

Introducing Greenswales: a Nature-based Approach to Preserve Seasonal Channels – Learnings from Chandigarh, India

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Abstract

For long, the cities depended on grey infrastructure for draining stormwater. However, incidences of pluvial flooding are increasing, and existing grey infrastructure is unable to take up the additional stormwater load. Consequently, planners are forced to think of new and sustainable alternatives for stormwater management. Natural channels can supplement the stormwater drainage systems, but these channels in cities are reclaimed to provide land for housing and other functions despite their crucial role. This study presents the case of a natural channel in Chandigarh (India) that is redeveloped as a greenspace without compromising its function of stormwater conveyance. We analytically discussed the non-intentional preservation of this seasonal natural channel and introduced a new term, green-swales, for similar arrangements. A greenswale is defined as the stretch of greenspaces laid over a natural channel, ephemeral or intermittent, having stormwater detention and conveyance as primary functions during precipitation. This study's significant finding is that the seasonal natural channels in a city can be safeguarded through the judicious superimposition of green spaces over them. Crucial lessons from this case can guide new developments in utilising natural seasonal channels as a nature-based solution for stormwater management, reducing the load on grey infrastructure and providing the city with a greenspace.

Keywords: greenswales; pluvial flooding; natural channels; nature-based solutions; stormwater management; urban streams

Introduction

Today cities are more vulnerable to pluvial flooding than ever (Miller & Hutchins, 2017), which is an urban water logging issue arising from the limited drainage after precipitation (Hammond, Chen, Djordjević, Butler, & Mark, 2015). Cities inherently generate about five times more runoff than a forest of the same size due to their high impermeability (EPA, 2010b; Khaladkar, Mahajan, & Kulkarni, 2009). Additionally, rainfall intensity is increasing worldwide, governed by climate change scenarios that cause more runoff in even short rainfall spells (IPCC, 2014). These two fac-

tors of high impermeability and climate change, are causing increased runoff volume in urban areas. Most cities are struggling to manage this additional load of surface runoff and hence face pluvial floods (Prokić et al., 2019; Savić et al., 2020).

The last century witnessed a complete dependence on grey infrastructure for stormwater management, which comprises pipes, culverts and pumps. Most of which are now proving undersized to take up the entire runoff volume (Huong & Pathirana, 2013; Miller & Hutchins, 2017; Zhou, 2014). It is an eye-open-

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er for new developments to design infrastructure with higher capacity than their current requirement, keeping in mind the future climate change scenarios. However, laying monofunctional grey infrastructure is unsustainable and cost-intensive (Pitman, Daniels, & Ely, 2015; U.S. Environmental Protection Agency, 2014; Zhou, 2014). Moreover, it is now proven that the fundamental approach of grey infrastructure to take stormwater immediately away from the city as waste causes problems like downstream flooding and groundwater depletion. So, this conundrum of the 21st century is forcing planners to find alternatives for managing stormwater in cities. Nature-based solutions (NbS), that weave natural features or processes into the built environment, have emerged as a sustainable solution to various urban issues stormwater management and pluvial flood mitigation (Anderson et al., 2022; Langergraber, Castellar, Andersen, et al., 2021; Langergraber, Castellar, Pucher, et al., 2021; Pearlmutter et al., 2021).

Undeveloped areas have a well-established system of draining stormwater. The vast network of seasonal channels drains the runoff from the land surface to the rivers and ultimately to the seas and oceans after any precipitation event (Hadley, 1968). These natural channels play a crucial role in flood abatement (Ray, Pandey, Pandey, Dimri, & Kishore, 2019; Tingsanchali, 2012). So how can the planners use this pre-established drainage network, as an NbS, to a city's advantage? It is the guiding question of this research. The broader research aim is to find a sustainable supplement to grey infrastructure for carrying additional stormwater in urban areas.

Direct utilisation of seasonal channels for stormwater drainage is challenging. Urban areas have negative connotations with seasonal channels. Ephemeral and intermittent natural channels with seasonal streams are highly vulnerable to encroachment and neglect in their non-functioning months. They get filled during the land reclamation process and become non-existent to provide land for infrastructure (Sood & Biswas, 2021). Those that survive are marred with encroachment, garbage and debris dumping, and consequently reduced stormwater carrying capacity (Satterthwaite, Huq, Pelling, Reid, & Lankao, 2007). Thus, there are two issues one is to safeguard seasonal channels during the city development phase, and the other is to preserve urban channels from the ill practices of garbage dumping and encroachment.

A seasonal channel in Chandigarh city (India), namely N-choe¹, survived the city development phase and has retained its function over the years without succumbing to the pressure of urbanisation. This pa-

per is a detailed case study of N-choe and results in identifying the factors that influenced its preservation during the city's development and afterwards. Results from this study will add to the inventory of sustainable stormwater management methods.

This paper is structured in five sections to elaborate on the study process. This introduction section further describes N-choe in Chandigarh and its new role as a public greenspace. Section 2 outlines the method employed in this study. Section 3 has results and discussion on the genesis and evolution of the Leisure valley to investigate the N-choe preservation. Section 4 has conclusions drawn from the analysis and presents the scope for future research.

About Chandigarh and N-choe

The city of Chandigarh (30.74°N, 76.79°E) lies in the foothills of the Shivalik mountain range of the Himalayas in the north of India (Figure 1). It is a union territory and a shared capital of the two adjacent states: Punjab and Haryana. The city has an area of approximately 114 km², a population of more than 1 million, and an elevation of around 321m from the mean sea level. It was built in the 1950s and was planned by the French architect Le Corbusier with 55 sectors in a grid-iron pattern. Chandigarh is globally known for its visionary planning and the contribution of Le Corbusier (Jonathan Glancey, 2015).

The city topography is majorly plane, with the backdrop of Shivalik hills in the north. Apart from N-choe, the city has three other seasonal channels: Sukhna choe, Patiala Ki Rao, and Choe Nala (Figure 1). N-choe originates in sector three of Chandigarh, meanders through various city sectors, and exits from the city at sector fifty-one. From there, it enters the adjacent Mohali city in Haryana state and finally descends into the Ghaggar river. Patiala Ki Rao and Sukhna choe originate in the Shivalik hills and flow through the western and eastern sides of the city, respectively. Choe Nala originates in sector 29 in Chandigarh city.

Symbiosis of N-choe and Leisure valley

A green belt named Leisure valley is strategically placed over the N-choe. This 8 km long green belt dominates the green landscaped areas in Chandigarh due to its size and influence. Leisure valley stretches from one end of the city to the other and covers eight sectors (Chandigarh Administration, n.d.). It comprises majorly ten public gardens (Figure 1). People from neighbouring sectors frequently use these themed gardens for walks, picnics, exercises, relaxation, and other leisure activities. The organic sprawl of Leisure valley is in stark contrast with the rigid grid-

¹ Choe means stream in the local (Punjabi) language.

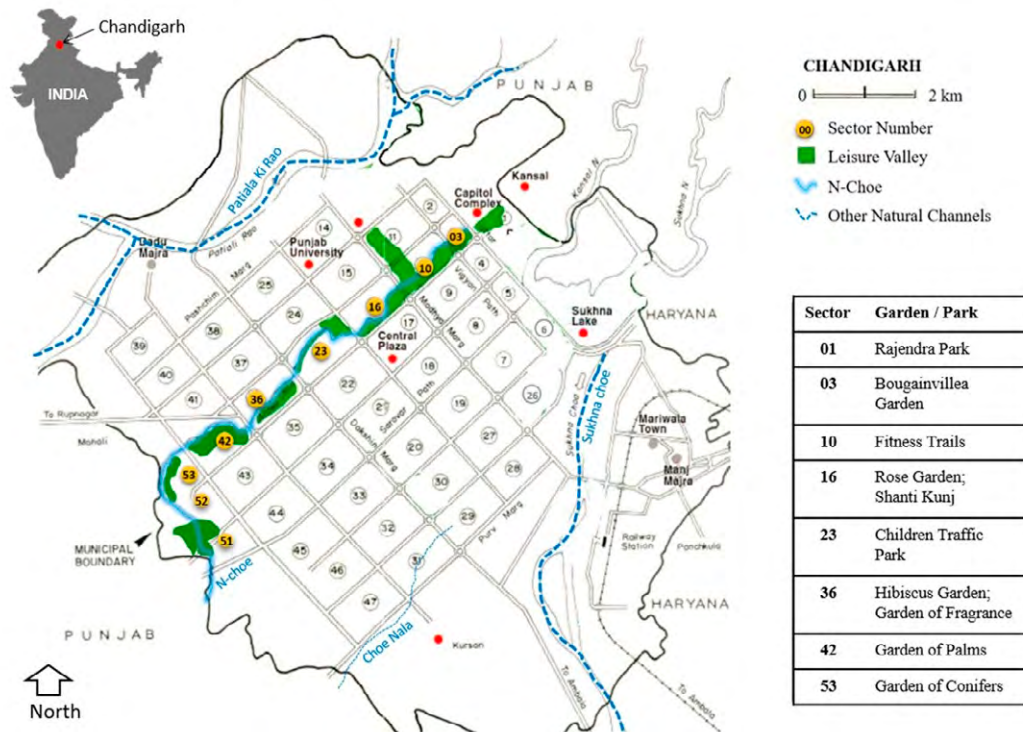


Figure 1. Location of Chandigarh city on the map of India (top-left); Location of N-choe and Leisure valley in Chandigarh
Source: Developed from the tourism map of Chandigarh

iron plan of Chandigarh. The N-choe underneath provides Leisure valley with its linearity and continuity. The Leisure valley's width and shape vary from 55m to 300m for accommodating functions like playgrounds, sports courts, parks and lakes (Figure 2). Leisure valley provides benefits associated with all greenspaces like shading, evaporative cooling, rainwater interception, storage and infiltration while reducing pollution and sequestering carbon (Bartens et al., 2008; Rosenzweig et al., 2015; Xiao, Mcpherson, Ustin, Grismer, & Simpson, 2000). Some artificial storm drains have outfall at N-choe in sector 51 (MC Chandigarh, 2017).

In many Indian cities, areas next to natural channels have a poor quality of life due to the excessive gar-

bage dumping in channels that reduces them to foul-smelling drains. In contrast, Leisure valley's presence has contributed significantly to enhancing the quality of life of its residents (Chaudhry & Tewari, 2010). Owing to the enormous size of Leisure valley, Chandigarh's per capita green cover is the highest among major Indian cities at 38m² (Ramaiah & Avtar, 2019). A study in 2013 found that air quality is better in areas near the Leisure valley, and the noise levels are lower in the gardens than in roads and habitat areas (Chaudhry, Sharma, Singh, & Bansal, 2013). Leisure valley is a part of the city's identity. It contributes to the city's aesthetic enhancement and is a popular tourist attraction in Chandigarh (Chaudhry & Tewari, 2010).

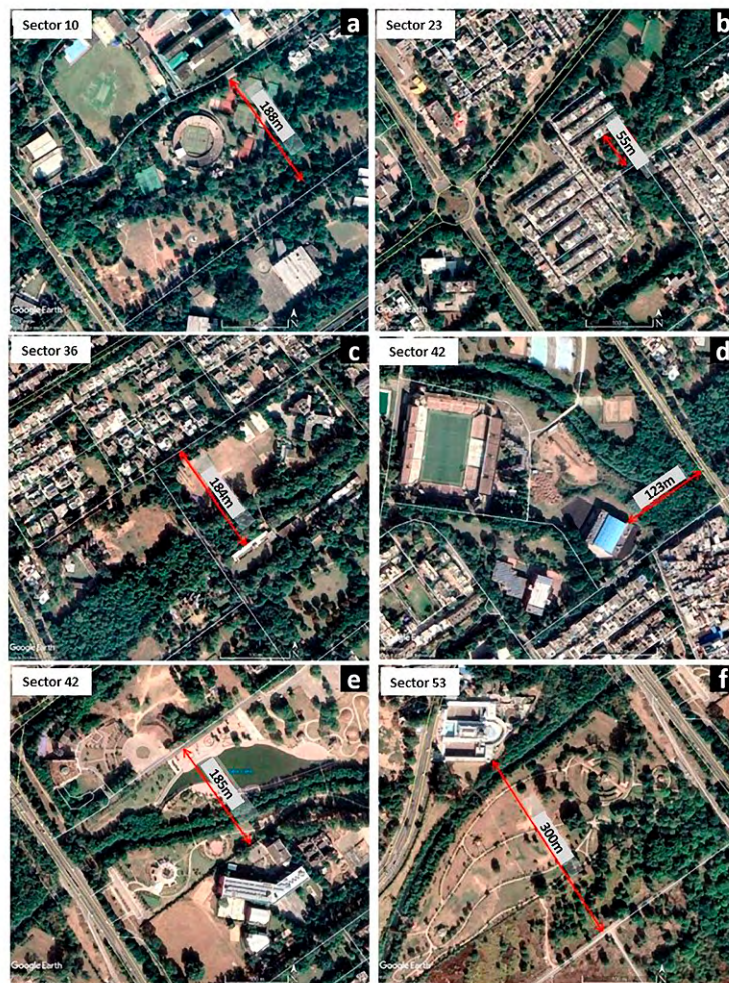


Figure 2. (a) In sector 10, the Leisure valley accommodates various sports courts within 188m width, (b) In sector 23, 55m wide section accommodates only the N-choe lined with fully grown trees, (c) Sector 36 has the N-choe with playgrounds within 184m width, (d) In sector 42, thick urban trees accompany the channel within 123m width, (e) To have a lake (water retention structure), the width at sector 42 is 185m, (f) The Leisure valley sees its maximum width of 300m in sector 53, accommodating a humongous park.

Source: Developed by authors using Google Earth

Data and method

The study is based on the case study research method exploring reasons for N-choe preservation. A mixed-method approach is adopted that includes literature review and survey. The two techniques supplement each other by overcoming the weakness of the other. From the literature review, this study critiques and synthesises the relevant literature on Chandigarh city, natural channels, and public spaces in an integrated way. The facts and data are obtained from journals, governmental web pages, and conference papers. A survey of locals has strengthened the argument.

The analysis finds two answers: Which urban planning decisions safeguarded the N-choe's existence during the city development phase; and which social factors made it a well-accepted public place afterwards?

Survey process

A survey research technique helps to gather information by asking questions to a predefined group of people. In this study, the survey group comprises people living in Chandigarh and its vicinity. A total of 134 people responded to the survey. The online questionnaire was limited to only three questions for a better response rate (Table 1). The first survey question filters respondents to people who have physically visited the N-choe site. The second and third questions are to investigate people's perception of N-choe. During the data cleaning process, the people who responded positively to question 3 but failed to mention it in question 2 were rejected because of their ambiguous responses.

Table 1. Survey questionnaire

Question	Choices
How did you get to know about Leisure Valley?	<ul style="list-style-type: none"> • I have visited the place • I have read/ heard about it
Which of the following are parts of Leisure Valley? (You may pick many options)	<ul style="list-style-type: none"> • Gardens • Golf course • A stream • Forest • A river • Parks • Lakes and ponds • Playgrounds • Other
Have you seen any stream running through Leisure Valley?	<ul style="list-style-type: none"> • Yes • No

Source: Authors

Results and discussion

The preservation of N-choe is purely non-intentional, confirmed by Chandigarh's documented history. There is no mention of the need to preserve N-choe or to use it as a stormwater management system, which is because i) the city was designed with well-laid grey infrastructure for handling stormwater, ii) pluvial flooding was not a recognised issue in the last century when Chandigarh was built, and iii) dependence upon nature-based solutions for stormwater management is a recent strategy. Many planning and design decisions made for Chandigarh city have contributed to the preservation of N-choe. Careful observations have led to the identification of those contributory factors, which are discussed below:

Planning strategy influence on the N-choe preservation

1. **Edict of Chandigarh:** Chandigarh planning edict required providing an uninterrupted view of Shivalik hills even from the farther end of the city (Chandigarh Development Authority, n.d.). It needed a long corridor running from North to South in the city, and the eroded N-choe in the site, with its north-south alignment, provided the opportunity to realise this vision. Therefore, though unintentionally, the Chandigarh planning edict served as a by-law and paved the way for N-choe's preservation. Otherwise, neo-developments often destroy the seasonal channels to reclaim construction land.
2. **Greenspace landuse assignment:** Establishing a visual connection with Shivalik hills required a judicious landuse assignment to the N-choe for curbing any future construction and encroachment possibilities. The desired corridor could be a plaza, an arcade or a broad shopping street. However, the

decision to develop this corridor as greenspaces is a significant factor that preserved N-choe.

Greenspaces do not necessarily require surface levelling, allowing N-choe to retain its concave cross-section and streamflow function. Moreover, greenspace landuse saved N-choe from concretisation and safeguarded its soft bed and edges. Concretisation of channels increases streamflow velocity and poses a threat of downhill flooding (Ramachandra, Shivamurthy, & Aithal, 2017). Contrary to paved surroundings, green surroundings give room for channel flooding by allowing it to swell during heavy rains. Greenspaces also accommodate and propagate riparian vegetation, which is essential for improving stream water quality (Dosskey et al., 2010) and checking soil erosion. Thus with the superimposition of greenspaces, N-choe could retain its function of streamflow, floodability, and water quality enhancement with minimal alterations.

3. **Bridges and culverts:** Leisure valley, seemingly a long green belt, is not a continuous stretch of greens but a series of greenspaces having roads as distinctive boundaries. Road construction in neo-developments is a leading cause of seasonal channels' destruction and extinction. Fortunately, in Leisure valley, bridges and culverted roads maintain traffic without hindering the streamflow continuity of N-choe underneath (Figure 3 and 4).

Social influence on the N-choe preservation

In many cities, public greenspaces are also threatened by encroachment and landuse change (Li et al., 2019). However, the Leisure valley is a well-accepted public place. Social surveillance and a sense of place attachment are two intangible aspects that have reduced the



Figure 3. Bridges (encircled yellow) allowing the vehicular and pedestrian traffic flow without disturbing the streamflow in N-choe

Source: Developed by authors from the Google Earth imagery



Figure 4. Pedestrian bridges over N-choe in Leisure valley;

Source: Chandigarh web portal, n.d.

chances of N-choe's encroachment by changing its perceived value from a wasteland to a utilitarian public place.

Social surveillance: Public places with high and uniform footfall benefit from social surveillance (Shehayeb, 2008). The underused areas face negligence, get subjected to rampant encroachment, and fall prey to malpractices like drug abuse and garbage dumping. Thus to keep negative elements at bay and keep a check on ill practices, a public place must strive for social surveillance by ensuring high and uniform footfall through design. Social surveillance instils a sense of security among women, children and other marginalised groups and increases their presence in the public realm. Diversification of footfall fosters social cohesiveness and makes social surveillance robust.

Sense of place attachment: Users develop a feeling of attachment with the place if a place is a part of their day-to-day lifestyle (Hashemnezhad, Heidari, & Ho-

seini, 2013). Place attachment is a psychological approach in bringing about positive behavioural change in people. Najafi and Kamal (2012) suggest that people who feel emotionally attached to a place are more involved in preserving the area and do not take undue advantage (Najafi & Kamal, 2012). There is active reporting of issues related to ill-maintenance or negligence and diligent pressure on the authorities for immediate redressal of complaints. Thus, the sense of place attachment plays a significant role in safeguarding a public space.

Leisure valley enjoys social surveillance and instils a sense of place attachment among users because of the intrinsic qualities of equity, variety, accessibility, activity and adaptability:

1. **Equity:** Equity and inclusion are imperative for a happy environment and to build successful public places (Ouf & El-Zafarany, 2018). Good governance has made the entire stretch of Leisure val-

ley open to the public. Therefore, it is frequented by people of all ages, genders, races, and socioeconomic statuses, including the urban poor and minorities. Leisure valley's location keeps it distinct from neighbourhood parks where people have a sense of ownership and restrict the entry of vulnerable and marginalised user groups. The places with controlled or limited access are more vulnerable to damage, encroachment, and vandalism by non-users. Equity generates high footfall by being receptive to all and strengthens social surveillance.

2. **Variety:**

a) **Variety in design:** By planting varying fauna, different Leisure Valley gardens have achieved distinctive visual characteristics. The variety reflects in the names of gardens which adds to the legibility of this public place. Rose garden, Bougainvillea garden, the garden of Palms, the garden of conifers, the Hibiscus garden, and the garden of fragrances have unique qualities and ambience. Design variety prevents monotony, encourages exploration of the green belt's entire length, and distributes footfall over the whole stretch.

b) **Variety in usage:** Themed parks and gardens in the valley are also associated with diverse usages. For example, Rajendra park and fitness trails are majorly associated with fitness activities, jogging, horse riding, and yoga. Rose garden, Bougainvillea garden, and Hibiscus garden are also used for fitness activities by the neighbouring people but are known for their aesthetics and association with recreational and leisure activities. Smriti upvan in sector one has a more sentimental value attached to it as people plant trees here in the memory of the departed souls. This variety in usage attracts people with diverse interests and adds to footfall.

3. **Accessibility:** Visual and physical connections with surroundings determine the accessibility of a public place (Madden & Schwartz, 2000). The Leisure valley has multiple access points in every sector. The choice of entering and exiting at any point promotes walkability and gives comfort. Its proximity to bus stops and parking gives the transportation mode choice and enhances the accessibility. Tree foliage help to establish visual connect from a distance and orients the visitors. This ease of access contributes to the high and spread-out footfall.
4. **Activity:** Leisure valley is part of people's day-to-day activities like exercise, play, and relaxation owing to its proximity to the residential area. People also visit these gardens for social interactions, picnics, and leisure. Leisure valley carnival is held every year in February and the annual Rose Festival in

February/ March when the roses bloom to their full glory. These festivals celebrate the uniqueness and grandeur of Leisure valley, attract a full range of diverse people and create inclusiveness (Ouf & El-Zafarany, 2018). Daily, seasonal, and annual activities make Leisure valley a significant part of citizens' lives and instill a deep sense of place attachment.

5. **Adaptability:** The valley is evolving and thriving over the years as per people and time demands. The flexibility in its concept and planning has allowed Leisure valley to grow, modify, change, and adapt. Landuse assignment as greenspaces during the conceptualisation period of the 1950s fixed the function of Leisure valley. However, the design and growth of the Leisure valley is a continuous process. For example, Bougainvillea garden in sector three was established in 1976, and Smriti upvan in sector one was developed in 1998. Moreover, by 2031, the cycle tracks will make their way into the Leisure valley to have sustainable transportation means in the city (Chandigarh Development Authority, n.d.). Thus adaptability has let the Leisure valley stay relevant in changing times and build an emotional connection with all generations.

The flowchart in figure 5 summarises the factors discussed in subsections 3.1 and 3.2. It shows the linkages between various contributory factors and their associated benefits which led to N-choe preservation.

Validation

Out of 134 respondents, 67 (50%) had not visited the leisure valley and, therefore, were not considered in the analysis. From the remaining 67, 10 were rejected on the grounds of ambiguity in their responses. Hence, the analysis is based on 57 responses from people who have visited the Leisure valley. 98% (56) of respondents claimed that Leisure valley is a garden or park, whereas only 67% (38) know of a stream or river in Leisure valley. Moreover, only 53% (30) of respondents have seen a stream in the leisure valley.

Survey results show that people definitely perceive leisure valley as a greenspace, but only a few know of it as a seasonal stream. Therefore, we can confidently conclude that greenspace landuse assignment to N-choe has changed its perception of a seasonal waterbody (or wasteland in dry months) to user desired public greenspace.

Concept of greenswales

The primary outcome from the N-choe case study is the knowledge that landuse change can safeguard the existence of seasonal channels, and judiciously overlapped greenspaces can preserve their function over the years. Conclusively, we introduce a new term,

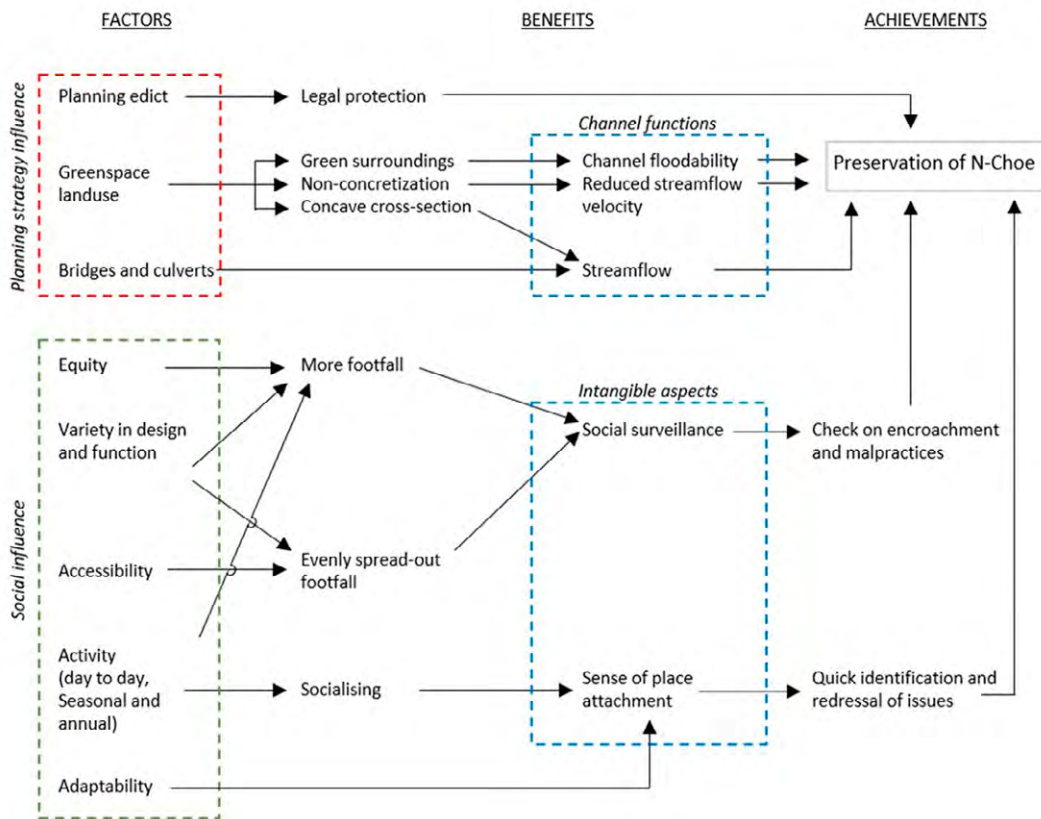


Figure 5. Summary of the contributory factors and their benefits that contribute to the N-choe preservation

greenswale, to convey the symbiosis of seasonal channels and overlapping greenspaces.

A greenswale is defined as the stretch of greenspaces laid over a natural channel, ephemeral or intermittent, having stormwater detention and conveyance as primary functions during precipitation.

The term greenspaces emphasise the type of landuse without any limitation to vegetation choice. The greens may vary from lawns to urban forests and be inclusive of bluespaces depending upon social, environmental and hydrological needs at the local level (L. Taylor & Hochuli, 2017). Greenswales qualify as a nature-based solution with ecological and social benefits of greenspaces, and hydrological advantages of natural channels.

The terminology greenswale finds its origin in the term bioswale. Bioswale or vegetated swale is a linear form of bioretention used to partially treat water qual-

ity, attenuate flooding potential and convey stormwater away from critical infrastructure (Mcpherson, 2017). Bioswales are designed as gently sloping depressions planted with dense vegetation or grass, and they treat stormwater runoff from rooftops, streets, and parking lots (Purvis et al., 2018). The need for introducing the new term greenswale lies in the differences between the two. Bioswales are plantations over artificial drains, whereas greenswales are plantations over seasonal natural channels. Planners have the choice to place bioswales anywhere depending upon need, whereas greenswales can only be at the natural channels. In principle, bioswales mimic natural hydrology; on the other hand, greenswales attempt to preserve the pre-development hydrology of the area. Additionally, greenswales can retent more water for flood mitigation than bioswales by virtue of the green spread on either side.

Conclusion

Planners in 21st century are finding sustainable solutions for managing stormwater and mitigating pluvial floods. Many studies on sustainable stormwater management suggest that nature-based solutions (NBS) can supplement the grey infrastructure in taking up the additional runoff and prevent pluvial flooding

(Chan et al., 2018; Suppakittpaisarn, Larsen, & Sullivan, 2019; The World Bank, 2019). NBS are solutions inspired and supported by nature, provide environmental, social, and economic benefits and help build resilience (European Commission, 2016).

This case study of non-intentional preservation of N-choe in Chandigarh city offers learnings to preserve crucial seasonal channels and yields the concept of greenswales. A greenswale is a natural channel overlapped by greenspaces. The provision of greenswales at the planning stage of neo-developments can provide upcoming cities with a sustainable and floodable public place. In addition, greenswales can accommodate shaded and scenic cycleways and walkways because of their linearity and city-long stretch. Greenswales' function of stormwater management and pluvial flood mitigation, along with other ecological and social benefits, situates it in the realm of nature-based solutions.

We identified that the N-choe survived land reclamation and is still functioning because of the greenspace landuse assignment. Greenspaces have replaced N-choe's seasonality with year-long utility. More importantly, the assigned function and design has not interfered with the channel's function. Following the detailed documentation of N-choe and Leisure valley in this paper, city planners can develop greenswales in neo-development projects. The city of Chandigarh

has focused on the aesthetic and recreational aspects of Leisure valley and has not fully utilised its potential as a stormwater management tool and floodable greenspace. However, the greenswales need not limit their function and should actively contribute to stormwater drainage and pluvial flood mitigation.

Scope for future research

This study has followed the qualitative approach and paves the way for quantitative research in the future. The catchment size of N-choe and its runoff carrying capacity can be investigated in future research to expand the concept of greenswales. This study is limited to understanding the preservation of N-choe, but there is a scope for advancing this research by investigating Leisure valley's role in biodiversity preservation and GHG reduction. The multi-faceted research on N-choe and Leisure valley may result in a holistic urban solution to climate change adaptation and mitigation. This study's results further open the way for pilot projects to implement and test the greenswale effectiveness.

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