



A systematic literature review and content analysis combination to “shed some light” on stream daylighting (Deculverting)



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ABSTRACT

Since the start of stream daylighting (decultverting streams buried to make way for urban development) in the 1970s, several case study/project-based reviews emerged. Yet, there is a need for literature-based reviews that identify the literature's themes, interconnections, pressing issues, and knowledge gaps. Therefore, we combine the systematic review and content analysis methods to investigate 115 peer-reviewed and grey literature publications on stream daylighting. Our findings reveal temporal shifts in the multi-/inter-disciplinary clustering patterns of the identified nine themes and 53 sub-themes. Furthermore, there is a dearth in this literature on 'built form and urban design', 'inclusive planning', and on case studies from the Global South. Last, the connections are absent between stream daylighting and nature-based solutions and climate change adaptation (e.g., vis-à-vis stormwater management, urban heat island, and rainwater harvesting) and climate mitigation (decreasing greenhouse gas emissions, such as through enhancing the opportunities for walkability, cycling, and connections to transit).

1. Introduction

The unprecedented urban development since the twentieth century often overlooked urban ecosystems including urban streams and rivers, which have been “diverted, straightened, confined, and channelled beyond recognition” [1: IV]. Environmental awareness brought the moral, ethical, and ecological consequences of development decisions under the limelight [2]. Simultaneously, the adverse impacts of global climate change on cities such as floods, heat waves, and droughts heightened the importance of nature-based solutions¹ (NbS) for ecosystem services [3,4]. Stream daylighting is one such solution that refers to “the practice of removing streams from buried conditions and exposing them to the Earth's surface in order to directly or indirectly enhance the ecological, economic and/or socio-cultural well-being of a region and its inhabitants” [5: 10]. Accordingly, stream daylighting has been ascribed to disciplines like socio-ecology for the ecosystem services that benefit humans (see: [6]) and hydro-ecology for improved water quality and stormwater management (see: [7–10]). Although practiced since the 1970s, daylighting received public attention with the increased interest in lost rivers, including the reintroduction in 2004 of the lost Cheonggyecheon stream in Seoul, South Korea. Since the first peer-reviewed publication in 1992 by Charbonneau and Resh,

however, the stream daylighting literature has been dispersed over a wide array of disciplines and fragmented over multiple themes. Furthermore, all existing reviews are case study/project-based (see: [1,11–13]), hence, warranting literature-based reviews that critically examine the literature's trends, intersections, and future research trajectories. More importantly, the contemporary global climate change challenges warrant a review of the stream daylighting literature vis-à-vis shifting environmental perspectives and the integration of nature-based solutions within urban areas.

Accordingly, we combine the systematic review and the content analysis methods to unravel the manifest and latent content of the literature on urban stream daylighting. Our findings identify the main themes and sub-themes in the literature, the discussions' geographic scope, and the case studies. Current omissions also provide opportunities for future empirical research, including a need for cross-/inter-disciplinary studies and for balancing the emphasis on case studies to present underrepresented cases. Furthermore, there is a need for empirical studies that connect stream daylighting and climate change particularly, its role as a nature-based solution that provides valuable ecosystem services for adaptation (e.g., stormwater management, urban heat island, and rainwater harvesting) and for mitigation (e.g., through walkability, cycling, and transit opportunities).

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¹ NbS refers to the “use [of] nature in tackling challenges such as climate change, food security, water resources, or disaster risk management” – an overarching term that extends beyond conservation to incorporate the sustainable use of biodiversity [86].

2. The research methodology

To date, there are a handful of case study/project-based reviews that offer important insights. The earliest, Pinkham [1] and Buchholz & Younos [11], are professional reports (grey literature) that provide valuable insights by experienced professionals, document the stream daylighting projects then completed in the USA, and evaluate these projects (ecologically and socially). Three are peer reviewed whereby Wild et al. [12] and Wild, Dempsey, and Broadhead [13] review stream daylighting projects globally while Broadhead, Horn, and Lerner [14] investigate lost rivers captured in combined sewers. All these reviews are case study/project-based that discuss best practices and engage practitioners in the collection of data. Thus, while they offer valuable insights, yet, there remains a need for reviews that analyze the literature's manifest data (explicit facts and figures) and latent content (hidden constructs and underlying trends) (see: [15]).

Accordingly, this paper combines the systematic literature review and content analysis methods (Appendix A, Fig. 1). By including all the literature that tackles stream daylighting, and which was published between 1992 and 2018, the systematic review facilitates an understanding of the discourse's general scope and nature [15,16]. Also, by scrutinizing the subject matter of the publications, the content analysis facilitates an understanding of critical themes and the derivation of rich insights [17–22]. Our combined method followed four steps beginning with identifying the research questions and study objectives, namely: what are the dominant themes and sub-themes in the stream daylighting literature? And, to what extent does the stream daylighting literature tackle climate change adaptation and mitigation?

Second, the literature research sought all the literature on stream daylighting using search engines like Primo (an academic search engine) supported by Google Scholar and Google. The Boolean search commenced with the following keywords: 'stream', 'river', 'creek', and 'brook' combined with one or more of the root words 'daylight' and/or its synonyms 'deculvert' and 'uncover'. We also used the keyword 'Cheonggyecheon' – the well-known lost stream that had been reintroduced in Seoul's urban landscape. Based on the careful reading of these sources' contents, we observed that they referred to the Cheonggyecheon as a 'restoration' not as a 'daylighting' project because the water was pumped from the nearby Han River and from underground sources as opposed to being released from a culvert [23]. Subsequently, the Boolean search terms expanded to include the root words: 'bury'; 'deculvert'; 'establish'; 'naturalize'; 'open'; 'reclaim'; 'recover'; 'regenerate'; 'rehabilitate'; 'renovate'; 'restore'; 'resurface'; 'revitalize'; 'uncover'; and/or 'unearth'. Concurrent with the Boolean search, we also supplemented our data collection by investigating the references cited in the yielded sources for their relevancy to stream daylighting.

As the sources accumulated, priority was given to English-language peer-reviewed sources (journal articles and university press publications), however, these were few. Therefore, we expanded the search to the grey literature while assessing its quality through careful reading of each source's contents and scrutinizing the authors' expertise and institutional affiliations. Resultantly, the search yielded 115 sources that were published between 1992 and 2018 (Table 1). All these sources are in English except one German-language² professional report on the City of Zürich's (Switzerland) unique stream daylighting policy adopted since 1986 that, thus far, ensued in daylighting nearly 24 km - [24].

Third, we extracted, organized, coded and recorded the data in two files: an Excel document that recorded each source's manifest data (i.e., explicit characteristics like title, year, type, and location) and a Word document that open coded the latent content (henceforth referred to

² The principal investigator translated this report from German into English due to its relevance and significance especially, given the dearth in sources on Zürich's unique stream daylighting initiative.

Table 1

The types and quantities of sources included in this study.

Publication Type		The quantity of sources
Peer reviewed	Journal articles	80
	Books and edited volumes	2
Grey literature ⁶	Books and edited volumes	4
	Book chapters	1
	Institutional reports	12
	Conference paper	1
	Supervised students' work	14
	Workshop proceeding	1
Total		115

⁶ This study is restricted to these types of grey literature and excludes multimedia sources, media reports, and social media.

simply as 'content'). The latter took the form of a standardized format for an annotated bibliography that organized thorough notes under headings (i.e., a rule-guided technique that controlled for researchers' bias) (Appendix A, Table 1) [19,20,25].

Last, we coded the headings from the Word document (latent content) and combined them with the manifest data in the Excel document in order to facilitate relational analysis, distill grouping (through sorting and collapsing (dis)similar headings), and identify (sub-) themes. This combination of both datasets in one Excel document increased our methodological rigour by converting the inductive categorization of the (sub-)themes into quantitative metrics [20]. We used Alteryx, a data management software, to clean the Excel document of data entry errors whereby the cleaned data became the analytical backbone of a database (dashboard) produced in Tableau³.

Our method capitalizes on the combined strengths of the systematic literature review and the content analysis methodologies [26]. The former summarizes and absorbs vast amounts of data [27] while the latter suits rigorous qualitative and quantitative analysis of textual data, hence, facilitates in-depth understanding of multifaceted and multi-disciplinary phenomena [17] and longitudinal analyses [17,19,28]. Yet, both methods face inconsistencies in the literature's inclusion and exclusion criteria [29] while the substantial number of publications yielded by systematic literature search [30] renders the content analysis effort and time intensive (see: [17,20,22,28,31,32]). We overcame these challenges through a clear, replicable, and user-friendly protocol that ensured credibility (truth value and objectivity), transferability (applicability and replicability), and dependability (consistency and accuracy). The protocol included: individual and team verification (of notes, extracted themes, organization, and coding), categorization and careful documentation (Appendix A, Table 1) that collectively ascertained the presence of an audit trail and reduced researcher's bias (see: [17,19,22,32,33]).

3. Data analysis

Beginning with the manifest data, the publication year analysis confirms the relative nascency of the literature on stream daylighting. Although the first documented project (Napa creek, USA) dates to the 1970s [34,35], the first peer reviewed journal article was published in 1992 (by Charbonneau and Resh) and it took another decade for publications to gradually increase (Fig. 1). Three points in 2004, 2012, and 2016 mark an increase in the number of publications. From only two sources in 2003, 2004 saw seven new publications: a) two on the Cheonggyecheon stream [36,37]; b) two on Zürich's policy [38,39]; and c) three on North American case studies [40–42]. In 2012, twelve new publications marked a threefold increase from 2011 while 19 new publications in 2016 marked nearly a fivefold increase from 2015. It is difficult to conclusively pin down the reasons behind these sudden

³ A software for visualizing data trends and streamlining analytical querying.

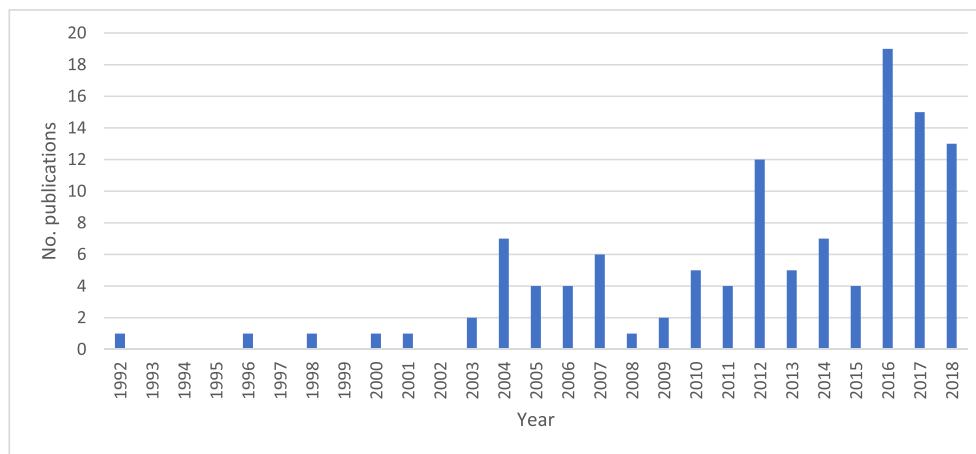


Fig. 1. The number of stream daylighting publications per year.

surges, but it is possible to correlate the number of publications per year (Fig. 1) and the publication year for the most cited sources (Table 2 and Appendix A, Table 2). These data indicate the possibility that the media attention toward the Cheonggyecheon project (in 2004) combined with influential publications like Kang and Cervero's [43] contributed to this increase. Indeed, 14 of the 21 articles published in the three years between 2010 and 2012 explicitly mention the Cheonggyecheon.

As for the latent content, a hierarchy of themes at two different levels emerged: nine higher-order categories that represented the dominant themes (daylighting, ecology, economy, hydrology, infrastructure, politics and policy, sociocultural, built form and urban design, and inclusive planning) under which 53 second-order categories or sub-themes fell (e.g., a source's stormwater management discussion is coded as a sub-theme under the 'hydrology' theme) (Table 3). The (sub-)themes are collectively exhaustive but not mutually exclusive; in other words, every source tackles at least one theme and may surely tackle additional sub-themes. Our analysis reveals an increase in these themes' diversity over time –indicative of increasing multi-/inter-disciplinary research on stream daylighting from only three themes in 1992 (i.e., sociocultural, ecological, and daylighting) to nine in 2018. The 2004, 2012, and 2016 points (Fig. 1) marked the emergence of new themes. The most frequently tackled themes are: 'ecological', 'sociocultural', and 'hydrological' (discussed in 70%, 69%, and 64% of the sources), while 'inclusive planning' and 'built form and urban design' remain the least discussed (in 42% and 41% of the sources) (Fig. 2).

Since the (sub-)themes may coexist within each source, we analyzed their overlaps. Interestingly, two clusters emerged (Fig. 3), the first includes ecology, sociocultural, hydrology, infrastructure, and economic that are simultaneously highly correlated to each other and are the most frequently discussed in the literature. For example, 80% to 90% of the sources that discuss stream daylighting through the lens of ecology also address hydrology; likewise, 70% to 80% of the sources that address hydrology also discuss infrastructure. The second cluster consists of correlations among the themes discussed in less than 50% of the sources: daylighting (in 46%), politics and policy (in 43%), and inclusive planning (in 42%). For example, more than 60% of the sources that delve into stream daylighting's 'inclusive planning' processes also discuss 'politics and policy'. The 'built form and urban design' theme maintains weak correlations with all the other themes except 'inclusive planning', hence, remains outside both clusters. Our analysis also reveals seven sub-themes that warrant further research (Appendix A, Fig. 2).

Overlaying the geographic scope and the themes reveals that the 115 sources exclude Africa and South America and only cover North America, Europe, Oceania, and Asia with variable theme distribution and with North America and Oceania the most and least discussed consecutively. 'Ecology' and 'hydrology' are the most frequently

discussed in studies on North America while 'built-form and urban design' is the least tackled. 'Hydrology' recurs in most studies on Europe whereas 'politics and policy' is hardly mentioned. The 'sociocultural' and 'daylighting' themes are, consecutively, the most and least prominent in Asia while 'ecology' and 'inclusive planning' are the most and least addressed in Oceania (Fig. 4).

Our analysis of the case studies'/projects' geographic distribution reveals 74 projects (53%) in North America followed by 59 (42%) in Europe of which 40 (or 29%) are in Switzerland (Fig. 5). These findings differ from Wild, Dempsey, and Broadhead's [13] who report only 51 (28%) projects in North America, 121 (67%) in Europe⁴, two in Asia (compared to four in the literature, including Wadi Hanifah in Saudi Arabia [44], and one in Africa (where none were reported in the literature). Furthermore, our analysis reveals that the locations discussed more frequently do not necessarily contain more daylighting projects, especially in Europe and Asia. Europe's 59 daylighting projects appear in 27 sources while Zürich's 40 projects (nearly a third of all case studies) appear in only four sources [24,38,45,46]. In contrast, 40 sources discuss only four projects in Asia of 36 sources exclusively discuss the Cheonggyecheon (1% of all projects) (Fig. 5).

Lastly, our analysis explored the relationships between the (sub-)themes and climate change adaptation (systems' adjustments) and mitigation (decreasing greenhouse gas emissions). Of the total 115 sources only 16 refer to climate change all of which, with the exception of Richards and Edwards [47], mention it only briefly without offering any detailed analyses. Beginning with adaptation, it was not until the 2007 redrafting of the European Chartered Institution of Water and Environmental Management's (CIWEM) report 'De-culverting of Water Courses' [48] that the limitations of culverts in managing increased flooding brought on by climate change were highlighted (Fig. 6). Generally, our findings indicate that the literature's sources avoid the term "adaptation" in many cases [7,49–52], and mostly discuss how stream daylighting can "mitigate"⁵ the impacts of climate change through the lens of five sub-themes: 'stormwater management' ('hydrology'); 'urban heat island'; ('ecology'); 'sustainable development' ('infrastructure'); 'biodiversity' ('ecology'); and 'urban resilience' ('built form and urban design') (Appendix A, Fig. 2). Among these sub-themes, 'stormwater management' appears more frequently in the literature that mentions climate change, whereas 'urban resilience' appears the least (Fig. 7). To elaborate, of the 16 sources that discuss stream daylighting

⁴ The data sources for Wild, Dempsey, and Broadhead's [83] study are based on volunteered data on case studies gathered primarily through engaging practitioners whereas our study extracts the data from the literature.

⁵ Mitigate in this context is used to literally mean "lessen" and not to refer to decreasing the greenhouse gas emissions.

Table 2
A sample from our database of the most cited papers in the literature on stream daylighting.

Author(s)	Publication year	Title	Publication type	Level of detail in discussing daylighting	Total citations ⁷	Citation rank in our database
Pinkham, Richard	2000	Daylighting: New Life for Buried Streams	Report (grey literature)	Very detailed	97	10
Bernhardt, E. S. Palmer, M. A. Allan, J. D. Alexander, G. Barnas, K. Brooks, S. Carr, J., et al.	2005	Synthesizing U.S. River Restoration Efforts	Journal article (peer reviewed)	In passing (mentions Pinkham's report(11))	1900	1
Kang, Chang Deok, Robert Cervero	2009	From Elevated Freeway to Urban Greenway: Land Value Impacts of the CGC Project in Seoul, Korea	Journal article (peer reviewed)	Discusses in detail the Cheonggyecheon (Cheong Gye Cheon) restoration in Seoul with a particular focus on the project's impact on land values	87	11
Wild, T. C. Bernet, J. F. Westling, E. L. Lerner, D. N.	2011	Deculverting: Reviewing the Evidence on the 'Daylighting' and Restoration of Culverted Rivers	Journal article (peer reviewed)	Very detailed	64	15

⁷ These total citations were obtained from Google Scholar

in relation to climate change adaptation: a) 11 sources connect climate-induced precipitation increases and stream daylighting's capacity to manage the excess stormwater runoff (e.g.: [10,49,53]; b) five sources investigate how uncovered streams facilitate climate change adaptation by improving thermal comfort, hence, alleviate the urban heat island effect [50,54–57]; c) two sources consider stream daylighting as a nature-based solution that enhances urban sustainability, which in turn contributes to climate change adaptation [12,54]; d) two sources emphasize stream daylighting's role in creating habitats and improved biodiversity that alleviate the effects of climate change [7,57]; and e) only one article specifically discusses the Cheonggyecheon project as an example of resilient urban design that reduces the negative impacts of climate change [57].

Similarly, our findings reveal that of the total 115 sources analyzed in this study, only three discuss issues related to climate change mitigation (these sources simultaneously discuss adaptation). This is in line with Kim and Jung's [54] finding that there is a deficit of sources in the literature that relate stream daylighting to climate change mitigation (Figs. 6 and 7). In fact, our content analysis reveals that these three articles do not specifically use the term "mitigation" although they discuss stream daylighting's capacity to reduce greenhouse gas emissions under the 'infrastructure' theme. Specifically, two of these three articles argue that stream daylighting, through creating opportunities for alternative transit options like cycling and walkability corridors (the 'transportation' sub-theme), can reduce the emissions of greenhouse gases [54,56]. The third article referred to stream daylighting as an opportunity for low impact development that, through Carbon sequestration, increases urban sustainability (the 'sustainable development' sub-theme) (Fig. 7) [58].

4. Discussion

Our thematic analysis identifies current trends and omissions in the literature. The trends indicate the inter-/multi-disciplinary nature of stream daylighting research and an increased (sub-theme) diversity over time (Figs. 1 and 2). Notably, 18 of the 19 sources published in 2016 tackle at least three themes each, while each of the 15 sources published in 2017 tackles at least two themes, and each of the 12 sources published in 2018 tackles three or more themes. Additionally, 2016, 2017, and 2018 witnessed a significant increase in the number of sources that simultaneously deal with 'ecology', 'sociocultural', and 'hydrology' and their interdisciplinary connections (Fig. 2 and Appendix A, Fig. 3). This multidisciplinary trend prevails for the 'ecology', 'sociocultural', 'hydrology', 'infrastructure', and 'economics' themes while their connections to the remaining 'daylighting', 'built form and urban design', 'inclusive planning', and 'politics and policy' themes remain relatively weak (Fig. 3). In particular, the most discussed sub-themes in the literature are 'wildlife habitat and connectivity' (under 'ecology'), 'stormwater management', and 'water quality and pollution' (both under 'hydrology'), consecutively discussed in 55, 54, and 44 sources (Appendix A, Fig. 2).

All the research themes persisted albeit with shifts over time. 'Ecology' dominates over three nine-year time periods (i.e., 1992–2000; 2001–2009; and 2010–2018) while 'built form and urban design', 'daylighting', 'hydrology', and 'inclusive planning' are declining. 'Economics', 'infrastructure', 'politics and policy', and 'sociocultural' themes fluctuate where each significantly increased in 2001–2009 but slightly decreased in 2010–2018 (Appendix A, Fig. 3).

In terms of omissions, there is imbalance in tackling the (sub-) themes and their correlations which may be the result of unequal representation of case studies and geographic regions. There is a dearth of stream daylighting case studies from the Global South while the literature's dominant themes emerge from the most discussed case studies. For example, case studies from water-rich countries abound, hence, daylighting's potential to address 'water scarcity' remains unexplored (e.g., through rainwater harvesting). Also, the 'sociocultural'

Table 3

The higher-order headings (the main themes) and the second-order headings (sub-themes) extracted from the contents of the urban stream daylighting literature.

The main themes in the urban stream daylighting literature	The sub-themes (discussed under each of the main themes)	Examples of sources that address each theme ⁸
Daylighting	Daylighting evaluation and monitoring; daylighting impacts and objectives; daylighting methods and management; daylighting typology	[1,11,35,51,54,56,58]
Ecology	Air quality; wildlife habitat and connectivity; bank stability and erosion; biodiversity; climate change; ecosystem function and integrity; ecosystem/bioregional scale; invertebrate/microbial communities; urban heat island effect/microclimate; urban stream syndrome	[12,37,55,57,61–63]
Economics	Cost efficiencies/inefficiencies; daylighting feasibility/valuation; economic development; economic depression; land cost/property value; land ownership	[34,64–68]
Hydrology	Stream geomorphology; stormwater management; water chemistry/nutrient cycling; hydrological connectivity; water scarcity/supply; water quality/pollution	[10,41,52,53,69–71]
Infrastructure	Energy production; channel/treatment design; green infrastructure/sustainable development; wastewater and sewage management; transportation	[12,57,72,73]
Politics and policy	Environmental social justice; law/legal background; politics of place; urban/regional policy	[74–77]
Sociocultural	Cultural revitalization; social consequences; ecosystem services; ecological authenticity; public amenities and aesthetics; public education; public health and safety; public perceptions of daylighting and nature; urban agriculture	[6,7,45,50,58,68,78–80]
Built form and urban design	Urban resilience; landscape design; place making/sense of place; urban form/morphology; urban/village renewal; land use and zoning	[44,81–83]
Inclusive planning	Citizen engagement; cooperation and collaboration; public participation and stakeholder engagement	[40,49,84,85]

⁸ The sources listed in this column may also fall under other themes.

theme dominates the 40 sources on Asia probably because 36 of them discuss the Cheonggyecheon project which is considered an urban revitalization and which relies on pumped rather than natural water flow (hence, whether it actually constitutes daylighting remains controversial) [59]. Interestingly, this single 7 km project (1% of all the literature’s projects) received more attention than the City of Zürich’s 24 km of daylighted streams attributed to its consistent policy since 1986. Surely, this warrants a shift away from landmark projects to ones that are less alluring but that might offer valuable insights into the (sub-)themes identified herewith and into the connections to climate change

mitigation and adaptation.

This imbalance also impacts the (sub-)themes’ correlations (Fig. 3). Although the daylighted streams contribute positively to climate change adaptation and mitigation yet, our findings reveal weak connections between ‘built form and urban design’, ‘ecology’, and ‘hydrology’ –providing ample opportunity for new empirical studies in areas like landscape ecological urbanism. For example, sub-themes like ‘urban form/morphology’ and ‘landscape design’ (under ‘built form and urban design’) could explore urban stream daylighting’s contribution, as a nature-based solution, to urban hydrology and ecology through:

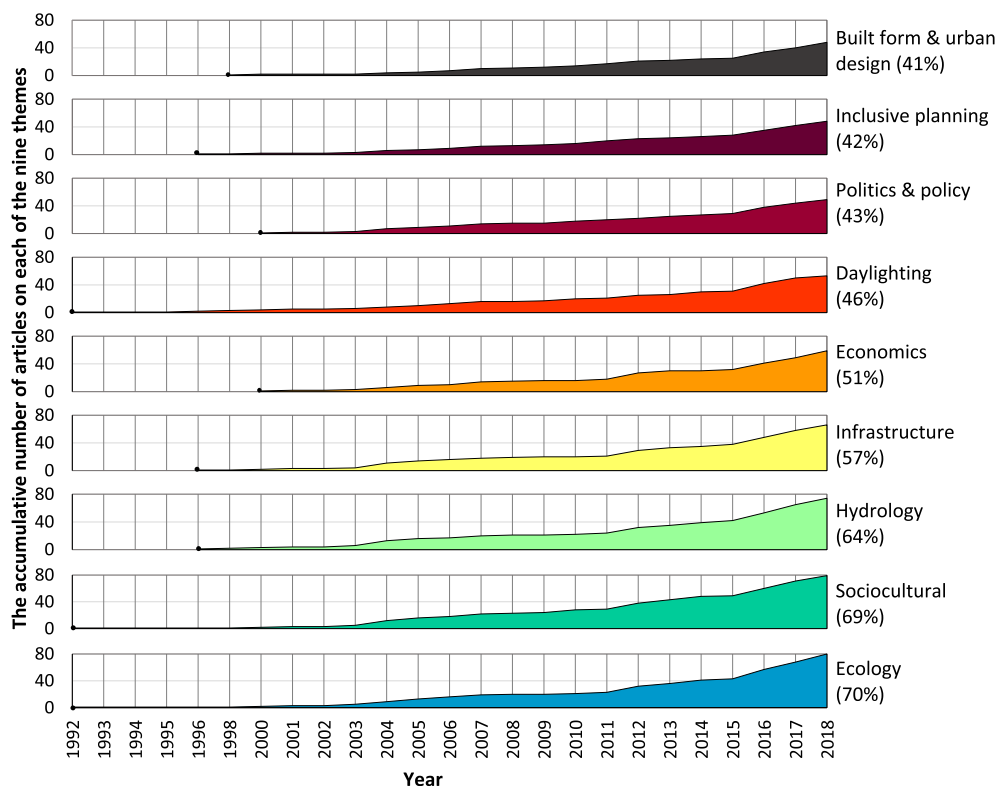


Fig. 2. The accumulative number of articles on each of the nine themes per year between 1992 and 2018.

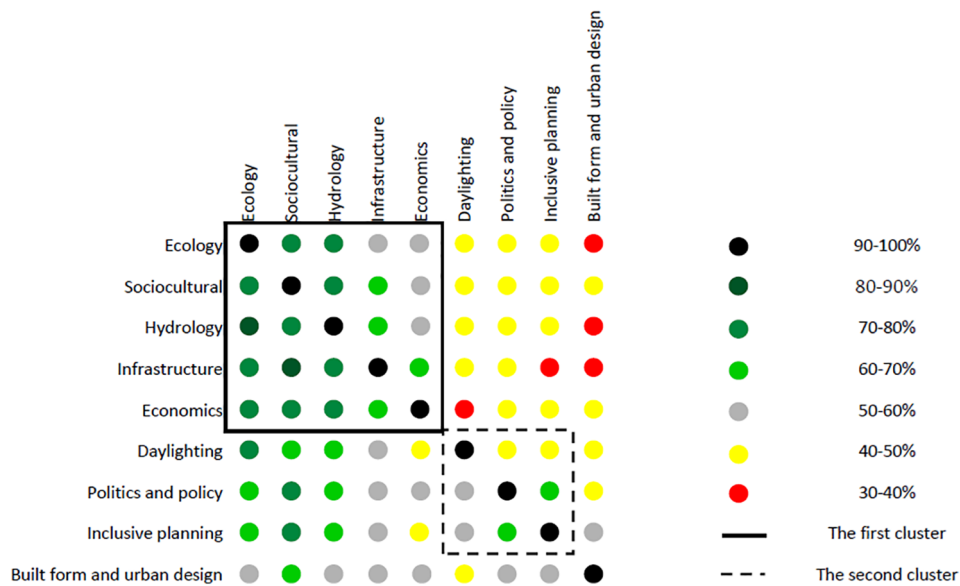


Fig. 3. A matrix showing two clusters of coexisting themes in the literature.

stormwater management and rainwater harvesting; water sensitive urban design that alleviates the urban heat island; and connected and permeable public realm that is conducive to walkability, cycling, and transit. Thus far, only a handful of articles explore these connections like the Navigli canal’s (Milan) and the Cheonggyecheon stream’s (Seoul) contribution to reducing greenhouse gas emissions, managing excess stormwater, and regulating urban temperature [10,47,57,59].

5. Conclusion

In this paper, we combined the methods of a systematic literature review with those of content analysis to offer a comprehensive review of English-language articles (except one German-language government report by the City of Zürich) on stream daylighting that were published between 1992 and 2018. There has been, thus far, a lack of such a comprehensive effort that identifies, codes, and categorizes the various perspectives and topics in the stream daylighting literature. The comprehensiveness of the systematic literature review combined with the

in-depth perspective of the content analysis approach facilitated a better understanding of the current status of research and writing on the daylighting/deculverting of urban streams. Specifically, it facilitated an identification of the themes, their corresponding sub-themes, and their correlations to each other. These nine dominant themes are: ‘ecology’, ‘sociocultural’, ‘hydrology’, ‘infrastructure’, ‘economics’, ‘daylighting’, ‘politics and policy’, ‘inclusive planning’, and ‘built-form and urban design’. Furthermore, the combined methodology allowed for a better understanding of the stream daylighting case studies, the geographical scope covered in the literature, and the connections between stream daylighting and climate change adaptation and mitigation. Accordingly, the analysis revealed the current research trends and the disciplinary connections that could be further enhanced in future studies as well as the current research gaps that warrant further empirical research, namely:

1. This study covered the peer reviewed and the grey literature but excluded policy documents, multimedia, media reports, and social

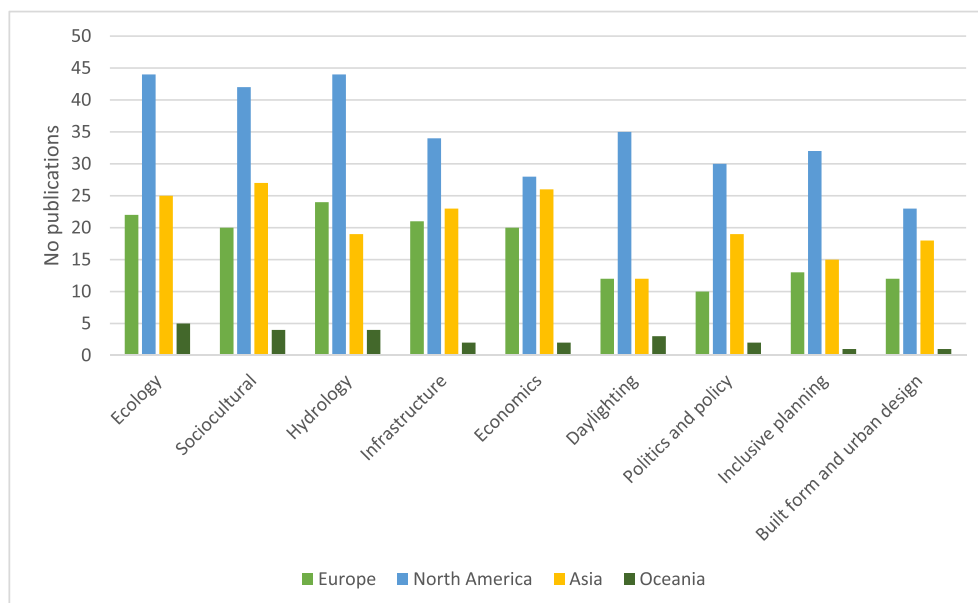


Fig. 4. The frequency of stream daylighting themes over the four different geographical areas covered in literature.

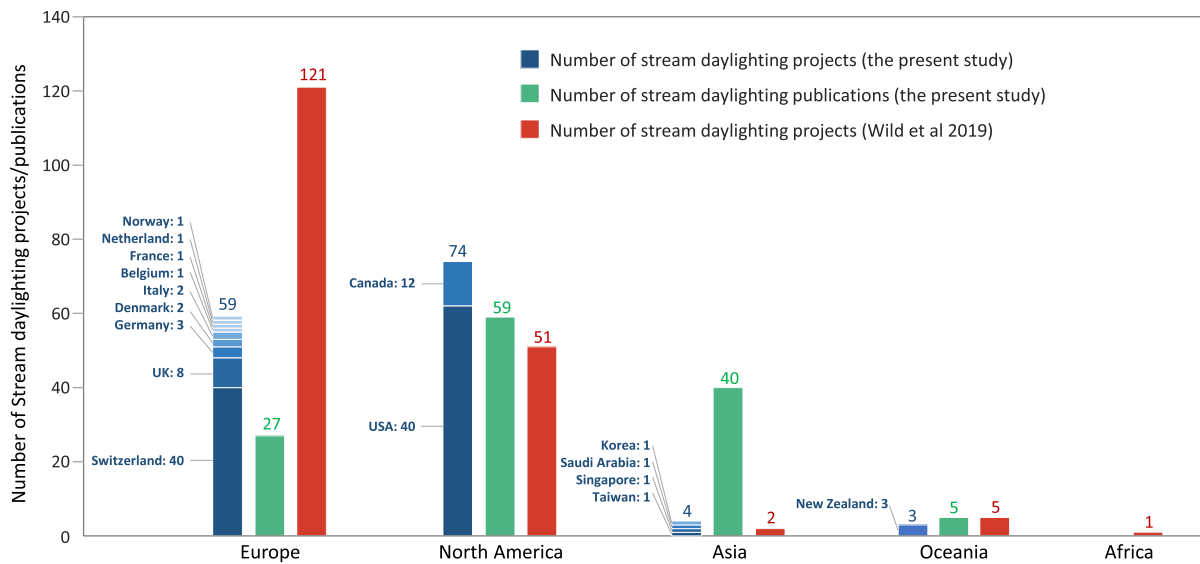


Fig. 5. The distribution of stream daylighting case studies around the world (this study’s findings versus Wild et al [13]’s findings) comparing the number of publications discussing these same geographic areas.

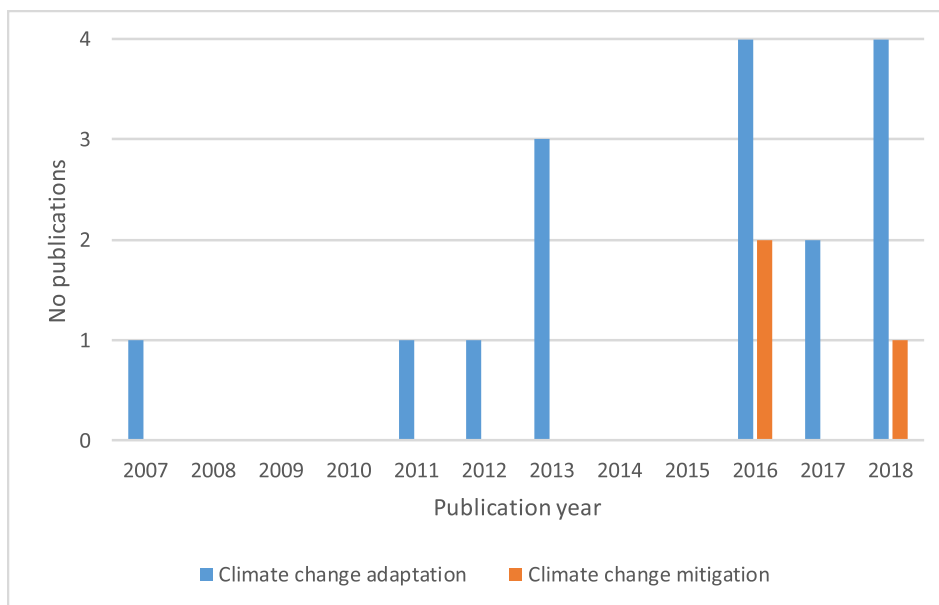


Fig. 6. The number of stream daylighting publications per year that refer (directly and/or indirectly) to climate change adaptation and/or mitigation.

- media (e.g., recorded lectures, documentaries, print and online news reports, blogs...etc.). Future reviews that include these sources would enrich our knowledge of stream daylighting.
- The literature on stream daylighting has been, and continues to be, inter-/multi-disciplinary while the diversity of the sub-themes continues to increase over time. The prominence of the themes and their sub-themes, however, continue to shift over time except for the ‘ecology’ theme, which persisted while its “wildlife habitat and connectivity” sub-theme is currently gaining prominence. There is a need for studies that analyze the reasons behind these shifts.
 - There is a lack of disciplinary connections firstly, between ‘built-form and urban design’ and nearly all of the other themes, especially the ‘ecology’ and ‘hydrology’ themes; and secondly, between the more frequently discussed themes in the literature (i.e., ‘ecology’, ‘sociocultural’, ‘hydrology’, ‘infrastructure’, and ‘economics’) and the less frequently discussed ones (i.e., ‘daylighting’, ‘politics and policy’, and ‘inclusive planning’).

- While stream daylighting is an intervention that affects land uses, there is still a need for empirical studies that investigate the connections between stream daylighting and the ‘built form and urban design’.
- The existing literature has yet to address the involvement of local stakeholders in stream daylighting projects. Hence, the ‘inclusive planning’ theme warrants explorations of how local inclusion and local ecological knowledge may contribute to planning, implementing, and maintaining stream daylighting initiatives [60].
- There is a need to shift the focus of the empirical studies on stream daylighting from landmark projects like the Cheonggyecheon stream in Seoul, to the less alluring and less well-known initiatives. Among the latter is Zürich’s policy, which resulted, thus far, in daylighting over 24 km throughout the city with significant results on a variety of fronts: ecological (e.g., flora and fauna), ecosystem services for climate adaptation (e.g., stormwater management), built form (e.g., public space and neighbourhood design), and cultural (e.g., local

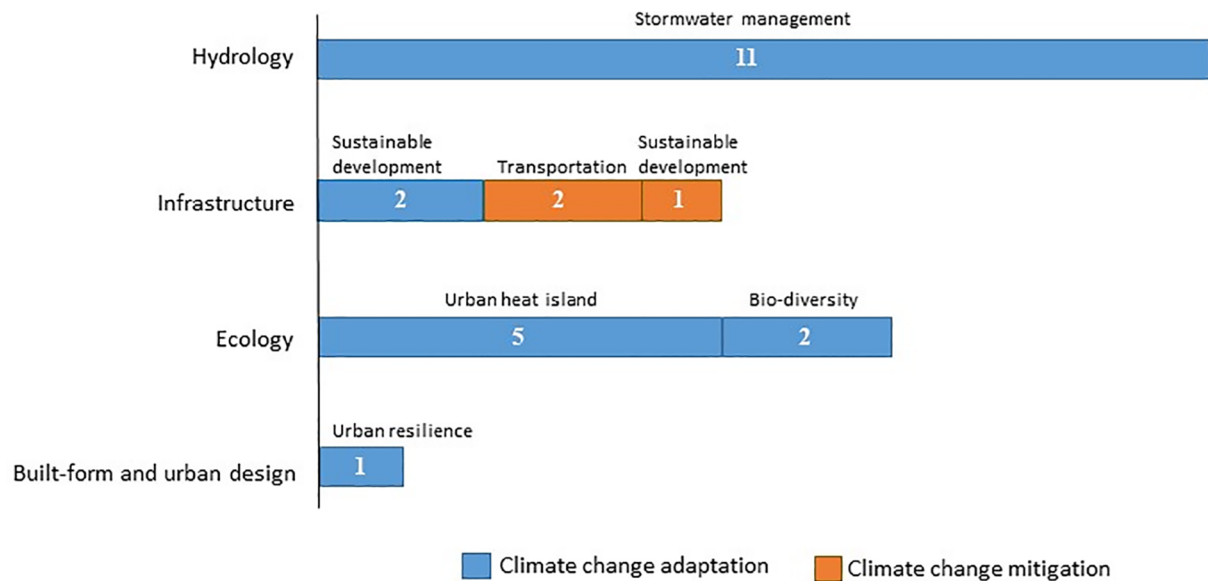


Fig. 7. The (sub-)themes that refer to climate change adaptation and mitigation whereby each source may address one or more (sub-)themes.

participation and the inclusion of the local ecological knowledge) (ERZ [24].

- Building on the previous point, there is a dire need for further empirical studies that focus on the Global South, such as regions where challenges like water scarcity are exacerbated by climate change. Such studies may lead to the emergence of new themes and sub-themes like environmental and climate justice as well as more robust correlations among the various themes/sub-themes.
- Finally, and more importantly, there is an urgent need for empirical studies that tackle stream daylighting as a nature-based solution for the challenges that arise from climate change. Specifically, studies should delve deeper into stream daylighting as an action that enhances the resilience of urban form in the face of the changing climate.

CRedit authorship contribution statement

Luna Khirfan: Investigation, Conceptualization, Methodology, Formal analysis, Writing - review & editing, Supervision, Funding acquisition, Project administration. **Niloofer Mohtat:** Data curation, Formal analysis, Writing - original draft, Visualization. **Megan Peck:** Formal analysis, Software, Data curation, Validation, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary Data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.wasec.2020.100067>.

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