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

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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

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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.

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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.

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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*

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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.

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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*).

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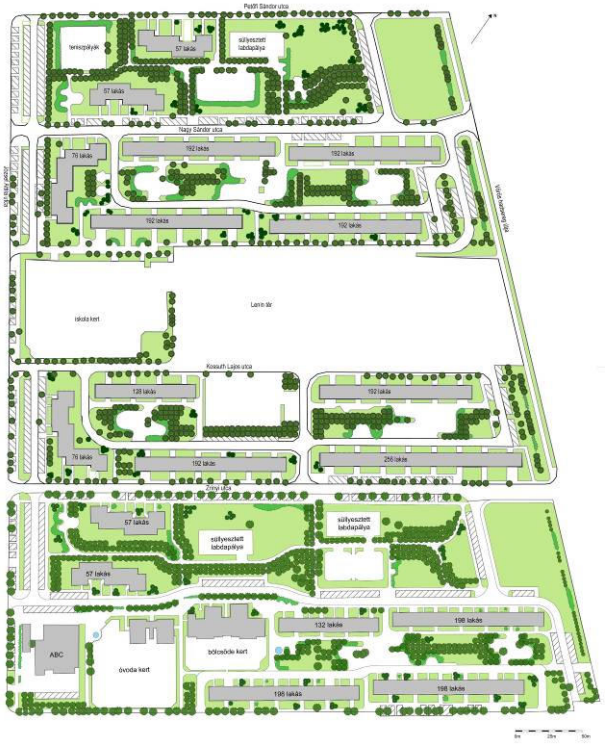
Indicator	Quantity	%
Total area (m^2)	274370	100
Built-in area (m^2)	34104	12.4
Solid pavements (m^2)	134446	49.0
Pervious pavements (m^2)	364	0.13
Water surface (m^2)	0	0
Green surface (m^2)	105456	38.4
Green+pervious surface (m^2)	105820	38.6
Multi- level vegetation (m^2)	8576	
Fragmented green surface (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.

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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*

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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

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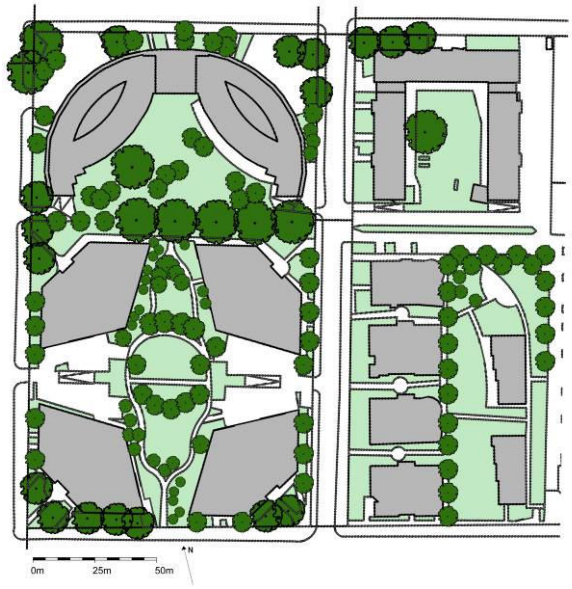
residential parks built recently as a private investment are guided only by quick return, which might have resulted in a sharp decline of green surface proportion. Extremely high density developments are typical, with high-rise buildings. But even in the cases of two extremely intensive housing developments, 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*

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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.

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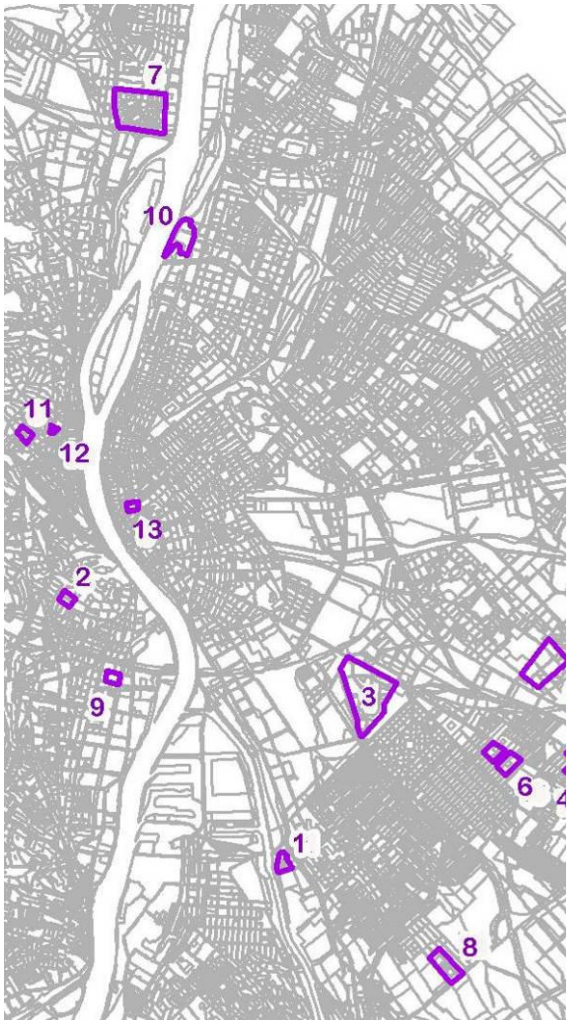

1 XIX. Gubacsi hídfő housing estate
2 XI. Villányi út 55-65. housing estate
3 IX. József Attila housing estate
4 XVIII. Lakatos út housing estate
5 X. Kőbánya Újhegy housing estate
6 XIX. Kispest Városközpont housing estate
7 III. Pók utca housing estate
8 XX. Szentlőrinci út housing estate
9 XI. Nádorliget residential park
10 IV. Marinapart residential park
11 II. Ganz park
12 II. Mechwart tér
13 V. Erzsébet tér

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.

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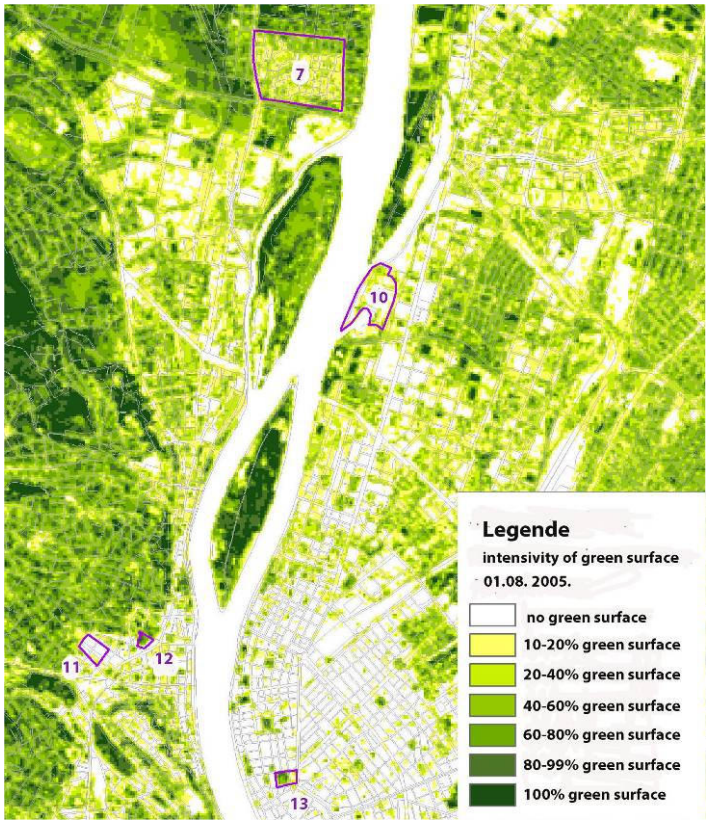

Figure 12. *NDVI of analyzed and reference sites in North Budapest in 2005*

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

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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.

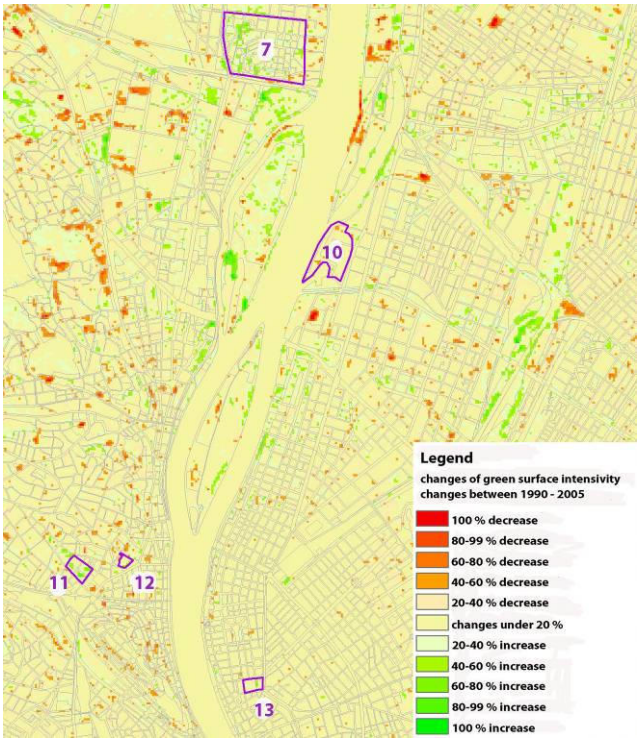

Figure 14. *Changes of NDVI between 1990 and 2005 at analyzed and reference sites in North Budapest*

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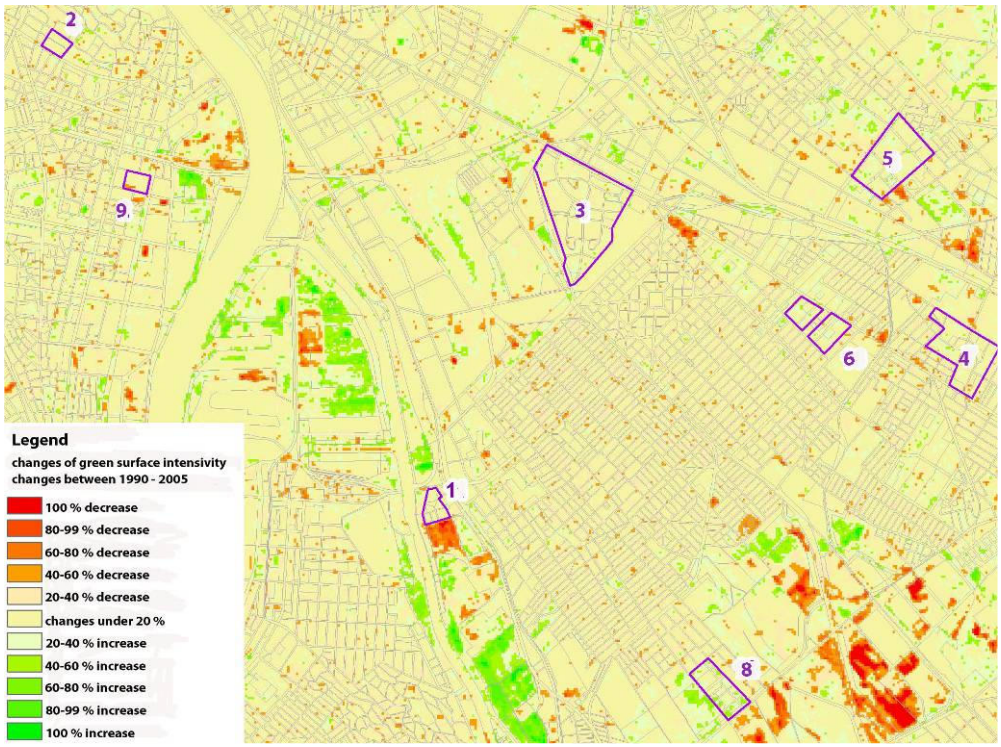

Figure 15. *Changes of NDVI between 1990 and 2005 at analyzed sites in South Budapest*

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.

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