of some settlements even though high rate of the village is Natura 2000 area, the rate of agri-environmental payments is low. In Győrsövényház even though the ratio of protected areas is low the ratio of agri-environmental payments are high. Farmers have to apply for agri-environmental payments and because of the strict application rules and shortages of the financial frames just few farmers got real compensations for the environmental restrictions. The Natura 2000 areas are mostly pastures in Hanság and Rábaköz and the low profitability of husbandry hardens the state of the farmers (*Fig. 5*).

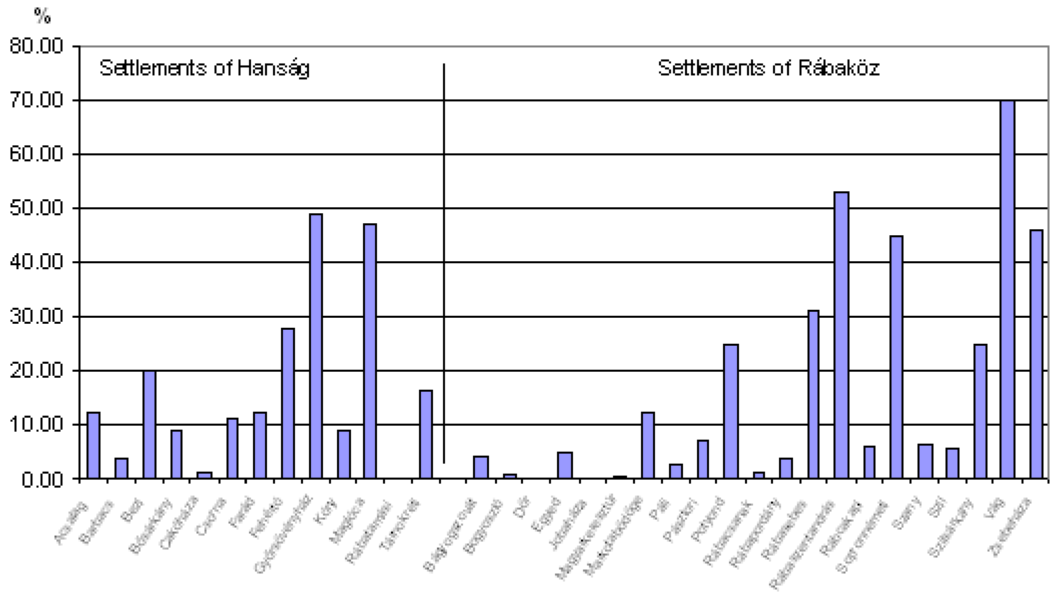


Figure 5. *Ratio of agri-environmental payments in relation to direct payments (source: http://www.mvh.gov.hu)*

Information functions

In the sphere of information functions we examined the cultural-educational function, recreational function and aesthetic function.

We analyzed the *cultural-educational function* of the landscape mainly through the unique landscape values using the on-line database of the recently finished TÉKA project (http://www.tajertektar.hu) and explored the exhibitions and study trails in the region. A special initiation of the Hungarian landscape protection is the listing of the unique landscape features. According to the Nature Conservation Act (Act No. LIII. of 1996. 6.§) the landscape element which has unique natural value, the man-made landscape elements which has special importance regarding to the nature, historical, cultural, scientific or aesthetic aspect and has special importance for the society can be considered as unique landscape values. Mainly it was the National parks directory's duty to list the unique landscape features. Because of the high portion of nature protection areas of these settlements the survey was mostly elaborated just for the built up areas, so about the 92% of the registered unique landscape features are cultural

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

landscape elements in spite of the diversity of natural values (*Fig. 6*). We can observe in the region high density of sweep wells (*Fig. 7*) reflecting the former wide-spread land use forms of grazing (Kollányi, 2009).

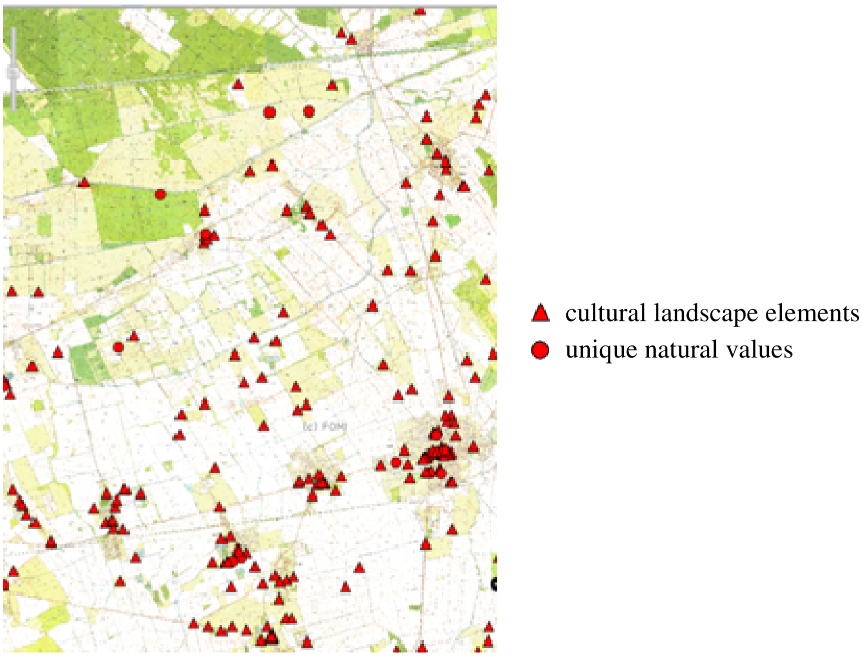


Figure 6. *Unique landscape features in the micro-region of Csorna*

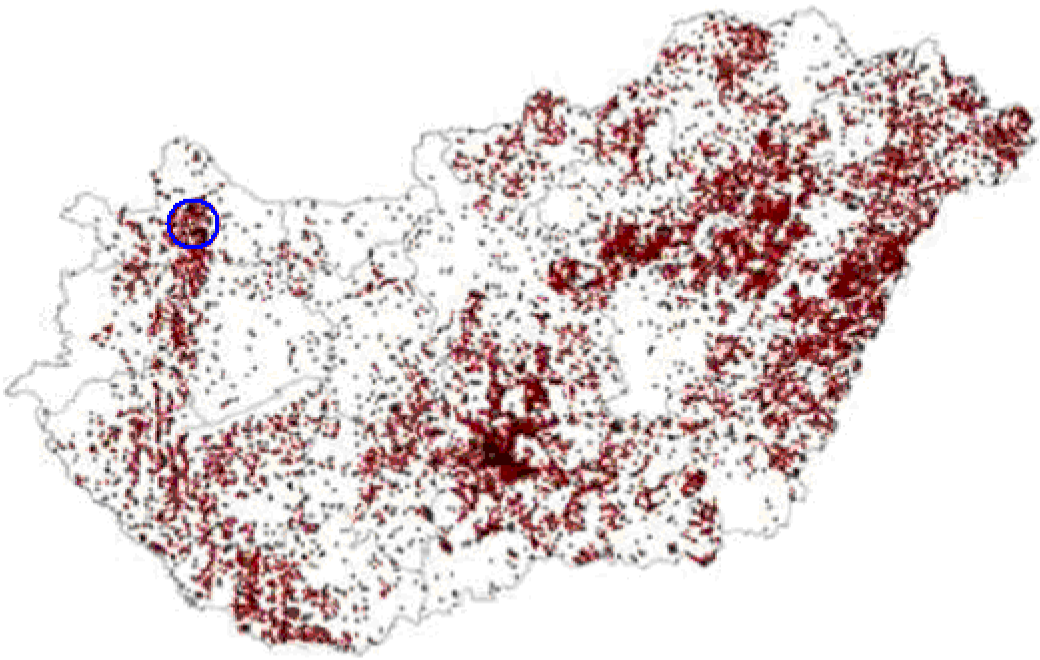


Figure 7. *High density of sweep wells in Rábaköz (indicated with the blue circle) reflecting the traditional land use forms*

In this part of the Fertő–Hanság National Park there is just one study trail, two look out towers and two exhibitions of smaller scale. The centre of the National Park

Directorate is in the vicinity of Lake Fertő, all the programs are concentrated here, the Hanság can be considered rather periphery from this point of view. Also the vulnerability of the strictly protected areas prevents publicity. In Rábaköz we do not find study trails or exhibitions related to natural values at all.

To explore the *recreational function* of the analyzed landscapes we scanned the data about rural tourism and other recreational possibilities available in the region. Analyzing the capacity of rural tourism and other recreational possibilities the results are also disappointing: in Hanság and Tóköz just in Csorna, Bősárkány, Farád and Kóny can we find some guesthouses, in Rábaköz with the exception of the settlements along the river Rába we can not talk about rural tourism at all. If we look at other recreational activities related to natural endowments we can see just ceasing possibilities: the thermal bath of Csorna in spite of the great development plans of the self-government is not functioning any more (because of ownership conflicts) the former beaches of Rába are abandoned, etc. In 2009 we carried out a questionnaire survey to explore the opinions of the people living in several settlements of the micro-region. The interviewees evaluated the state of the micro-region from different point of view on a 10 point scale. According to the results of the survey, it became clear that great deficiency is the lack of social, cultural and active recreational possibilities. So it is important to use the means of landscape architecture as well for broadening the possibilities of recreation.

Analyzing the *aesthetic function* of the landscape we have to relay on the most subjective elements. We can distinguish four major landscape character types in the micro-region:

1. The remnants of the former marshland mostly characterized by wetlands, pastures, forests, mosaic landscape, low intensity cultivation. Mostly typical for the northern part of the micro-region and are part of the Fertő–Hanság National Park. Here can we find the remnants of the former magic world of Hanság with lakes and moors in the low lying areas, the regular system of canals, poplar forest plantations and alder forests, pastures with willows, etc.
2. Drained marshland mostly characterized by plow fields and pastures with low and medium intensity cultivations especially the settlements of the so called Tóköz. We can see mosaic-like landscape plow fields fragmented by forest belts and canals, mostly where we can find the last habitat rehabilitations such as the Nyirkai–Hany. The characteristic and remained landscape features bear aesthetic values of great importance. Here would be important to enhance the characteristic landscape elements of canals, wetlands (Konkoly-Gyúró, 2010).
3. Plain landscape with dominant plough land
   a. Monotonous plain landscape with large plough fields.
   b. Plain landscape with mosaic like cultivation with smaller plough fields, forest belts, pastures.

   Rábaköz is mostly characterized medium and high intensity of cultivation with the remnants of pastures along the watercourses which mostly are Natura 2000 areas. In Rábaköz there are great areas characterized by monotonous plough fields.
4. Riverside landscape characterized by high rate of gallery forests with small pastures (because of its relatively narrow lane we have not distinguished it as individual landscape unit).

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

Looking at aesthetics naturally the former marshlands and areas of low intensive cultivation and mosaic like landscape are of greater value. Especially in the area of Rábaköz is it important to break the monotony of the vast plough fields by forest belts, patches and pastures.

Cultivation function

Among the carrier functions we have analyzed the cultivation function by the ratio of cultivated areas. Especially the ratio of plough fields are extremely high in the micro-region (national average 48%, local 66% with great local differences), in spite of the traditional predominance of grazing the ratio of the grass fields in the region is average nowadays (*Fig. 8*). The conversion of pastures into plough fields continued still in the last years as well which process is not appropriate with the natural conditions this is proved by the high share of waterlogged areas. According to the village administrator 10–20% of cultivated areas are waterlogged. The area of fruit and vegetable gardens is much less than the national average in spite of the considerable growth during the socialism and during the 1990s when the vegetable growing especially the cucumber which was called the “gold of Rábaköz” was significant.

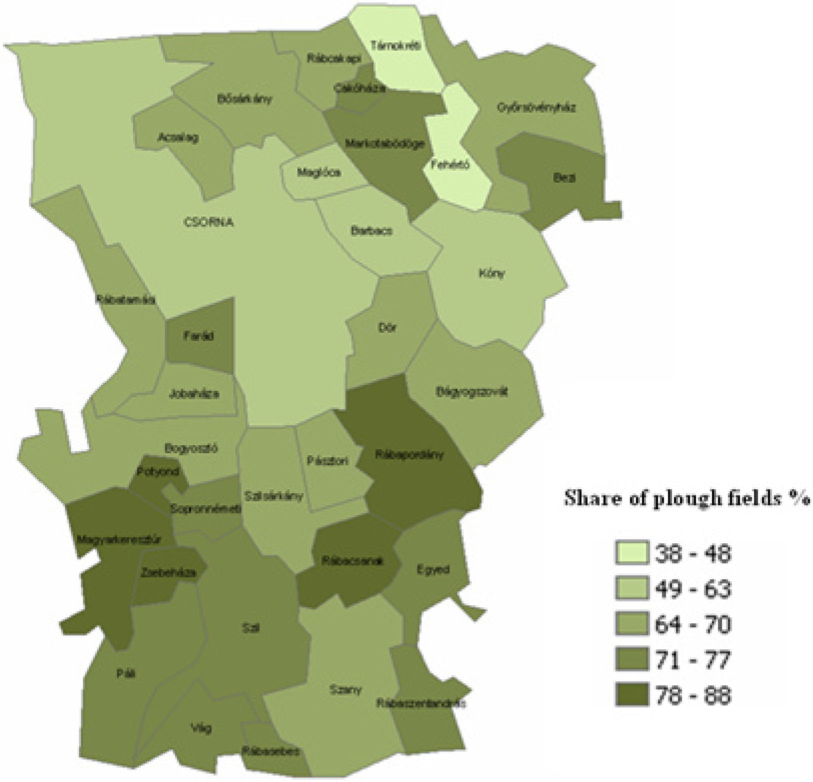


Figure 8. *Share of plough fields in the micro-region (source: http://www.takarnet.hu)*

Discussion

For a complex and effective rural development it is important to consider the landscape conditions and functions as well. Analyzing the landscape functions, next to different social and economic factors helps to support sustainable development of rural regions. Especially the agriculture and tourism are the main economic sectors which are

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

affected by the natural and cultural endowments. To preserve the population of rural regions it is important to fulfil the various social needs as well (profitability, recreation, aesthetics, etc.). As the human society is also just a part of the nature maybe the most important constraints limits are the aspects of environmental sustainability.

Through indicators we analyzed the habitat, information and carrier functions of the landscape in both landscape units in the micro-region of Csorna and in both cases we revealed imbalances. The cobweb diagram (*Fig. 9*) shows the level of different landscape functions in the analyzed region.

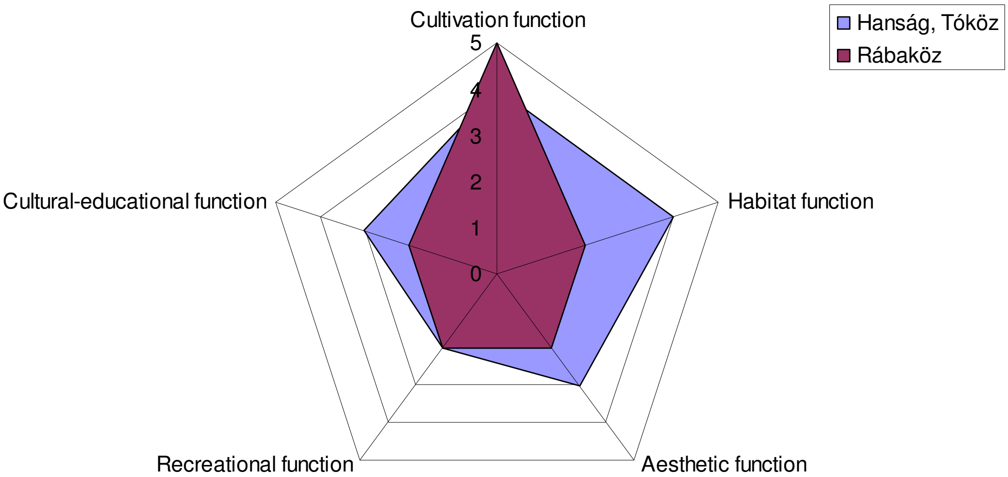


Figure 9. *Level of landscape functions in the micro-region of Csorna*

The micro-region is comprised of two major landscape units. One is Hanság and Tóköz which still preserved and bear the values of the former vast marshland and which landscape's majority is under nature protection (so the habitat function has got relatively high value). The analyzed indices have shown that for the region the natural values mostly mean land use restrictions and the population can not really enjoy the benefits (recreation, rural tourism, agri-environmental compensations) so the recreational services are inadequate, under average. In spite of the high rate of the nature protection areas the natural values do not appear as attractions even among the unique landscape values are not listed because of the nature protection status and there are just few possibilities (study trails, exhibitions) for publicity, so the level of cultural-educational services is inadequate. It would be important to list natural landscape values in the protected areas as well in spite of the current practice. The ratio of cultivated areas in spite of the high rate of protected areas is extremely high (in cobweb diagram the cultivation function above average). In order to avoid the damages of farmers because of the high rate of waterlogged areas it would be important to increase the share of pastures and forests in the low lying areas. Looking at the landscape aesthetics the protected areas are of high value but in the cultivated areas especially plough fields, the landscape is monotonous (so the aesthetic function got medium value in the cobweb diagram). So the planting of elements of mosaic like and the traditional landscape such as vegetation along canals, forest belts, trees and greater areas of pastures should be enhanced. The second part of the micro-regions is Rábaköz which can be characterized by high intensity of cultivation. Here the enhancement of ecologic values and services are important so the habitat and information (aesthetics, recreation, education) services are inadequate so these should be developed. In Hanság and along Rába the

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

development of ecotourism has possibilities in Rábaköz the agro-tourism. The rural development strategies in the region should focus on adjusting the land use forms to the landscape conditions and fulfil the needs of the society.

Acknowledgements. We would like to thank Márton Kiss who provided valuable comments to the study and Rita Várszegi for her help in fulfilling the formal requirements. The research was co-financed by the TÁMOP-4.2.1/B-09/1/KMR-2010-0005 project.

REFERENCES

[1] Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R. V., Paruelo, J., Raskin, R. G., Sutton, P., van den Belt, M. (1997): The value of the world's ecosystem services and natural capital. – Nature 387: 253-260.

[2] EEC (1992): 2078/92 EU Tanácsi Rendelet a tájfenntartás és a környezetvédelem követelményeinek megfelelő mezőgazdasági termelés támogatásáról.

[3] Ghimessy, L. (1984): A tájpotenciál. Táj, víz, ember, energia. – Mezőgazdasági Kiadó, Budapest

[4] Glatz, F. (2010): Sikeres vidéki térségek. – MTA Történettudományi Intézet – MTA Társadalomkutató Központ, Budapest, 192 p.

[5] de Groot, R. (1992): Functions of Nature: Evaluation of Nature in Environmental Planning, Management and Decision Making. – Wolters-Noordhoff, Groningen, 315 p.

[6] de Groot R.S., Wilson M., Boumans R. (2002): A typology for the description, classification and valuation of Ecosystem Functions. – Goods Services Econ. 41(3): 393-408.

[7] de Groot, R. (2006): Function-analysis and valuation as a tool to assess land use conflicts in planning for sustainable, multi-functional landscapes. – Landscape and Urban Planning 75: 175-186.

[8] Kollányi, L. (2009): Tájértékek kataszterezésének metodikája. – Ormos Imre Tudományos Ülésszak, LOV 2009, Tájépítészeti tanulmányok, p. 159-165.

[9] Konkoly-Gyúró, É. (2010): Határon átívelő tájak karaktere, A Fertő-Haság medence és Sopron térsége. – Nyugat-Magyarországi Egyetem Kiadó, Lővérprint

[10] LEADER European Observatory (2001): Global competitiveness for rural areas. – http://www.aeidl.be/publications/rural.php

[11] MEA (Millennium Ecosystem Assessment) (2005): Ecosystems and human well-being: Biodiversity synthesis. – World Resource Institue, Washington D.C., 86 p.

[12] Takács, G., Pellinger, A. (2006): Nyirkai-Hany vizes élőhelyrekonstrukció. – http://www.ferto-hansag.hu/nyirkai-hany

[13] Török, K. (2009): A Föld ökológiai állapota és perspektívái (a Millennium Ecosystem Assessment alapján). – Magyar Tudomány 170(1): 48-53.

[14] Vejre, H., Abildtrup, J., Andersen, E., Andersen, P.S., Brandt, J., Busck, A., Dalgaard, T., Hasler, B., Huusom, H., Kristensen, L.S., Kristensen, S.P., Præstholm, S. (2007): Multifuncional agriculture and multifunctional landscapes – land use as an interface. – In: Mander, U., Wiggering, H., Helming, K. (eds): Multifunctional land use – meeting future demands for landscape goods and services. Springer, Berlin, Heidelberg (Germany)

COMPLEX SHORE ZONE EVALUATION OF LAKE VELENCE, HUNGARY

BOROMISZA, ZS.

Corvinus University of Budapest, Department of Landscape Protection and Reclamation
1118 Budapest, Villányi út 29-43., Hungary
(phone: +36-1-482-6510, fax: +36-1-482-6383)

e-mail: zsombor.boromisza@uni-corvinus.hu

(Received 28th November 2011; accepted 22nd December 2011)

Abstract. Considering the social demands lakeshores have many special functions, such as: landscape protection functions (e.g. special habitat, buffer-function) and land use functions (e.g. recreation-tourism, public places. The shore of Lake Velence (Hungary) was evaluated according to four viewpoints: pressures, naturalness, buffer-function and suitability for changing shore fortification. A detailed survey of the lakeshore was made by dividing the shoreline into 100 m long and 50-50 m wide sections to land (riparian zone) and to water (littoral zone) directions. According to the results low pressures, being characteristic for more than half of the lakeshore are partially due to the land use peculiarities. It is mainly the sections near boat harbours and ship docks which have connection between pressures and naturalness and which are pressured to critical extent, being heavily modified at the same time. Areas with good buffer-capacity are typical between the reed-works of Pákozd and the boat harbour in Sukoró. It is mainly a short shore section in Velence that can be considered to have advantageous features for changing shore fortification.
Keywords: *lakeshore assessment, shoreline restoration, Lake Velence, landscape architecture*

Introduction

In Hungary the full area of standing waters makes approx. 1685 km^2 (almost 2% of the country's territory). About 75% of the 3500 registered standing water bodies are artificial lakes. There are 296 standing water bodies exceeding 50 ha, out of which 123 are artificial ones (KvVM, 2009b). The increased use resulted in disadvantageous change of the chemical and ecological status at several places all over the world that will become even worse through the global climate changes in most regions.

These environmental problems occur more intensively in the Hungarian shallow lakes having primary recreational utilization in many cases. Proper management of lakes is often hindered by the missing information and knowledge of their status, especially their most sensitive part, i.e. lakeshores. Considering the social demands lakeshores have many special functions, such as: landscape protection functions (e.g. special habitat, buffer-function) and landuse functions (e.g. recreation-tourism, public spaces). There are several factors that affect lakeshore conditions: water-level regulation, shore- and lake-bed regulation, shore-use (which may involve structures, buildings on the shore), as well as external effects (e.g. climatic change).

Though several national programs, plans (KvVM, 2007, 2008, 2009a, 2009b) set objectives, tasks concerning lakeshores, at present there is no proper technique to assess, evaluate them with a complex approach considering both landscape-ecology and landuse, at the same time.

Review of literature

The assessment methods of lakeshores go back to the assessment traditions of standing waters and wetland habitats having mainly an ecological approach. The significance of wetland habitat nature protection that marks also lakeshores and the pressured functions resulted in many methodologies (e.g. Adamus et al., 1991; Bain et al., 2000; Fenessy et al., 2007). Innis and her colleagues (2000) examined definitely the assessment methods of habitats at the border of surface waters – land, specifying surveys, assessments and evaluations. While classifying wetland habitats several authors term transitional habitats on the border of standing waters special type (Brinson and Malvárez, 2002; Cowardin et al., 1979; Smith et al., 1995) and refer to lakeshores as potential wetland habitats (Lehner and Döll, 2004). Out of the above the guidance (Common implementation strategy, Wetlands horizontal guidance, 2003) dealing with the significance of wetland habitats, made in connection with EU Water Framework Directives (WFD), is of high importance, specifying lakeshores' wetland habitat as relevant ecosystems as to the goals of the Directives.

In the international professional literature one can find sources which elaborate both the ecological and landuse significance of lakeshores (Ostendorp et al., 2004; Pieczynska, 1990; Schmieder, 2004; Strayer and Findlay, 2010). Some authors deal with the role of landzone-type processes, e.g. buffer/biofilter (Boyd, 2001; Davies and Lane, 1996; Fischer and Fischenich, 2000; White, 2010). Most lakeshore researches focus on the above functions, in addition to other impacts of lake-utilization. The analysis of Engel and Pederson (1998), Löffler (1990), Ness (2006), Strayer and Findley (2010) regarding the effects of lakeshore-development belong to the most complex ones, similarly to the works of Schmieder (2004) on human disturbances of Europe's lakeshores.

Most of the authors processing survey, assessment and evaluation methods of lakeshores treat shores as part of surveying wetland habitats (including lakes) (e.g. USEPA, 2007; Rowan, 2008). A part of the literature regarding survey of lakeshores aims at assessing a certain feature of the lake concerned. The assessments and evaluation methods in the USA that focus on defining the ecological sensitivity of lakeshores (McPherson and Hlushak, 2008; Perleberg et al., 2009) are well applicable also for the Hungarian landscape architecture. In connection with WFD, Ostendorp (2004) studied the assessment methods of lakeshores and a method has been elaborated also in Italy to evaluate the ecological status of lakeshores (Siligardi et al., 2010). Furgala-Selezniow et al. (2011) made assessment of a lake in Poland with regard to recreation - tourism landuse and pressures at the shore.

The hydrobiological science realized quickly the ecological significance of lakeshores in Hungary, too, as one can see in the scientific researches on Balaton. Olga Sebestyén has an outstanding professional activity concerning lakeshore researches. She deals with conditions, processes of Lake Balaton's shore in many works (Entz and Sebestyén 1942; Sebestyén, 1943, 1957, 1963). Felföldy (1981, 1986) also deals with the importance that lakeshores have in the biology of lakes. The hydrobiological researches of lakes (Baranyi, 1980), served first of all as scientific basis for the large lakes' recreational developments (Bökfi et al., 1987). In the period between 1970-1990 utilization and water-quality improvements were made partly by large-scale human interventions, shore- and lakebed regulations – many authors deal with these processes, facilities and results (Goda, 1991; Ligeti, 1976; Szappanos, 1978; Zorkóczy, 1985).

The assessment methods of the Hungarian lakeshores appeared mainly in connection with plans (KSzI, 1998). A fundamental change was induced by the regional plan made for the Lake Balaton's recreational district (VÁTI, 1998). This plan deals separately with lakeshore settlements, besides, it draws the attention to the landuse conflicts concerning shore-zone being „highly sensitive to surface pollution", to the „overuse" of land-zone and ordered to make so called "lakeshore-restoration plans". As to Lake Velence conceptions and programs have been elaborated since the '70s connected with the shore regulation (KDTVIZIG, 1974). At the Faculty of Landscape Architecture of Corvinus University Budapest assessments have been made on the mining lakes in Délegyháza since 2009 by 20x30 m survey plots of the shore. The features of each and every plot were registered in a data-sheet, while separate assessments were made on the shore's wider surroundings, the riparian zone, the riparian slope as well as on the littoral zone (Sallay and Boromisza, 2011).

Materials and methods

Study area

Lake Velence is one of the largest Hungarian shallow lakes (24 km^2), having significant natural values, for which there are continuous development ideas, yet the knowledge of the present, exact status of lakeshore is missing. The lake has a length of 10.8 km, and an average width of 2.3 km (Baranyi, 1980). The full length of legal shoreline (including piers) makes 40.67 km, belonging to four settlements (Gárdony, Velence, Sukoró, Pákozd). The average water depth is 1.45 m (Szilágyi et al., 1989), on basis of the data available, similar water depth has been typical since its origin (Bendefy, 1971). The lakebed has almost steady depth, more significant breaks originated through dredgings, the maximum water depths makes about 5 m. The selection of the study area is justified by the varied shore conditions caused by diversified natural and landscape features and by the – relatively big – size of the lake. For the long-term utilization of the lake it is essential to consider the lakeshore's landscape and natural features.

Lakeshore evaluation method

The evaluation sets the objective to establish the lakeshore's landscaping and regulation by means of special evaluation points of view. When defining the evaluation method it is supposed to characterize the shore's landscape-ecological and landuse features, as well as the landscape protection functions, besides being repeatable and applicable for other lakes (Boromisza, 2010). The lakeshore's detailed survey was made by dividing the legal shoreline into 100 m long sections to land direction (riparian zone) and to water direction (littoral zone), both in a distance of 50-50 m. By this method 351 assessment plots were placed along the shoreline. During the assessments the following basic maps were used: topographic map 1:10000 (1986), colour, high-resolution ortophoto (2009) used by Central-Danubian Water Authority also for survey and qualification of reeds and the so called combined register map of Lake Velence 1:4000 (2007). As a primary assessment method on-site field survey was applied. My partial researches on the study area has been carried out since 2004, including various seasons and shore sections. Between June-September 2011, during my field survey, including the whole lakeshore the earlier results were made up-to-date and also completed.

In the evaluation work-part the shore sections that vary in their pressures, naturalness, buffer-function and in the possibility to change shore fortification were dealt with separately. Within the individual evaluation factors the possible categories get scores (from 1 to 3). The highest scores (3) mean the most advantageous conditions from the given point of view. The individual evaluation factors are weighted in every evaluation aspect (between 1-3). The plots are classified into categories made according to the evaluation aspects, on basis of the scores modified by weighting. When defining categories the plots getting the highest scores are always highlighted.

Pressures

The pressures of the lakeshore (PR) were defined as below:

$$PR= P_{sd}xW_{sd} + P_{lu}xW_{lu} + P_{po}xW_{po} + P_{el}xW_{el} + P_{hu}xW_{hu}. \quad \text{(Eq.1)}$$

For evaluation of the pressures the following factors were considered: shoreline development – the shape of a shoreline (sd), land use (lu), point sources of water pollution (fo), significant linear landscape elements in the riparian zone – roads, ditches, embankments (el), degree of human existence (hu).

The pressures of the shore include all human induced effects, which may involve not only pollutions, but structures or disturbing utilization forms (Csima and Göncz, 2003). The plots with higher shoreline development (higher specific pollution-exposure), with intensive utilization and human use bordered by point sources of pollution and significant linear landscape elements (non-point sources of pollution, disturbance) were considered to be the most pressured ones. *Table 1* shows the evaluation factors, weight numbers, and qualification points.

Table 1. *Evaluation factors and qualification method while defining pressures*

Evaluation factor	Qualification	Score (P)	Weight (W)
Shoreline development (sd)	High Moderate Low	1 2 3	1
Land use (lu)	Intensive (lake-dependent and not dependent) Extensive (lake-dependent and not dependent)	1 3	3
Point sources of pollution (po)	Available Not available	1 3	2
Significant linear landscape elements in the riparian zone (el)	Considerable None, less considerable	1 3	3
Degree of human existence (hu)	Much intensive in whole year Much intensive in season, medium intensive in whole year Less intensive in whole year	1 2 3	1

Classification of the possible categories: 10-16 points – lakeshore is pressured to critical extent, 17-23 points – significantly pressured lakeshore, 24-29 points – lakeshore is pressured to small extent, 30 points – unpressured lakeshore.

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

Naturalness

Naturalness (NA) of lakeshore has been defined as below:

$$NA= P_{sc}xW_{sc} + P_{rc}xW_{rc}+ P_{vn}xW_{vn} + P_{zo}xW_{zo} + P_{sf}xW_{sf} + P_{lz}xW_{lz}. \qquad (Eq.2)$$

While defining naturalness, in addition to several features of vegetation (naturalness (vn) and zonation (zo) of the vegetation were weightly considered) also soil conditions (sc) and shore fortification (sf) are decisive. The most near-natural areas are on natural soil (without significant impervious, filled up surface), the riparian vegetation cover (rc) is high, shore fortification is most similar to natural shore (shore-wall is least similar), no structures in the littoral zone (lz), advantageous species and zonation of the vegetation. *Table 2* shows the evaluation factors, weight numbers and qualification scores.

Table 2. *Evaluation factors and qualification method while defining naturalness*

Evaluation factor	Qualification	Score (P)	Weight (W)
Soil conditions of riparian zone (sc)	Impervious, filled up surface Natural soil	1 3	1
Riparian vegetation cover (rc)	< 40% 40-70% 70% <	1 2 3	2
naturalness of vegetation (vn)	Fully altered Moderately or slightly modified Near-natural	1 2 3	3
Vegetation zonation (zo)	Lack of near-natural zonation Partially modified zonation Near-natural zonation	1 2 3	3
Typical shore fortification (sf)	Shore-wall Slope-rip rapping or other fortification Near natural	1 2 3	2
Structures in the littoral zone (lz)	Significant Less significant None	1 2 3	2

Classification of the possible categories: 13-21 points – heavily modified lakeshore, 22-30 points – modified lakeshore, 31-38 points – slightly modified lakeshore, 39 points – near-natural lakeshore.

Buffer-function

Buffer-function (BU) of lakeshore has been defined as below:

$$BU= P_{sc}xW_{sc} + P_{sl}xW_{sl} + P_{wc}xW_{wc} + P_{wv}xW_{wv} + P_{rc}xW_{rc}+ P_{zo}xW_{zo}. \qquad (Eq. 3)$$

For the evaluation the following factors were considered: soil conditions of riparian zone (sc), riparian slope (sl), water surface cover with emergent machrophytes (wc), width of zone covered with emergent macrophytes (wv), riparian vegetation cover (rc), vegetation-zonation (zo).

While evaluating buffer-function – as determinant landscape protection shore function – I assessed first of all how much the shore’s existing features are suitable to retain the nutrients, sediments that come from the riparian zone (bio filter function). In addition to the higher vegetation cover (both in the riparian and littoral zones) and to the wide zone of emergent macrophytes joining the shoreline (latter was regarded as the most important factor for weighting), the vegetation diversity is advantageous feature. Because of the different nutrient uptake dynamic of the individual vegetation zones and species, the varied shore zonation was considered to be advantageous (Adamus et al., 1991; Tóth, 1982), and the slight slope (smaller surface run-off, erosion). One should have in mind that the areas filled up with typically clayey sediments (Karászi, 1984) hinder the nutrients to get into lake water due to their high adsorption capacity (mainly fixing phosphorus). *Table 3* shows the evaluation factors, weight numbers and qualification scores.

Table 3. *Evaluation factors and qualification method while defining buffer-function*

Evaluation factor	Qualification	Scores (P)	Weight (W)
Soil conditions of riparian zone (sc)	Impervious surface Natural soil Filled up surface	1 2 3	2
Riparian slope (sl)	75°< 30-75°, varied < 30°	1 2 3	2
Water surface cover with emergent macrophytes (wc)	< 10%, 10-40% 40-70% 70% <	1 2 3	2
Typical width of zone covered with emergent macrophytes (wv)	< 1 m 1-4 m, 4-20 m 20 m <	1 2 3	3
Riparian vegetation cover (rc)	< 40% 40-70% 70% <	1 2 3	3
Vegetation zonation (zo)	Lack of near-natural zonation Partially modified zonation Near-natural zonation	1 2 3	1

Classification of possible categories: 13-21 points – lakeshore with poor buffer-capacity, 22-30 points – lakeshore with medium buffer-capacity, 31-38 points – lakeshore with good buffer-capacity, 39 points – lakeshore with excellent buffer-capacity.

Possibility to change shore fortification

In this case I evaluate separately pull down of (artificial) shore fortification and a chance to make a near-natural shore, as a key issue of lakeshore-restoration. The suitable zones have been defined as below:

$$CF= P_{we}xS_{we} + P_{lu}xS_{lu} + P_{sf}xS_{sf} + P_{pr}xS_{pr.} \quad \text{(Eq.4)}$$

The following factors have been considered when evaluating: wave exposure (we), land use (lu), typical shore fortification (sf), property relations of riparian zone (pr). During the evaluation I intended to determine the shore zones being potentially suitable, but – through the use – the necessity of restoration to a certain extent (e.g. in case of an intensive, lake-dependent land use it is not a near-natural shore with emergent

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

macrophytes that should be developed) was also considered. Wave exposure is an important viewpoint in the evaluation, also the emergent macrophytes refer to sheltered lentic areas. In case of properties in private ownership I reckoned with limited landscaping chances. Out of the existing shore fortification forms I deemed those, requiring smaller human interventions, more advantageous (slope-rip rapping shore fortification, other shore fortification). Near-natural shores – as they do not need such interventions – have been excluded. *Table 4* shows the evaluation factors, weight numbers and the qualification scores.

Table 4. *Evaluation factors and qualification method while defining shore zones being suitable to change shore fortification*

Evaluation factor	Qualification	Score (P)	Weight (W)
Wave exposure (we)	Exposed-exposed Protected-protected, exposed-protected Protected-exposed	1 2 3	3
Land use (lu)	Lake-dependent, intensive Not lake-dependent, intensive Lake-dependent extensive Not lake-dependent, extensive	1 2 2 3	1
Typical shore fortification (sf)	Near-natural shore Shore-wall Slope-rip rapping, other fortification	- 1 3	3
Property conditions of riparian zone (pr)	Private property, anglers' association State-owned property, property of local government	1 3	2

Possible category classification: 9-14 points – less suitable to change shore fortification, 15-26 points – suitable to change shore fortification, 27 points – excellently suitable to change shore fortification.

Results

It was found that 58% of the plots are slightly pressured, 37% are significantly pressured and 3% are pressured to critical extent. *Fig. 1* shows the evaluation of the individual shore sections regarding pressure.

Fig. 2 shows the naturalness of the individual shore sections. 52% of the lakeshore have been modified, 30% slightly modified, 16% heavily modified and 2% are near-natural.

Concerning the buffer-function, 48% of lakeshore has medium buffer-capacity, 34% good buffer-capacity, 17% poor buffer-capacity, 1% excellent buffer-capacity. *Fig. 3* shows the evaluation of the individual shore sections.

26% of the lakeshore is suitable to change shore fortification, 25% are less suitable and 4% are excellently suitable. In this evaluation aspect the near-natural "shore fortification" that makes almost half (45%) of the plots was excluded. Accordingly, the assessments show that a high percentage of lakeshore is suitable for changing present shore fortification (*Fig. 4*).

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

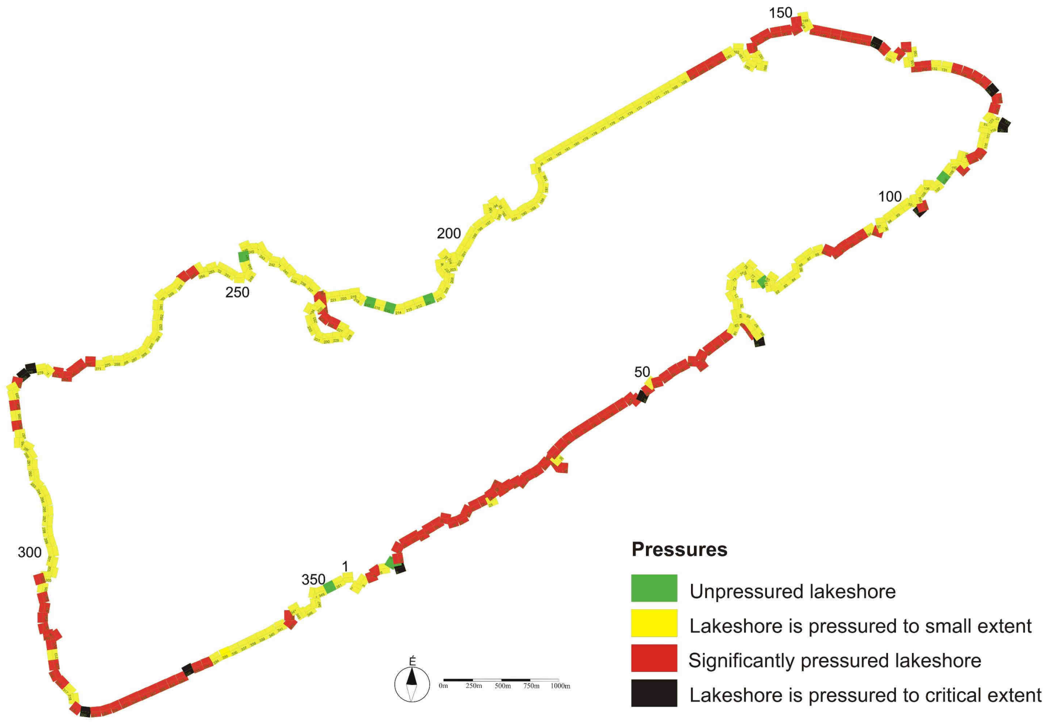


Figure 1. *Lakeshore evaluation regarding pressures*

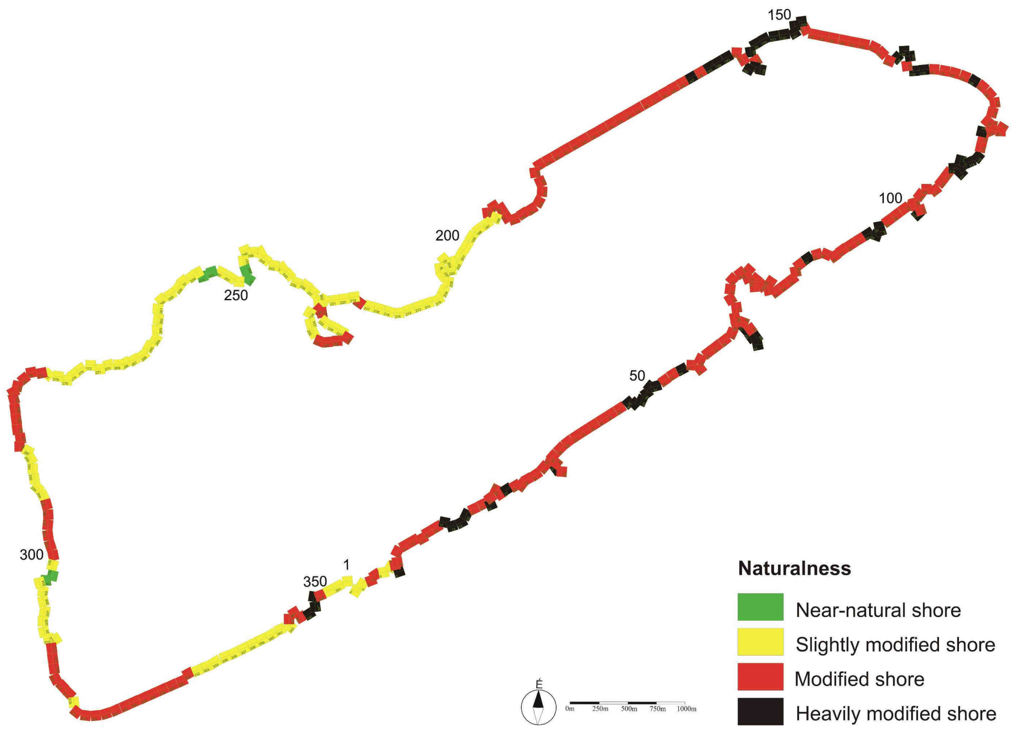


Figure 2. *Lakeshore evaluation regarding naturalness*

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

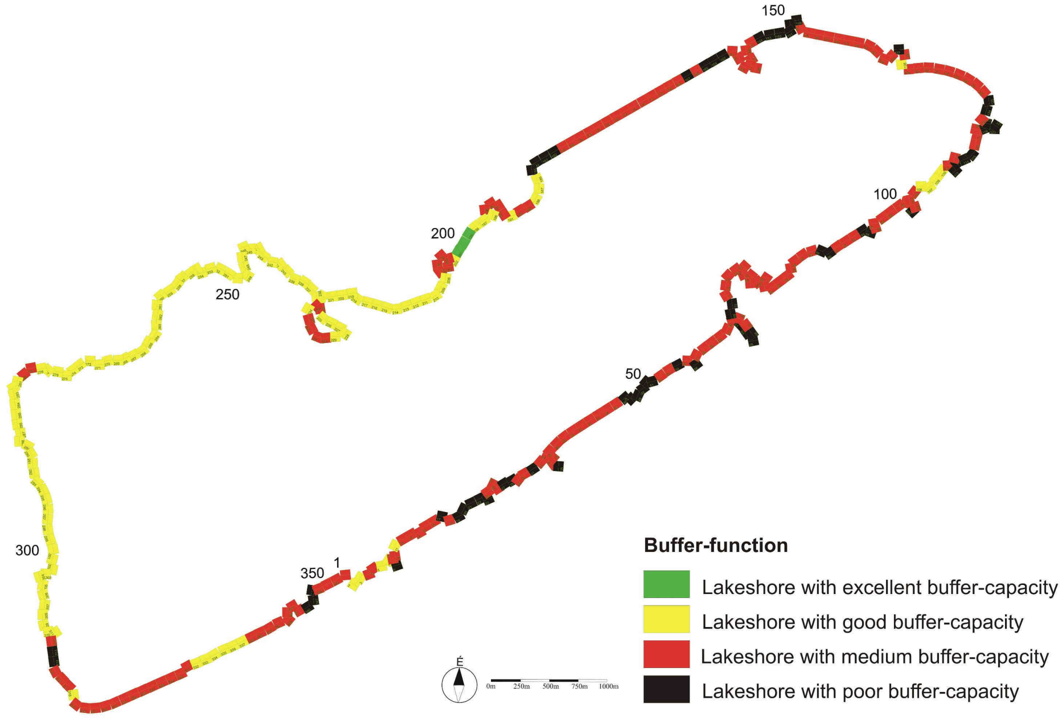


Figure 3. *Lakeshore evaluation regarding buffer-function*

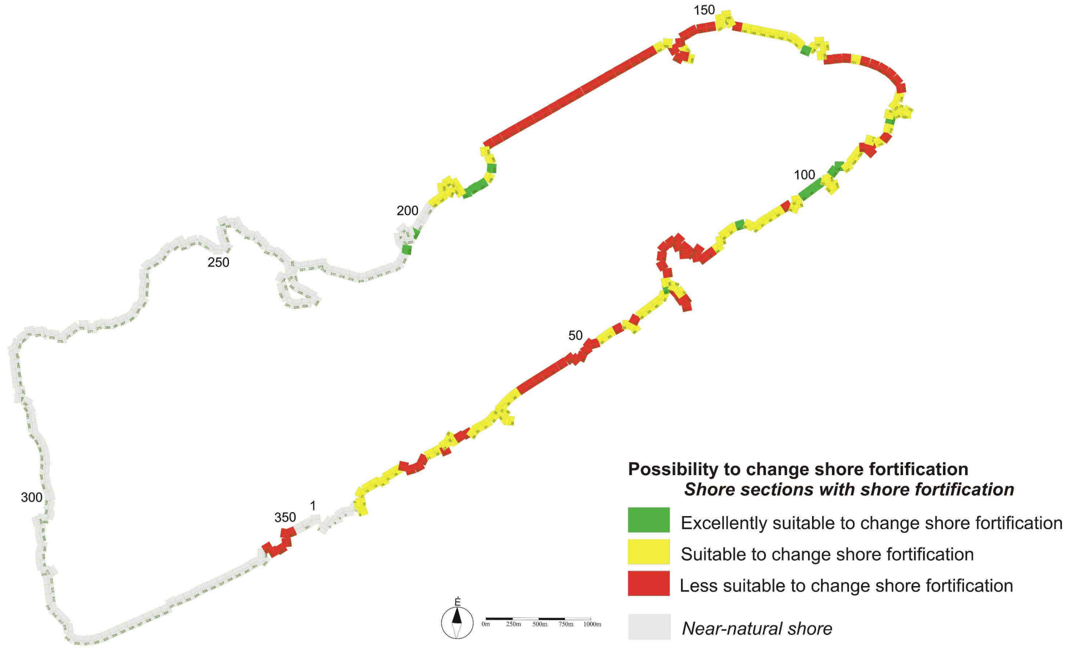


Figure 4. *Lakeshore evaluation regarding change of shore fortification*

Discussion

Pressures

The low pressures, being characteristic for more than half of the lakeshore are partially due to the landuse peculiarities (extensive landuse, dominating greater human use in the seasons). It is also an explanation for the results that point sources of pollutions or significant linear landscape elements are present in low percentage of the assessment plots in the riparian zone. The largest, contiguous section with poor pressures can be found on the northern shore (Sukoró, plots 168-210). Large zones can be observed also on the western shore (Pákozd, plots 287-303) and on the southern shore (Gárdony, plots 66-78).

The highly pressured sections are typical mainly on the lakeshore between Agárd and Velence, on the southern part of the lake. The most areas with intensive utilization and often with lake-dependent landuse (e.g. beach, campings) belong to this category. The longest contiguous section can be found near the free-entry beach of Agárd (plots 37-47). It is an unexpected result that on the southern-western shore sections there are relatively many plots with high pressures, what can be caused by the near public roads and factories.

It is only a small percentage of the plots (12 pcs) that belong to the category "pressured to critical extent", what – in itself – may be deemed advantageous. These sections are located in many cases near boat harbours, where public roads are close to the shoreline, besides, these are the spots where point sources of pollution reach the lake (creek mouths, stormwater outlets). There are two highly pressured plots on the northern-western part of the lake, near the motorway M7 in Pákozd and at the mouth of Vereb-Pázmánd in Velence.

Regarding all the pressures of the lake the above results are much shaded by the fact that only 8 plots have been classified into the not-pressured category. These plots can be found on the southern and northern lakeshores. The individual categories appear in the most mosaic-like way in the southern-eastern and northern-western parts of the lake (near the motorway M7).

Gárdony has the largest average pressures (score: 24.02), followed by Velence (24.27), Pákozd (25.87) and Sukoró (27.9). Considering the above it is somehow unexpected that there are relatively many unpressured sections in Gárdony, and Velence has the most ones being pressured to critical extent. Sukoró is the only settlement which has no plot being pressured to critical extent.

Naturalness

The high percentage of the "modified" category is due to different human interventions of lake regulation (water-level regulation, shore- and lake-bed regulation) and to the effects of recreational utilization, based thereon. For the "modified" areas it is really characteristic that westward from the boat harbour near Bird Reserve "Madárvárta" to that in Sukoró this category is dominant, forming greater contiguous sections. The longest "modified" zone can be found in the region of the rowing course in Sukoró (plots 168-195). Because of the public road and piers near the south-west and north-west shore zone there are also "modified zones".

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

The slightly modified areas dominate the northern shore of the lake, westward from the rowing course. Also the largest contiguous sections can be found here (plots 196-217, 255-277). On the southern shore it is the surroundings of the disposal area (used for storing dredged sediment) in Dinnyés that form longer sections (plots 332-342). The plots belonging to this category are similar in most evaluation factors despite partly being located on the filled up areas.

The "heavily modified" category can be found in most cases on the southern shore at boat harbours and ship docks. On these areas artificial elements and larger impervious surfaces are also connected with the intensive use. This is typical for the largest contiguous section from the ship dock of Óvelence to the eastern part of the rowing course (plots 149-156), mainly with shore-walls. By the western lakeshore there are no plots belonging to the "heavily modified" category.

The near-natural areas are limited to 6 plots only, i.e. there is a remarkably low percentage of the most advantageous types, similarly to pressures. This result is due – on the one hand – to the small share of near-natural vegetation and – on the other hand – to the large built-up area on natural soil. The zones belonging to the individual categories can be seen in the most mosaic-like way near the boat harbour in Dinnyés and next to the Bird Reserve "Madárvárta". The lakeshore involved in lake-regulation does not show any diversification as to naturalness. Among the plots 9-195 you can find exclusively "modified" and "highly modified" ones.

Regarding the administrative areas the individual settlements show significant differences. Pákozd got the highest average naturalness value (score: 31.9), followed by Sukoró (24.91), Gárdony (22.32) and Velence (19.26). All the near-natural areas are in Pákozd, whereas Velence has exclusively modified and highly modified zones.

It is mainly the sections near boat harbours and ship docks which have connection between pressures and naturalness and which are pressured to critical extent, being heavily modified at the same time. In case of the sections with shore-wall fortification, pressures and naturalness can be separated much better, since these zones are not pressured to critical extent necessarily, yet, mainly they are "modified". The effect of shore-walls on the zonation (and thus on the naturalness) is remarkable for the whole lake, as no emergent macrophytes exist in the water in front of them – except for 1-2 plots, there is no reed-zone being wider than 20 m in front of a shore-wall at Lake Velence.

Buffer-function

The category of medium buffer-capacity includes the areas involved in lake-regulation. At many plots medium buffer-capacity is due to the lack of emergent macrophytes. The longest zone, qualified for "medium" is located on the rowing course of Sukoró (plots 168-181). Although the rowing course does not have good conditions as to its shore fortification and emergent macrophytes, yet it is compensated by the cover of the riparian zone (e.g. shelter forest belt). The south-western zones, being in more near-natural status partly, are also belonging to this category.

The areas with good buffer-capacity are typical between the reed-works of Pákozd and the boat harbour in Sukoró. They form long contiguous sections between the plots 236-278 and 281-311. In these sections the advantageous results are due to the high cover of emergent macrophyte vegetation as well as of the riparian ones.

The areas with poor buffer-capacity have low cover of riparian vegetation and emergent macrophytes that are missing and they have shore-wall fortification. These conditions can be found in larger sections near boat harbours in many cases. The area of the northern beach of Velence also belongs to this category (plot 149-154).

Out of the 351 plots there are only 3 that have excellent buffer-capacity. This result may be caused by the fact that the combination of the clayey fill-up, considered to be good in this aspect, with high vegetation cover (especially emergent macrophytes) is very rare, as the typically more intensive utilization of filled up areas is rarely coupled with such features. The mosaic-like arrangements of different categories is characteristic first of all for the areas involved in lake-regulation. At these landscape parts longer sections with medium buffer-capacity are broken by sections with poor buffer-capacity.

In many cases sections with poorer buffer-capacity are more pressured. This comparison gives more consequences as to the ecological status of Lake Velence, than the evaluation of buffer-capacity in itself. It is characteristic first of all of the Agárd and Gárdonyfürdő regions. These areas with dominantly medium buffer-capacity are pressured at least to medium extent. This strong connection can be noticed in many cases near boat harbours (heavily modified, poor buffer-capacity). Similar connection could be found in the eastern shore section and by the south-west parts – along the main road no. 7. The heavily modified shore sections have typically medium, or poor buffer-capacity, yet, the areas with good buffer-capacity are not necessarily near-natural.

The individual administrative regions have the following average buffer-capacity: Pákozd (score: 34.21), Sukoró (27.91), Velence (24.05), Gárdony (23.87). The outstanding result of Pákozd is due to the fact that out of the 114 plots for this settlement, 93 plots have good buffer-capacity, whereas the 3 plots with excellent buffer-capacity belong to the administrative district of Sukoró.

Possibility to change shore fortification

The shore sections, deemed suitable to change shore fortification on basis of the evaluation, the longer one in Agárd (plots 8-16), Gárdony (plots 29-39) and Velence (plots 140-146) do not have optimal features in no respect for restoration, nevertheless this may be modified e.g. by a changed landuse in the future. Unfortunately there are no exact figures of the lakebed depth-conditions what is disadvantageous for the evaluation.

For the “less suitable” areas application of shore-wall is characteristic. As qualification is influenced by several factors in addition to shore fortification, shore sections with shore fortification are supposed to be similar also in their other attributes (e.g. type and intensity of landuse, wave exposure). The longest, less suitable section is on the rowing course of Sukoró. In case of “excellently suitable” areas plots are concentrated basically in two landscape parts: among the plots 185-198 in Sukoró and 95-109 in Velence there are more “excellently suitable” plots, one after another. Knowing the “neighbourhood conditions” it is mainly the shore section of Velence that can be considered to have advantageous conditions to change shore fortification (the shore section of Sukoró is located directly near the rowing course).

After having compared the results with the pressures evaluation, definite connection was found between the two indicators. The a/m plots of the shore sections in Velence and Sukoró mainly belong to the slightly pressured category. There is no strong connection between the results of naturalness and suitability to change shore fortification. The zones that are suitable for transformation consist of modified or heavily modified plots in greater part. Buffer-capacity does not show connections with

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

the above results, either. Most shore sections qualified for excellently suitable belong to Velence, followed by Sukoró and Pákozd. It is the low percentage of shore fortification, because of which one cannot find sections, being suitable for changing shore fortification, either. The significance of restoration possibilities in the administrative region of Velence is absolutely high, as this is the settlement with the least near-natural shore sections, being much pressured while having relatively few sections with good buffer-capacity.

Conclusion

The shore of Lake Velence was evaluated according to four viewpoints: pressures, naturalness, buffer-function, suitability for shore fortification. The results of the research can be applied for the landscape planning practice in several aspects. The evaluation of the shore fortification transformability can be considered during lakeshore-restoration in compliance with WFD documents of different scale – nationwide and catchment subordinate unit. The other evaluation results may serve as basis for further landscape planning processes of the lake's surroundings. The results of pressure assessments can be applied to define pressures of landscape, for concepts of recreation-tourism development, to manage protected landscape parts from nature protection viewpoint (or for nature protection management plan of Bird Reserve of Lake Velence) as well as for the environment protection programs of the settlements. Many results can be regarded as disadvantageous considering landscape ecology and landscape protection what is due – in a way – to the lack of a proper regulation system. This may apply to lake-use and shore-use activities, which have not been duly coordinated (e.g. tourism forms disturbing each other), as well as to the maintaining duties. The local code typically disregards the specialities of lakeshores and cannot treat the individual appearance forms, the shore-types in a properly differentiated manner. Another main reason for problems and landuse conflicts is the lack of knowledge of lakeshore functions.

During the evaluation lacks have been found in basic researches: the non-point-source pressures of the lake, importance of the individual shore fortification solutions for habitats are not known, besides, it is a significant deficiency that there are no exact data available on lakebed depth conditions as well as on the present status of silting up.

Also, regarding practical use of the research made on the shore of Lake Velence, it is of high importance to extend the prospectives in time, thus, the dynamic processes of lakeshore can also be evaluated (e.g. emergent macrophytes, changes of use intensity). The research can be well completed with a survey of utilization customs and demands, sustaining problems, and involving all concerned parties comprehensively (e.g. local governments, competent national park management, supervisory boards of environment-, nature protection and water affairs, managements of nature protection and water affairs, local rural development office, companies being interested in recreation-tourism services, local people, NGOs).

As further objective, applicability of this method for other medium-size, or large lakes with primary recreational utilization should be assessed. The assessment method of lakeshores' visual features is to be worked out as a part of evaluating the role that lakeshores play in landscape character. As lakes of various characters require special considerations while defining assessment methods of lakeshores, lake-classification from landscape architecture point of view is essential.

Determination of landuse directions and priorities for the long run need a complex approach comprising the whole lake. The tasks connected with the individual shore features (giving priority to water level regulation) and with the landscape parts having various functions can be planned on the basis of this knowledge. In the future, utilization of lakeshore, landscaping, regulation and management of landzone are to be defined together. The above professional duties should be completed with a continuous development of environmental consciousness.

Acknowledgements. I have to thank Mr. Péter Csima (Department of Landscape Protection and Reclamation, Corvinus University of Budapest, Head of Department) and Mrs. Piroska Pomogyi (Central-Transdanubian Water Authority) for the help they rendered to me to write this article.
The study was prepared as part of the TÁMOP-4.2.1/B-09/1/KMR-2010-0005 research project.

REFERENCES

[1] Adamus, P.R., Stockwell, L.T., Clairain, Ellis J., Jr., Morrow, M.E., Rozas, L.P., Smith, R.D. (1991): Wetland Evaluation Technique (WET), Volume I: Literature Review and Evaluation Rationale, Technical Report WRP-DE-2. – US Army Engineer Waterways Experiment Station, Vicksburg

[2] Bain, M.B., Harig, A.L., Loucks, D.P., Goforth, R.R., Mills, K.R. (2000): Wetland ecosystem protection and restoration: advances in methods for assessment and evaluation. – Environmental Science & Policy 3: 89-98.

[3] Balaton Kiemelt Üdülőkörzet Területrendezési Terve (1998). Egyeztetési anyag. – VÁTI Magyar Regionális Fejlesztési és Urbanisztikai Kht, Budapest.

[4] Baranyi, S. (1980): A tavak hidrológiája. – VITUKI, Budapest

[5] Bendefy, L. (1971): A Velencei-tó kialakulása és fejlődéstörténete. – VITUKI, Budapest

[6] Bökfi, S., Divinyi, T., Patkós, M. (1987): Állóvizek üdülési, hasznosítási célrendszere, különös tekintettel a Velencei-tó fejlesztésére. – In: Vízkészletvédelem. Magyar Hidrológiai Társaság VII. Országos Vándorgyűlés. Salgótarján 1987. június 9-11. II. kötet.

[7] Boromisza, Zs. (2010): Parti sáv értelmezési lehetőségek és lehatárolási módszerek állóvizek tájértékelésében. – 4D Tájépítészeti és kertművészeti folyóirat 19: 46-53.

[8] Boyd, L. (2001): Buffer zones and beyond. Wildlife uses of wetland buffer zones and their protection under the Massachusetts Wetland Protection Act. – Department of Natural Resources Conservation, University of Massachusetts, Amherst

[9] Brinson, M.B., Malvárez, A.I. (2002): Temperate freshwater wetlands: types, status and threats. – Environmental Conservation 29 (2): 115-133.

[10] Common Implementation Strategy (CIS) for the Water Framework Directiv (2000/60/EC). Wetlands Horizontal Guidance. Horizontal Guidance Document on the Role of Wetlands in the Water Framework Directive. Final Draft (2003).

[11] Cowardin, L.M., Carter, V., Golet, F.C. , LaRoe, E.T. (1979): Classification of wetlands and deepwater habitats of the United States. – U. S. Department of the Interior, Fish and Wildlife Service, Washington

[12] Csima, P., Göncz, A. (2003): A területrendezési tervek tájterhelési és táj-terhelhetőségi vizsgálatának módszere. Tervezési útmutató. – SZIE Tájvédelmi és Tájrehabilitációs Tanszék - VÁTI Kht, Budapest

[13] Davies, P.M., Lane, J.A.K (1996): The impact of vegetated buffer zones on water and nutrient flow into Lake Clifton, Western Australia. – Journal of the Royal Society of Western Australia 79: 156-160.

[14] Engel, S., Pederson Jr., J.L. (1998): The construction, aesthetic and effects of lakeshore development: a literature review. Research report 177. – Wisconsin Department of Natural Resources, Madison
[15] Entz, G., Sebestyén, O. (1942): A Balaton élete. Királyi Magyar Természettudományi Társulat, Budapest
[16] Felföldy, L. (1981): A vizek környezettana. Általános hidrobiológia. – Mezőgazdasági Kiadó, Budapest
[17] Felföldy, L. (1986): A tavak nádasainak vízminőségi jelentősége és jövője. In. Magyar Hidrológiai Társaság VI. Országos Vándorgyűlés. I. szekció. A tavak élete és vízgazdálkodása. Hévíz. 1986. június 17-19.
[18] Fennessy, M. S., Jacobs, A.D., Kentula, M.E. (2007): An evaluation of rapid methods for assesssing the ecological condition of wetlands. – Wetlands 27(3): 543-560.
[19] Fischer, R.A., Fischenich, J.C. (2000): Desgin recommendations for ripatian corridors and vegetated buffer strips. – US Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg
[20] Furgala-Selezniow, G., Skrzypczak, A., Kajko, A., Mamcarz, A. (2011): Characterization of the management of the shore zone of Ukiel Lake (Olsztyn, Poland). – In. Móra, A., Bíró, P. (ed.): Programme and abstracts of conference on „Ecological problems of tourist lakes". 20-23 June, 2011, Tihany Hungary. Balaton Limnological Research Institute of the Hungarian Academy of Sciences.
[21] Goda, P. (1991): Folyószabályozás, tószabályozás, árvízvédelem, ármentesítés. – Typotex Kft., Budapest
[22] Innis, S.A., Naiman, R.J., Elliott, S.R. (2000): Indicator and assessment methods for measuring the ecological integrity of semi-wetland terrestrial environments. – Hydrobiologia 422/423: 111-131.
[23] Karászi, K. (ed., 1984): A Velencei-tó rekreációja. – Vízgazdálkodási Intézet, Budapest
[24] KDTVIZIG (1974): A Velencei-tó part és mederrendezés munkáinak általános terve (1974). – Közép-dunántúli Vízügyi Igazgatóság (KDTVIZIG), Székesfehérvár
[25] KSzI (1998): A Kiskörei-tározó (Tisza-tó) víztereinek és partjainak környezethasználati terve és szabályzata I. ütem. – Kulturmérnöki Szolgáltató Iroda Bt, Budapest.
[26] KvVM (2007): Nemzeti Fenntartható Fejlődési Stratégia (2007). – Nemzeti Fejlesztési Ügynökség, Környezetvédelmi és Vízügyi Minisztérium (KvVM), Budapestplaces
[27] KvVM (2008): Nemzeti Éghajlatváltozási Stratégia 2008-25. – Környezetvédelmi és Vízügyi Minisztérium (KvVM), Budapest
[28] KvVM (2009a): Nemzeti Környezetvédelmi Program 2009-14. – Környezetvédelmi és Vízügyi Minisztérium (KvVM), Budapest
[29] KvVM (2009b): A Víz Keretirányelv hazai megvalósítása. Vízgyűjtő-gazdálkodási terv. A Duna-vízgyűjtő magyarországi része – Környezetvédelmi és Vízügyi Minisztérium (KvVM), Vízügyi és Környezetvédelmi Központi Igazgatóság, Budapest
[30] Lehner, B., Döll, P. (2004): Development and validation of global database of lakes, reservoirs and wetlands. – Journal of Hydrology 296: 1-22.
[31] Ligeti, L. (1976): A tószabályozás alapvető szempontjai. In. Balaton ankét. Keszthely 1976. szeptember 30 – október 1. Magyar Hidrológiai Társaság, Budapest.
[32] Löffler, H. (1990): Imapct by man. – In. Jorgensen, S.E. (ed.): Guidelines of lake management. Vol. 3. Lakeshore management, UNEP, ILEC Series
[33] McPherson, S., Hlushak, D. (2008): Windermere Lake Fisheries and Wildlife Habitat Assessment. Consultant report prepared for the East Kootenay Integrated Lake Management Partnership. – Interior Reforestation Co. Ltd., Cranbrook
[34] Ness, K.L. (2006): The effets of shoreline development on lake littoral and riparian habitats: are shoreline protection regulations enough? Thesis. – Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science, University of Maine, Orono

[35] Ostendorp, W. (2004): New approaches to integrated quality assessment of lakeshores. – Limnologica 34: 160-166.

[36] Ostendorp, W., Dienst, M., Jacoby, H., Kramer, I., Peintinger, M.s, Schmieder, K., Werner, S. (2004): General Framework for a Professional Evaluation System for Lakeshore Conservation and Water Body Protection, using Lake Constance as an Example. – Expertise of the Arbeitsgruppe Bodenseeufer (AGBU) for the Bodensee-Stiftung and the Global Nature Fund, Radolfzell, Constance

[37] Perleberg, D., Radomski, P., Woizeschke, K., Thompson, K., Perry, P., Carlson, A. (2009): Minnesota's sensitive lakeshore identification manual: a conservation strategy for Minnesota' lakeshores. – Minnesota Division of Ecological Resources, Minnesota Department of Natural Resources, St. Paul

[38] Pieczynska, E. (1990): Litoral habitats and communities. – In. Jorgensen, S. E. (ed.): Guidelines of lake management. Vol. 3. Lakeshore management, UNEP, ILEC Series

[39] Rowan, J.S. (2008): Lake habitat survey in the United Kingdom. Field survey guidance manual. Version 4. – The Scottland and Norther Ireland Forum for Environmental Research (SNIFFER), Edinburgh

[40] Sallay, Á., Boromisza, Zs. (2011): Partfelmérés a délegyházi bányatavaknál. Tájökológiai Lapok 9(1): 87-98.

[41] Schmieder, K. (2004): European lakeshores in danger – concepts for a sustainable develpment. – Limnologica 34: 3-14.

[42] Sebestyén, O. (1943): A parti öv jelentősége a tó életében. pp. 301-308. – In. Entz Géza (ed.): A Magyar Biológiai Kutatóintézet munkái. XV. Kötet. Magyar Biológiai Kutatóintézet, Tihany.

[43] Sebestyén, O. (1957): Parti tanulmány. Klny. –MTA Tihanyi Biológiai Kutatóintézetének évkönyvéből, Akadémiai Kiadó, Tihany

[44] Sebestyén, O. (1963): Bevezetés a limnológiába. A belvizek életéről. – Akadémiai Kiadó, Budapest

[45] Siligardi, M., Bernabi, S., Cappelletti, C., Ciutti, F., Dallafior, V., Dalmiglio, A., Fabiani, C., Mancini, L., Monauni, C., Pozzi, S., Scardi, M., Tancioni, L., Zennaro, B. (2010): Lake shorezone functionality index (SFI). A tool for the definition of ecological quality as indicated by Directive 2000/60/CE. – Autonomous Province of Trento, Provincial Environmental Protection Agency, Trento

[46] Smith, R.D., Ammann, A., Bartoldus, C., Brinson, M.B. (1995): An approach for assessing wetland functions using hydrogeomorphic classification, reference wetlands, and functional indices. Wetlands Research Program Technical Report. – US Army Corps of Engineers, Waterways Experiment Station, Washington

[47] Strayer, D.L., Findley, S.E.G. (2010): Ecology of freshwater shore zones. – Wetland Science 72: 127-163.

[48] Szappanos, Z. (1978): A tószabályozás fejlesztése. – In. Kovács, D. (ed.): Árvízvédelem, folyó- és tószabályozás, víziutak Magyarországon. Országos Vízügyi Hivatal, Budapest

[49] Szilágyi, F., Szabó, Sz., Mándoki, M. (1989): Restoration of Lake Velence. – In. Saláni, J., Heródek, S. (ed.): Conservation and Management of lakes. Symposia Biologica Hungarica Vol. 38. Akadémiai Kiadó, Budapest

[50] Tóth, L. (1982): A parti zóna szerepe a Balaton tápanyagforgalmában. – VITUKI, Vízminőségvédelmi Intézet, Budapest

[51] USEPA (2007): Survey of the Nation's Lakes. Field Operations Manual. – U.S. Environmental Protection Agency (USEPA), Washington

[52] Zorkóczy, Z. (1985): Folyó- és tószabályozás. – Pollack Mihály Műszaki Főiskola Vízgazdálkodási Intézete, Baja, Tankönyvkiadó, Budapest

THE LONG TERM PRESERVATION OF AN 18TH CENTURY GENE BANK HERITAGE – CASE STUDY OF THE SZÉCHENYI LIME TREE ALLÉE AT NAGYCENK

GERZSON, L. – SZILÁGYI, K.* – BEDE-FAZEKAS, Á.

Corvinus University of Budapest, Department of Garden and Open Space Design
1118 Budapest, Villányi út 29–43., Hungary
(phone: +36-1-482-6288)

**Corresponding author*
e-mail: kinga.szilagyi@uni-corvinus.hu

(Received 3rd November 2011; accepted 23rd November 2011)

Abstract. The allée is one of the oldest instruments and forms of landscape architecture, which has often been used from the Antiquity for the expression of visual and functional relationships, for the delimitation of space, or for the pictorial creation of movement. The several hundred years old allées of the late baroque age, which still live among us as the witnesses of bygone times, represent a special value throughout Europe. The longevity and the respectable size as such bestow a certain value upon the trees. However, the allées also stand for a garden art, landscape, culture historical and natural value, which in a summarized way are called cultural heritage. Furthermore, the gene pool of the proven longevous, high tolerance tree specimens is a natural and genetic heritage of scientific signification. The age of the trees and allées is finite. Even with a careful and professional care, the renewal is inevitable, which, beyond technical problems of landscape architecture might raise many scientific, nature conservation, yes, esthetical and ethical questions. This is why there is no universal methodology, but there are aspects and examination procedures of general validity with the help of which a renewal can be prepared. The renewal concept of the lime tree allée in Nagycenk aims at the protection and the transmission of the value-ensemble embodied in the allée. One part of the value-ensemble is the spiritual, cultural heritage, the extraordinary value of the landscape-scaled, landscape architectural creation planted and taken care of by the Széchenyis. On the other hand the two and a half centuries old trees represent an inestimable botanical and genetic wealth. Its transmission and preservation is a scientifically important program coming up to the Széchenyi heritage. After the registration of the originally planted old trees, the complete nursery material of the "Széchenyi limes" necessary for the replanting can be produced by vegetative propagation. The gradual replacement of the stand with its own propagation material, by the carefully raised nursery trees of the same age can be a model for the gene-authentic renewal method – a novelty even at an international level.
Keywords: *historic allée, preservation of gene bank heritage, nature conservation, renewal and protection of cultural heritage*

Introduction

The almost 2.3 km long double lime tree allée in Nagycenk is a national culture-historical, landscape architectural and natural value, which we inherited from the 18th century. According to the old travelers, the grandiose allée, initially planted with 600 small-leaved lime trees, counted as an outstanding allée amongst the landscape architectural creations of the late baroque estates of the nobility. "The beautiful castle and the garden with the orangery are a property of count Széchenyi. From the garden, there is an allée of 600 limes lasting for almost five quarters of an hour leading to a small grove on a hill." This is what Gottfried Edlen von Rotenstein (1783) wrote, who made notes of his travels to Hungary in the 1760s and who is also quoted by Rapaics (1940).

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

The allée was part of the Széchenyi estate in Nagycenk and represents an organic northward continuation of the castle garden, way out until the high shore of the Lake Neusiedl. The allée is today part of the administrative territory of three municipalities, besides Nagycenk that also hosts the castle, the larger part is reaching along the territory of the village of Hidegség, while the small grove terminating the allée, and in it the shrine of Hanna Erdődy and Béla Széchenyi already belong to the municipality of Fertőboz. It is thus justifiable to call the allée the *Széchenyi lime tree allée*, since this name does not only solve the "municipality conflict", but it also denominates the creator and the owner, the Széchenyi family, a Hungarian noble family of an incomparable high-thinking, whose members once gave an example not only in the development of their property, but also in that of the entire country.

Review of literature

The Nagycenk estate became the property of the Széchenyi family at the beginning of the 18th century. Count Antal Széchenyi began the development of the estate and the construction of the castle in the middle of the 1700s. The allée has been, according to family memories, planted by his wife, Zsuzsanna Barkóczy between 1754 and 1760 as a continuation of the main axis of the baroque garden, on the opposite side of the main road, way up until the high shore of the Lake Neusiedl (Örsi, 1976; Örsi, 1992). On the first military survey (1783-85), the lime tree allée has already been represented as a significant landscape element (*Fig. 1*). On the cadastral map of Hidegség from the middle of the 19th century (1856), not only the proportions and the planting order of the allée can be seen, but also the fact that the lime tree allée ends before the small grove on the high shore of the Lake Neusiedl; from this point, the allée is continued until the terminating grove by a much narrower allée, of a different mode of representation, planted with trees of a smaller canopy, thus of a different species. The grove housed a hermitage for a short time and the small chapel attached to it, this way the termination of the allée, its close, has also been reinforced. Unfortunately no documents have been found yet about the allée leading through the grove, so we can only assume that this might have been a fruit tree allée. This is also indicated by the planting distance, which is 3 fathoms, that is 5.68 m, and the function of the hermitage also supports this idea. The first inhabitant of the hermitage settled down here in 1773, the chapel was built in 1774 (Kelemen, 2011). The hermitage was torn down quite early, but the chapel stood there until the beginning of the 1900s. The Széchenyi allée, extraordinarily imposing even among the other allées typical for the ensembles of baroque gardens and landscapes, figured in almost every contemporary travelogue and property description, like for instance in the garden description of great garden historical value by Rajmund Rapaics from the beginning of the 20th century, which then mentioned an allée of 567 small-leaved lime trees, each of 3-4 m trunk girth (Rapaics, 1940).

Miksa Földváry and Károly Kaán drew attention to the natural, culture-historical, and landscape architectural merits of the lime tree allée in Nagycenk already in the 1930s (Földváry, 1934), until the Royal Hungarian Minister of Agriculture declared it a nature conservation area with its 80.855/1942. decree. According to the valid conservation decision, the allée is primarily a natural monument, where the old, often rotting, hollow trees are home to many protected species (xylophagous insect, bats and birds).

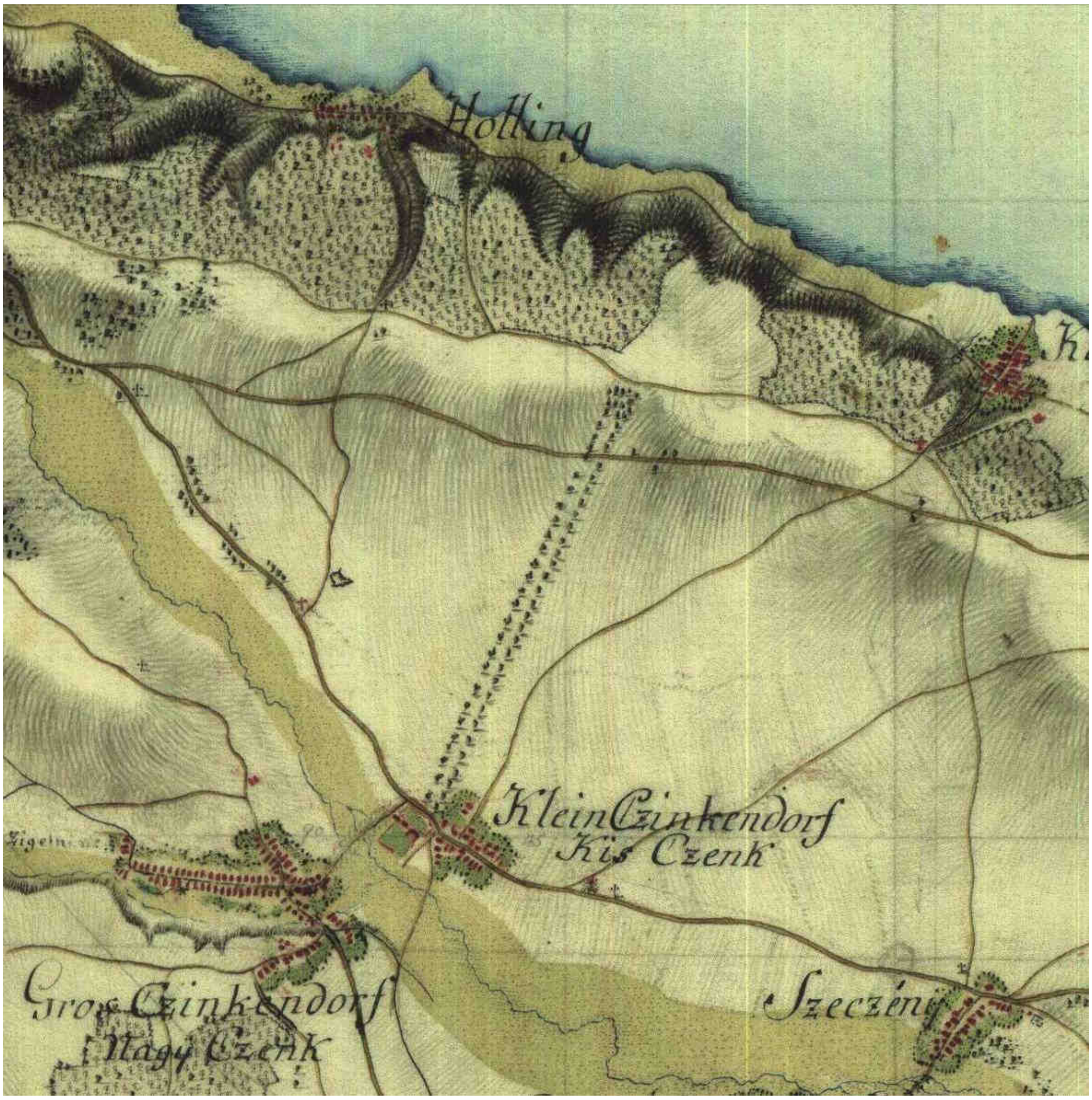


Figure 1. *Nagycenk and its surroundings on the first military survey (1780-1784 IV/5). At this time, the Széchenyi lime tree allée is recorded as a characteristic landscape element.*

The protection today has several levels, since the allée (at least its segment in Nagycenk), along with the castle, is considered from 2001 on a monument and a world heritage (*Fig. 2*). Among the Hungarian protected allées there is no one of similar value from those that belong to castle gardens; we might only mention here the similarly landscape-scaled black pine allée in Keszthely, which has been planted much later as a creation of Tasziló Festetics.

Concerning the original length of the allée and the number of trees various sources impart different data, but the ones conferred by Rapaics (1940) mentioning 600 specimens in the approximately 2.3 km long allée, with a 4 fathom (7.58 m) planting distance between the trees seem to be acceptable. The distance between the two rows was 12 fathoms (22.75 m). Here Rapaics indicates 23 meters and 7 meters as a planting distance, but this can by no means be considered accurate, since back then instead of metric units fathoms were used in measurement.

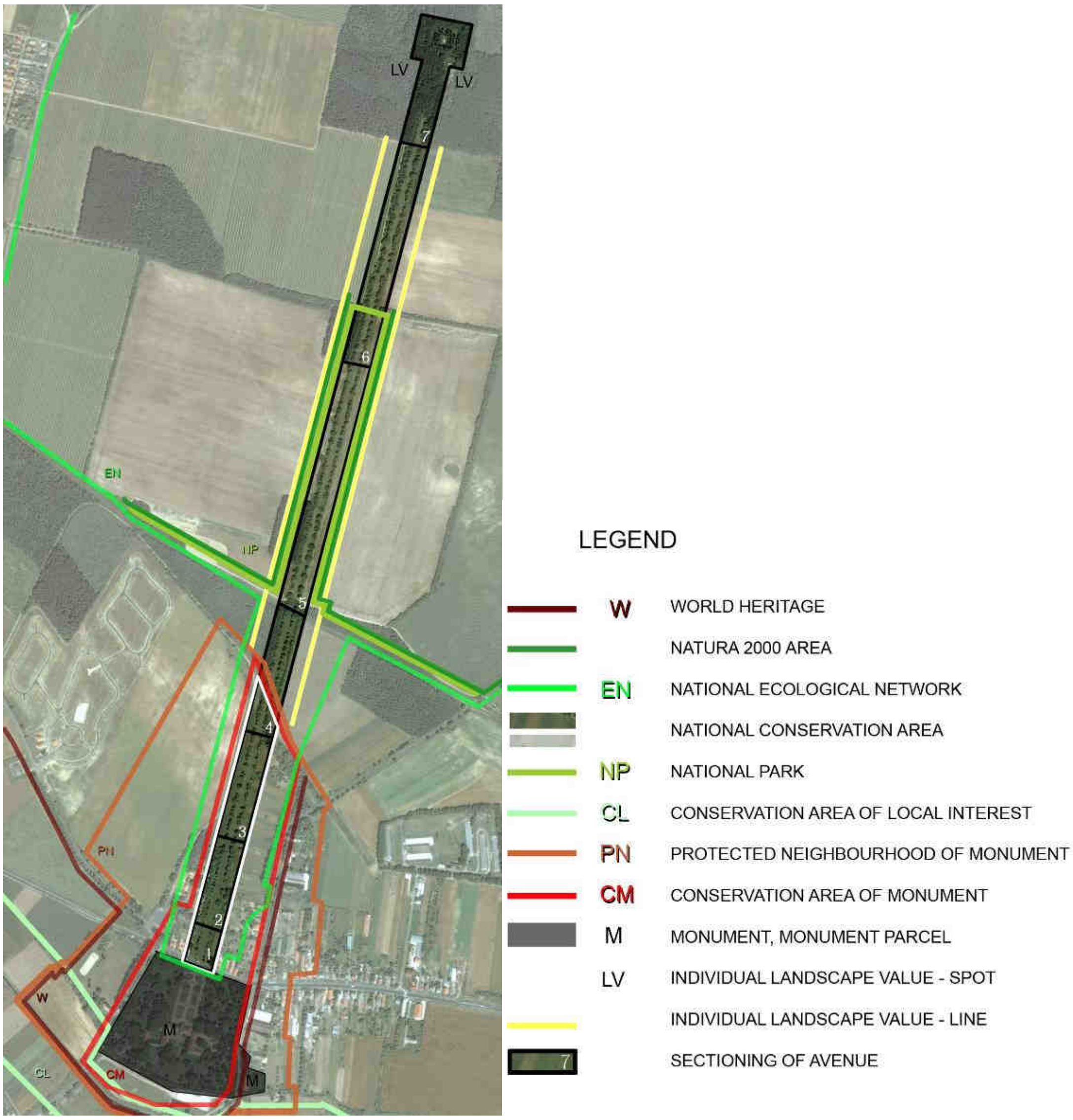


Figure 2. *An about 2.3 km long segment of the allée with the indication of the different levels and types of protections (edited by Dora Hutter)*

The double allée proves to be a typical example of the so called “allée verte”, in the middle of which there is a turf field, and people only have trodden a path on its two sides. Thus the allée cannot be considered a greenway in the traditional sense, where there would have been regular riding, horse-carriage, wagon and pedestrian traffic (*Fig. 3*). The allée was pastured: documentations show that sometimes even the stud was out at feed here and there are pictures representing the practice of the pasturage by sheep flocks. The old postcard testifies that until the bottom of their canopy, the intermediate spaces of the trees were kept clear and transparent. We can take it for granted that the family of the count also used this allée for riding their horses, probably regularly until the construction of the railroad (*Fig. 4*).

Figure 3. *As shown by the postcard from the end of the 19th century, the greenway of the allée was not, or rarely used (around 1890, source: http://www.profila.hu)*

Figure 4. *According to the old postcard showing the Széchenyi allée, the space between the trees was once maintained by pasturage (around 1920, source: http://www.profila.hu)*

The Széchenyi lime tree allée can be considered one of the most important among the numerous extraordinarily significant landscape architectural and dendrological values in Hungary. Its historical and culture-historical value is enhanced by its connection to the Széchenyi family who planted and used it. Its landscape architectural and esthetical specialty has its source in the monumentality of the whole ensemble, and the fascinating beauty of the individual specimens. Its scientific significance and its nature conservational value is evident from the inestimable research value of the living gene bank (genetic reserve) composed of the documented, at least 250 years old specimens. The preservation of this extraordinary national value is equally necessary from a scientific, ethical, historical and touristic aspect; it is a priority task that requires a joint effort of monument protection and nature conservation.

The Tanulmányi Erdőgazdaság (Practicing Forestry) Zrt., in charge of the maintenance of the allée, has since 2002 a nature conservation management plan available (upon the order of the Fertő-Hanság National Park Directorate the management plan has been prepared by the Department of Botany of the University of West Hungary and the Department of Landscape Protection and Rehabilitation of the Szent István University). The management plan aims at the prolongation of the life of the old lime trees by 50-60 years, and at the same time the gradual renewal of the allée (Csima and Módosné Bugyi, 2003). Yet the management plan does not reject the idea of the complete exchange of tree species either. Instead of the actual small-leaved lime (*Tilia cordata*) it suggests the large-leaved lime (*Tilia platyphyllos*) already used for substitution in the beginning of the 19th century or the hybrids of the two species (*T. cordata* and *T. platyphyllos*), and it theoretically does not reject the planting of silver lime (*T. tomentosa*) either, which is very different and incompatible with the landscape (smaller with a different canopy shape thus not matching the original planting system either).

The plan suggests many actions for the protection of the allée, including the designation and maintenance of a freely unfolding protection zone along the allée, free of any buildings and competing plant stands, as well as the individual, that is, horticultural care of the trees. The regular allée-cleaning, maintenance, tree treatment works included in the management plan are – unfortunately – not carried out at all, and there is a risk that the old trees might collapse in a rapid succession.

An allée of such a great culture-historical value deserves particular attention; everyone agrees in that, in this subject, all concerned scientific circles, professional associations and authorities represent the same standpoint. However, opinions about the protection methodology vary. Partly because the monumentality of the task furnishes everyone with food for thought, primordially because of the putative impossibility of its completion within a reasonable time. Although there is a possibility that can simultaneously preserve and transmit the culture-historical, landscape architectural, monumental and natural values to posterity. There is a need for a novel allée renewal methodology, which has never yet been applied in our country, which allows for the safeguarding and the renewal of all these values, so that the imposing allée created by the Széchenyis can once again appear as a uniform picture – keeping its original character, ambience, culture-historical value, even its gene pool. Nevertheless, the renewal can only be fruitful through an extensive social collaboration, exclusively based on the carefully defined professional criteria, taking into account the specific characteristics of the group as a whole and of the individual plant specimens (trees) as well as those of the site. This methodology is the authentic allée renewal using the same genes, which has to be carried out in stages and according to a long-term schedule.

The originally planted specimens of the lime tree allée in Nagycenk are small-leaved limes (*Tilia cordata* Mill.). It is a seedling population, the propagation material of which might have been collected from the seminiferous trees of the surrounding forests or parks. Whether they are the seedlings of one or more trees that can be clarified by genetic studies. This detail is also important because such an investigation, in the case of favourable results, might reveal a field of the 18th century Hungarian horticulture, which has been quite ignored until now, the propagation of ornamental trees and their nursery raising, that is, we can get an idea of the beginnings of the Hungarian ornamental nursery cultivation. A complication with these genetic studies is that while the genetic mapping of our important industrial crops and the marking serving the identification of the genes is solved, no such investigations have been carried out for the limes, which means that even the necessary basic research for the gene identification has to be done. We have already started our research in this field.

Figure 5. *A specimen of nice canopy, growing in an open space without competitors (photo: L. Gerzson)*

According to its role in plant communities, the small-leaved lime is a so-called precursor species, that is, its genetically encoded life expectancy is shorter than that of the climax species building a population on the given territory (Soó, 1973) This is why in the case of small-leaved limes one cannot count on the survival of such record-sized and very old specimens as in the case of oaks and beeches, of which many several hundred years old specimens are known countrywide, being a subject to many legends. The small-leaved lime specimens of over 150 years are considered very old, in closed forest communities they hardly ever reach that age; when in parks or in a row, they are often fallen because of the hazardousness resulting from their decaying branch system and their reducing esthetical value even before they reach this age. Only independently positioned specimens growing in open spaces, without competitors can survive at this age as a showy, beautiful tree (*Fig. 5*). The good quality, uniform genetic material, the favourable environmental conditions (soil characteristics, exposure and precipitation) and the lack of competing vegetation – which is first of all due to the probably long-lasting professional and intense management and care – might offer an explanation for the extraordinary age of the lime trees in Nagycenk. Way until the 20th century, the maintenance of the allée and its environment was carried out in a very simple and economic manner, by pasturage. The flocks of sheep most suitable for this task can do a very "thorough and meticulous" work and thus the area to be maintained – the allée and its environment – turned into a lucrative unit of the Széchenyi property without raising the maintenance costs. The fact about the pasturage is not a mere assumption, this is also testified by the photos from the beginning of the 1900s (*Fig. 6*). After (or even before) the successful renewal of the allée it would be also worthwhile to dedicate a thought to the revitalization of the maintenance of the area by pasturage.

Figure 6. *Once, the pasturage by sheep played an enhanced role in the maintenance of the Széchenyi lime tree allée, which still appears to be a good solution after its renewal. (around 1930, source: http://www.szikszi.sulinet.hu/nevado/szechenyi.htm)*

Materials and methods

In spring 2010 we made a site visit. At that time it was obvious that the majority of the old specimens of the allée is in very poor health conditions, their branches breaking, decaying, many of them very close to complete degradation. During the years, numerous specimens died, indeed, many of them have already been replaced during the last decades. Thus, among the old trees of the allée we can find 30-50 years old specimens and even young timberlings planted a couple of years ago (*Fig. 7*). These substitutions make a rupture in the uniform picture of the allée. At some parts of the allée, scrubs growing adjacently or spontaneously between the trees represent a competition, which is a further threat to the older trees. The earlier treated, cement-solidified trees deteriorated even more, this procedure did not stand the test of time. The old, sick trees are doomed to a total degradation unless professionally taken care of.

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

Even a good tree care and treatment could do nothing but extend this agony and this work could only be carried out at very high costs, with the contribution of well-experienced experts during the course of many years. By contrast, the condition of the allée shows that there has been no substantial and professional maintenance work carried out for years.

Figure 7. *In some parts of the allée there is an ensemble of trees in good condition or decaying old ones, as well as healthy young plants and empty tree spaces (photo: L. Gerzson)*

The renewal of the allée is not to be delayed on the one hand because of the condition of the trees – in many cases standing close to total degradation – on the other hand due to the long time required for the renewal. The renewal of the allée can namely only be accomplished in a way that protects the spirituality, the “genius loci” manifested in the individual trees and in the allée as a whole, so that it can be experienced and perceived by everyone. This requires a renewal program that takes on the spirituality.

The spiritual background or the basis of the renewal program is that these very old, even in their degradation beautiful trees “have seen” the Széchenyis, when these took a walk there, passed by, rode their horses along and among the trees, and at the sight of the imposing allée you can feel the spirituality of the masterminds Ferenc and István Széchenyi. Thus the renewal of the allée can only be conceived with the salvage of this “wood material”. And since the characteristics and environmental conditions of the landscape have not changed considerably, the small-leaved lime will still find here a favourable habitat and living conditions, although there is no doubt that the 20th century has brought important changes to the environment of the allée in many aspects. The intensive farming, the road and railway constructions and other works of similar scale have changed the groundwater flows and the groundwater level. The shoreline of the Lake Neusiedl has moved, compared to earlier times, much further to the north.

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

Although the allée has never been in direct contact with the lake, among many reasons due to the terrain conditions, but between the small grove terminating the allée and the shore there was only a distance of a few hundred meters, while nowadays it can be measured in kilometers. On the place of the former fishing colonies' activity, one can find roads, buildings, extensive reed beds and agricultural areas. It is quite certain that this ecological change has also contributed to the acceleration of the degradation process of the trees in the allée. There is no question however that the current environmental conditions are suitable for the survival of the small-leaved lime in this region, thus the allée planted with this species does not only have a past and a present, but a future as well.

During the renewal of the allée we can still count on appropriate habitat conditions for the lime trees, which means that there is absolutely no need to change the tree species. On the contrary, the necessary nursery propagation material for the renewal has to be produced from the here already present original plant species.

We have sized up and registered the existing plant stand of the allée in spring 2011. The registration took into account almost the whole length of the 2.3 km long Széchenyi allée, only omitting the short final segment, originally of a different planting system, where due to the forestation and the maintenance failures the place original trees and even the line of the allée can hardly be found. During the survey, we divided the double allée to an even (eastern) and an odd (western) side, the numbering started from the castle's (southern) side, and occurred along two principles: firstly the original planting spaces were numbered, then the "inter-plantations" which were implemented later (between the original tree spaces). We also numbered the original places even in the case when the tree itself on it had died or was not recognizable. Thus, at last, the tree cadastre takes over the function of a tree- and tree spot cadastre. During the definition of the original planting space, the former information (Rapaics, 1940) was very helpful, which revealed that the trees had originally been planted at a 4 fathom distance from each other. It is however important to mention – and this could also add some important detail to the studies investigating the historical context of the plantation – that the real spacing distance grew northwards, and thus based on the spacing distance the allée can be divided into three segments. We also verified the 12 fathom line spacing known from the literary source with on-site measurements.

Next to the number in the cadastre we indicated if the given specimen is still a living, existing one, if it was inter-planted, we also indicated its location by the distance measured from the next living specimen with original spacing preceding it in the number list. The estimation of the tree ages accurate to five years was also entered into the cadastre, and to the most probably originally planted specimens we indicated 250 years uniformly. Based on the health status we classified the living plants into 6 categories, where 1 stands for healthy free-growing specimens and 6 for those that only live on through their offshoots (*Table 1*).

Table 1. *Health status categories applied during the tree-survey*

Category	Meaning
1	Habit characteristic of the species, healthy
2	Canopy in good condition, partially truncated
3	Canopy in good condition, heavily truncated
4	Deteriorated status, truncated
5	Decaying
6	Decayed trunk, only root or stem shoots

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

We also included in the cadastre the trunk girth and diameter, as well as the canopy diameter, and we also added a lot of written comments with respect to the canopy, branch system and the trunk (*Table 2*). We find it necessary to complete the cadastre by a new on-site survey, which can help to record further weaknesses and defects of the trees in other vegetation periods and thus complements the already existing data. There is also a need for the further broadening of the initiated photo gallery.

Table 2. *A detail from the tree cadastre. The three consecutive specimens of the western allée: an inter-planted tree, a dead one and old one on its original spot.*

Number	Age	Health status						Trunk diameter / girth		Trunk status: straight
								4 cm	13 cm	
K87	15	1	2	3	4	5	6	Canopy diameter		Canopy status: one-sided
								1.0 m		
Distance	Comments:									
3.60 m	Place of ear tag:									
Number	Age	Health status						Trunk diameter / girth		Trunk status:
195		1	2	3	4	5	6	Canopy diameter		Canopy status:
Distance	Comments:									
	Place of ear tag:									
Number	Age	Health status						Trunk diameter / girth		Trunk status: cracks
								99 cm	311 cm	
197	250	1	2	3	4	5	6	Canopy diameter		Canopy status: heavily truncated, branches bending to the ground
								11.0 m		
Distance	Comments: mistletoe, shoots									
	Place of ear tag: at the bottom to the left									

The next step in the tree survey was the digitalization, where we aimed at the creation of such an overall (extendable and updateable) map database, which can be used for traditional (tabular) and map (polling) analyses for the planning of the reconstruction steps and schedule but would also be helpful for future maintenance. A significant role of the database is that it enables the documentation of the single stages of the reconstruction and the further management. For all this, a correct mapping was necessary, thus – in lack of a geodetic survey – we geo-referred the point-like entities to an aerial photo and placed all that into the Unified National Projection System (EOV) used in Hungary. This way this geoinformatic database can be confronted with earlier cartographic sources, so it can offer a basis for historical research. The major steps of the digitalization were the organization of the completed cadastre into a database of an appropriate structure, the insertion of the aerial photo with coordinates, the search for characteristic specimens and with their help the matching of the numbered points to the photo, finally the combination of the two systems. All this and the following data analysis have been carried out with the help of the MapInfo software for geoinformatics (Bede-Fazekas, 2011).

During the analysis we created thematic map sheets and the distributions according to the significant data were illustrated with diagrams (*Fig. 8*).

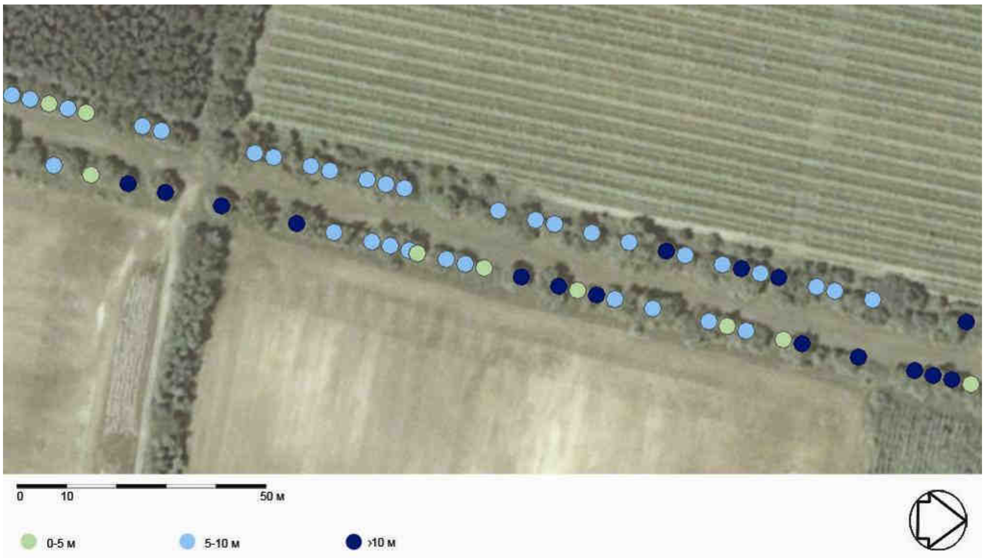


Figure 8. *One of the thematic map sheets of the allée divided into six segments, where we have regrouped the specimens standing at their original place into three categories based on to the canopy-diameter*

Results

From the surveyed 581 original spots altogether there are 327 originally planted living trees, the number of the inter-plantations is 193. Altogether we found 167 dead and 280 young specimens, certainly not planted at the outset, but they might have been renewed through the shoots of the original ones (*Fig. 9*). The inter-plantations occurred primordially in the southern segment.

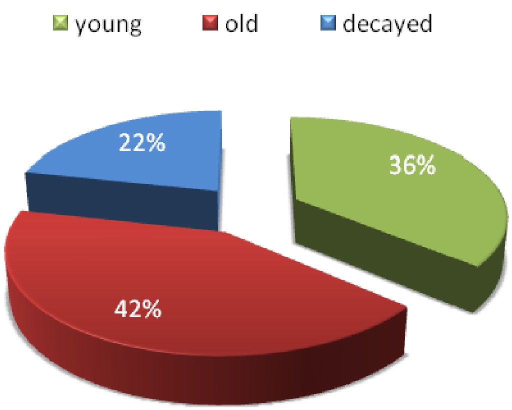


Figure 9. *The distribution of the (250 years) old, the young and the decayed specimens in the cadastre*

Interesting information of the age distribution is that 59% of the stand is from the original plantation, nevertheless only 1% is over 100 years, but under 250. Thus it can be stated about only a few specimens that they are of a late plantation. The trees between 41 and 100 (which are mostly the renewals from old ones through their shoots, thus genetically not uninteresting) make up for 5% of the whole stand, 29% of the trees is 11-40 years old, 6% 0-10 years old (*Fig. 10*). The distribution shows well that in the last years the need for the renewal of the allée has become obvious, which has been

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

carried out, in default of overall, long-term objectives (requiring drastic interventions) mainly with the planting of young saplings. On the southern segment there are more recently planted young specimens, but most of them are planted with an intermediate spacing. The odd (western) side shows a much more varied age distribution.

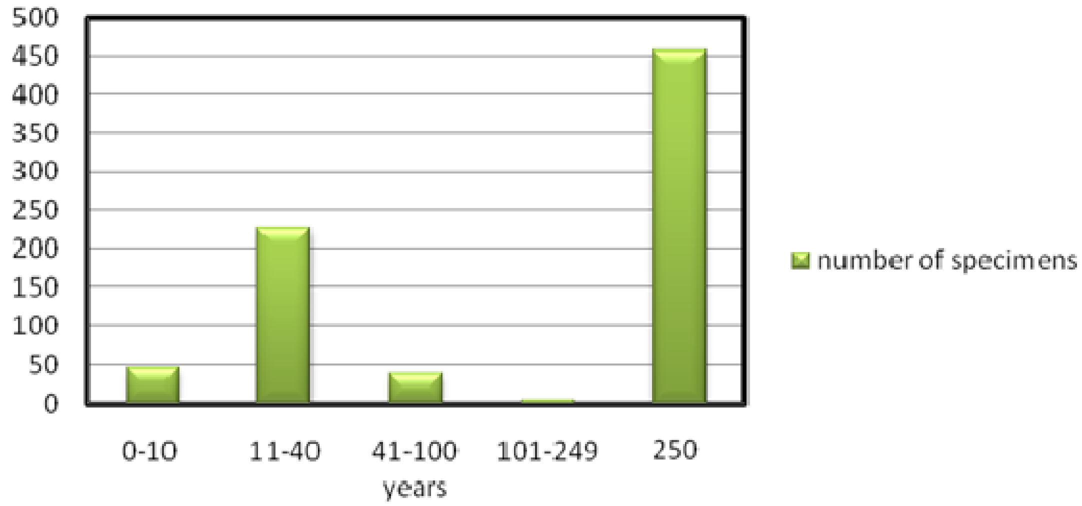


Figure 10. *The estimated age distribution of the inventoried trees. The category of 250 years also includes the already decayed trees (129 out of 456). The diagram also shows well the acceleration of the decaying of the original specimens.*

From the health status distribution it is important to highlight that the specimens classified into (the most valuable) category 1 make up for 10% of the whole stand. We have found an extremely high number of specimens in good condition north from the railway embankment (on both sides) and on the final segment (odd side). Beyond these the allée has a very mixed composition with respect to health condition, most specimens can be classified into the categories 2 and 4 (*Fig. 11*).

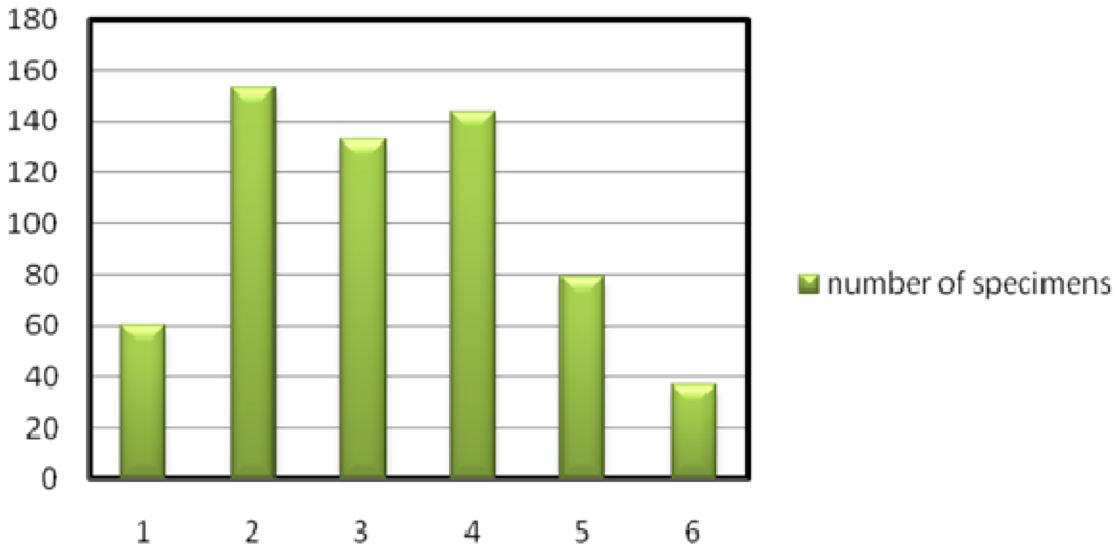


Figure 11. *Distribution of the six health status categories (meanings of the categories can be found in Table 1)*

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

The specimens with a canopy diameter under 5 m (young plants and suppressed specimens) account for 57% of the stand, while 14% of the surveyed trees had grown a canopy wider than 10.5 m. The majority of the latter acts as a solitary plant, growing in an open space, since its neighbours decayed or got covered by them (*Fig. 12*). 5% (37 specimens) of the complete strand grew a trunk with a diameter over 1 m. For the future reconstruction planning we have also prepared analyzing map sheets where we have also indicated the old, healthy specimens (classified into categories 1, 2, 3) standing at their original spot. The substitution of these is the least urgent, thus their distribution is not uninteresting.

Figure 12. *The neighbours died, so the No. 197 is growing as a solitary specimen (photo: L. Gerzson)*

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

It is important to highlight that south from the railway embankment, on the odd side we can find valuable specimens in large numbers, but next to the forest patches planted close to the allée, the old, healthy specimens are almost completely missing (*Fig. 13*), which can be explained by the disappearance of the open spacing and the free aeration in these segments. On the other areas we can mostly find a scattered distribution which does not underpin the idea of the spatially segmented renewal. The combined reconstruction lends itself as a possible alternative, by which the large part of the allée would be renewed in segments, but these tree specimens of good condition would remain as solitaries until the last planting operation of the allée-renewal, or until their unavoidable final decay.

Figure 13. *We projected the originally planted species of good condition (health status categories 1, 2, 3) on the aerial photo on this map sheet. Next to the oak patch on the northwest, there are but a few vital specimens, since this forest grew too tight on the allée.*

The analyses made it obvious that the allée, looking vital at the first sight, in reality decays continuously and at a very rapid pace (*Fig. 14*), so the removal of the trees' shoots, the cutting back of the branch system of certain specimens and the clearing of the trees' environment is a desperately urgent task. The limes tend to grow root shoots and stem shoots. Thus the removal of the shoots should be part of the usual yearly maintenance. This is easy to do with young shoots, along with the mowing of the lawn. This same question could be solved by pasturage as well. However, the removal of the now visible 5-10 years old shoots, often of a size of a smaller tree, is a serious task which has to be carried out with the appropriate precision (not too deep, nor to high). The shoots accelerate the weakening and decaying of the old trees, since the roots supply nutrients more easily to the shoots that are spaced closer and have young, healthy conducting tissues, than to the shoot tips in the canopy where they have to press them through the century-old tightened tissues.

Figure 14. *Before spring braird it is easy to see that the branch system of the old trees is without exception heavily truncated and constantly decaying. (photo: L. Gerzson)*

It is also a matter of urgency to clear out the various weed trees and especially to suppress the aggressively expanding forest growing onto the allée at places. The different planted forest patches – of acacia, sessile oak, turkey and sessile oak – at certain segments completely grew onto the allée and almost completely surrounded the trees of the allée at some places.

In 2012 the nursery propagation of the inventoried specimens from the original plantation has to be initiated. From every single specimen planted at the establishment of the allée 20-30 pieces of vegetative propagated offspring have to be produced in the nursery designated for this purpose. This is necessary so that in the future we can substitute the old specimens by their own progeny. We need a quite large number of progeny because during the several years long nursery raising the young trees might decay, get deformed, and all the specimens that are left over, as a so called surplus, can be sold at an elevated price due to their special ideal value (Gerzson, 2011).

The replacement of the allée can be done in one step or in stages. For the substitution conducted in one phase it is necessary to designate a final deadline based on a merely professional planning (on our opinion around 20-25 years), by which the complete replacement has to be carried out. By then, the previously propagated specimens in the nursery cold grow into substantial trees and could lend themselves for the substitution. This will probably meet a high resistance from many sides, so it can only be realized after a very profound and broad agreement. The other possible solution is to continuously substitute only the trees that just decayed or are close to derogation. Since the plantations at different times occur with trees of the same age and development stage, after the plantation – even if it takes decades – we would finally get a uniform allée, even though the nursery specimens which are replanted every 4-5 years develop more slowly than the ones growing undisturbed at their final position. In this case we will need to take care of the propagated specimens, their nursery maintenance and protection for decades (Gerzson and Szilágyi, 2011a).

The nursery growing of the trees might raise a number of questions. Since we are talking about a seedling population, it might happen that the growth vigour of the propagated clones will be very different. This is why, from a purely practical point of view, we need to look at the possibility of a renewal of the allée only based on the clones of some (5-15) old trees. This solution would of course significantly reduce the ideality behind the principle that says that by replacing the original trees with their own clones we could provide for certain continuity in the renewal of this value which we inherited from the historical past. Taking it further, an even more practical solution would be to use the vegetative propagated clones of one single specimen – the one with the nicest form and the best characteristics – to grow all trees for the replacement of the complete allée. This solution would result in the most uniform allée but in this case that might not be the most important priority (Gerzson and Szilágyi, 2011b)!

Discussion

The above outlined several decades long renewal program can only be imagined with a social and institutional collaboration. As a first step therefore the consultative board of the competent, the stakeholders and the experts need to be set up, the members, supporting members and seconders of which would come from the experts elaborating the allée renewal methodology, from the Academy founded by István Széchenyi, the managing Practicing Forestry, the competent (local and county) municipalities and main authorities (ministries, heritage and nature conservation inspectorate, national parks directorate). This panel (Consultative Board for the Széchenyi Lime Tree Allée) could perform its task after the approval of the renewal concept in the framework of the elaboration of a long-term action plan (for 20-30 years), then by directing and controlling its implementation. The above outlined reconstruction proposal is, due to its scale and the mentioned long time period an extraordinarily costly enterprise. This is why it is necessary that the association to be created works as a high level cooperation and assures the complete implementation of this enormous task with an accurate cost analysis and by finding the right funds. In this project, half-measures, half-completed plans would result in an impermissible loss of value.

The guideline of the renewal program was to safeguard and transmit the spiritual and genetic heritage manifested in the decaying, but still grandiose trees. By the vegetative propagation of the "historical tree stock" we can preserve and transmit an ornamental tree stand of a proven long lifetime. In Hungary no similar authentic allée renewal has taken place yet and we can't find any renewal of such scale and of such spiritual-cultural and scientific value neither among the examples abroad. We are convinced that the above outlined renewal methodology is a program that comes up to the remembrance of the Széchenyi family.

Acknowledgements. The financing of the research was supported by the TÁMOP-4.2.1/B-09/1/KMR-2010-0005 program.

REFERENCES

[1] Bede-Fazekas Á. (2011): A nagycenki hársfasor felvételezése és állapotának értékelése. − Workshop, Nagycenk (ppt presentation).

[2] Csima P., Módosné Bugyi I. (2003): A nagycenki hársfasor természetvédelmi kezelési terve. − In: Csemez, A. (ed) Száz éve született Ormos Imre. Szent István Egyetem Tájépítészeti, -védelmi és -fejlesztési Kar. Budapest. p.73-84.

[3] Földváry M. (1934): A nagycenki rezerváció és hársfasor. − Erdészeti Lapok 73(7): 597.

[4] Gerzson L. (2011): A nagycenki hársfasor megújításának lehetőségei és módszertana. − Workshop, Nagycenk (ppt presentation).

[5] Gerzson L., Szilágyi K. (2011a): Egy pusztuló műemlék – A nagycenki hársfasor megújításra vár. − Műemlékvédelem 15(1): 46-56.

[6] Gerzson L., Szilágyi K. (2011b): Gondolatok a nagycenki hársfasor állapotáról és megújításának lehetőségeiről. − 4D 6(21): 2-19.

[7] Kelemen I. (2011): Adatok a cenki kastélykápolna és remeteség történetéhez. − Soproni szemle, A Széchenyi család nemzedékei. 2011(2): 149.

[8] Örsi K. (1976): Nagycenk építéstörténete. − Műemlékvédelem (20): 6.

[9] Örsi K. (1992): Történeti kertek – A magyar kertépítészet legszebb alkotásai. − Ökotáj Kert (2): 6.

[10] Rapaics R. (1940): Magyar kertek. – Reprint: 1993, Magyar Könyvbarátok, Budapest.

[11] Rotenstein, G.E. (1783): Reisen durch einen Theil des Königreichs Ungarn, im 1763sten und folgenden Jahren. Erster Abschnitt. − In: Bernoulli, Johann: Sammlung kurzer Reisebeschreibungen und anderer zur Erweiterung der Länder- und Menschenkenntniß dienender Nachrichten. IX. Bey dem Herausgeber, Berlin-Leipzig.

[12] Soó R. (1973): A magyar flóra és vegetáció rendszertani−növényföldrajzi kézikönyve V. − Akadémiai Kiadó, Budapest.

REPRESENTING THE FOREST MANAGEMENT DILEMMAS IN THE ECOLOGICAL FOOTPRINT INDICATOR

TABI, A.* – CSUTORA, M.

Corvinus University of Budapest, Dept. of Environmental Economics and Technology
1093 Budapest, Fővám tér 8., Hungary

**Corresponding author*
e-mail: andrea.tabi@uni-corvinus.hu

(Received 7th November 2011; accepted 20th December 2011)

Abstract. Over the last decade the ecological footprint (EF) methodology has become widely used for estimating the biocapacity and the impact of human consumption in terms of global hectares. Although it represents a very impressive method for calculating the EF and biocapacity of an area, problems can arise regarding the incorporation of ecological factors into the calculation process. In this study we point out some problematic issues with use of the current EF methodology from an ecological point of view, taking as our focus forest biocapacity in Hungary. The EF concept ignores the differences in productivity of different species and forest types and their associated ecological values as well. We argue that the ecological 'quality' of different kinds of forests and tree species should be reflected in EF calculations in order to obtain a more accurate estimation of biocapacity. The presence of invasive and non-local species may reduce biodiversity and crowd out native tree species. As a result we distinguish between three main forest types (natural, cultural and energy forests) and additionally suggest the introduction of an additional parameter which refers to the 'naturalness' of the specified forest types. Results show a 15% increase in forest biocapacity when incorporating the naturalness factor.
Keywords: *ecological footprint, biocapacity, forest footprint, yield factor*

Introduction

The use of the Ecological Footprint (hereafter, EF) methodology that was introduced by Wackernagel and Rees (1996) has become more widespread in the literature as a defining measure of sustainability over the last decade. Ecological Footprint accounting has been designed to measure actual human demands for biological resources and the generation of wastes in terms of land area, which is then compared to the productive capacity of the land area in a given year (Kitzes et al., 2009). Despite the numerous advantages of the EF indicator, criticism has arisen concerning the evaluation methods on both the input and output sides (i.e. human demand on ecosystems and biocapacity).

The EF concept is basically a static measurement; it does not incorporate the long term impacts of different technologies or biodiversity or soil conservation measures. The most problematic issue with the EF indicator is that it does not capture land degradation (van Kooten et al., 2000). The footprint cannot take into account the harmful effects caused by intensive agricultural practices on soil, and so using it for comparisons of biocapacity is liable to generate erroneous results. In summary, the EF does not distinguish between sustainable and unsustainable land use (Fiala, 2008; van Kooten and Bulte, 2000; Bergh and Verbruggen, 1999; Kitzes et al., 2009; Mozner et al., 2011), and by not doing so, it fails to be of use in the calculation of one of the most important factors for sustainability.

The EF indicator very strong correlates with GHG-emission calculations, not surprisingly, as carbon uptake accounts for 50% or more of the entire footprint

(Fiala, 2008; van Kooten et al., 2000). This indicates that EF largely accounts for CO_2 emissions and does not include other crucial ecological factors.

In this paper we focus on the current use and methodology of the EF, which in turn creates a dilemma about sustainability in the case of forest footprint and biocapacity. We argue that the forest biocapacity calculations ignore differences in the productivity of different species and forest types and their ecological values, too. Ecological values of different kinds of forests and tree species should be reflected in the EF calculation so as to obtain accurate estimates of the biocapacity of an area - which should also reflect carrying capacity which is influenced by different forest management practices. An assumption is made that the current EF method does not represent the actual ecological value of a forested land area, and thus is not an appropriate sustainability indicator for using in forest management.

Calculating forest biocapacity and forest footprint

According to the methodology specified by Kitzes et al. (2008) there are only three factors required to calculate national forest biocapacity: the given forest area in national hectares, the yield factor and an equivalence factor for forests:

$$\text{Biocapacity (gha)} = \text{Area (nha)} * \text{YF (wha/nha)} * \text{EQF (gha/wha)} \qquad \text{(Eq.1)}$$

Biocapacity, as well as forest footprint, is accounted for in global hectares (gha) which are a hypothetical measure used to facilitate comparison of the environmental deficit/surplus of different nations. The yield factor (YF) and equivalence factor (EQF) are the most crucial points in the calculation methodology. The yield factor expresses the relative productivity of national hectares (nha) compared to world average hectares (wha). This proportion is calculated every year for each land type. Forest yield factor identifies the roundwood equivalent produced.

The equivalence factor measures the relative productivity of world average hectares of different land types, which as a constant variable does not change over time and is the same for all countries. The equivalence factor is the ratio of the average suitability index for a given land type divided by the average suitability index for all land types. For the concrete measurement of different land types, suitability indexes are derived from data from Global Agro-Ecological Zones combined with the information available at FAOSTAT. Five categories are used to evaluate the quality of cropland, forest and grasslands (*Table 1*).

Table 1. *Land ranking by suitability (source: Kitzes et al., 2008)*

Land quality	Suitability score	Land type
Very suitable	0.9	cropland
Suitable	0.7	forest
Moderately suitable	0.5	forest
Marginally suitable	0.3	forest
Not suitable	0.1	grassland and shrub

Behind the idea of EQF a very clear assumption is made; namely that the most productive land must be used in the most productive way. In this context the most ‘productive use’ is agricultural. Forests may only be ranked as being either ‘suitable’ or ‘marginally suitable’ land areas, according to the specifications.

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

The forest footprint explained by the Global Footprint Network (GFN) guidelines (Kitzes et al., 2008) embraces the human usage of different wood products as raw materials for primary products, which include fuels and also secondary timber products. The final forest footprint area indicator is supposed to represent the world average forest land area needed to meet demand for wood.

To calculate the forest footprint the annual amount of harvested wood is compared with the net annual growth rate of the world's forests and is then multiplied by the equivalence factor, as shown below:

$$EF = \frac{P}{Y_W} \cdot EQF \quad \text{(Eq.2)}$$

Where:

EF Ecological Footprint associated with product or waste (gha)
P amount of product extracted or waste generated (t/yr)
EQF equivalence factor for given land type (gha/wha)
Y_W world-average yield for product extraction or waste absorption (t/wha/yr).

The GFN calculation (Kitzes et al., 2008) of global and country specific forest yields (i.e. net annual increments) rely on data from the FAO Temperate and Boreal Forest Resource Assessment, FAO's Global Fibre Supply Model, and on IPCC accounting methodology.

Issues with the calculation method

Although at first glance EF methodology delivers a very impressive tool for calculating the ecological production load of in terms of physical indicators (using an obvious and comparable unit suitable for use even in decision-making processes), some problematic issues arise concerning calculated biocapacity.

Estimating the ecological footprint basically means collecting data on production, import and exports of roundwood or its equivalent. Assessing biocapacity at the national level is more challenging because the impact of biocapacity on humans and entire ecological networks has not been defined. The indirect impacts of ecosystems on our lives are not taken into account, and by ignoring them a lot of additional benefits may go uncounted. Apart from this caveat, there are some problematic methodological concerns with the current method of calculating biocapacity:

1. The EQF suggests that the conversion of forest area into agricultural land would be more favourable because it would increase biocapacity in the calculation
2. The calculation method using the yield factor favours fast-growing invasive species which can outcompete slower growing native tree species
3. EQF does not take into account the ecological value of a forest area
4. The yield factor does not reflect yields derivable from different forest types (e.g. energy forest versus natural forests).

Issue 1

The equivalence factors used in the calculations of EF for Hungary are shown in *Table 2*. It can be observed that the biocapacity of cropland is twice as high as for forest land, which suggests that if all forest areas were converted into cropland biocapacity

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

would be two times as high. This outcome is a logical extension of the initial assumption; namely that the ‘most suitable’ land areas should be used to produce food.

Table 2. *Equivalence factors for different land types (source: Kitzes et al., 2008)*

Land type	EQF (gha/wha)
Cropland	2.6441
Forest	1.3326
Grazing land	0.4965
Marine	0.3972
Infrastructure	2.6441
Inland Water	0.3972
Hydro	1.0000
Carbon	1.3326

Issue 2

The yield factor compares the national yield to the average world yield of roundwood, which practically implies that tree species with a short growing period are preferable for their use in industry. This technical implication also suggests that the presence of invasive species has a favourable effect on biocapacity. According to calculations the logging of alien species increases biocapacity more than natural native species. Several studies have shown that invasive species have a negative impact on native ecosystems by decreasing biodiversity and changing soil nutrient cycling processes (Koutika, 2011).

The main native tree species in Hungary such as oaks (*Quercus petraea, Quercus robur, Quercus pubescens*), beech (*Fagus sylvatica*), elm (*Ulmus sp.*), maple (*Acer sp.*), ash (*Fraxinus sp.*), and hornbeam (*Carpinus betulus*) have been already outcompeted by alien species such as *Prunus serotina*, *Robinia pseudacacia*, *Ailanthus altissima*, *Impatiens glandulifera*, *Asclepias syriaca*, *Ambrosia artemisiifolia*, *Fallopia×bohemica*, *F. japonica*, *F. sachalinensis,* etc. In Hungary, approximately the one fourth of woodland area is now composed of non-native *Robinia pseudoacacia*, which has become one of the most critical ecological problems. This North American species was introduced into Hungary as a planted tree for use in hedgerows, shelter belts, etc. in the first half of the 18th century. After a while it became widespread in lowland sandy and loess soil regions exposed to wind and rain erosion. Unfortunately, the areas occupied by *Robinia* have continuously increased, and nowadays *Robinia* takes the largest share of woodland area in Hungary (*Table 3*), thus the black locust is also the most widespread tree species in Hungary (Balogh, 2008).

In most cases *Robinia* occupies ‘suitable’ land as well, crowding out native tree species. Reversion of these areas to a pre-*Robinia* state is difficult due to financial constraints. Species like *Robinia* essentially change the characteristic features of the conquered community or landscape through changing the structure of the soil. For instance, *Robinia* and *Ailanthus* have nitrogen-fixing bacteria on their root systems thus they can easily grow on poor soils and spread quite quickly, thereby increasing the rate at which other nitrogen loving plants (mainly weeds) can grown as well.

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

Table 3. *The spread of different tree species in Hungary (source: KSH, 2011)*

Tree species	Forest area (ha)	Proportion (%)	Tree stock capital (thd m^3)	Proportion (%)
Quercus sp.	388 186	21%	84 134	23%
Quercus cerris	206 319	11%	45 212	13%
Fagus sp.	110 026	6%	39 404	11%
Carpinus betulus	95 611	5%	17 277	5%
Robinia pseudoacacia	446 832	24%	48 090	13%
Other leafy hardwoods	105 177	6%	19 303	5%
Populus sp.	197 227	11%	28 444	8%
Other leafy softwoods	99 746	5%	23 137	6%
Pinus sylvestris	124 010	7%	34 872	10%
Pinus nigra	64 650	3%	11 906	3%
Other Pinus sp.	24 219	1%	7 286	2%
Total	1 862 002	100%	359 065	100%

Issue 3

The value of protected forests is not represented in calculations because they are not used for roundwood production. In Hungary in 2010 about 20% of forest land was under protection (KSH, 2011). These forests are not used for roundwood production; in other words, these areas are ignored in EF and biocapacity calculations. Nevertheless they are very valuable from an ecological perspective (as biodiversity refugia). Biodiversity is also not included in any part of the footprint or biocapacity calculations which is another failure of the EF concept. According to a recent mapping of natural habitats in Hungary conducted by the Hungarian Academy of Sciences, the NCI (Natural Capital Index) of the country (which indicates the land area covered by natural or semi-natural vegetation) amounts to 17%. The remaining 83% land area is covered by agricultural fields, forestry plantations and settlements (Czúcz et al., 2008).

Issue 4

As a result of the intensive afforestation efforts of the last 50 years in Hungary, newly introduced species such as the black locust, scots pine, and improved poplars were widely planted and forest area increased by 50% (Szepesi, 1998). For this reason, one should distinguish between native and alien forest types because from an ecological perspective as well as from an industrial (wood as raw material) perspective they do not provide equivalent yields. As yields in fact change for different forest types, in order to improve the current EF calculation method we consider 3 forest types:

- naturally developed mixed-age forests, with mostly native tree species
- culture forests, with mostly non-native or site-foreign tree species
- forest plantations or energy forests, planted to produce fuel (biomass).

Not ecological, but rather forest management considerations are reflected in this grouping of forest types which clearly differ from each other. The average yield of an energy plant depends on several factors (such as cutting age and the density of plantation) but average annual yields are 3-4 as much as for naturally developed, mixed-age forests where average annual yields are between 3-4 t/ha. Culture forests consist of mainly invasive or site-foreign tree species. They are often dominated by one tree species which is contemporaneous, tree stock capital which has outcompeted the native

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

tree species. The original flora is entirely or substantially altered; often the habitat has changes over the long term (Ódor, 2011).

Forest plantations are grown primarily for roundwood production. Energy forests are also special targeted short rotation forests which are grown mainly for biomass production (*Table 4*). Traditional forest management cannot deliver an equivalently high energy yield (15-20 GJ/ha/year). Energy forests are planted with a higher density of trees (8-15 thousand trees/ha) which are cut at 3-4 years of age. The lifetime of such an energy forest is about 20 years, with a total energy yield of 150-250 GJ/ha/year (Marosvölgyi, 2004). Energy forests are mostly planted on floodplains or non-usable agricultural areas.

Table 4. *Typical yields of short rotation energy forests in Hungary (source: Bai et al., 2006)*

Tree species	Cutting age (year)	Yield (t/ha/year)
Robinia pseudocacia	2	11.4
Robinia pseudoacacia	4	11.7
Ailanthus altissima	5	12.95
Salix sp.	3	20.67
Salix sp.	3	13.67

In Hungary, natural forests usually contain 5-15 main tree species of which the most important and widespread are the *Quercus* and *Fagus* species. In the wood industry beeches and oaks provide the most suitable hardwood materials. The age of cutting of beech and oaks under natural circumstances would be 80-150 years, depending on the trees state of health and habitat.

Recommendation

The average afforestation level at the European Union level is about 40%; in Hungary it is 22%, falling in at 22nd place among EU countries in 2010 (Eurostat, 2011). As mentioned in the previous chapter, one should remember that this does not imply that the proportion of afforested area is equivalent to the ecologically valuable land area, or in other words, to the quality of forest area.

In Hungary the 'naturalness' of forests, according to a survey conducted in 2005, is estimated at being 57.6% of all woodlands. Naturalness of forests is defined using two main features:

- the degree of nativity,
- the site-nativity of tree species.

The proportion of site-foreign, but native forests in Hungary is 51% and alien forests 38.7% of total forest area (Bartha et al., 2005). In order to calculate the actual national yield we have to take into consideration the difference between forest types in roundwood yield and their ecological value. Almost half of all wooded areas are under private ownership, the proportion of state-owned forests is 55.6% and only 40% of them are under protection (KSH, 2010). In our domestic forests approximately 13 million m^3 of roundwood per year is produced (through natural renewal) and about 10 million m^3 (about 7.5 million tones) can be produced in a sustainable way. In the last decade logging accounted for 7 million m^3 per year (about 5.3 million tones) (Magyar Agrárkamara, 2011). The sustainable rate of logging should not exceed 4.027 t/ha. The

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

actual logging rate for Hungary (for all tree types) was only about 2.84 t/ha over the last decade, which is regarded as being considerably less than the sustainable forest management limit. *Table 5* shows the average roundwood yield by tree type produced in all naturally or semi-naturally developed forest area, divided by forest land area.

Table 5. *Roundwood yields(t/ha) by tree type (source: KSH, 2011)*

Tree species	2004	2005	2006	2007	2008	2009	2010
Quercus sp.	2.157	2.238	2.146	1.973	2.097	1.883	1.958
Quercus cerris	3.519	3.375	3.289	2.834	3.155	3.153	3.143
Fagus sp.	4.643	4.526	4.099	4.095	4.322	4.618	5.661
Carpinus betulus	2.536	2.568	2.494	2.251	2.325	2.348	1.984
Robinia pseudoacacia	2.850	2.662	2.513	2.149	2.511	2.570	2.805
Other leafy hardwoods	1.564	1.556	1.612	1.376	1.388	1.397	1.422
Populus sp.	2.906	2.853	2.600	2.397	2.385	2.217	2.249
Other leafy softwoods	1.200	1.105	1.164	1.113	1.099	1.091	1.052
Pinus sp.	1.702	1.534	1.607	1.631	1.748	2.191	2.214

Since the naturally and semi-naturally developed, mixed-age forests mostly contain oaks, beech, hornbeam and some other alien species, we consider the yield of natural forest to be about 4 t/ha per annum, which is also the limit of sustainable forest management in Hungary.

For forest plantations and energy forests the annual yield cannot be unambiguously defined because it depends on the age of cutting of the tree and other external factors as well. Thus we calculate using the average amount of roundwood produced, which is approximately 12 t/ha per annum.

Table 6 shows the naturalness of forest land by the six main geographical regions of Hungary.

Table 6. *Naturalness of forests by forest type (source: Bartha et al., 2005)*

Forest types	Naturalness (%)	Description
Potential natural forests	62-50.6	Beech forests, sessile oak-hornbeam forests, sessile oak-turkey oak forests, forest steppe woodland, etc.
Culture forests	40.5-31.1	*Robinia pseudoacacia, Pinus nigra, Pinus sylvestris, Populus x euramericana, Quercus rubra, Juglans nigra*
Energy forests	0	*Robinia*, Poplar clones

These data are based on the results of forest mapping conducted in Hungary in 2005. The degree of naturalness refers to the content of tree species and their nativity and site-nativity as well. In our calculations we used the average value of each forest type and introduced a naturalness factor in order to reflect the quality of forests from an ecological point of view. We set the range of naturalness at between 1 and 2, where the highest value of naturalness would effectively double the amount of biocapacity. The value is 1 when the forest makes no real ecological contribution to habitat (so a designation of '1' does not change the final outcome).

Table 7 shows two estimations of forest biocapacity; the first was carried out by GFN and the second one is the authors' estimation using a modified yield factor and naturalness factor by forest type.

Table 7. *Estimation of biocapacity for Hungary, 2005 (source: Kitzes et al., 2008; Bartha et al., 2005)*

2005	National yield (t/ha)	World average yield (t/ha)	Yield factor	Modified yield factor	Area (ha)	EQF	Naturalness factor	Biocapacity (ha)
GFN estimation								
Forest biocapacity	4.96	2.36	2.101	-	1 780 217	1.33	-	4 976 159.11
Authors' estimation								
Natural forests	4	2.36	1.694	4	657 782	1.33	1.563	2 317 611.26
Culture forests	4	2.36	1.694	4	1 120 935	1.33	1.358	3 431 467.02
Forest plantations	12	2.36	5.084	12	1 500	1.33	1	10 144.07
Total					1 780 217	-	-	5 759 222.35

So far, only about 1500 hectares of land have been occupied by energy forests, but according to calculations 100 000 hectares area could be used for producing fuel. Introducing the new factors has increased forest biocapacity by 15% in Hungary.

Summary

The EF concept and calculation procedure are open to criticism and it can be concluded that the EF should not be used as a comprehensive sustainability indicator, especially from an ecological point of view. The current method fails to capture a number of important sustainability issues, mostly because it captures natural resources in a static snapshot and does not pay attention to the dynamics of natural processes.

Ecological aspects are not reflected in calculations of biocapacity at all. If we aggregate roundwood production and divide this by the entire wooded area, both the source of the roundwood and also the ecological values of the separate elements of the forest are lost, and by doing so, the measurement of sustainability fails.

In this piece of research the introduction of a new factor is suggested as an additional parameter required capturing the ecological values of different forest types. We consider that the naturalness of forests should be incorporated into EF calculations so that one of the most important ecological factors is incorporated in the calculation. However, further research needs to be done on other important factors (e.g. quality of forest soils) which influence the ecological quality of forests in order to obtain a more sophisticated – and accurate – estimation of forest biocapacity.

Acknowledgements. The research described herein was financed by TÁMOP-4.2.1/B-09/1/KMR-2010-0005 project.

REFERENCES

[1] Bai, A., Ivelics, R., Marosvölgyi, B. (2006): A rövid vágásfordulójú nemesnyárból előállított apríték gazdasági vonatkozásai – In: Az alternatív energiaforrások hasznosításának gazdasági kérdései. Sopron, Nyugat-magyarországi Egyetem Közgazdaságtudományi Kar

[2] Balogh, L., Dancza, I., Király, G. (2008): Preliminary report on the grid-based mapping of invasive plants in Hungary – In: Rabitsch, W., Essl, F., Klingenstein, F. (Eds.) Biological Invasions – from Ecology to Conservation. NEOBIOTA 7 (2007): 105-114.

[3] Bartha, D., Bodonczi, L., Szmorad, F., Aszalós, R., Bölöni, J., Kenderes, K., Ódor, P., Standovár, T., Tímár, G. (2005): A magyarországi erdők természetességének vizsgálata II. (downloaded at: http://ramet.elte.hu/~ramet/project/termerd/2EL2005%20Bartha.pdf)

[4] Czúcz, B., Molnár, Zs. , Horváth F., Botta-Dukát, Z. (2008) The Natural Capital Index of Hungary – Acta Botanica Hungarica 50(Suppl.): 161-177.

[5] EUROSTAT (2011): Statistical database
http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=lan_lcv_woo&lang=en)

[6] Fiala, N. (2008): Measuring sustainability: Why the ecological footprint is bad economics and bad environmental science – Ecological Economics 67: 519-525.

[7] Kitzes, J., Galli, A., Rizk, S.M., Reed, A., Wackernagel, M. (2008): Guidebook to the National Footprint Accounts. – Oakland: Global Footprint Network.

[8] Kitzes et al. (2009): A research agenda for improving national Ecological Footprint accounts. – Ecological Economics 68: 1991-2007.

[9] Koutika, L-S., Rainey, H.J., Dassonville, N. (2011): Impacts of Solidago gigantea, Prunus serotina, Heracleum mantegazzianum and Fallopia japonica invasions on ecosystems – Applied Ecology and Environmental Research 9(1): 73-83.

[10] KSH (2010): Statisztikai Tükör – Erdők Magyarországon IV. évfolyam 75. szám

[11] KSH (2011): Statistical database (downloaded at:
http://portal.ksh.hu/pls/ksh/docs/hun/xstadat/xstadat_eves/i_ome002b.html)

[12] Magyar Agrárkamara (2011): (downloaded at:
http://www.agrarkamara.hu/%C3%81gazatiinform%C3%A1ci%C3%B3k/Erd%C5%91vad%C3%A9shalgazdas%C3%A1g/Erd%C5%91gazd%C3%A1lkod%C3%A1s.aspx)

[13] Marosvölgyi, B. (2004): Magyarország biomassza-energetikai potenciálja. – Energiagazdálkodás 45(6): 16–19.

[14] Mózner, Z., Tabi, A., Csutora, M. (2011): Modifying the yield factor based on more efficient use of fertilizer - The environmental impacts of intensive and extensive agricultural practices – Ecological Indicators, doi:10.1016/j.ecolind.2011.06.034

[15] Ódor, P. (2011): Kulturterületek
(downloaded at: http://ramet.elte.hu/~ramet/staff/Op/vegetacio/kulturteruletek.pdf)

[16] Szepesi, A. (1998): Forest Health Status in Hungary. – USDA Forest Service Gen. Tech. Rep. PSW-GTR-166.

[17] Van den Bergh, J.C.J.M., Verbruggen, H. (1999): Spatial sustainability, trade and indicators: an evaluation of the ecological footprint. – Ecological Economics 29: 61-72.

[18] van Kooten, G. Cornelis, Bulte, Erwin H. (2000): The ecological footprint: useful science or politics? – Ecol. Econ. 32: 385-389.

[19] Wackernagel, M., Rees, W. (1996): Our Ecological Footprint: Reducing Human Impact on the Earth. – New Society Publishers, Gabriola Island.

COMPARISON OF BUDBURST MODELS PREDICTIONS FOR KÉKFRANKOS

HLASZNY, E.[1]– HAJDU, E.[2]– BISZTRAY, GY.[3]* – LADÁNYI, M.[1]*

[1]*Corvinus University of Budapest, Dept. of Mathematics and Informatics*
1118 Budapest, Villányi út 29-43., Hungary
(phone: +36-1-482-6261; fax: +36-1-466-9273)

[2]*Corvinus University of Budapest, Institute for Viticulture and Oenology,*
Research Station of Kecskemét
6000 Kecskemét, Katona Zsigmond. u. 5., Hungary
(phone: +36-76- 483-311; fax: +36-76-501-432)

[3]*Corvinus University of Budapest, Institute of Viticulture and Oenology, Dept. of Viticulture*
1118 Budapest, Villányi út 29-43., Hungary
(phone: +36-1-482-6283; fax: +36-1-466-4650)

**Corresponding authors*
e-mail: marta.ladanyi@uni-corvinus.hu
gyorgy.bisztray@uni-corvinus.hu

(Received 11th November 2011; accepted 5th December 2011)

Abstract. Modelling the budburst dates are vital tools in viticulture, amongst others, for learning the response of the plants to climate change. We compared two budburst date models for Kékfrankos, the most important red variety of Hungary. The one is based on the accumulated effective heat sum with optimized starting date. The other one considers also the chilling effects and predicts the date of dormancy brake as well. The models were fitted and validated on phenological observations from 1977-2003 in a plain region of Central Hungary, Kecskemét. The optimization was made for the root mean square of the deviance between the predicted and the estimated dates measured in days.
Keywords: *Vitis vinifera L., Kékfrankos (Blaufränkisch), chilling effect, degree day, climate change*

Introduction

As temperature is one of the main driving factors of plant development processes, phenology scheduling of *Vitis vinifera* L. and its connection to climate change plays an important role in current studies (Penuelas and Filella, 2001; Walther et al., 2002; Khanduri et al., 2008). Budburst is an important ampelographic symptom. Every vine bud has one main bud and two side buds. The main buds break earlier as the side buds. In this work only budburst of main buds is studied.

Budburst is the beginning phenophase of grapevine vegetation period that depends on several climatic factors and genotype of the varieties. Budburst begins when some necessary (critical) biologically sufficient and necessary conditions are hold and contributes efficiently to the further development process of the plant. Thus, budburst can be a sensitive and well applicable indicator of clime change impact on the seasonal scheduling response of the plants which then have considerable ecologic and economic consequences.

When developing models one should decide which conditions should be considered as very important and which should be ignored in order to make the model as simple and as effective as possible. The suitability of the models is varying from varieties to varieties. Also the model parameters can be characteristic of varieties or sites.

Learning and forecasting the budburst dates are very important because we can deduce to the rate and probability of frost damage of the buds (Kramer, 1994a; Kramer et al., 1996). After budburst grape becomes sensible to chilly temperature, late spring frosts risk is high especially in May. The green sprouts can be injured even between -0.5 °C and -1 °C. If chilly temperatures after the expected budburst are forecasted, plant protection can more successfully be managed. Some pests, for example mites (*Eriophyes vitis* Pag., *Callepitrimerus vitis* Nal., *Tetranychus urticae* L.) and the fungus diseases (*Uncinula necator* (Schw.) Burr) spend the winter in the buds in great number and after the budburst they damage the young sprouts. Damages caused by these pests can be reduced if the budburst date is known and plant protection action is executed in the right time (Bognár, 1978).

There occurred some heat sum models even in the 1950s (Baggiolini, 1952) which were followed by intensive experimental and simulation work on the phenological responses of the plants on climatic effects (Hänninen, 1990, 1991, 1995, 1996; Hänninen et al., 1993). The late 1990s could bring significant improvement in modelling (Bonhomme, 2000; Chuine and Cour, 1999; Chuine et al., 1998, 2003). Chuine (2000) gives a pretty review and synthesis about the published models up to 2000 while a nice spatial and temporal comparison can be found in Cortázar-Atauri et al. (2009). In Hungary such kind of models are not yet in practice.

Several phenology models for the estimation of budburst dates are based on the wide accepted concept that budburst date of *Vitis vinifera* L. is mainly determined by the effective heat sum after the chilling effect in dormancy (Carbonneau et al., 1992; Jones, 2003; Jones et al., 2005).

According to this, dormancy can be separated in two periods: the first one is defined as the period when buds are dormant due to physiological conditions (endodormancy) and the second is when buds remain dormant just because of unfavourable environmental conditions (ecodormancy) (Lang et al., 1987; Cesaraccio et al., 2004).

In the literature there are several budburst models for different varieties and regions. The most of them agree in the concept of heat accumulation, i.e. the daily average temperature above a base temperature (mostly above 10 °C) is summed from a starting date. Budburst occurs when a critical threshold is reached (Moncur et al., 1989). This model can be regarded as the simplest model of budburst prediction with three parameters to calibrate: the starting date, the base temperature and the critical value to reach.

The simplest model can be refined from several aspects. Setting out from the average daily temperatures accumulation can be made as a linear or other (e.g. logarithmic) function (Oliveira 1998; Riou, 1994). The scale of accumulation can be chosen as daily or hourly steps (Cortázar-Atauri et al., 2005). In case hourly steps are applied detailed (observed or estimated) data on sunrise and sunset are needed. Then we can decide whether triangle, exponential or sine type approximation of the daily heat distribution is used (Spano et al., 2002). In several cases, however, highly sophisticated models do not fill the expected accuracy because of the great number of estimated parameters (Riou, 1994; Cortázar-Atauri et al., 2009).

The starting date of accumulation is of great importance, though the most widely used date is the 1st of January (Riou, 1994; Bindi et al., 1997 a,b). However, setting the starting date more precisely with optimization has a great advantage.

Chuine and Cour (1999) have investigated four temperate-zone tree species. Their results show that the more chilling units are cumulated in endodormancy, the earlier the ecodormancy starts and the less effective heat accumulation is needed for budburst. Several other researchers agree this (Nienstaedt, 1966; Farmer, 1968; Nelson and Lavender; 1979; Heide, 1993; Hänninen and Backman, 1994; Myking and Heide, 1995). Therefore the relationship between the length of the chilling period and the length of the forcing period required for budburst is important in predicting budburst timing.

Materials and methods

Our study was focused on Kékfrankos red wine variety. Its origin is uncertain, but according to Németh (1967) it belongs to the *Vitis vinifera* L. *convarietas orientalis subconvarietas caspica*. It spread mostly in Hungary. It can be found in most of the red wine-growing areas; moreover, Kékfrankos is a relevant variety in the most regions. It is the first amongst the regional hierarchy of the red wine varieties. Because of many valuable properties, Kékfrankos remains as a promising variety even in the future (Bényei and Lőrincz, 2005). It is winter hardy until -19 ºC.

The examined vineyard is in high cordon training system with Sylvoz pruning (Hajdu and Saskői, 2009). The phenology data we used came from the Research Institute for Viticulture and Oenology, Kecskemét. There were collected 20-years data between 1977 and 2003 with missing values in years 1980, 1987 and from 1993 to 1997. The experimental station is situated in South Great Hungarian Plain Region in Kecskemét, in the part of the Kunsági wine region. The observed vineyard is situated in north of Kecskemét towards Nagykőrös. In this region the soil is sandy with very low (below 1%) humus content (Pernesz, 2004). The ground-water is high (2-5 m) in general, but nowadays its diminution was experienced (Bényei et al., 1999). Its climate is continental. Drought summers, frosty cold winters, early frosts in autumn and late frosts in spring are very frequent in this region. (For example there is winter frost even with -21 °C detected at the Great Hungarian Plain in every third year as an average.) On scorching hot days sunburn and heat shock events of vine are common. The yearly average precipitation is 550 mm (1962-2004). It can usually be detectable about 100 mm yearly precipitation lack. Amongst the wine-growing areas the growing security is the worst here (Kozma, 1991).

Meteorological data with daily average temperatures are from the Hungarian Meteorological Service. For climate change impact study we applied RegCM 3.1 which was downscaled at Eötvös Loránd University, Department of Meteorology for A1B scenario (Bartholy et al., 2007, 2009, 2010; Torma et al., 2008). We considered three different time scales: 1961-1990 as reference period, 2021-2050 and 2071-2100 as prediction time intervals.

The Degree Days Model

We tried to find a relatively simple model that can estimate the budburst date of Kékfrankos from Kecskemét, Hungary in the time period 1977-2003 as accurate as possible.

The average daily temperatures above the base temperature were accumulated from a starting date up to the observed budburst in each year. Gladstones (2000) proposed that also an upper base temperature should be considered because the plant is unable to utilise the heat above a critical limit. For that purpose we also applied the upper base temperature as follows:

$$GDD_j = \sum_{i=start}^{budburst} \max\left[\left(\min\left(T_{aver\_i,j}, T_{upperbase}\right) - T_{lowerbase}\right); 0\right]$$

where:

$T_{aver\_i,j}$ denotes the daily average temperature in a year *j* and on a day *i*,

$T_{lowerbase}$ and $T_{upperbase}$ are the base temperature parameters.

The model indicates the budburst date when a critical sum denoted by GDD_{d_crit} is reached.

The Unified Model

The Unified Model is more sophisticated than Degree Days Model as it takes the information of the chilling effect into account (Chuine, 2000). In addition to breaking dormancy, chilling temperatures have an accelerating effect on bud growth. The more chilling effect indicates less degree days that are necessary to reach the budburst (Nelson and Lavender, 1979; Cannell and Smith, 1983; Murray et al., 1989; Kramer, 1994b; Chuine et al., 1999). Thus we distinguish the chilling (*CH*) and the forcing (*F*) effects and define them dimensionless as:

$$CH_j = \sum_{1.Sept.}^{t_j} \frac{1}{1 + \exp\left(a\left(T_{aver\_i,j} - T_{base,CH}\right)^2 + b\left(T_{aver\_i,j} - T_{base,CH}\right)\right)}$$

$$F_j = \sum_{t_j}^{budbreak} \frac{1}{1 + \exp\left(c\left(T_{aver\_i,j} - T_{base,F}\right)\right)}$$

where:

a, b, c are empirical parameters,

$T_{aver\_i,j}$ denotes the daily average temperature in a year *j* and on a day *i*,

$T_{base,CH}$ and $T_{base,F}$ are base temperature parameters regarding the chilling and forcing effects, respectively,

t_j is the point of time when the required chilling effect (CH_{crit}) is fulfilled in a year *j*.

At this point the model indicates the end of the endodormancy and the heat accumulation of F_j sets off. Budburst date is highlighted by the model when the required effective heat sum GDD_{u_crit} is reached.

The range of the chilling and forcing functions is the interval]0,1[. The shape of the chilling effect function is a curve with a peak at the point where the chilling effect is optimal and limits of zero as tending to positive or negative infinity; while the forcing function has a sigmoid type curve (*Fig. 1*).

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

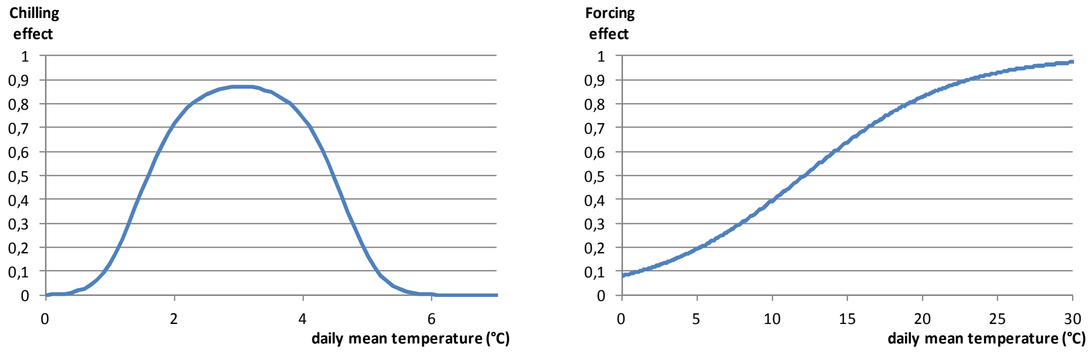


Figure 1. *Chilling and forcing effect characteristic curves*

In *Fig. 2* we can see the chilling and forcing effect accumulation process in a randomly chosen year. The horizontal lines are for the chilling (CH_{crit}) and forcing (GDD_{u_crit}) accumulation criteria. The vertical lines are for the model predicted date of dormancy break and date of budburst, respectively.

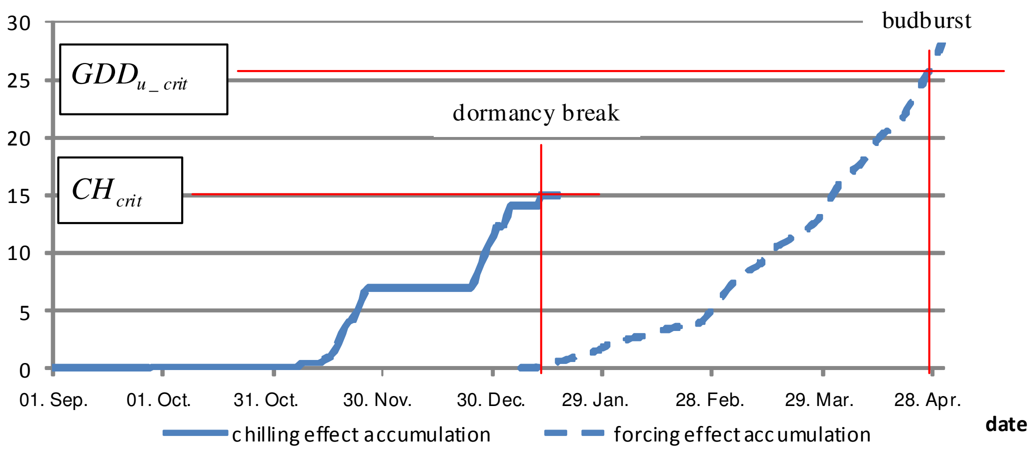


Figure 2. *Chilling and forcing effect accumulation during the dormancy and after the dormancy break in an arbitrary chosen year. At the point of time when the required chilling effect is fulfilled, the model indicates the end of the endodormancy and heat accumulation sets off. Budburst date is highlighted by the model when the required effective heat sum is reached.*

Fitting and validation procedure

The available dataset was split into two parts: data of 10 years were used for calibration while the remaining ones for validation.

The root mean square error (RMSE) was defined as the root of the average sum of the squares of the differences between the observed (BB_{obs}) and estimated budburst dates BB_{pred} measured by days:

$$RMSE = \sqrt{\frac{1}{N}\sum_{j}\left(BB_{obs} - BB_{pred}\right)^2}$$

where *N* denotes the number of years. In case of Degree Days Model RMSE was minimized while both the base temperatures $T_{lowerbase}$ and $T_{upperbase}$ and the starting

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

date together with the critical value GDD_{d_crit} were varied. For optimization we used Palisade's Risk Evolver that is based on innovative genetic algorithm (GA technology), a stochastic directed searching technique with several thousands of iteration. This method does not get stuck at local solutions, but instead looks at the entire range of possible solutions which enables us to find the global optimal solution instead of a local extreme value (Weise, 2009).

For Unified Model again the root mean square error was minimized with innovative genetic algorithm while seven parameters namely *a, b, c*, $T_{base,CH}$ and $T_{base,F}$ as well as CH_{crit} and GDD_{u_crit} were varied in the parameter space.

Regional climate model prediction survey

The calibrated and validated model was run with input coming from the regional climate model RegCM 3.1 for three time intervals: 1961-1990 as reference period, 2021-2050 and 2071-2100 for prediction. We calculated the distributions of the budburst date predictions for these three time intervals and compared them with one-way ANOVA. Variance homogeneity was checked with Levene test. Post Hoc test was made by Tukey test. The error terms and the distributions were fitted to normal distribution with Shapiro-Wilk test using @Risk of Palisade. Finally we compared the fitted distributions.

Results and discussion

The optimized parameters of the Degree Days Model and the ones of the Unified Model can be found in *Table 1*. The error terms are normally distributed (p=0.08; p=0.42).

Table 1. *The optimized parameters of Degree Days Model and the ones of the Unified Model*

Degree Days Model		Unified Model			
		Chilling effect		Forcing effect	
starting Julian day (day)	47	a	1	c	-0.20
$T_{lowerbase}$ (°C)	4.54	b	2.65		
$T_{upperbase}$ (°C)	18.4	$T_{base,CH}$	4.58	$T_{base,F}$ (°C)	12.11
GDD_{d_crit} (°C)	260	CH_{crit}	14	GDD_{u_crit} (°C)	25

We judged the Unified Model as a better tool for estimation as the RMSEs, the mean and the absolute error values are considerably smaller in case of this model (*Fig. 3*). The explained variances (R^2) are significant for both models ($p<0.05$), the ones of Unified Models are higher. Moreover, for the model validation any of the four values (RMSE, mean error, absolute error, R^2) worse significantly compared to the calibration results.

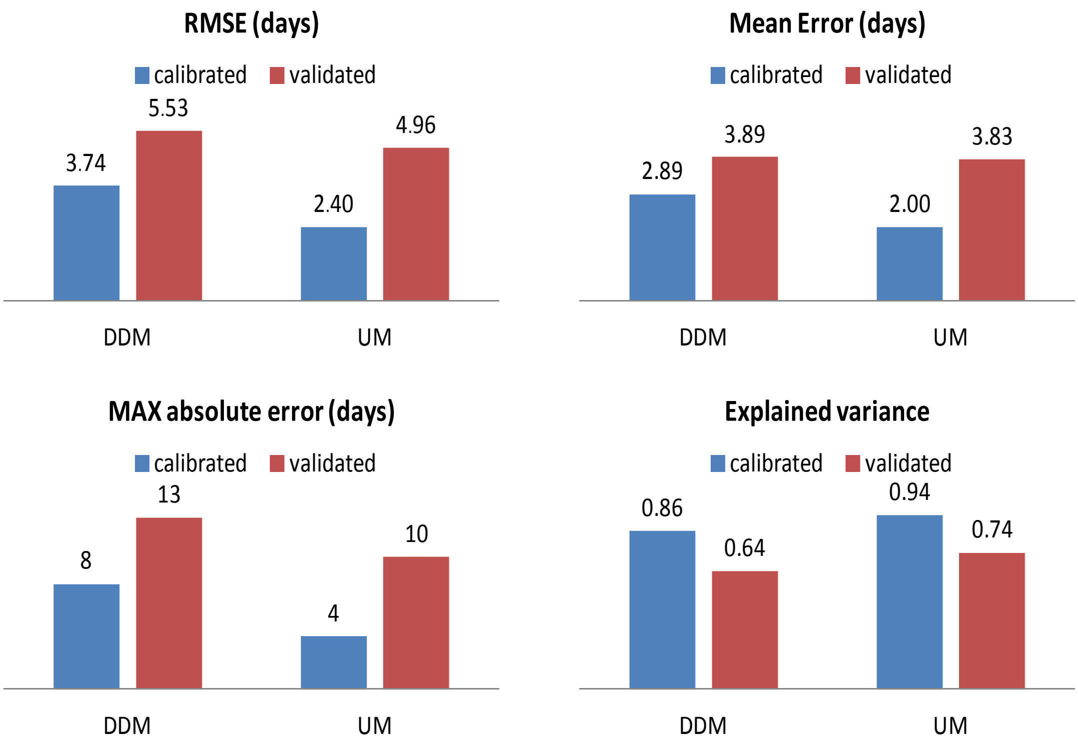


Figure 3. *Root mean square errors (RMSE, days), mean errors (days), maximal absolute values of the errors (days) and the explained variances (R^2) of the Degree Days Model (DDM) and Unified Model (UM) for the calibrated and the validated data set*

The budburst predictions of the Unified Model for the future are significantly different from the ones of the reference period ($p<0.01$, Levene test $p=0.87$; Shapiro-Wilk normality test for the residuals $p=0.09$). However, the future predictions do not differ from each other significantly, Tukey $p=0.94$). The budburst distributions of all the three time periods can be fitted to normal distribution with parameters of *Table 2*. ($p>0.2$). With time it is expected that the distributions shift to the left for earlier mean budburst date at a rate of about ten days and have increasing estimated variances and thus increasing coefficients of variation (*Table 2*, *Fig. 4*).

Table 2. *Means of the budburst dates predicted by the Unified Model, their variances and coefficients of variances referring to 1961-90 as reference period as well as to the time intervals 2021-2050, 2071-2100 based on the daily outputs of regional climate model RegCM3.1*

Time interval	Mean (J. day)	Standard deviation	CV
1961-1990	113.26	10.83	0.096
2021-2050	104.67	11.27	0.11
2071-2100	103.67	12.21	0.12

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

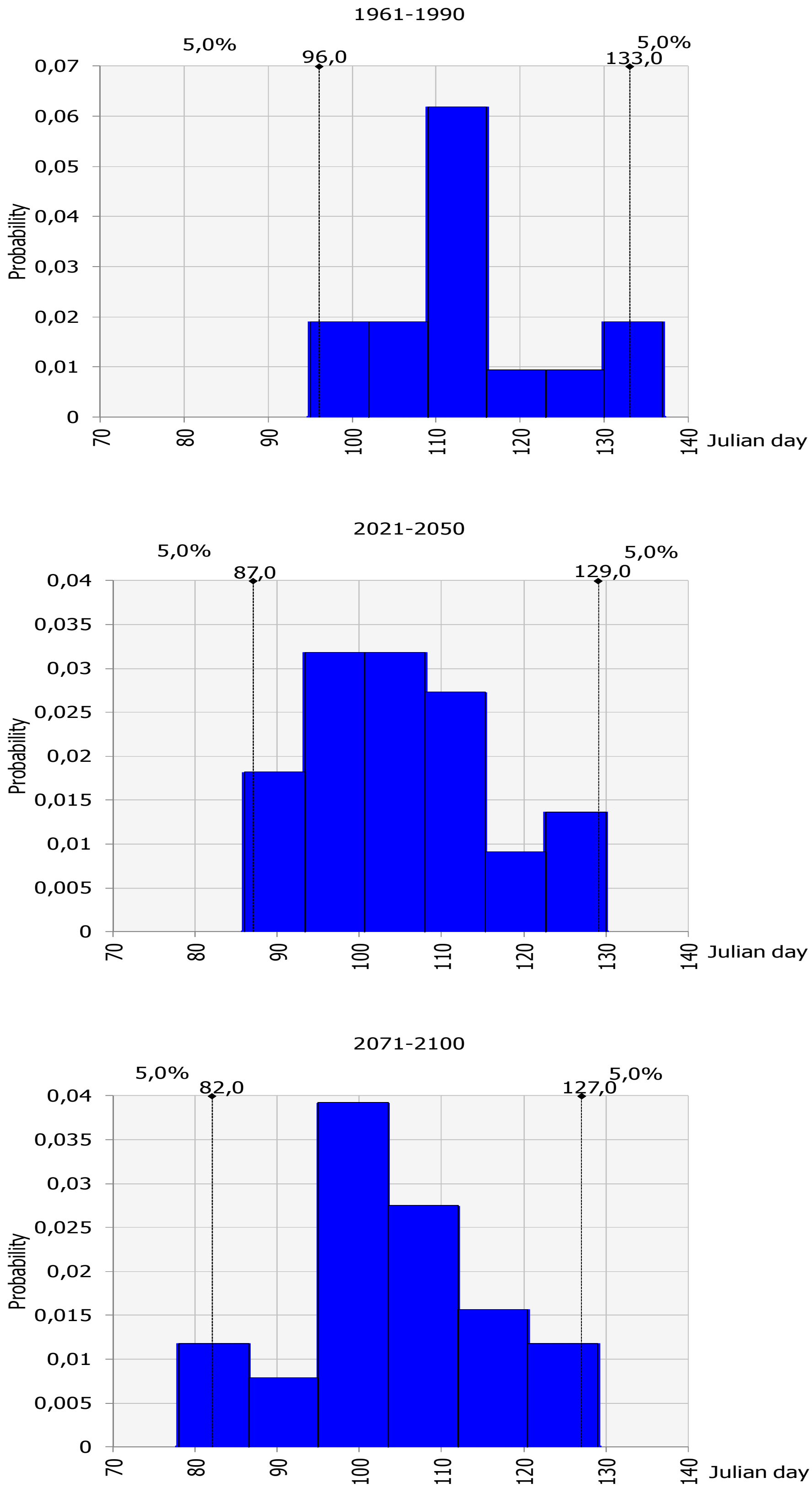


Figure 4. *Budburst date relative frequency histograms predicted by the regional climate model RegCM 3.1 for time intervals 1961-1990, 2021-2050 and 2071-2100 with their 90% confidence interval highlighted*

In *Fig. 5* we can compare the normal distributions that can be fitted to the relative frequency histograms with the mean and standard deviation parameters predicted by the Unified Model run with the regional climate model RegCM 3.1.

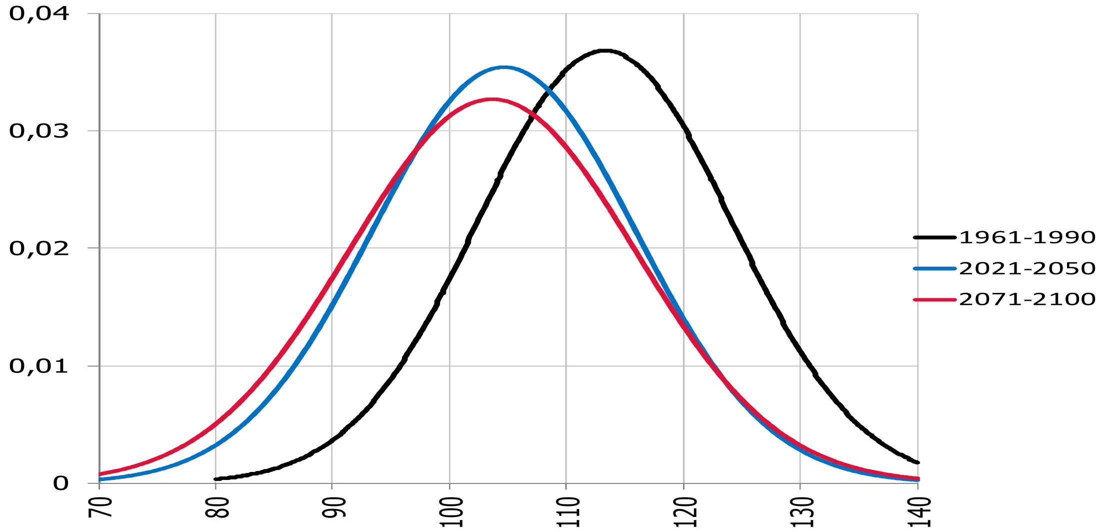


Figure 5. *Fitted normal distribution curves for the budburst dates predicted by the regional climate model RegCM 3.1 for time intervals 1961-1990, 2021-2050 and 2071-2100*

The predicted phenological shift of budburst of about ten days (2021-2050, 2071-2100) compared to the reference period 1961-90 can have considerable biological consequences. This result, on one hand, verifies the necessity and usefulness of modelling budburst dates and, on the other hand, motivates the researchers to find more and more accurate models which can predict and warn future tendencies. We stress the need of further and continuous improvement of the models because climate change impact itself can change with time if delayed feedback is also considered. Moreover, the impact of climate change is manifested not only in tendentious changes but also in the extreme events with increasing frequencies and seriousness. This latter impact, however, is still very poorly modelled. Nevertheless, the impact of tendentious changes can be overwritten by some kinds of extreme event impact such as warm winters, spring frosts etc. Therefore we emphasize that budburst models based on chilling effect calculations can be applied mostly in regions where chilling requirements are usually largely fulfilled which is the case of Hungary now but can be changed while climate character varies.

Though our model was calibrated specially for one of the most important Hungarian red grape variety, Kékfrankos (Blaufränkisch), we can successfully apply it also for other varieties while keeping in mind that the calibrated parameters can be very sensitive to varieties and sites.

The consequences of the earlier budburst events forecasted by the phenology models together with the regional climate models can be both beneficial and also detrimental. Earlier budburst with similar or lightly warming spring temperature distribution involves the increasing risk of spring frost. The most serious spring frost events occur usually after an early budburst followed by an intensive temperature drop. Though Kékfrankos is frost resistant pretty well, young sprouts can be injured after budburst caused by even a moderately serious frost. Therefore, beyond the model based prediction of budburst dates, we emphasize that the forecast of the probability of spring frost events together with accurate calculations of frost risk damages are also the sorely demanded.

Acknowledgements. This research was supported by TÁMOP-4.2.1/B-09/1/KMR-2010-0005 project.

REFERENCES

[1] Baggiolini, M. (1952): Les stades repères dans le développement annuel de la vigne et leur utilisation pratique. – Rev. Romande Agric. Vitic. Arbor. (8): 4-6.

[2] Bartholy, J., Pongrácz, R., Barcza, Z., Haszpra, L., Gelybó, Gy., Kern, A., Hidy, D., Torma, Cs., Hunyady A., Kardos, P. (2007): A klímaváltozás regionális hatásai: a jelenlegi állapot és a várható tendenciák. – Földrajzi Közlemények. CXXXI. (LV.) kötet, 4. szám, pp. 257-269.

[3] Bartholy, J., Pongrácz, R., Torma, Cs. (2010): A Kárpát-medencében 2021-50-re várható regionális éghajlatváltozás RegCM-szimulációk alapján. – “KLÍMA-21” Füzetek, 60: 3-13.

[4] Bartholy, J., Pongrácz, R., Torma, Cs., Pieczka, I., Kardos, P. and Hunyady, A. (2009): Analysis of regional climate change modelling experiments for the Carpathian basin. – International Journal of Global Warming 1(1-2-3.): 238-252.

[5] Bényei, F., Lőrincz, A. (2005): Borszőlőfajták, csemegeszőlő-fajták és alanyok. – Mezőgazda Kiadó, Budapest

[6] Bényei, F., Lőrincz, A., Sz. Nagy, L. (1999): Szőlőtermesztés. – Mezőgazda Kiadó, Budapest

[7] Bindi, M., Miglietta, F., Gozzini, B., Orlandini, S., Seghi, L. (1997a): A simple model for simulation of growth and development in grapevine (*Vitis vinifera* L.). I. Model description. – Vitis 36(2): 67-71.

[8] Bindi, M., Miglietta, F., Gozzini, B., Orlandini, S., Seghi, L. (1997b): A simple model for simulation of growth and development in grapevine (*Vitis vinifera* L.). II. Model validation. – Vitis 36(2): 73-76.

[9] Bognár, S. (1978): Kertészeti növényvédelem. – Mezőgazdasági Kiadó, Budapest

[10] Bonhomme, R. (2000): Bases and limits to using “degree-day” units. – Eur. J. Agron. (13): 1-10.

[11] Cannell, M. G. R., Smith, R. I. (1983): Thermal time, chill days and prediction of budburst in Picea sitchensis. – J. Appl. Ecol. (20): 951-963.

[12] Carbonneau, A., Riou, C., Guyon, D., Riom, J., Schneider, C. (1992): Agrométéorologie de la vigne en France. – EUR-OP, Luxembourg

[13] Cesaraccio, C, Spano, D., Snyder, R.L., Duce, P. (2004): Chilling and forcing model to predict bud-burst of crop and forest species. – Agric. For Meteorol. (126): 1-13.

[14] Chuine, I. (2000): A unified model for budburst of trees. – J. Theor. Biol. (207): 337-347.

[15] Chuine, I., Cour, P. (1999): Climatic determinants of budburst seasonality of temperate-zone trees. – The New Phytol. (143): 339-349.

[16] Chuine, I., Cour, P., Rousseau, D.D. (1998): Fitting models predicting dates of flowering of temperate-zone trees using simulated annealing. – Plant, Cell Environ. (21): 455-466.

[17] Chuine, I., Cour, P., Rousseau, D.D. (1999): Selecting models to predict the timing of flowering of temperate trees: implications for tree phenology modelling. – Plant, Cell Environ. (22): 1-13.

[18] Chuine, I., Kramer, K., Hänninen, H. (2003): Plant development models. – In: Schwartz, M.D. (ed) Phenology: an integrative environmental science. Kluwer, Milwaukee, pp. 217-235.

[19] Cortázar-Atauri, G.I., Brisson, N., Seguin, B., Gaudillere J.P., Baculat, B. (2005): Simulation of budbreak date for vine. The BRIN model. Some applications in climate

change study. – In: Proceedings of XIV International GESCO Viticulture Congress, Geisenheim, Germany, 23–27 August, 2005, pp 485-490.
[20] Cortázar-Atauri, G.I., Brisson, N., Gaudillere, J.P. (2009): Performance of several models for predicting budburst date of grapevine (*Vitis vinifera* L.) – Int. J. Biometeorol DOI 10.1007/s00484-009-0217-4.
[21] Farmer, R.E. (1968): Sweetgum dormancy release : effects of chilling, photoperiod, and genotype. – Physiologia Plantarum (21): 1241-1248.
[22] Gladstones, J. (2000): Past and future climatic indices for viticulture. – Proc. 5th Intl. Symp. Cool Climate Vitic. Oenol., Melbourne, Australia. p. 10.
[23] Hänninen, H. (1990): Modelling bud dormancy release in trees from cool and temperate regions. – Acta For. Fenn. (213): 1-47.
[24] Hänninen, H. (1991): Does climatic warming increase the risk of frost damage in northern trees? – Plant, Cell Environ. (14): 449-454.
[25] Hänninen, H. (1995): Effect of climatic change on trees from cool and temperate regions: an ecophysiological approach to modelling of bud burst phenology. – Can. J. Bot. (73):183-199.
[26] Hänninen, H. (1996): Effects of climatic warming on northern trees: testing the frost damage hypothesis with meteorological data from provenance transfer experiments. – Scan. J. For. Res. (11): 17-25.
[27] Hänninen, H., Backman, R. (1994): Rest break in Norway spruce seedlings: test of a dynamic temperature response hypothesis. – Canadian Journal of Forest Research (24): 558-563.
[28] Hänninen, H., Kellomag Ki, S., Laitinen, K., Pajari, B., Repo, T. (1993): Effect of increased winter temperature on the onset of height growth of Scots pine: a "led test of a phenological model. – Silva Fennica (27): 251-257.
[29] Heide, O.M. (1993): Daylength and thermal time responses of budburst during dormancy release in some northern deciduous trees. – Physiologia Plantarum (88): 531-540.
[30] Hajdu, E., Saskői, B.-né (2009): Abiotikus stresszhatások a szőlő életterében Agroinform Kiadó, Budapest, p. 222.
[31] Jones, G.V. (2003): Winegrape phenology. – In: Schwartz, M.D. (ed) Phenology: an integrative environmental science. Kluwer, Milwaukee, pp. 523-540.
[32] Jones, G.V, Duchene, E., Tomasi, D., Yuste, J., Braslavksa, O., Schultz, H., Martinez, C., Boso, S., Langellier, F., Perruchot, C., Guimberteau, G. (2005): Changes in European winegrape phenology and relationships with climate. – In: Proceedings of XIV International GESCO Viticulture Congress, Geisenheim, Germany, 23–27 August, 2005, pp. 55-62.
[33] Khanduri, V.P., Sharma, C.C.M., Singh, C.S.P. (2008): The effects of climate change on plant phenology. – Environmentalist (28):143-147.
[34] Kozma, P. (1991): A szőlő és termesztése I. A szőlőtermesztés történeti, biológiai és ökológiai alapjai. – Akadémiai Kiadó, Budapest
[35] Kramer, K. (1994a): A modelling analysis of the effects of climatic warming on the probability of spring frost damage to tree species in The Netherlands and Germany. – Plant, Cell Environ. (17): 367-377.
[36] Kramer, K. (1994b): Selecting a model to predict the onset of growth of Fagus sylvatica. – J. Appl. Ecol. (31): 172-181.
[37] Kramer, K., Friend, A., Leinonen, I. (1996): Modelling comparison to evaluate the importance of phenology and spring frost damage for the effects of climate change on growth of mixed temperate-zone deciduous forests. – Clim. Res. (7): 31-41.
[38] Lang, G.A., Early, J.D, Martin, G.C., Darnell, R.L. (1987): Endo-, para-, and ecodormancy: physiological terminology and classification for dormancy research. – HortScience 22(3): 371-377.

[39] Moncur, M.W., Rattigan, K., Mackenzie, D.H., McIntyre, G.N. (1989): Base temperatures for budbreak and leaf appearance of grapevines. – Am. J. Enol. Vitic. 40(1): 21-26.
[40] Murray, M. B., Cannell, M. G. R., Smith, R. I. (1989): Date of budburst of fifteen tree species in Britain following climatic warming. – J. Appl. Ecol. (26): 693-700.
[41] Myking, T, Heide, O.M. (1995): Dormancy release and chilling requirements of buds of latitudinal ecotypes of Betula pendula and B. pubescens. – Tree Physiology (15):697-704.
[42] Nelson, E.A, Lavender, D.P. (1979): The chilling requirement of western hemlock seedlings. – Forest Science 25: 485-490.
[43] Németh, M. (1967): Ampelográfiai album I. (Termesztett borszőlőfajták 1.). – Mezőgazdasági Kiadó, Budapest
[44] Nienstaedt, H. (1966): Dormancy and dormancy release in white Spruce. – Forest Science (12): 374-384.
[45] Oliveira, M. (1998) Calculation of budbreak and flowering base temperatures for *Vitis vinifera* cv. Touriga Francesa in the Douro Region of Portugal. – Am. J. Enol. Vitic. 49(1):74–78.
[46] Penuelas J., Filella, I. (2001): Phenology: responses to a warming world. – Science (294): 793-794.
[47] Pernesz, Gy. (2004): New resistant table grape cultivars bred in Hungary. – Proceedings of the First International Symposium on Grapewine Growing, Commerce and Research, Acta Horticulturae (652): 321.
[48] Riou, C. (1994): The effect of climate on grape ripening: application to the zoning of sugar content in the European community. – CECACEE- CECA, Luxembourg.
[49] Spano, D, Cesaraccio, C., Duce, P. and Snyder, R.L. (2002): An improved model for estimating degree days. – ISHS Acta Horticulturae 584: VI International Symposium on Computer Modelling in Fruit Research and Orchard Management.
[50] Torma, Cs., Bartholy, J., Pongrácz, R., Barcza, Z., Coppola, E., Giorgi, F. (2008): Adaptation and validation of the RegCM3 climate model for the Carpathian Basin. – Időjárás 112(3-4): 233-247.
[51] Walther, G.R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T.J.C., Fromentin, J.M., Guldberg, O.H., Bairlein, F. (2002): Ecological responses to recent climate change. – Nature (416):389–395.
[52] Weise, T. (2009): Global Optimization Algorithms – Theory and Application – http://www.it-weise.de/projects/book.pdf.

CLIMATIC RISK FACTORS OF CENTRAL HUNGARIAN GRAPE GROWING REGIONS

SZENTELEKI, K.[1]* – LADÁNYI, M.[1] – GAÁL, M.[1] – ZANATHY, G.[2] – BISZTRAY, GY.[2]*

[1]*Corvinus University of Budapest, Department of Mathematics and Informatics*
1118 Budapest, Villányi út 29-43., Hungary
(phone: +36-1-482-6261; fax: +36-1-466-9273)

[2]*Corvinus University of Budapest, Institute of Viticulture and Oenology*
1118 Budapest, Villányi út 29-43., Hungary
(phone: +36-1-482-6283; fax: +36-1-466-4650)

**Corresponding authors*
e-mail: karoly.szenteleki@uni-corvinus.hu
gyorgy.bisztray@uni-corvinus.hu

(Received 4th October 2011; accepted 25th October 2011)

Abstract. Under global climate change we mean the observed increasing tendency of the yearly mean temperature together with the more and more frequently occurring extreme events (floods, frosts, droughts, heat waves). The border of the sites suitable for grapevine growing and the growing regions are defined mainly by climatic conditions. Quality wine production can be maintained between the isothermals of 10-16°C yearly mean temperature. Though Hungary is expected to remain amongst the regions with good quality grapevine growing conditions, according even to the most pessimistic forecasts, the expected frequency and the impact of extreme climatic events are rather serious warning signs. Continental climatic conditions in Carpathian basin can generate stress effects which can cause negative economic consequences through quality and quantity unsuitability. In this study some impactful climatic indicators are analysed which are of high importance in grapevine production. Historic data are compared with regional climate model predictions of RegCM 3.1 with A1B scenario, concerning to the Central Hungarian grape growing regions.
Keywords: *grapevine, climate change, climatic indicators, Central Hungarian region, climatic risk*

Introduction

Ecological demands of various plants are influenced different ways and in distinct extent by climate change since beneficial and unfavourable or detrimental effects of temperature, precipitation and other climatic factors are activated not generally but specifically (spatially and temporally) distributed. Yearly averages of temperatures and precipitation, therefore serve too few information for conclusions. However, learning the distributions of the climatic parameters with emphasized importance of some main time intervals of the growing season specialized for plant species is of main interest.

In this study we consider the climatic conditions of grapevine growing regions in Central Hungary according to three different time scales: 1961-1990 as reference period, 2021-2050 and 2071-2100 as prediction time intervals. Regional studies have been enabled since global climate models have been downscaled to about 10 km grid points. We applied RegCM 3.1 which was downscaled at Eötvös Loránd University, Department of Meteorology for A1B scenario (Bartholy et al., 2007, 2009, 2010; Torma et al., 2008).

The most important climatic factor in grapevine growing is temperature as higher mean temperature generally indicates higher sugar content at ripening (Zanathy, 2008).

In low risk site selection first the yearly mean temperature is checked whether it is between 9°C and 21°C isothermals. The highest quality regions are mainly between 10°C and 16°C isothermals (Oláh, 1979). Thus regions can be suitable with latitudes between 20° and 50° north and between 20° and 40° south. Grapevine with its several varieties with wide range climatic demands can be regarded as well adaptable plant; nevertheless, special varieties need special treatment (Varga et al., 2007).

Historical wine regions in Hungary, however, have their well defined and widely requested character based on their typical varieties grown there. Cool climate regions with short growing season are famous for their early ripening, fragrant, aromatic varieties while warmer regions with plenty of sunny hours benefit from their varieties with longer growing season demand. With only 1°C mean temperature increase of cool climate regions classified by Huglin Index (Huglin, 1978) the change can be quite favourable as the variety assortment can be widen with bringing nice varieties from southern regions into production. 2°C or higher mean temperature increase, however, can endanger the suitability of the region for fragrant varieties such as Pinot gris or Traminer (Jones, 2006) as the typical taste and flavour can disappear from the wine. Huglin Index calculations throughout European wine regions all agree in an expected shift towards a warmer or hotter class (Schultz, 2000; Battaglini, 2003). Phenological phases are expected to occur earlier and the time intervals between the phenological phases are becoming shorter (Wolfe et al., 2005; Jones and Davis, 2000; Jones, 2006).

Accordingly, veraison and maturation can be connected to higher temperature conditions which can cause a definite change in wine character when the sugar content of the berries at maturation together with the alcohol content of wine increase (Bindi et al., 2001; Duchêne and Schneider, 2005) and acid content decrease with a higher pH value (Jones and Davis, 2000; Stock et al., 2003). Quality changes are expected to be associated with a moderate impact of vintage. However, the increasing frequencies and seriousness of pest and disease events (DeLucia et al., 2008), the higher UV-radiation (Schultz, 2000), the site and soil dependent nutrient stress as well as water stress can endanger the security of production. Meanwhile, a low level water stress can be advantageous to the quality; water supply and irrigation potential are of great importance (Bravdo and Hepner, 1987; Carbonneau, 1998).

Materials and methods

Risk assessment was made for each of the 17 subregions of Central Hungary. To this the predictions of regional climate model RegCM 3.1 were used with 10 km resolution. As there were more grid points than subregion, the most representative 17 grid points were chosen that are situated the closest to the subregion centres. Calculations were made for three time scales: 1961-1990 as reference period, 2021-2050 and 2071-2100 as prediction time intervals. The time intervals cover 30 years, therefore the modelled data can represent the distribution of the climatic parameters.

Though Central Hungary is not belonging to the most prominent grape growing regions and no wine producing region is involved entirely in it, it lies on three wine regions (Kunsági, Etyek-Budai, Mátrai). Thousands of hectares of Kunsági wine region together with the one third part of Etyek-Budai region and some wine communities of Mátrai wine region are situated in Central Hungary (*Fig. 1*). This study is a part of an extensive object to measure the regional and plant specific climate potential of Hungary in order to learn the present state and the future possibilities of adaptation strategies.

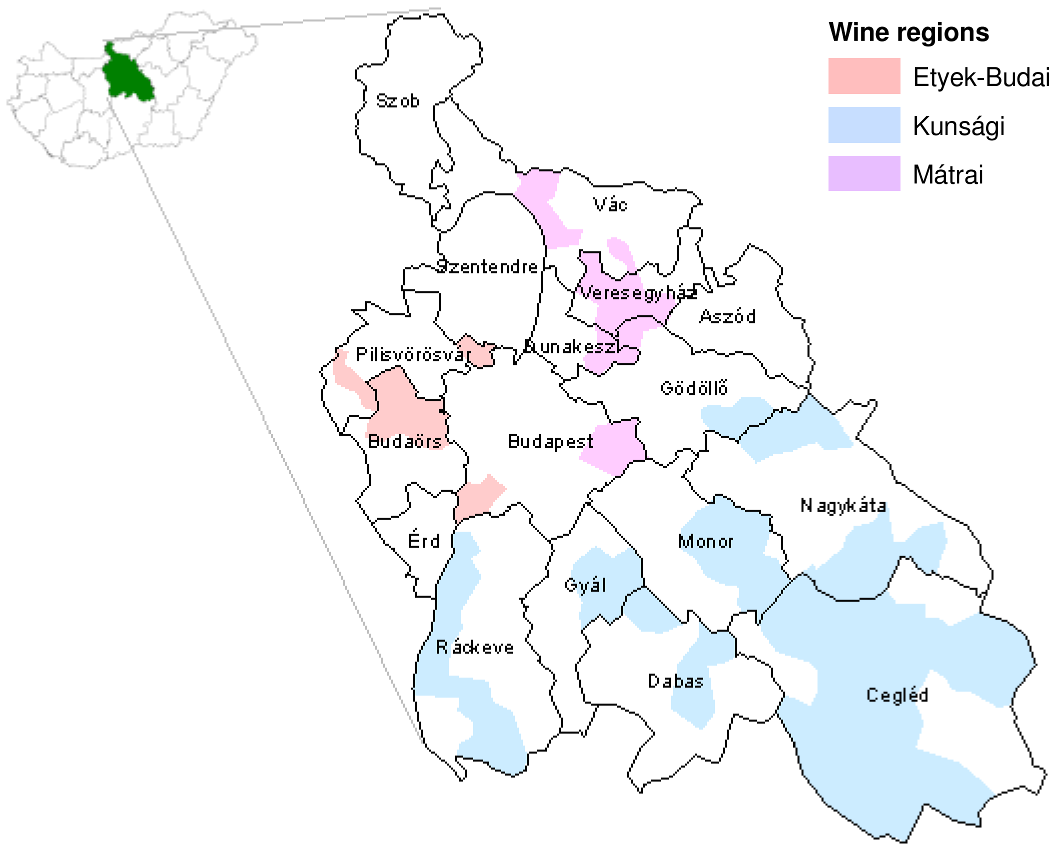


Figure 1. *Central Hungary (with 17 subregions) and the wine regions*

The most important climatic factors of grape growing are temperature and precipitation (Dunkel et al., 1981). The distributions of these two factors are the most important determinants of vintage. From these main factors the following indicators were focused:

- effective degree days above 10°C (EDD, °C)
- Huglin Index (HI, °C)
- the number of days with maximal daily temperature above 30°C (C30, days)
- the number of days with maximal daily temperature above 35°C (C35, days)
- the number of frosty days (below -1°C) after the 1st of April (F-1, days)
- the number of days with minimal daily temperature below -15°C (days)
- the number of days with minimal daily temperature below -18°C (days)
- the first, second and third maximal lengths of consecutive days with precipitation less than 1 mm (D1, D2, D3, days)
- the maximal length of consecutive days with precipitation more than 5 mm (days)
- yearly precipitation sum (mm)
- precipitation sum of the growing season (1st of April – 30th of September) (mm)

With a software developed specially for our aims all the 13 indicators above were calculated for each year of the three time series with 30 years and each of the 17 subregion grid points.

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

The data from three wine regions (Cegléd of Kunsági wine region, Budaörs from Etyek-Budai wine region and Veresegyház of Mátrai wine region) were analysed and compared. Moreover, we checked a subregion named Szob which is not belonging to any wine region yet whether it is expected to become to be suitable for grape growing.

Effective degree days and Huglin Index

The effective degree days (EDD, °C) are calculated as the cumulated sum of daily mean temperatures above the base temperature (10°C) between the 1^{st} of April and 30^{th} of September (Oláh, 1979). Grape varieties can be grouped according to their effective degree days demands up to full ripening.

The groups of grape varieties according to their effective degree days demand up to full ripening are displayed in *Table 1.*

Table 1. *Groups of grape varieties according to their effective degree days demand up to full ripening (Botos and Hajdú, 2004)*

Effective degree days	Ripening categories
690–850°C	very early ripening varieties
850–1150°C	early ripening varieties
1150–1350°C	medium ripening varieties
1350–1600°C	late ripening varieties
above 1600°C	very late ripening varieties

We also calculated the widely applied Huglin Index (HI, °C) which takes the maximal daily temperatures into consideration as well:

$$HI = k * \frac{\sum_{1.Apr.}^{30.Sept.} \max\left((T_{mean} - 10);0\right) + \sum_{1.Apr.}^{30.Sept.} \max\left((T_{\max} - 10);0\right)}{2}$$

where T_{mean} and $T_{\max}$ are the daily mean and maximal temperatures and k is a latitude coefficient that takes into account increasing day lengths from 35° to 50°, starting with 1.00 at 35°, ending with 1.06 at 50° and is based upon day lengths using Julian day and latitude as inputs. In case of Hungary k=1.05 was applied.

According to the values of Huglin Index the following site type classes are defined (Tonietto and Carbonneau, 2004, *Table 2*).

Table 2. *Groups of site types according to their Huglin Index*

Huglin Index (°C)	Class name
HI ≤ 1500	very cool
1500 < HI ≤ 1800	cool
1800 < HI ≤ 2100	temperate
2100 < HI ≤ 2400	warm temperate
2400 < HI ≤ 3000	warm to very warm
3000 < HI	hot

Results

Cegléd subregion

The effective degree days and Huglin Index values of Cegléd subregion are presented in *Table 3*.

Table 3. *Effective degree days and Huglin Indices in Cegléd subregion*

	Time interval		
	1961-1990	**2021-2050**	**2071-2100**
EDD (°C)	1240	1433	1898
Huglin Index (°C)	1760	1960	2427

In Cegléd while the medium ripening varieties were expected to ripen appropriately in the reference time interval (1961-1990), the heat demands of the late ripening varieties can be filled in the middle of the 21st century and even the effective degree days suitable for the very late ripening varieties can be reached at the end of the century.

According to the Huglin Index values Cegléd subregion was belonging to the cool class in the last century and up to the middle of the 21st century it is expected to belong to the temperate class tending to the warm temperate one at the end of the century.

The increase of the effective degree days and Huglin Index values is moderate in medium term and more intensive in the long run.

Though Huglin Index is used quite widely, in case of extreme heat events it does not express the negative effects. Above 30°C respiration increases rapidly resulting in a rapid decrease in net photosynthesis, net assimilation is impeded. Above 35°C extra energy is used to maintain the life processes. Moreover, extreme high temperature events mainly associated with lack of precipitation and high level of solar radiation with high risk of sunburn.

The frequencies of extreme temperature events in Cegléd subregion are presented in *Table 4*. According to the regional climate model RegCM 3.1 the expected number of extreme warm days with maximum daily temperature above 30°C seem to increase moderately up to the middle of the 21st century, however, it is estimated to double up to the end of the century, compared to its value of the reference period 1961-1990, from a yearly mean of about 18 to about 35 days.

Table 4. *Frequencies of extreme temperature events in Cegléd subregion (days / 30 years)*

	Time interval		
	1961-1990	**2021-2050**	**2071-2100**
Daily max. temperature above 30°C	544	597	1046
Daily max. temperature above 35°C	73	172	557
Daily min. temperature below -1°C (after 1st of April)	49	18	8
Daily min. temperature below -15°C	11	1	0
Daily min. temperature below -18°C	3	0	0

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

The expected number of extreme hot days with maximum daily temperature above 35°C is estimated to increase more drastically, from the yearly mean of about 2 days to almost 6 days at medium term and above 18 days at long term (*Table 4*).

These trends are risk factors of unfavourable sugar-acid ratio of some white varieties as well as harvest management and vinification (Hajdú, 2005; Horváth, 2008). Thus agricultural and phytotechnical practices should newly be adjusted to varieties and changed climate in order to minimize the risk of quality degradation.

Extreme cold events are also very harmful (Dunkel and Kozma, 1981). Minimum temperature below -15°C can cause significant damage of several varieties; frost injury is surely serious if temperature is below -18°C. Late spring frost events below -1°C can bring a meaningful yield loss.

Nevertheless, the risk of extreme cold events is expected to decrease. The yearly mean numbers of spring (1.6 days which means about 2 days in three years) and winter frost events (0.36 below -15°C – about once in three years; or 0.1 below -18°C – about once in ten years) are expected to decrease remarkably even in medium term and the frost risk becomes very low up to the end of the century with an only spring frost event expected in three years.

Let us consider the precipitation indices in Cegléd subregion presented in *Table 5*. The yearly mean precipitation sum is a relevant parameter of a site. Having a deep growing root system grapevine can tolerate moderate water stress relatively well with a yearly precipitation sum demand of 500-600 mm. From this amount it is necessary to have at least 260-320 mm precipitation sum in the growing season to ensure the appropriate shoot and berry development. Precipitation risk factors are long term rainfall events and drought events.

Yearly and vegetation period precipitation sum demand of grapevine is satisfied in all the three time intervals (1961-1990, 2021-2050, 2071-2100), according to the regional climate model RegCM 3.1. The distribution of the precipitation in vegetation period, however, is expected to change disadvantageously.

Table 5. *Averages of precipitation indices in Cegléd subregion*

	Time interval		
	1961-1990	**2021-2050**	**2071-2100**
Yearly precipitation sum (mm)	645	605	639
Precipitation sum 1st of Apr – 30th of Sept (mm)	301	306	291
The max. length of consecutive days with precipitation less than 1 mm (days)	22.1	25.6	28.0
The 2nd max. length of consecutive days with precipitation less than 1 mm (days)	16.2	17.8	18.6
The 3rd max. length of consecutive days with precipitation less than 1 mm (days)	12.3	14.0	12.7

In *Table 5* we display the lengths of the three longest dry periods as a 30-year mean. The length of the longest dry period with consecutive days of daily precipitation less than 1 mm increases significantly both at medium and long term level reaching its value of 28 days up to the end of the 21st century. The lengths of the second and third longest periods are also estimated to increase. Considering the significant increase of the expected daily average and maximum temperatures, the negative impacts of these

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

phenomena can only be mitigated if the variety structure, the training system as well as the agricultural and phytotechnical practices are adequately modified.

According to the regional climate model RegCM 3.1 the three longest wet periods with consecutive days of precipitation above 5 mm do not indicate significant change in the future. The longest period has its yearly mean of 3.2 days with respect to the reference period 1961-1990.

Veresegyház subregion

Veresegyház subregion is situated in the west hilly border of Mátra wine region, north to Cegléd subregion (Gödöllő hills).

The effective degree days and Huglin Index values of Veresegyház subregion are presented in *Table 6*.

Table 6. *Effective degree days and Huglin Indices in Veresegyház subregion*

	Time interval		
	1961-1990	**2021-2050**	**2071-2100**
EDD (°C)	1050	1216	1649
Huglin Index (°C)	1549	1721	2182

In Veresegyház mainly the early ripening varieties were expected to ripen appropriately in the reference time interval (1961-1990), the heat demands of the medium ripening varieties can be filled in the middle of the 21st century and the effective degree days demand of the late and very late ripening varieties can be reached at the end of the century.

According to the Huglin Index values Veresegyház subregion was belonging to the cool class in the last century and up to the middle of the 21st century it is expected to remain in the same class tending to be warmer and warmer and it probably reaches the warm temperate class at the end of the century.

Similarly to Cegléd subregion the increase of the effective degree days and Huglin Index values is moderate in medium term and more intensive in the long run.

The frequencies of extreme temperature events in Veresegyház subregion are presented in *Table 7*. The numbers of extreme warm days with maximum daily temperature above 30°C as well as of the extreme hot days with maximum daily temperature above 35°C are lower than they were detected in Cegléd subregion.

Table 7. *Frequencies of extreme temperature events in Veresegyház subregion (days / 30 years)*

	Time interval		
	1961-1990	**2021-2050**	**2071-2100**
Daily max. temperature above 30°C	371	414	899
Daily max. temperature above 35°C	22	64	316
Daily min. temperature below -1°C (after 1st of April)	60	27	10
Daily min. temperature below -15°C	22	2	0
Daily min. temperature below -18°C	4	0	0

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

However, the expected number of extreme warm days is estimated to increase up to the end of the 21st century from yearly mean of about 12 days to about 30 days, compared to its value of the reference period 1961-1990. The expected number of extreme hot days is estimated to increase again more drastically, from the yearly mean of less than 1 day to about 2 days at medium term and above 10 days at long term (*Table 7*).

The risk of extreme cold events is expected to decrease in Veresegyház subregion, too. The yearly mean numbers of spring (2 days) and winter frost events (0.7 days below -15°C – about twice in three years; or 0.13 below -18°C – about once in eight years) are expected to decrease remarkably even in medium term and the frost risk becomes very low up to the end of the century with an only spring frost event expected in three years which declares a very similar distribution of frost events to the one we learned in Cegléd subregion.

The precipitation indices in Veresegyház subregion are presented in *Table 8*. The precipitation sum demand of grapevine is profusely satisfied in all the three time intervals (1961-1990, 2021-2050, 2071-2100) regarding for both the yearly and the vegetation period, according to the regional climate model RegCM 3.1. The distribution of the precipitation in vegetation period is optimal and it also remains as optimal.

In *Table 8* we display the lengths of the three longest dry periods as a 30-year mean. The length of the longest dry period with consecutive days of daily precipitation less than 1 mm increases insignificantly. The lengths of the second and third longest dry periods are also estimated to increase very slightly. The longest wet periods with consecutive days of precipitation above 5 mm indicates an increase of 20 % up to the end of the 21st century compared to its yearly mean value (3.2 days) of the reference period 1961-90. The increase of the lengths of second and third longest wet periods is insignificant.

Table 8. *Averages of precipitation indices in Veresegyház subregion*

	Time interval		
	1961-1990	**2021-2050**	**2071-2100**
Yearly precipitation sum (mm)	743	696	730
Precipitation sum 1st of Apr – 30th of Sept (mm)	335	342	310
The max. length of consecutive days with precipitation less than 1 mm (days)	22.0	24.2	24.9
The 2nd max. length of consecutive days with precipitation less than 1 mm (days)	14.8	16.1	16.9
The 3rd maxi. length of consecutive days with precipitation less than 1 mm (days)	11.6	12.2	12.9

Budaörs subregion

Some parts of the Etyek-Budai wine region are situated in Central Hungary. The climatic conditions of Budaörs subregion are very similar to the ones of Veresegyház subregion with a slightly less mean temperature and precipitation sum values. Further survey should examine how the change of ecological conditions of the region with a long history of sparkling wine production affects the decrease of the acidity of the yield. What is the future of production of base wine? Should we introduce new technology such as verjus addition in order to preserve the original character of Törley sparkling wine?

Szob subregion

Since Hungarian wine regions have their particular character of soil, relief and historical traditions, the climatic shift to north does not have its direct consequence of change of wine region locations at all. Nevertheless, from time to time it is reasonable to check the changed climatic conditions of some new regions as well to find out whether some new regions are developed with suitable climatic conditions for grape growing. The increase of the mean temperature at a rate of 1°C can cause a geographical shift of the border of the suitable wine regions with 180 km to north (Moisselin et al, 2002).

Szob subregion is situated in the north part of Central Hungary. At present it does not belong to any wine region. In what follows we check the future climatic conditions of Szob subregion whether it is expected to become suitable land for grape growing.

The effective degree days and Huglin Index values of Szob subregion are presented in *Table 9*.

Table 9. *Effective degree days and Huglin Indices in Szob subregion*

	Time interval		
	1961-1990	**2021-2050**	**2071-2100**
EDD (°C)	881	1017	1422
Huglin Index (°C)	1318	1463	1917

According to the classification of effective degree days (*Table 1*) in Szob only the early ripening varieties were expected to ripen appropriately in the reference time interval (1961-1990), the heat demands of again only the early ripening varieties can be filled in the middle of the 21st century and the effective degree days suitable for the late ripening varieties can be reached at the end of the century (*Table 9*).

According to the Huglin Index values Szob subregion was belonging to the very cool class in the last century and up to the middle of the 21st century it is expected to remain in the same class tending to be warmer and warmer and it probably reaches the temperate class at the end of the century.

The frequencies of extreme temperature events in Szob subregion are presented in *Table 10*.

Table 10. *Frequencies of extreme temperature events in Szob subregion (days / 30 years)*

	Time interval		
	1961-1990	**2021-2050**	**2071-2100**
Daily max. temperature above 30°C	203	244	700
Daily max. temperature above 35°C	9	26	166
Daily min. temperature below -1°C (after 1st of April)	101	38	17
Daily min. temperature below -15°C	30	3	0
Daily min. temperature below -18°C	8	0	0

The numbers of extreme warm days with maximum daily temperature above 30°C as well as of the extreme hot days with maximum daily temperature above 35°C are lower than they were detected in Cegléd and in Veresegyház subregions. However, the expected number of extreme warm days is estimated to increase up to the end of the 21^{st} century from yearly mean of about 7 days to about 23 days, compared to its value of the reference period 1961-1990.

The expected number of extreme hot days is estimated to increase again more drastically, from the yearly mean of about 0.3 day to about 1 day at medium term and above 5 days at long term (*Table 10*).

The risk of extreme cold events is expected to decrease in Szob subregion, too. The yearly mean numbers of spring (3 days) and winter frost events (1 below -15°C; or 0.27 below -18°C – about once in four years) are expected to decrease remarkably even in medium term; the frost risk becomes very low up to the end of the century with an only spring frost event expected in two years which declares a very similar distribution of frost events of Cegléd and Veresegyház subregions.

Table 11. *Averages of precipitation indices in Szob subregion*

	Time interval		
	1961-1990	**2021-2050**	**2071-2100**
Yearly precipitation sum (mm)	873	828	858
Precipitation sum 1^{st} of Apr– 30^{th} of Sept (mm)	418	420	373
The max. length of consecutive days with precipitation less than 1 mm (days)	19.1	19.8	20.4
The 2^{nd} max. length of consecutive days with precipitation less than 1 mm (days)	13.2	14.6	15.3
The 3^{rd} max. length of consecutive days with precipitation less than 1 mm (days)	10.6	10.7	11.5

The precipitation indices in Szob subregion are presented in *Table 11*. The precipitation sum demand of grapevine is exceeded in all the three time intervals (1961-1990, 2021-2050, 2071-2100) regarding for both the yearly and the vegetation period, according to the regional climate model RegCM 3.1. The amount of precipitation in vegetation period is expected to decrease slightly up to the end of the 21^{st} century but still remains too much.

In *Table 11* we display the lengths of the three longest dry periods as a 30-year mean. The length of the longest dry period with consecutive days of daily precipitation less than 1 mm increases insignificantly. The lengths of the second and third longest dry periods are also estimated to increase very slightly. All the estimated lengths of dry periods are shorter in Szob subregion than in Cegléd or Veresegyház subregions.

According to the regional climate model RegCM 3.1 the longest wet periods with consecutive days of precipitation above 5 mm are the longest in Szob subregion, compared to Cegléd and Veresegyház subregions.

Comparison of the subregions

The comparison of the subregions can be made considering the *Figures 2* and *3* with the effective degree days (°C) and Huglin Indices (°C) of all the three time periods (1961-1990, 2021-2050 and 2071-2100).

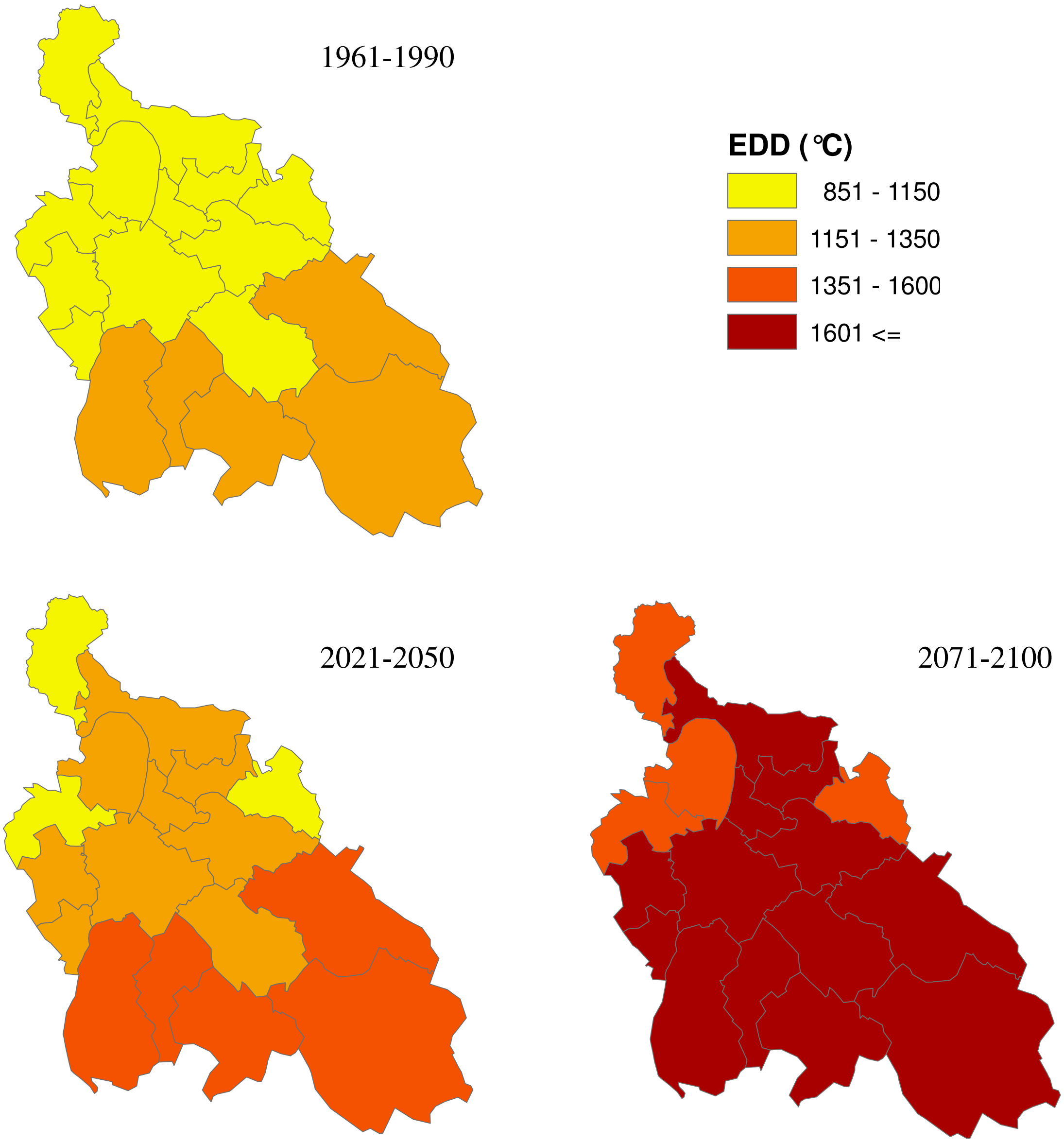


Figure 2. *Effective degree days(°C) of Central Hungarian subregions estimated by the regional climate model RegCM 3.1 for the time intervals*

According to the map of effective degree days (°C) as well as the one of Huglin Indices (°C) displayed in *Figures 2 and 3* there can be detected a significant increase in all the subregions of Central Hungary, especially in the long run up to the end of the 21st century. The region, however, preserves its character with differences between the subregions: Cegléd subregion remains the warmest one, Szob keeps being cooler with no reason to introduce it as a new grape growing region.

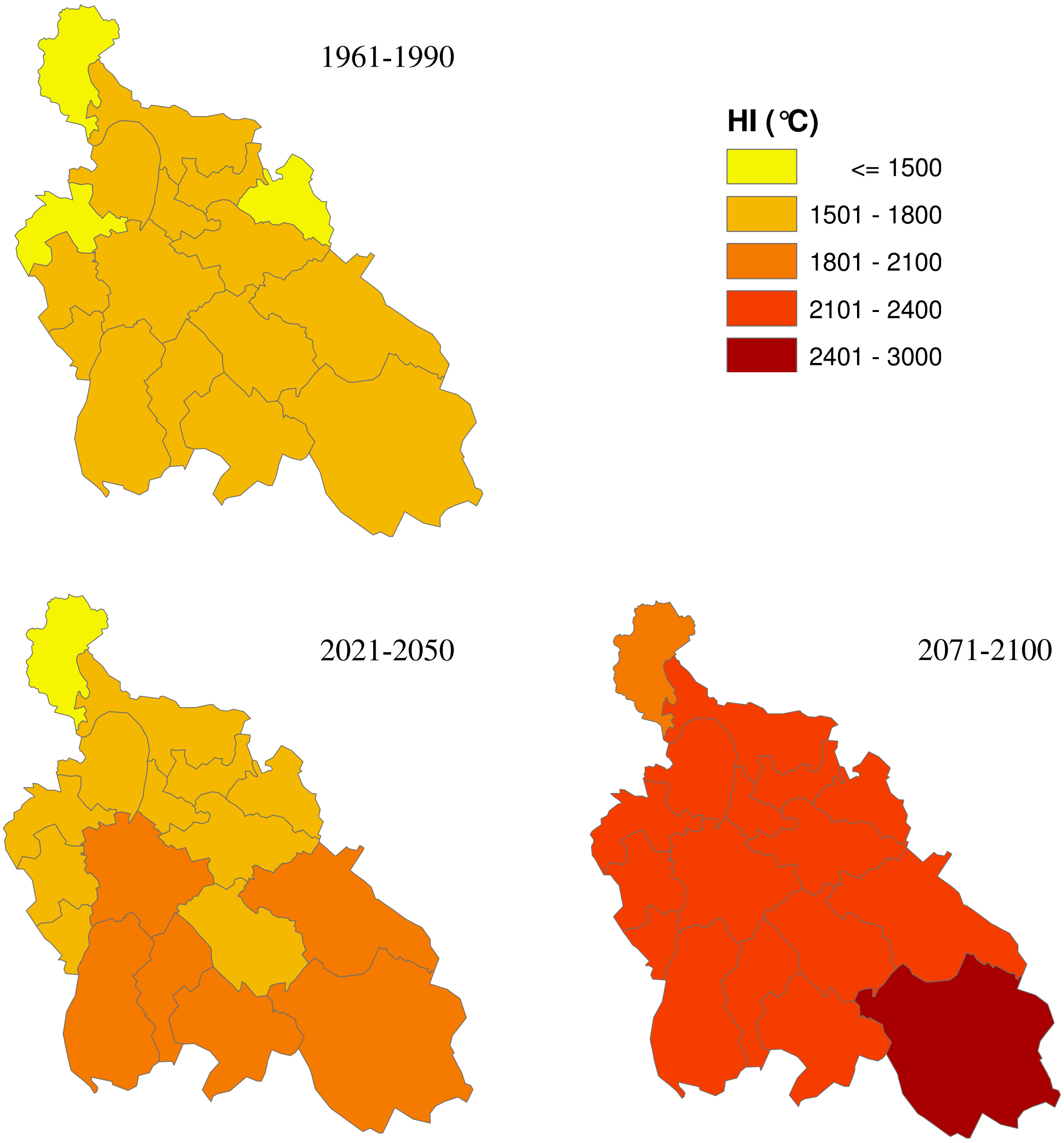


Figure 3. *Huglin Indices(°C) of Central Hungarian subregions estimated by the regional climate model RegCM 3.1 for the time intervals*

The numbers of extreme warm and extreme hot days with maximum daily temperature above 30°C and 35°C, respectively, estimated by the regional climate model RegCM 3.1 for the time intervals (1961-1990, 2021-2050, 2071-2100) and for Central Hungarian subregions can be seen in *Figures 4 and 5*. The increasing trends we can observe on the figures are more significant in long term time scale.

We can state that the expected numbers of spring and winter frost events seem to decrease intensively. The frequency of spring frost events is estimated as about one in three years while the frequency of winter frost events becomes very low.

http://www.ecology.uni-corvinus.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)

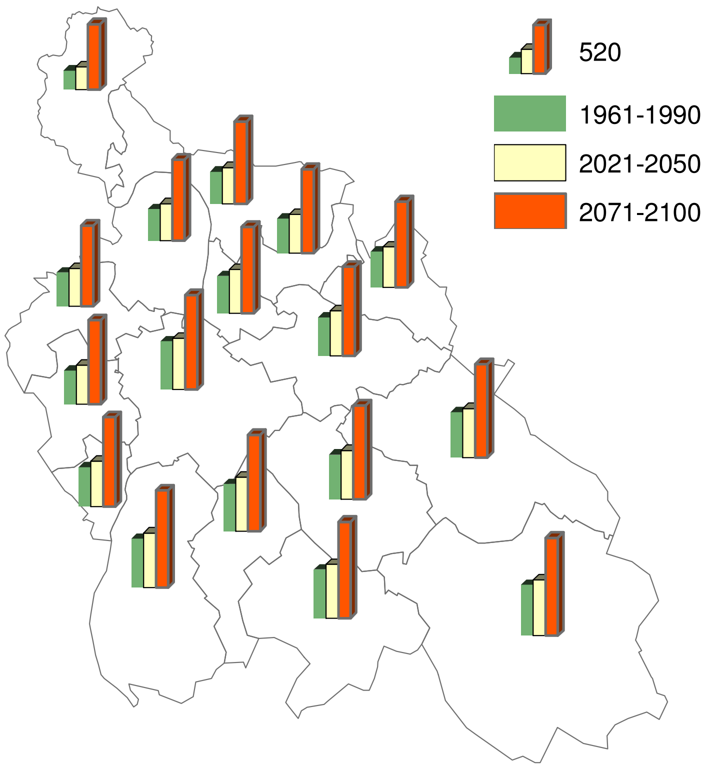


Figure 4. *The numbers of extreme warm days with maximum daily temperature above 30°C (the value refers to the highest column in the chart symbol)*

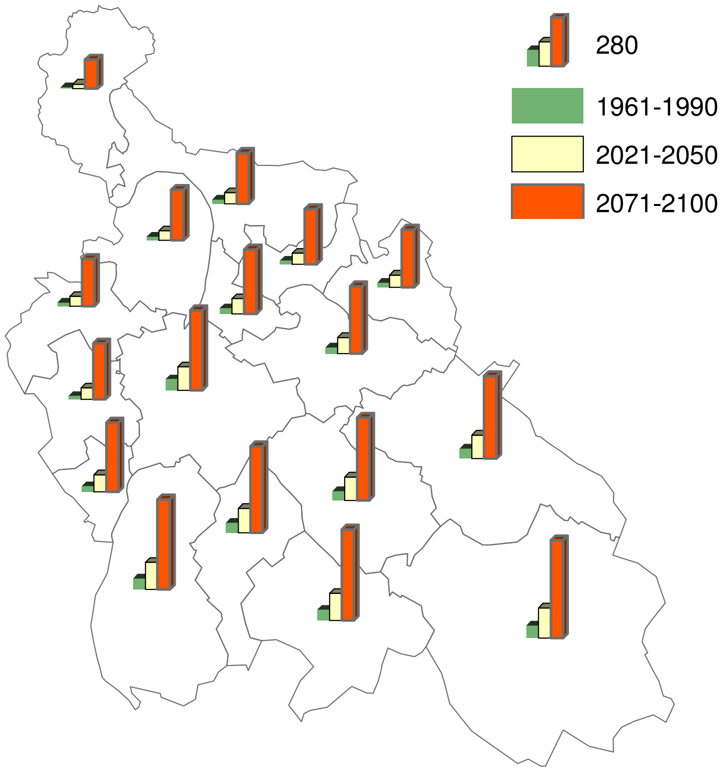


Figure 5. *The numbers of extreme hot days with maximum daily temperature above 35°C (the value refers to the highest column in the chart symbol)*

General characterization of Central Hungary region

Now we consider the climatic indices calculated for the whole Central Hungary region with its all the 17 subregions.

The effective degree days and Huglin Index values of Central Hungary region are presented in *Table 12*.

Table 12. *Effective degree days and Huglin Indices in Central Hungary*

	Time interval		
	1961-1990	2021-2050	2071-2100
EDD (°C)	1091	1265	1705
Huglin Index (°C)	1593	1776	2236

In Central Hungary mainly the early ripening varieties were expected to ripen appropriately in the reference time interval (1961-1990), the heat demands of the medium ripening varieties can be filled in the middle of the 21st century and the effective degree days demand of the late and very late ripening varieties can be reached at the end of the century.

According to the Huglin Index values Central Hungary region was belonging to the cool class in the last century and up to the middle of the 21st century it is expected to remain in the same class tending to be warmer and warmer and it reaches the warm temperate class at the end of the century.

The frequencies of extreme temperature events in Central Hungary region are presented in *Table 13*. The numbers of extreme warm days with maximum daily temperature above 30°C as well as of the extreme hot days with maximum daily temperature above 35°C are all estimated to increase intensively up to the end of the 21st century.

The expected number of extreme warm days grows from about 14 days to about 31 days in the long run, compared to its value of the reference period 1961-1990.

The expected number of extreme hot days is estimated to increase more drastically, from the yearly mean of about 1 day to about 2 days at medium term and to about 13 days at long term (*Table 13*).

Table 13. *Frequencies of extreme temperature events in Central Hungary (days / 30 years)*

	Time interval		
	1961-1990	**2021-2050**	**2071-2100**
Daily max. temperature above 30°C	420	473	939
Daily max. temperature above 35°C	40	100	388
Daily min. temperature below -1°C(after 1st of April)	61	24	9
Daily min. temperature below -15°C	17	1	0
Daily min. temperature below -18°C	3	0	0

The risk of extreme cold events is expected to decrease in Central Hungary region. The yearly mean numbers of spring (2 days) and winter frost events (0.6 below -15°C – about once in two years; or 0.1 below -18°C – about once in ten years) are expected to decrease remarkably even in medium term; the frost risk becomes very low up to the end of the century with an only spring frost event expected in three years.

The precipitation indices in Central Hungary region are presented in *Table 14*. The precipitation sum demand of grapevine is satisfied in all the three time intervals (1961-1990, 2021-2050, 2071-2100) regarding for both the yearly and the vegetation period, according to the regional climate model RegCM 3.1. The amount of the yearly precipitation sum is expected to decrease slightly up to the middle of the 21st century and to increase thereafter. In the growing season there is only a decreasing trend detected up to a rate of about 10 % in a century.

Table 14. *Averages of precipitation indices in Central Hungary*

	Time interval		
	1961-1990	**2021-2050**	**2071-2100**
Yearly precipitation sum (mm)	714	656	693
Precipitation sum 1st of Apr– 30th of Sept (mm)	327	324	298
The max. length of consecutive days with precipitation less than 1 mm (days)	22.4	24.5	26.7
The 2nd max. length of consecutive days with precipitation less than 1 mm (days)	15.6	16.7	17.6
The 3rd max. length of consecutive days with precipitation less than 1 mm (days)	12.1	13.0	13.5

In *Table 14* we display the lengths of the three longest dry periods as a 30-year mean. The length of the longest dry period with consecutive days of daily precipitation less than 1 mm increases from 22.4 to 26.7 in the long run, compared to the reference period 1961-1990. The lengths of the second and third longest dry periods are also estimated to increase.

According to the regional climate model RegCM 3.1 the length of the longest wet periods (3.2-3.4 days) with consecutive days of precipitation above 5 mm does not generate notable risk with an expected stagnancy in the future.

The comparative diagrams of the relative change of risk factors in Central Hungary expressed by the climatic indicators referring to medium term (2021-2050) and long term (2071-2100) can be seen in *Figures 6 and 7*. From the factors involving risk or benefit with changing values we highlight the most important ones which have decisive impact on the crop quality. In the figures we use the following abbreviations:

- D1, D2, D3, days: the first, second and third maximal lengths of consecutive days with precipitation less than 1 mm;
- F-1, days: the number of frosty days (below -1°C) after the 1st of April;
- C35, days: the number of days with maximal daily temperature above 35°C;
- C30, days: the number of days with maximal daily temperature above 30°C;
- HI, °C: Huglin Index;
- EDD, °C: effective degree days

The lengths of the dry periods (D1, D2, D3) do not increase drastically, however, considering their approximate values in the reference period (above 20 days for D1, above 15 days for D2 and above 12 days for D3), a still existing risk of water stress is warned with a motivation for making efforts toward risk mitigation practices.

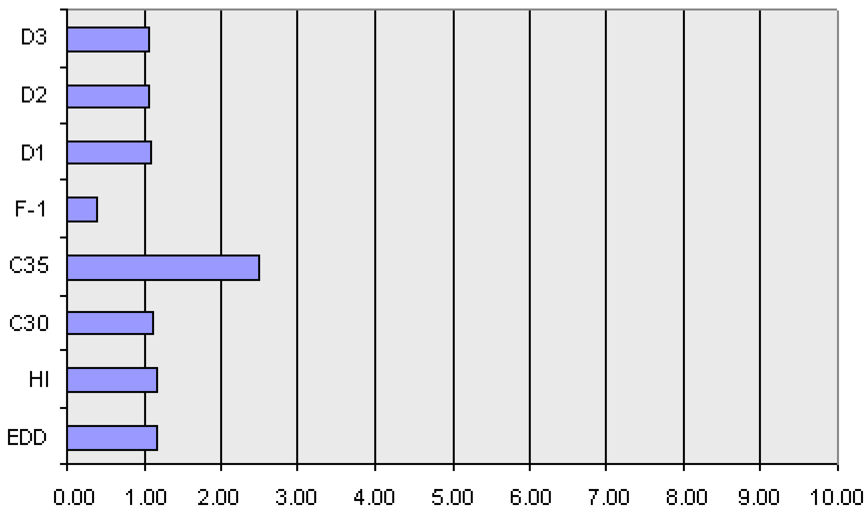


Figure 6. *The change of risk in Central Hungary expressed by the climatic indicators and calculated by the regional climate model RegCM 3.1 for the time interval 2021-2050 related to 1961-1990 (D1, D2, D3, days: the first, second and third maximal lengths of consecutive days with precipitation less than 1 mm; F-1, days: the number of frosty days (below -1°C) after the 1st of April; C35, days: the number of days with maximal daily temperature above 35°C; C30, days: the number of days with maximal daily temperature above 30°C; HI, °C: Huglin Index; EDD, °C: effective degree days)*

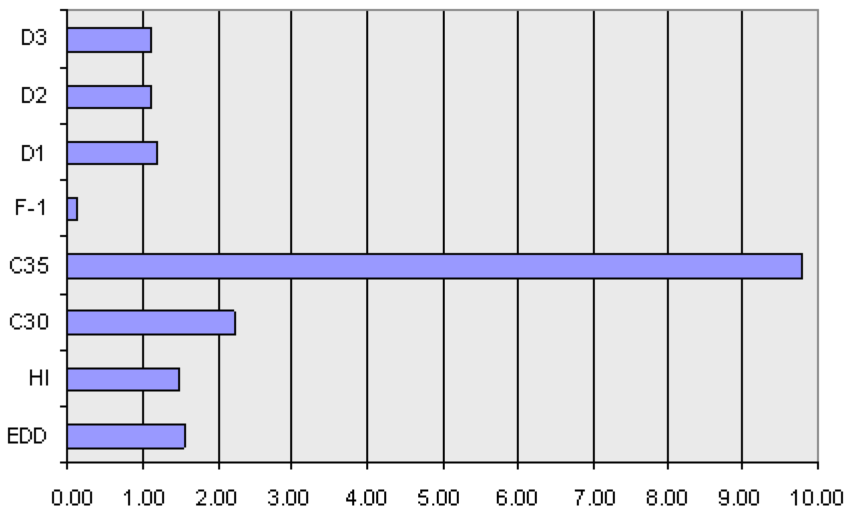


Figure 7. *The change of risk in Central Hungary expressed by the climatic indicators and calculated by the regional climate model RegCM 3.1 for the time interval 2071-2100 relative to 2021-2050 (D1, D2, D3, days: the first, second and third maximal lengths of consecutive days with precipitation less than 1 mm; F-1, days: the number of frosty days (below -1°C) after the 1st of April; C35, days: the number of days with maximal daily temperature above 35°C; C30, days: the number of days with maximal daily temperature above 30°C; HI, °C: Huglin Index; EDD, °C: effective degree days)*

The number of hot days (C35) doubles in the middle term and increases almost to its tenfold value in long term. The number of warm days (C30) increases significantly and doubles in the second half of the 21st century, only.

The spring frost risk (F-1) decreases throughout the whole century.

The increasing tendency of Huglin Index values (HI) together with the one of the effective degree days (EDD) can affect fairly beneficial.

Conclusions

Considering the climatic indicators of Central Hungarian grape growing region we can state that in middle or even in long term with the increasing values of the temperature indices (effective degree days, Huglin Index) besides early and medium ripening varieties some late varieties can be introduced in the production in the subregions changing their cool climate class into temperate one. With warming the probabilities of spring and winter frost events are decreasing and therefore some frost sensitive table grape varieties can gain their higher security of crop production.

Nevertheless we stress the point that low probability events with high damage can still be very harmful. Low probability-high impact events are very complex to handle as their distributions are very difficult to estimate and even 10 km resolution regional climate model outputs have still too high error term to solve this problem appropriately.

The significantly decreased probability of frost events does not give enough reason to give up the research, breeding or application of frost resistant varieties especially in plain region viticulture regions with lower altitude or sites with cool collecting structure of terrain. Still at present we regularly observe quite serious frost events. For example, one of the typical frost affected areas of Kunsági wine region, *Gál Vineyard and Winecellar* sustained winter frost damage in the last two years. On the 21st of December, 2009 temperature dropped to -19.6°C and on the 19th of December, 20010 to -15.8°C which caused 60% and 30% bud frost in case of the Kékfrankos variety that is moderately sensitive to winter frost (Gál et al., 2011; Zanathy et al., 2011). Meanwhile, in case of more sensitive varieties even 80% of buds were frost dead in 2009 (Sz-Nagy, personal communication).

According to our results the significant increase of the number of warm and hot days involves both quantity (biomass increase) and quality risk of production (change of balance of sugars and acids). The structure of plantation, the system of cultural practices, especially the canopy manipulation and soil management practices have probably be modified and adjusted to the changed conditions in order to prevent the damages or mitigate the risk of loss. Moreover, we have to prepare for the possible modification of the characteristics of wines and the feature of some regions. The deviation between the results of the different years can moderate as the climate factors affect together with their interaction with the shifted phenological stages. The realized change of the character of a region is very difficult to prognosticate. Not only the change of the climate with its direct impact but also the effect of the modified edaphic factors, the plantation structure and the applied cultivation and practices with their interactions should be taken into consideration.

The water supply even with its possible decrease remains in the optimal range, considering the yearly precipitation sum, the risk of serious water stress is not high. The precipitation sum in the vegetation period tends to be near optimal. Moderate water stress, however can be caused by the longer and longer dry periods growing up to 27 days by the end of the 21st century. As a consequence of the increased aridity, we also have to prepare for unbalanced growing process.

To sum it up we can state that regional climate model RegCM3.1 forecasts a warmer and dryer future in Central Hungary with respect to the long term mean distribution parameters which does not endanger the growing demands of grapevine producers. However, the increasing frequencies and seriousness of extreme events, especially warm and hot days as well as long dry periods bring us new risk factors to face which motivates us to find out new strategies such as modified or new plantation systems, vineyard establishment practices or viticultural management techniques. Since grapevine is planted for a long time (30-40 years), new plantations should be introduced considering the expected changes in the future.

Both regional and subregional surveys are necessary to learn the present and the expected future situation of a region with the possible changes of its border. Responsible decisions on the modification of grape growing regions can be made according to the evaluations of the continuous monitoring and survey.

Acknowledgements. This research was supported by the research project of the National Development Agency TÁMOP-4.2.1/B-09/1/KMR-2010-0005.

REFERENCES

[1] Bartholy, J., Pongrácz, R., Barcza, Z., Haszpra, L., Gelybó, Gy., Kern, A., Hidy, D., Torma, Cs., Hunyady A., Kardos, P. (2007): A klímaváltozás regionális hatásai: a jelenlegi állapot és a várható tendenciák. – Földrajzi Közlemények. CXXXI. (LV.) kötet, 4: 257-269.

[2] Bartholy, J., Pongracz, R., Torma, Cs. (2010): A Kárpát-medencében 2021-50-re várható regionális éghajlatváltozás RegCM-szimulációk alapján. – "KLÍMA-21" Füzetek 60: 3-13.

[3] Bartholy, J., Pongracz, R., Torma, Cs., Pieczka, I., Kardos, P., Hunyady, A. (2009): Analysis of regional climate change modelling experiments for the Carpathian basin. – International Journal of Global Warming 1(1-2-3): 238-252.

[4] Battaglini, A. (2003): Perceptions des changements climatiques par les viticulteurs européens. – Le lien de la vigne, Assemblée générale du 4 avril 2003, la viticulture mondiale face à l'évolution du climat.
http://www.vinelink.org/Home/Ang/DefaultAng.htm

[5] Bindi, M., Fibbi, L., Miglietta, F. (2001): Free air CO2 enrichment (FACE) of grapevine (Vitis vinifera L.): II. Growth and quality of grape and wine in response to elevated CO2 concentrations. – European Journal of Agronomy 14: 145-155.

[6] Botos, E.P., Hajdú, E. (2004): A valószínűsíthető klímaváltozás hatásai a szőlő- és bortermelésre. – "AGRO-21" Füzetek, 34: 61-73.

[7] Bravdo, B.A., Hepner, Y. (1987): Irrigation management and fertigation to optimize grape composition and vine performance. – Proceedings of the Symposium on Grapevine Canopy and Vigor Management. Acta Hortic 206: 49–67.

[8] Carbonneau, A. (1998): Irrigation, vignoble et produits de la vigne. Chapitre IV., Traité d'irrigation, Aspects qualitatifs. – Paris, Lavoisier, 257–276.

[9] DeLucia, E.H., Casteel, C.L., Nabity, P.D., O'Neill, B.F. (2008): Insects take a bigger bite out of plants in a warmer, higher carbon dioxide world. – Proceedings of the National Academy of Sciences of the United States of America. 105: 1781-1782.

[10] Duchêne, E., Schneider, C. (2005): Grapevine and climatic changes: a glance at the situation in Alsace. – Agron. Sustain. Dev. 24: 93-99.

[11] Dunkel, Z., Kozma, F., Major, Gy. (1981): Szőlőültetvényeink hőmérséklet- és sugárzásellátottsága a vegetációs időszakban. – Időjárás 85(4): 226-234.
[12] Dunkel, Z., Kozma, F. (1981): A szőlő téli kritikus hőmérsékleti értékeinek területi eloszlása és gyakorisága Magyarországon. – Légkör 26(2): 13-15.
[13] Gál, Cs., Zanathy, G., Lukácsy, Gy., Győrffy, G., Lőrincz, A., Bisztray, Gy. D. (2011): Egyesfüggöny művelésű Kékfrankos termékkategóriák szerint beállított rügyterhelésének vizsgálata a Kunság borvidéken. – Borászati füzetek 22(3): 1-9.
[14] Hajdú, E. (2005): A fajtapolitika alkalmazkodása az agrometeorológiai viszonyok változásához a szőlő–bor ágazatban. – "AGRO–21" Füzetek 42: 121-127.
[15] Horváth, Cs. (2008): A szőlő és a klímaváltozás. – Kertészet és szőlészet 57(50): 12-15.
[16] Huglin, P. (1978): Nouveau mode d'évaluation des possibilites héliothermiques d'un milieu viticole. – Proceedings of the Symposium International sur l'ecologie de la Vigne. Ministère de l'Agriculture et de l'Industrie Alimentaire, Contança, 89–98.
[17] Jones, G.V., Davis, R.E. (2000): Climate Influences on Grapevine Phenology, Grape Composition, and Wine Production and Quality for Bordeaux, France. – Am. J. Enol. Vitic. 51(3): 249-261.
[18] Jones, G.V. (2006): Climate and Terroir: Impacts of Climate Variability and Change on Wine. – In: Macqueen, R.W., Meinert, L.D. (eds.): Fine Wine and Terroir – The Geoscience Perspective, Geoscience Canada Reprint Series Number 9, Geological Association of Canada, St. John's, Newfoundland, 247.
[19] Moisselin, J.M., Schneider, M., Canellas, C., Mestre, O. (2002): Les changements climatiques en France au XX siècle: étude des longues séries homogénéisées de température et de précipitations. – La Météorologie 38: 45-56.
[20] Oláh, L. (1979): Szőlészek zsebkönyve. – Mezőgazdasági Kiadó, pp. 38-42.
[21] Schultz, H.R. (2000): Climate Change and viticulture: A European perspective on climatology, carbon dioxide and UV-B effects. – Austr. J. of Grape and Wine Research 6: 2-12.
[22] Stock, M., Badeck, F., Gerstengarbe, W., Kartschall, T., Werner, P.C. (2003): Weinbau und Klima – eine Beziehung wechselseitiger Variabilität. – Terra Nostra 6: 422-426.
[23] Tonietto, J., Carbonneau, A. (2004): A multicriteria climatic classification system for grape growing regions worldwide. – Agricultural and Meteorology 124: 81-97.
[24] Torma, Cs., Bartholy, J., Pongracz, R., Barcza, Z., Coppola, E., Giorgi, F. (2008): Adaptation and validation of the RegCM3 climate model for the Carpathian Basin. – Időjárás 112(3-4): 233-247.
[25] Varga, Z., Varga-Haszonits, Z., Enzsőlné Gelencsér, E., Milics, G. (2007): Az éghajlati változékonyság hatása a szőlőtermesztésre. – Kertgazdaság 39(2): 27-34.
[26] Wolfe, D.W., Schwartz, M. D., Lakso, A. N., Otsuki, Y., Pool, R.M., Shaulis, N.J. (2005): Climate change and shifts in spring phenology of three horticultural woody perennials in northeastern USA. International Journal of Biometeorology 49(5): 303-309.
[27] Zanathy, G. (2008): Gondolatok a klímaváltozás szőlőtermesztésre gyakorolt hatásáról – Agro napló 12(2): 92-94.
[28] Zanathy, G., Csaba, G., Lukácsy, Gy., Győrffy, G., Donkó, Á., Bisztray, Gy.D. (2011): The effect of bud density on the vegetative and generative performance of the Kékfrankos grape variety in Szigetcsép. – Erdei Ferenc VI. Tudományos Konferencia, Kecskemét. 2011. augusztus 25-26.