DEVELOPING HUNGARIAN CADASTRAL DATABASE OF GREEN ROOFS AND THE TRENDS IN GREEN ROOF CONSTRUCTION INDUSTRY

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ABSTRACT

Our research goal was – taking into account the needs mentioned above – developing a cadastral database of green roofs, as well as the presentation of the first results. Main data used in the database: year of construction, type of green roof (extensive, intensive), dimensions (m^2), customer's name, contractor company's name, maintenance services (presence, absence), irrigation system (presence, absence). The big advantage of the database is that it can be expanded to meet additional demande, the downside is its voluntary basis. Based on the results of three years of research we can say that spreading of green roofs in the 90s in Hungary was slow. Real breakthrough was observed from 2000, mainly due to large investments in the city. Based on the analysis of the customers, it became clear that the growth was not due to a general increase in environmental awareness of the people, but to the stricter rules for creating green spaces in the National Requirements Regarding Town Planning and Construction (OTÉK, annex No. 5.) The amount of green roofs constructed (m^2) has a hectic fluctuation in the studied period (1991-2012), which comes from the fact that both office and residential buildings are mostly developed in a project-like way. The analysis of the database showed that a total of 287,843 m^2 green roofs were built in Hungary by 31/12/2012 – of which 64,799 m^2 (22.75%) was extensive green roof, and 219,943 m^2 (77.25%) was intensive green roof. We evaluated the analysis of the model with SPSS 20.0 for Windows software package, based on the research of HARNOS and LADÁNYI (2005). The data for curve fitting algorithm was the following:

$$N(t)=\frac{\chi_1}{1+\exp\left\{\frac{\ln(81)}{\Delta t_1}\left(t-t_{m_1}\right)\right\}}+\frac{\chi_2}{1+\exp\left\{\frac{\ln(81)}{\Delta t_2}\left(t-t_{m_2}\right)\right\}}$$

The coefficient of determination $R^2 = 0.996$, so the model offers a good explanation for the data dispersion. Processing the related ANOVA we obtained $F = 1678.52$, which is very high so we can claim that the choosen bi-logistic model fits well. Based on the t-tests related to the parameters (calculated values are: $t_{\chi1} = 16.43$; $t_{\chi2} = 7.99$; $t_{m1} = 61.80$, $T_{m2} = 58.75$; $\Delta t_1 = 6.4$, $\Delta t_2 = 4.34$), we accept the parameter estimates as good ones. In the last two years decline in the construction industry has a significant influence on the development volume of green roofs which is mainly due to global trends.

Keywords: Hungarian cadastral database, bi-logistic regression model, trends in green roof

INTRODUCTION

In Hungary the first green roof was built in 1991. It's been more than two decades since then, and the field of designing and building green roofs has gained some momentum – mainly based on experiences and know-how from Germany. The predecessor of today's Zöldtető- és Zöldfalépítők Országos Szövetsége (ZÉOSZ – National Association for Green Roofing) charitable civil organization was founded in 1999 with the main goal of joining experts together to promote building green roofs in Hungary. Customers, designers, builders, and codifiers expected to get an accurate overview on the green roofs built so far.

There are a multitude of different demands: the customer side needs financial data primarily (cost investment and maintenance, life-cycle, energy savings etc.), designers and builders are looking for the performance indicators and the related experiences (species used, thickness/mass/structural stability of the medium, water conservancy, etc.), while codifiers focus on information needed to introduce legal controls. To this day there is no comprehensive study on green roofs built in Hungary.

We've set the goal of our study to assess the data derived from a green roof cadastre (originating from a 3-year research project). We have the following questions to answer in our work:

1. What's the total area of green roofs built in Hungary? What is the ratio of extensive and intensive green roofs?
2. What model could be used to characterize the timeline of green roof building?
3. What tendencies could be found, and what background factors could be held responsible for the fluctuations between years?

MATERIAL AND METHOD

The green roof database has the following input parameters: year of construction, type of green roof (extensive, intensive), size of the green roof (m^2), name of customer, name of the building company, maintenance contract (whether there is one, or not), sprinkler system (whether there is one, or not).

We used the SPSS 20.0 for Windows software package to fit our model on the data on amount of green roofs built in Hungary, to make estimations on model coefficients, to carry out the regressive diagnostics and to assess conditions – as described by HARNOS and LADÁNYI (2005). Some steps were done as described by SAJTOS and MITEV (2007) through the following stages:

1. An approximation of the graph by plotting the data
2. Modelling
3. Estimation of modelling coefficients
4. Regressive diagnostics
    a. estimation of the deterministic coefficient (R^2), testing its significance (R^2=1–(Residual Sum of Squares)/(Corrected Sum of Squares)
    b. t-tests on estimation of parameters (decisions on what variables to use in the model)
    c. ANOVA of the model (how good the model is at explaining the deviation of data)
5. Condition assessment
    a. independence of residues (correlation)
    b. normality of residues $\varepsilon_i \sim N(0;\sigma)$

RESULTS

The analysis of the database containing data from three years of research showed that a total of 287,843 m^2 green roofs were built in Hungary by 31/12/2012 – of which 64,799 m^2 (22.75%) was extensive green roof, and 219,943 m^2 (77.25%) was intensive green roof. (The main parameters stored in the database are the following: year of construction, type of green roof (extensive, intensive), size of the green roof (m^2), name of customer, name of the building company, maintenance contract (whether there is one, or not), sprinkler system (whether there is one, or not). After plotting the values we assumed that a bi-logistic curve could be fitted to the graph (see *Figure 1.*)

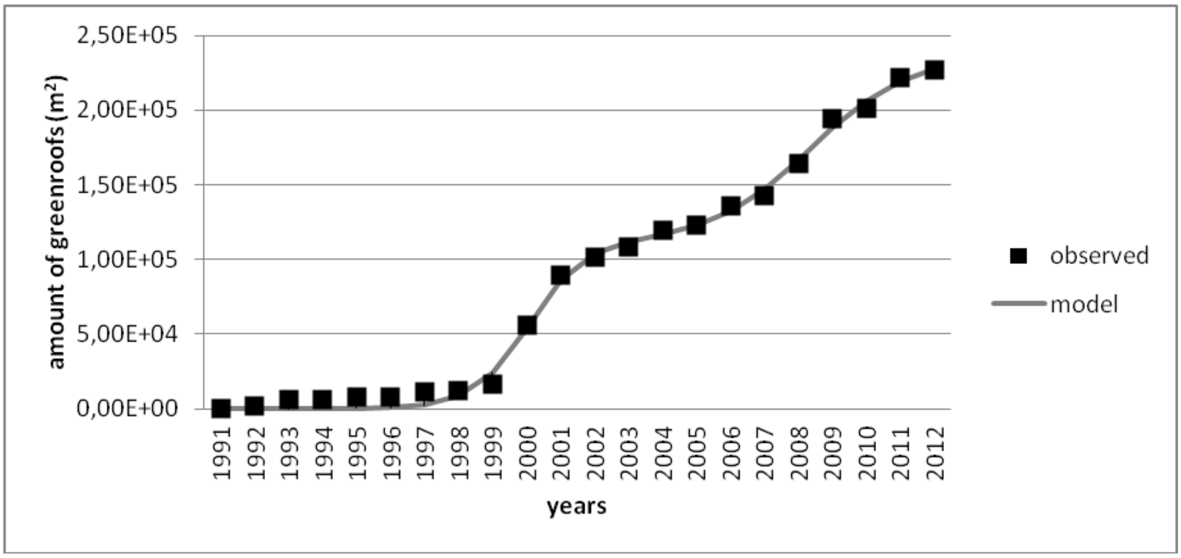

Figure 1. Amount of green roofs built with the bi-logistic model fitted

Data points on *Figure 1*. clearly show the fact that in Hungary green roofs were spreading at a low rate in the 1990s. A real break-through came in the 2000s. It can be stated that the amount of green roofs built shows rather hectic fluctuations in the period assessed (1991–2012). Analysis of the customers made it clear that the motivation behind the increasing figures was definitely not the people's shift towards a general approach focusing more on ecology, but an executive decree (namely: OTÉK – 253/1997. (XII. 20.)) that regulates the amount of green areas. Fitting of the model was based on a bi-logistic model (*equation (1)*:

$$N(t) = \frac{\chi_1}{1+\exp\left\{\frac{\ln(81)}{\Delta t_1}\left(t-t_{m_1}\right)\right\}} + \frac{\chi_2}{1+\exp\left\{\frac{\ln(81)}{\Delta t_2}\left(t-t_{m_2}\right)\right\}} \quad \textit{equation (1)}$$

Estimations of our modelling coefficients are included in the table below (*Table 1.*)

Table 1. Parameter Estimates

Parameter	Estimate	Standard Error	95% Confidence Interval	
			Lower Bound	Upper Bound
χ_1	111.874	6.807	97.443	126.305
χ_2	125.102	15.651	91.923	158.281
tm_1	10.055	0.163	9.710	10.399
tm_2	18.368	0.313	17.705	19.031
Δt_1	3.564	0.557	2.383	4.744
Δt_2	6.366	1.466	3.257	9.475

As the first step of our regressive diagnostics we tested the estimated value of the deterministic coefficient and its significance. The deterministic coefficient $R^2=0.996$ proved to be very solid, showing that the model is a close fit, which means that years have a significant correlation to the amount of green roofs built ($R^2=0.996$; $p<0.001$). The second step was to carry out t-tests on the parameter estimates. The equation of the approximative function used is the following (*equation (2)*:

$$N(t)=\frac{16.43}{1+\exp\left\{\frac{\ln(81)}{6.40}(t-61.8)\right\}}+\frac{7.99}{1+\exp\left\{\frac{\ln(81)}{4.34}(t-58.75)\right\}} \qquad \textit{equation (2)}$$

Results confirmed that the estimation of our coefficients was significant, as shown by the following calculated values: $t_{\chi 1}(16)=16.43$; $p<0.001$; $t_{\chi 2}(16)=7.99$; $p<0.001$; $t_{m1}(16)=61.80$; $p<0.001$; $t_{m2}(16)=58.75$; $p<0.001$; $\Delta t_1(16)=6.40$; $p<0.001$; $\Delta t_2(16)=4.34$; $p<0.001$. Step 3 was carrying out ANOVA on the model to determine how good the model was at explaining the deviation of values. Results indicated that the bi-logistic model was effective at explaining the variance of the amount of green roofs built ($F(5;16)=1678.52$; $p<0.001$) (see *Table 2*.)

Table 2. ANOVA on the bi-logistic model

Source	Sum of Squares	df	Mean Squares
Regression	307753.607	6	51292.268
Residual	488.929	16	30.558
Uncorrected Total	308242.536	22	
Corrected Total	134456.645	21	

Condition assessment shows that according the results years have no correlation to residues ($R^2=0.153047$), and this was proved by a t-distribution analysis at the significance level given ($p=0.071802$). Normality of residues $\varepsilon_i \sim N(0;\sigma)$ was tested by the Kolgomorov-Smirnov and the Shapiro-Wilk method (*Table 3*).

Table 3. Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Residuals	0.106	22	0.200*	0.970	22	0.715

*This is a lower bound of the true significance.

[a] Lilliefors Significance Correction

CONCLUSIONS AND DISCUSSION

The amount of green roofs built (m^2) shows a rather hectic fluctuation pattern in the period studied (1991–2012), and that comes primarily from the project-like construction of residential blocks and office-blocks. In Hungary the total of 284,743 m^2 (100%) green roofs included only 64,799 m^2 (22.75%) extensive green roofs. This looks controversial at first sight as it is a well-known fact that extensive roofs require less investment – due to the lower thickness, lower mass, and lower load-carrying capacity roof construction required, and no irrigation system needed –, and they require minimum care and maintenance (HIDY et al. 1995). This controversy can be resolved easily when referring to Appendix 5 of the above said OTÉK decree: extensive green roofs have a 25% factor when calculating the renewal of green areas, while intensive green roofs are considered to have a 50–75% factor (*Table 4*).

Table 4. Green area weight of roof gardens as per OTÉK

Thickness of soil above supporting structure	Composition of plants to populate the area	Accountable green area / total area of roof garden
20 cm tilth	One level, covered at herb layer	25 %
20–50 cm tilth	Two-layered, stand closed at herb layer, semi-closed at shrub layer	50 %
tilth thickness over 100 cm	Three-layered, plantation with herb, shrub and tree layers	75 %

Maximizing area-utilization is a key element when designing residential areas and office-blocks in big cities, and that led to the higher ratio of intensive green roofs. Examples in Germany show that building aesthetic green roofs are motivated by the ecology-centered approach, so extensive roofs built in the past few years have a 85% volume of all green roofs (WERTHMANN, 2007).

The current study focused on the quantitative parameters of the green roofs built, but it might prove beneficial to include other aspects into further analyses to come. A major advantage of the database created is that it can be expanded on demand with parameters like the following: investment and maintenance costs, lifetime, energy savings, thickness/mass/structural stability of the medium, water conservancy, species planted, inter-species competition and dynamics of areas habited by certain species, registering furrow-weed, registering settled-in species, status assessment, determining the net green area, water retention, etc. The existing cadastre also has a draw-back: it is on a voluntary basis, so green roofs with owners who could not or would not provide data are not included in this information system. This could be changed by introducing or improving some motivational factors to companies through regulations or mutual benefits. Accuracy of data included in the cadastre can be further improved by integrating the data of municipal licences issued to build green roofs and on-site checking of the data from voluntary data submissions.

In the next 3 to 4 years – short term – the effects and consequences of a recessing building industry will determine the demand for green roofs. The regulations regarding the amount of green roofs are not expected to change considerably either primarily because of the relatively low lobbying power of ZÉOSZ. Extrapolating current tendencies to medium-term – next 10–15 years – would be pointless as future events are very hard predict due to the volatile nature of input data, and nothing can be said about the validity of past tendencies in the future. Unfortunately the quality of the roofs finished are limited by the fact that inspectors involved in the acceptance process are required to have a degree in architecture, and they do not possess the necessary knowledge in phytology, phyto-physiology, ornamental gardening, botany and topography ecology. As a solution we recommend to modify the relevant regulations, and starting the education of specialized engineers focusing on green roofs.

Effects of green roofs on energetics, water utilization, economy, ecology and landscape aesthetisc are known to professionals. To support the spreading of green roofs it might be beneficial to integrate the international experience accumulated in various incentive systems based on either direct/indirect subsidies or legal requirements. In some countries various 'benefits' of green roofs are supported specifically through building such roofs: Germany (retention of meteoric water), England (biodivesity), USA (reducing the heat-island effect), China (improving air quality) (GRANT, 2006; HAMMERLE, 2009; LIVINGSTONE et al., 2008).

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