Simon Colwill

The Root of the Problem: Addressing the Conflicts between Spontaneous Vegetation and Built Landscape

Conference paper | Accepted manuscript (Postprint)
This version is available at https://doi.org/10.14279/depositonce-9277

COLWILL, Simon (2018): The Root of the Problem: Addressing the Conflicts between Spontaneous Vegetation and Built Landscape. Delarue, S. & Dufour, R. (Eds.): Landscapes of conflict : ECLAS Conference 2018, University College Ghent, Belgium. Conference proceedings, pp. 264-274, ISBN: 9789491564130.

The Root of the Problem: Addressing the Conflicts between Spontaneous Vegetation and Built Landscape

BA (Hons), Dip. (Hons) Simon Colwill
Technische Universität Berlin, Institut für Landschaftsarchitektur und Umweltplanung
Fachgebiet Landschaftsbau-Objektbau
Simon.Colwill@tu-berlin.de

ABSTRACT

Built landscapes are under relentless–attack from both **spontaneous urban vegetation** (plants that colonise naturally without cultivation) and the gradual **encroachment** (spreading) of existing plantings onto adjacent surfaces. The **location**, **spread** and **rate** of this **growth** is highly influenced by microclimatic factors, the availability of soil and propagules, and the frequency of disturbance. **Spontaneous urban plants** are highly adapted to the harsh urban environment and colonise the built landscape both **overground** through seed dispersal and **underground** by means of regeneration from rhizomes. The **encroachment** of plantings beyond planned boundaries onto surrounding surfaces often occurs due to unrestrained growth and the insufficient removal of rooting substrate from the border area between soft and hard landscape. This paper discusses these conflicts by analysing the causes and effects of this growth over time, pinpointing areas of weakness and vulnerability, diagnosing the underlying issues, and developing optimisation strategies.

Current research at the Technische Universität Berlin is focusing on analysing the processes of patination and subsequent deterioration of built landscapes over time. A low-threshold and non-destructive monitoring method to 'read' and decipher these traces of time is being developed in order to determine and analyse the agents of landscape transformation. The principles of construction pathology are used to identify relationships between the observed 'visual signs and symptoms' (effects) and 'pathological conditions' (causes). This enables causes to be determined and recommendations for the most appropriate course of action to be made. This paper will focus on developing optimisation strategies for the areas of weakness and vulnerability identified, and therefore aims to enhance the durability of our built works.

KEYWORDS: Spontaneous urban vegetation, encroachment, built landscape, vulnerability, monitoring

INTRODUCTION

> *'And what is a weed? A plant whose virtues have yet to be discovered … Time will yet bring an inventor to every plant'* (Emerson 1879: 3)

Hard surfaces are considered harsh substrates for vegetation due to the general lack of rooting space, low moisture availability, minimal soil volumes, soil compaction, climatic stress and regular disturbance from human activities such as trampling and maintenance (Lundholm 2014: 93; Kowarik 2003: 293-308). Spontaneous plants are however highly adapted to this harsh urban environment (Del Tredici 2014: 206). Colonisation takes place **overground** through seed dispersal using the wind, gravity or water, animal droppings, or by attaching to animals and being carried away. Dispersal can also occur through human trampling, maintenance operations or by being transported by vehicles (Darlington, 1981). Spontaneous colonisation can also takes place **underground** by means of regeneration from rhizomes (underground stems). The **location**, **spread** and **rate** of **spontaneous urban vegetation** is highly influenced by microclimatic factors, the availability and quality of rooting substrate, moisture availability and the frequency of disturbance from use or maintenance (Lundholm 2014: 94; Lisci & Pacini 1993: 16, 23; Del Tredici 2010: 4).

The most common conflicts involve **damage from roots** due to **spontaneous urban vegetation** growth directly onto the built landscape and the **encroachment of existing plantings** over planned boundaries onto neighbouring surfaces. Furthermore, the **biological staining of materials** was identified together with **drainage conflicts** due to the build-up of sediments and spontaneous growth. The consequences of spontaneous urban growth on the built landscape range from surface patination to subsurface damage which can become severe over time, see Figure 1 (Loidl-Reisch 2016).

Figure 1: Consequences of spontaneous urban growth on the built landscape. a) Filling of joints, cracks, fissures and recesses, b) Encroachment and spreading of plantings over surfaces and boundaries resulting in the veiling of structures, c) Leverage effects through root wedging and heave leading to further weathering, d) Loss of functionality, usability, stability or safety.

METHODS

Current research at the Technische Universität Berlin (TU-Berlin) is based on the hypothesis that it is possible to optimise design, detailing, construction and maintenance techniques by monitoring and evaluating project development at regular intervals after completion. The processes of patination and subsequent deterioration of built landscapes highlight the weak points of the design as well as deficiencies in detailing, construction and maintenance. A low-threshold and non-destructive monitoring method to 'read' and decipher these traces of time is being developed in order to pinpoint the agents of landscape transformation and identify points of weakness and vulnerability in built landscapes. In order to obtain uniform and comparable research results in terms of climate, culture and contextual conditions, and to achieve the required design, material and constructional bandwidth, the research focuses upon landscape details (e.g. steps, paths, drainage elements, tree grids, seating and walls) in typologically different public or semi-public open spaces in Berlin. The current often desolate state of many of these projects reflects the reduced resources of the city, a fact that increasingly applies to cities throughout Europe (BMUB 2015: 12, 33, 74). The research method is based on empirical inquiry following the case study methodology involving both qualitative and quantitative evidence (Yin 2014: 109). Each of the case studies resulting from the field research represents “a contemporary phenomenon within its real life context” (Ibid: 13). Photographic recordings were taken at regular intervals over a 5-8 year period from the time of project completion. Through comparisons between the original state and successive recordings process-dependent changes become visible. The principles of construction pathology are used to identify relationships between the ‘visual signs and symptoms’ (effects) observed and ‘pathological conditions’ (causes). This enables causes to be determined and recommendations for the most appropriate course of action to be made (Watt 1999: 1-7, 159-165). Frequently occurring points of conflict highlight areas of weakness and vulnerability that need especial attention in design, detailing, implementation and maintenance.

SPONTANEOUS GROWTH TYPOLOGIES

The main typologies of pronounced spontaneous urban growth in the built landscape identified through this field research are shown in figure 2. The increased frequency and intensity of spontaneous growth in these areas suggests points of high vulnerability.

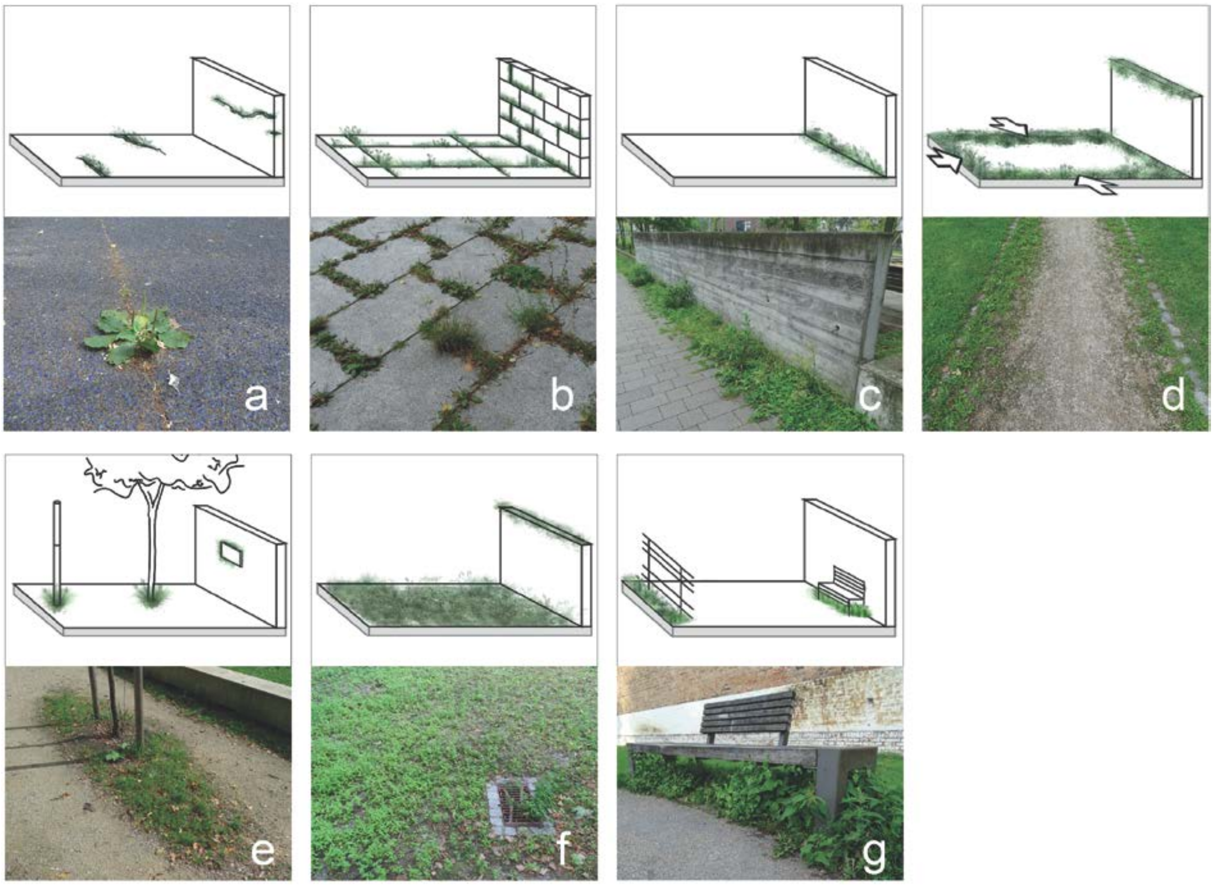

Figure 2: *Spontaneous urban growth typologies. a) Cracks and fissures on horizontal or vertical surfaces, b) Paving or walling joints and seams, c) Junctions between horizontal and vertical surfaces, d) Peripheral encroachment over surfaces, e) Areas surrounding fixtures in horizontal or vertical surfaces, f) Surface area growth, g) Undisturbed areas due to inadequate maintenance or as a result of insufficient usage (under benches, behind railings etc.).*

Many of these vulnerable areas arise because they are particularly difficult to maintain and require meticulous attention to detail, which is often not possible due to financial constraints. Some can however be optimised by selecting more appropriate materials, finishes and constructions for the specific location and function. Spontaneous growth was repeatedly found at the periphery of paved areas, surrounding trees, manhole covers, lighting fixtures and other obstructions. Construction work in these areas is impeded which may result in a lower quality of construction and consequently to an increased vulnerability to spontaneous growth.

COLONISATION OF THE BUILT LANDSCAPE

Horizontal surfaces

Horizontal surfaces offer less hostile growing conditions and therefore generally lead to an increased vulnerability to spontaneous growth (Lisci & Pacini 1993: 20). The main difference to vertical surfaces is the presence of disturbance through trampling or handling which leads to the relocation of substrate, direct damage and substrate compaction (Lundholm 2014: 94-96; Segal 1969: 239-240). Surface colonisation begins with the formation of rooting substrate. The deposition of airborne sediments such as dust, dirt, organic matter (falling leaves, blossom, etc.) and other atmospheric contaminants is increased on the lower-velocity lee of vertical elements such as walls, edgings and plantings as well as on structured surfaces and in corners, joints and gaps. This accumulation of parent material together with actions of climatic factors and biota (bacteria, fungi, worms etc.) slowly breaks down and decays over time leading to soil formation (Bot & Benites 2005: 13; Loidl-Reisch 1987: 63-80). In turn this provides the perfect physical and hydric conditions for spontaneous plant growth (Bot & Benites 2005: 13). Initial spontaneous urban growth leads to the establishment of further microclimatic niches which promotes further growth. Continued growth over time leads to a process of succession in the plant communities that develop. The successive stages of spontaneous vegetation develop deeper and more extensive root systems which can gradually have an impact on the effectiveness and performance of the surface (Antos & Halpern 1997: 97). These more resilient communities (e.g. improved drought resistance) may damage the construction through physical penetration of roots, acids produced by the roots and direct contact (Lisci & Pacini 1993: 25; Lundholm, 2014: 101). In general, more aggressive woody plants that can severely damage a construction require higher levels of substrate (Jim 2008: 359-366; Lisci & Pacini 1993: 24). Growth is however often maintained in a perpetually early-successional state due to usage (trampling, contact with hands etc.) and maintenance regimes such as cleaning, brushing or the salting of surfaces (Lundholm 2014: 96, 99).

Plant encroachment onto surrounding surfaces occurs due to the insufficient removal of organic debris and rooting substrate from the border area between soft and hard landscape through regular maintenance (e.g. brushing). Creeping and groundcover plants with a lateral growth habit that spread from suckers, rhizomes or stolons are particularly prone to rapid encroachment [Fig. 3a-d] (Niemiera 2012: 2). Surfaces adjacent to lawns are also at risk due to the accumulation of clippings at the periphery which degrade rapidly to become rooting substrate. This build-up of substrate allows the grasses to creep over edgings and encroach onto the paved surface by sending out shoots, rhizomes or seeds as shown in Figure 3e-h.

Figure 3: Sequence a-d: *The encroachment of planting from embankment onto paving surface over 8 years. a) Year 1. b) Year 2. c) Year 6. d) Encroachment of vegetation promotes further spontaneous growth, Year 8.*
Sequence e-h*: The encroachment of lawn onto a self-binding gravel surface over 10 years. e) Year 1, f) Year 3. g) Year 5. h) Almost complete vegetation cover, Year 10.*

Conflicts concerning encroachment can be optimised through the selection of less rampant, invasive species together with an increased intensity and frequency of maintenance. The implementation of wide or raised edgings surrounding vulnerable plantings such as lawns, meadows and groundcover helps to suppress encroachment and allows for increased maintainability.

Vertical surfaces

Vertical elements such as walls, facades or lamp posts are generally more difficult for plants to colonise due to gravity, wind currents and precipitation runoff. As Darlington (1981: 17) observed, vertical elements interrupt horizontal air currents leading to an increased deposition of sediments and propagules which, due to gravity and runoff, leads to an increased rate of soil formation at the base. The increased levels of rooting substrate, moisture and low evaporation levels (due to shading) in this area often lead to an increased rate of spontaneous growth [Fig. 4] (Darlington 1981: 5; Lisci & Pacini 1993: 20). Furthermore, this niche is seldom disturbed by human trampling and is particularly difficult to maintain, which enhances growing conditions. (Lundholm 2014: 95-96).

Conflicts can be reduced by implementing fixtures with as few supports punctuating the surface as possible. A permanently elastic grouting material needs to be used for the joints immediately surrounding each support in order to allow for structural movement whilst sealing the joints against spontaneous growth. The maintainability of vertical elements in unbound materials (gravel, hoggin etc) can be improved by paving surfaces immediately surrounding the supports.

Figure 4: *Conflicts around fixtures. a) Impeded maintenance access when in use, year 7. b) Inaccessible spontaneous growth, year 8. c) Growth around street lamp, year 4. d) Hindered maintenance of covered surface, year 7.*

Covered surfaces and areas that are inaccessible for maintenance equipment should be avoided wherever possible. Where necessary, these surfaces either need to be intensively maintained or implemented with joint-free poured surfaces or paving units with sealed joints (e.g. polymer resin or cement based) in order to minimise spontaneous growth.

Subsurface damage

The fine roots of spontaneous urban plants and encroaching vegetation penetrate into the joints, crevices and niches of horizontal or vertical surfaces of the built landscape in search of water, air and nutrients which may result in **root wedging.** Continued root growth over time leads to an increase in root girth thus exerting pressure and forcing materials apart. This in turn can result in increased moisture penetration, increased spontaneous growth and sustained damage through both root and frost wedging. Many spontaneous plants also develop tap roots or extensive fibrous root systems below the surface which, in time, can also exert subsurface upward or outward pressure. This **'root heave'** can cause extensive damage by displacing or fracturing surfaces, resulting in safety issues such as slip and trip hazards. Subsurface roots are protected from the harsh surface climate, disturbance through trampling and maintenance activities which allow spontaneous plants to regenerate from the root base even after dieback or removal of the vegetation above ground. Seeds of spontaneous vegetation can also regenerate after many years of dormancy (Del Tredici 2010: 10. Wittig 1991: 68-69). This makes maintenance measures for the permanent removal of spontaneous growth and the repair of root damage to hard landscape elements especially laborious.

Spontaneous urban vegetation therefore needs to be removed with their roots at a young age before the subsurface root systems can establish. Management of spontaneous vegetation by mechanical means achieves immediate results, however '*cannot eliminate the basal portion of the vegetation, so that the weeds soon re-grow, resulting in the need to repeat the operations at considerable expense several times during the year*' (Benvenuti 2004: 349). Figure 5 shows the development of spontaneous urban vegetation which was eventually removed in year 7, however one year later this vegetation had significantly regrown from its subsurface root system.

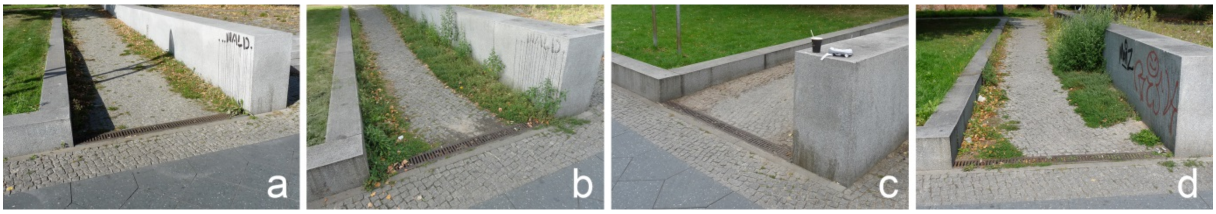

Figure 5: *Spontaneous growth between short walls over 8 years. a) Spontaneous growth at the base of short walls, Years 3. b) Year 6. c) Removal of growth in year 7. d) Rapid regrowth of vegetation in year 8.*

The most effective method of non-chemical weed control depends on the spontaneous plant species present, maintenance standard and cost effectiveness (Marble et al. 2015a: 854). The best results are achieved when employing a variety of methods such as mowing, brushing, hand-pulling, hoeing and thermal control techniques (Rask & Kristoffersen 2007: 374-377). Knowledge of the flowering periods of the predominant spontaneous species allows for maintenance to take place before the seeds become viable and are dispersed into the surrounding built landscape (Benvenuti 2004: 349, 351).

Environmental (exposure to light, intensity of use), technical (paving type, joint width and material), and construction design (design, finishing) factors influence the intensity of spontaneous plant growth on hardscapes (Boonen at al. 2012: 4-12). Therefore, preventative weed control strategies need to be commenced in the design and detailing phase by selecting appropriate materials (e.g. jointing materials) and construction techniques (Boonen at al. 2012: 2-12; Rask & Kristoffersen 2007: 371, 378) that are tailored to the requirements of the specific site conditions.

Shaded locations [Fig. 6a-d]

Hardscapes in the shade of buildings, trees and overhanging vegetation are especially vulnerable to spontaneous plant growth and encroachment. Shading protects hardscapes against evaporation and sun exposure which increases the level of humidity and provides cooler temperatures (Lisci & Pacini 1993: 24, Wittig 1991: 154). A student assisted field study at the TU Berlin comparing exposed and shaded paved surfaces revealed that tree shade reduced maximum surface temperatures by up to 19°C. Surface humidity was measured to be constantly higher in shade than on exposed surfaces during daylight hours. The study concluded that shaded hardscape surfaces therefore provide significantly better conditions for spontaneous vegetation growth than exposed surfaces. Spontaneous growth is particularly intense in shaded areas below or adjacent to vegetation due to the increased abundance of organic matter [Fig. 6a-d, Fig. 8e-h].

Figure 6: Images a-d*: Increased vulnerability to spontaneous growth in shade. a) Limestone setts in full sun/full shade of a building, year 3. b) Increased spontaneous growth due to overhanging tree, year 3. c) Spontaneous vegetation adjacent to hedge, year 3. d) Spontaneous growth on compacted gravel surface below tree, year 4.*
Images e-f: *Conflicts with drainage elements. e) Encroachment of vegetation from neighbouring embankment, year 3. f) Growth within gully in compacted gravel surface, year 8. g) Blockage of slit drain due to organic debris and spontaneous growth, year 3. h) Minimal gradient leading to sedimentation and growth on surface, year 10.*

Drainage conflicts [see Fig. 6e-h]
Organic matter shed by plants such as leaves, fruit, flowers, seeds or sap together with other debris such as dirt, litter and mulch is transported to **the** lowest points of built works through the surface runoff of natural precipitation and erosion (Colwill 2017: 296). This debris therefore accumulates where drainage inlets (gullies, linear drains etc.) are located which often leads to conflicts due to enhanced spontaneous growth and blockages. This is especially problematic on unbound surfaces where, during heavy rainfall, surface runoff can wash out surface or jointing materials thus causing the increased sedimentation of drainage systems. Gullies with a low intake capacity or narrow inlet (slot channel drains) are especially susceptible to blockages [Fig. 6g]. Conflicts due to insufficient surface gradients were also identified. Low surface gradients reduce the flow rate of surface precipitation resulting in an increased deposition of sediments and the retention of moisture, thus providing ideal conditions for spontaneous growth [Figure 6h].

These conflicts can be reduced through increased surface gradients, the regular removal of debris from the surfaces of built landscapes (e.g. by brushing) together with frequent sediment removal from the inlets, channels and sediment filters of drainage elements. Furthermore, drainage inlets need to be planned away from the niches and corners of the built landscape where increased sedimentation and spontaneous growth is inevitable e.g. at the base of walls, the foot of steps or adjacent to abundant vegetation.

THE COLONISATION OF MATERIALS [see Fig. 7]

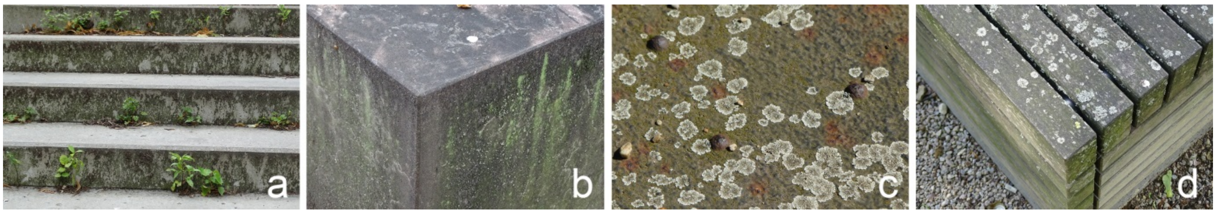

Figure 7: *Primary succession of materials. a) Concrete steps, year 7. b) Natural stone, year 8. c) Aluminium alloy, year 11. d) Wood, year 7.*

Contributing factors for the colonisation of materials include the degree of exposure, surface structure and roughness, surface wetness, and the specific material properties such as chemical composition, water absorptivity and porosity (Rindi 2007: 623). Furthermore, the deposition of fruit, sap, insect honeydew (excreted by aphids) and other organic substances by plants onto the surfaces of built elements leads to an increased level of **surface colonisation**. Rougher surface materials retain and trap particles of debris more readily allowing for increased soil formation and spontaneous growth. Porous materials are more easily colonised due to their water retaining capacity and the facilitation of substrate formation (Lisci & Pacini 1993: 22). The presence of surface moisture, for example in shaded areas, enables airborne deposits to adhere to surfaces more readily thus promoting the processes of surface colonisation. As a result, materials that are prone to moisture-related defects such as rot or rust require surface protection in these locations. Water-resistant materials such as granite or concrete which remain permanently moist are susceptible to biological surface growth (algae, moss, fungi, and lichens). This biological growth retains moisture for a long period of time after rainfalls which results in reduce traction and risk of slipping. Therefore surfaces prone to moisture, such as areas in deep shade, need to be implemented with slip resistant surfaces.

Figure 8: *Spontaneous urban growth. a) Growth in jointing material of paving, year 3. b) Vegetation in open joint between surface and wall, year 7. c) Growth in joints of steps, year 7. d) Spontaneous growth in gravel joint at the foot of an inclined wall, year 6. e) Growth surrounding tree in self-binding gravel surface, year 3. f) Self-binding gravel surface in full shade of trees, year 5. g) Tree in self-binding gravel surface, year 7. h) Increased growth in gravel joints of paving beneath a tree, year 8.*

Unbound materials such as self-binding gravel and surfaces with a high proportion of aggregate joints are particularly prone to spontaneous growth, especially in shaded areas. The irregular granular surface layer leads to a rapid accumulation of sediments and enhanced conditions for spontaneous vegetation growth. The distribution of this spontaneous growth reflects patterns of disturbance through maintenance and usage, see Fig. 8e-g.

Jointing materials are also prone to spontaneous growth, see Fig. 8a-d. Seeds, dirt and detritus that land on surfaces can be washed or blown into these recesses thus improving growing conditions. Research at Ghent University highlights the following factors in order to reduce spontaneous urban growth in paving joints:

- Bedding layers should have a high permeability
- Joints should be narrow to reduce the surface of attack
- Narrow joints should be filled with fine-grained jointing sand (grain size <2mm). Wide joints should be filled with coarse-grained materials in order to reduce the amount of water available for vegetation growth (grain size <6,3mm)
- Reduce the level of organic pollution from surrounding areas through regular sweeping
(De Cauwer et al. 2014: 157-161)

Materials and their surface treatments therefore need to be selected by taking not only the form and function into consideration but also the specific microclimatic factors of the location. The predicted intensity of use, the foreseen level of maintenance and the presence of organic matter also need to be duly considered.

DISCUSSION

> *'From a horticultural perspective, a truly sustainable landscape design is one that is in balance with the financial resources available to maintain it'* (Del Tredici 2006: 52)

Maintenance plays a major role in all the conflicts depicted as case studies presented in this paper. The frequency and quality of maintenance operations together with the quality of design and construction have a huge impact on how a project will change, develop and eventually degenerate throughout the project lifecycle. Many authorities are however under financial constraints that limit the ability to maintain public space sufficiently (Kühn 2006: 58). Poor maintenance, however, may also result from reduced maintainability due to poor design and detailing. It is therefore essential to optimise maintainability in the design and construction phase by addressing the key points of weakness and vulnerability. This is also crucial in understanding how an object may fail, thus allowing for optimisation in the planning process.

Poor or improper maintenance can also results from the lack of skills of maintenance staff or supervisors, the quality of workmanship and the available of suitable equipment. In the interests of optimising maintainability and durability, essential information on the availability of skills and equipment for the construction and maintenance of the project needs to be considered in the design and detailing process.

Traditional maintenance concepts aim to completely remove all spontaneous growth leading to high costs. It is however possible to create aesthetical and ecological performative spaces by allowing for the growth of spontaneous vegetation (Seiter 2016: 30). Combining spontaneous plants and ornamental plant would help to make spontaneous vegetation more attractive to the public (Kühn, 2006: 64, 65). More research is however necessary in order to generate a thorough understanding of planting design and maintenance strategies involving spontaneous vegetation.

CONCLUSIONS

> *'Feedback into the growth or decay of a landscape allows the landscape architect to have a positive, creative role in its development, rather than a negative, mitigating view of change, which is encompassed in the notion of 'maintenance''* (Raxworthy 2013: 193).

The results of our field research depict evolving conflicts between hardscape and spontaneous growth over time thus highlighting many frequently occurring points of weakness and vulnerability. The most common conflicts involve the growth of spontaneous urban vegetation directly onto hardscapes and the encroachment of existing plantings over surrounding structures.

The reduced budgets available for maintenance operations (Kühn 2006: 58) force landscape architects to focus more on the maintainability of their projects in the design and detailing phase of the project. This process should aim to predict points of weakness and vulnerability, and focus on optimising or resolving these. Management and maintenance strategies also need to consider the long term guiding image of the design. Insufficient maintenance leads to the development of successive stages of spontaneous vegetation which can become damaging over time as more aggressive, woody plants establish. Effective maintenance relies on the regular removal of potentially damaging, or particularly resilient root systems at regular intervals before they can establish. Integrated control strategies should focus on preventive measures in the design and detailing phase as well as remedial maintenance measures such as brushing or flaming during occupancy (Boonen at al. 2012: 12). Alternatively, a long term guiding image of the design allowing for the growth of spontaneous vegetation may be pursued. The necessary budget for long-term maintenance of the project should be secured in advance as part of lifecycle management.

The field research forming the basis for this study demonstrates how the monitoring of the development of built works over time allows for continuous learning through an improved understanding of design, detailing, and material performance through time. Observation and analysis of project development allows for increased opportunities to carry out alterations before damage or more significant failure can arise. The findings need to be fed back to the profession, thus providing practitioners with a tool for forecasting points of weakness and vulnerability, informing judgments on future projects and avoiding repeated failure.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the financial support provided by the German Research Foundation (DFG).

REFERENCES

ANTOS, Joseph A.; HALPERN, Charles B. (1997): *Root System Differences Among Species. Implications for Early Successional Changes in Forest of Western Orego*n. In American Midland Naturalist 138 (1), pp. 97-108.

BENVENUTI, S (2004): *Weed dynamics in the Mediterranean urban ecosystem: ecology, biodiversity and management*. Weed Research 44, pp. 341–354.

BMUB - Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit, Berlin (Ed.) (2015). *Grün in der Stadt – Für eine lebenswerte Zukunft. Grünbuch Stadtgrün.* [*Green in the city - for a livable future. Green Paper on Green Cities*] Berlin: Self-published.

BOONEN, E., BEELDENS, A., FAGOT, M., DE CAUWER, B., REHEUL, D., & BULCKE, R. (2012) *Preventive Weed Control on Pavements: Reducing the Environmental Impact of Herbicides Part 1: A Field Survey Study*. In: Proceedings 2012 10th International Conference on Concrete Block Paving (24-26 November, Shanghai, People's Republic of China). 1-14.

BOT, Alexandra; BENITES, Jose (2005): *Importance of soil organic matter*. Rome: FAO (FAO soils bulletin 80).

COLWILL, Simon (2017): *Time, Patination and Decay. In Creation/Reaction*. ECLAS Conference 2017, University of Greenwich, London UK. Conference proceedings, pp. 293-314.

DARLINGTON, Arnold (1981): *Ecology of walls*. London: Heinemann Educational Books.

DE CAUWER B, F AGOT M, BEELDENS A, B OONEN E, BULCKE R&REHEUL D (2014). *Reduced weed growth with different paving constructions*. Weed Research 54, pp. 151–161.

DEL TREDICI, Peter (2006): *Brave New Ecology. The magazine of Landscape Architecture*. February 2006. pp. 46-49.

DEL TREDICI, Peter (2010): *Wild urban plants of the Northeast. A field guide*. Ithaca: Cornell University Press (Cornell paperbacks).

DEL TREDICI, Peter (2014): *The flora of the future.* In: C. Reed and N.-M. Lister (eds.) Projective Ecologies, pp. 198-217. Actar Press and Harvard Graduate School of Design, New York.

EMERSON, Ralph Waldo (1879): *Fortune of the republic*: lecture delivered at the Old South Church, March 30, 1878. Boston: Houghton, Osgood.

JIM, C. Y. (2008): *Urban Biogeographical Analysis of Spontaneous Tree Growth on Stone Retaining Walls*. In Physical Geography 29 (4), pp. 351–373. DOI: 10.2747/0272-3646.29.4.351.

KOWARIK, Ingo (2003): *Human Agency in Biological Invasions. Secondary Releases Foster Naturalisation and Population Expansion of Alien Plant Species*. In Biological Invasions 5 (4), pp. 293–312. DOI: 10.1023/B:BINV.0000005574.15074.66.

KÜHN, N., 2006: *Intentions for the Unintentional. Spontaneous Vegetation as the Basis for Innovative Planting Design in Urban Areas*. Jola. Autumn 2006: 46-53

LISCI, M; PACINI, E. (1993): *Plants growing on the walls of Italian towns 2: Reproductive ecology*. Giornale Botanico Italiano , Vol. 127, pp. 1053-1078.

LOIDL-REISCH, Cordula (1987): *Der Hang zur Verwilderung*. [*The tendency to run wild*] Wien, Picus Verlag.

LOIDL-REISCH, Cordula (2016): *Born to be Wild.* Lecture presented at the Symposium Reading Patina: Learning from the deterioration of built landscapes through time, 7th July 2016, Technische Universität Berlin

LUNDHOLM, Jeremy (2014): *Vegetation of Urban Hard Surfaces*. In Jari Niemelä (Ed.): Urban ecology. Patterns, processes, and applications. Reprinted with corrections. Oxford: Oxford University Press (Oxford Biology), pp. 93–102.

MARBLE, S. Christopher; KOESER, Andrew K.; HASING, Gitta (2015a): *A Review of Weed Control Practices in Landscape Planting Beds. Part I–Nonchemical Weed Control Methods.* In HortScience 50 (6), pp. 851–856.

NIEMIERA, Alex (2012). *Selecting Landscape Plants: Groundcovers*. Virginia State University. Retrieved 02.02.2018.

RASK, A. M.; KRISTOFFERSEN, P. (2007): *A review of non-chemical weed control on hard surfaces*. In Weed Res 47 (5), pp. 370–380

RAXWORTHY, Julian (2013): *Novelty in the entropic landscape. Landscape architecture, gardening and change.* PhD Thesis, The University of Queensland.

RINDI, Fabio (2007): *Diversity, Distribution and Ecology of Green Algae and Cyanobacteria in Urban Habitats.* In J. Seckbach (Ed.): Algae and cyanobacteria in extreme environments, vol. 11. Dordrecht: Springer. pp. 619–638.

SEGAL, S. (1969): *Ecological notes on wall vegetation.* The Hague: W. Junk.

SEITER, David (2016): *Spontaneous urban plants. Weeds in NYC.* New York: Archer.

WATT, David (1999): *Building pathology. Principles and practice*. Malden, Mass: Blackwell Science (Building pathology series).

WITTIG, Rüdiger (1991): *Ökologie der Grossstadtflora. Flora und Vegetation der Städte des nordwestlichen Mitteleuropas.* [*The ecology of city flora. Flora and vegetation of the cities of north-western Central Europe*] Stuttgart: G. Fischer.

YIN, Robert (2014), *Case Study Research: Design and Method,* 5th edition (first edition, 1984), Sage Publications, Los Angeles.

Translations by the author

All figures are original works of the author unless otherwise stated.

LIST OF FIGURES

All figures are original works of the author unless otherwise stated.