#55 - Challenges for the integration of natural channels in the urban drainagesystems

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Highlights

- The land reclamation process is a leading cause of natural channel destruction
- Natural channels are replaced by roads, buildings, and agricultural land
- Perennial channels are losing crucial floodplains to agricultural practices

Introduction

Cities need natural channels now more than ever. Climate change has altered the rainfall patterns of cities. High-intensity rainfall events are now a frequent occurrence generating more surface runoff in less time (IPCC, 2014). Also, cities have a higher percentage of paved surfaces in the form of roads, rooftops, parking lots, and other impervious surfaces. These paved surfaces prevent infiltration and generate a lot of surface runoff (Barah, Khojandi, Li, & Hathaway, 2018; Barbosa, Fernandes, & David, 2012). The coupled effect of high-intensity rainfall and imperviousness has exposed the cities to unprecedented volumes of surface runoff. Large unmanaged volumes of surface runoff also pose the threat of pluvial floods. Therefore the future cities need to have high capacity stormwater drainage systems.

The artificial drainage system, also known as grey infrastructure, drains off the surface runoff in urban areas. It has a series of inlets and pipes (typically underground) to collect and convey stormwater to a discharge point such as a stream, river, lake, or other water bodies. Installation of grey infrastructure is cost-intensive, mono-functional, and not sustainable (Pitman, Daniels, & Ely, 2015; U.S. Environmental Protection Agency, 2014; Zhou, 2014). Therefore, future cities can not be entirely dependent upon the grey infrastructure. Hence, there is a pressing need for utilising natural channels as a supplementary stormwater drainage infrastructure.

The study aims to find the challenges for integrating natural channels in the urban drainage systems. The paper is structured in six sections to elaborate on the study process and its findings. The study's primary outcome is the knowledge that land reclamation in the Greater Mohali region is a leading cause of the destruction of natural channels. The basics of natural channels and their function are explained briefly in a subsection of the introduction section. Following this introduction section, section 2 outlines the method employed in this study. A brief introduction to the study area is in Section 3. Section 4 has the time-series analyses of cases of land reclamation from neo-developments. Section 5 is about results and discussions supplemented with a subsection that elaborates on the need to preserve natural channels. The conclusion follows this in section 6, which throws light on the limitations of this study and paves the way for future research.

Methodology

Research method: Case study

This paper lies within the realm of finding sustainable and nature-based solutions for urban issues. The leading question in the research is: what are the challenges that prevent the integration of natural channels in the urban drainage system? The study is based on the case-study research method and examines the case of Greater Mohali Region in Punjab.

The technique employed is landuse change assessment, an effective way to analyse any development trajectory and project the future to ensure sustainable development (Paul & Rashid, 2016). The basis of landuse change assessment is time-series analysis, where data is analysed from repeated observations of a single unit at regular time intervals (Velicer & Fava, 2003). The data for time-series analysis can be acquired from satellite images, aerial images or survey sheets. For analysis in this study, high-resolution images are obtained from the google earth pro platform. Since its launch in 2005, google earth has found its application in many fields related to urban spatial planning (Dodsworth & Nicholson, 2013; Liang, Gong, & Li, 2018; Malarvizhi, Kumar, & Porchelvan, 2016; Ngom Vougat et al., 2019; Taylor & Lovell, 2012). High-resolution images for the Greater Mohali region are available on the google earth pro platform from the year 2002. Cloud-free and seamless images are used for clarity in comparisons. Every case presented in this study has varying years for image acquisition because the timeline of spatial changes is never consistent. Also, note that the year of image acquisition does not correspond to the year of spatial change.

Study area: Greater Mohali Region

Greater Mohali Region (GMR) is located in the Punjab state in the north of India. It shares its boundary with the capital of the state, Chandigarh. The GMR comprises the entire SAS Nagar district and Banur area of the adjacent Patiala district; and has a geographical area of about 1190 sq. km. The entire region has six local planning areas (LPA), namely, Sahibjada Ajit Singh Nagar (SAS Nagar), Zirakpur, Kharar, Mullanpur, Derabassi, and Banur (figure 1). These six LPAs have their respective master plans. The region's population is about 0.7 million, of which the rural share is about 60% (as per census 2001). A large proportion of the 40% urban population is concentrated in SAS Nagar and Zirakpur, which have grown along the periphery of Chandigarh owing to development pressures from the capital city. The planning proposal for the physical development of the region is based upon a population projection of 4.5 million people by the year 2031.

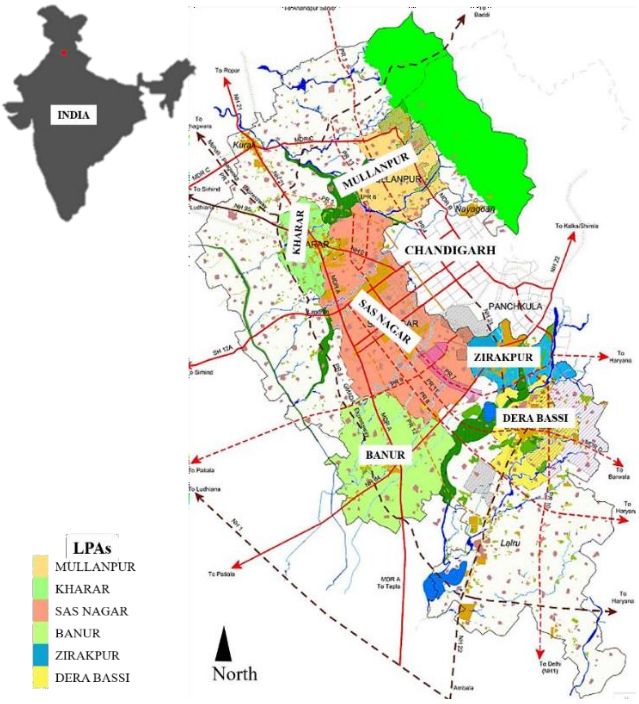

Figure 1: Location of GMR in the map of India; and location of LPAs in the GMR (not to scale)

The region has a flat topography, and the elevation ranges from 400m above MSL in the foothills of Shivalik to 200m in the plains. The slope is moderate gentle towards the southwestern side, where all the streams of GMR drain. The region is landbound with no scope of land reclamation from the sea. The area lies in the Ghaggar river basin and has many natural channels but no significant lakes. The annual average rainfall in the Greater Mohali region is 114 cm and is heavy during the monsoon season that starts in the first week of July and continues till the middle of September. The region experiences extreme weather conditions. The period of April to June experiences a hot and dry season with the maximum temperature reaching 45°C. November to February is cold weather, and the minimum temperature goes down to about 1°C.

Time-series analysis

The GMR is seeing a surge in construction activities in accordance with the proposals in master plan 2031. In the year 2020, when this study is conducted, the signs of development are evident on the google earth pro platform. The time-series analysis of neo-development areas has guided in identifying the land reclamation trend in the region. Out of the six LPAs, cases from five are illustrated in the subsections below. Dera Bassi area is not included for the lack of conclusive results. *(Only 1 case is demonstrated in this extended abstract).*

Case 2: Kharar LPA

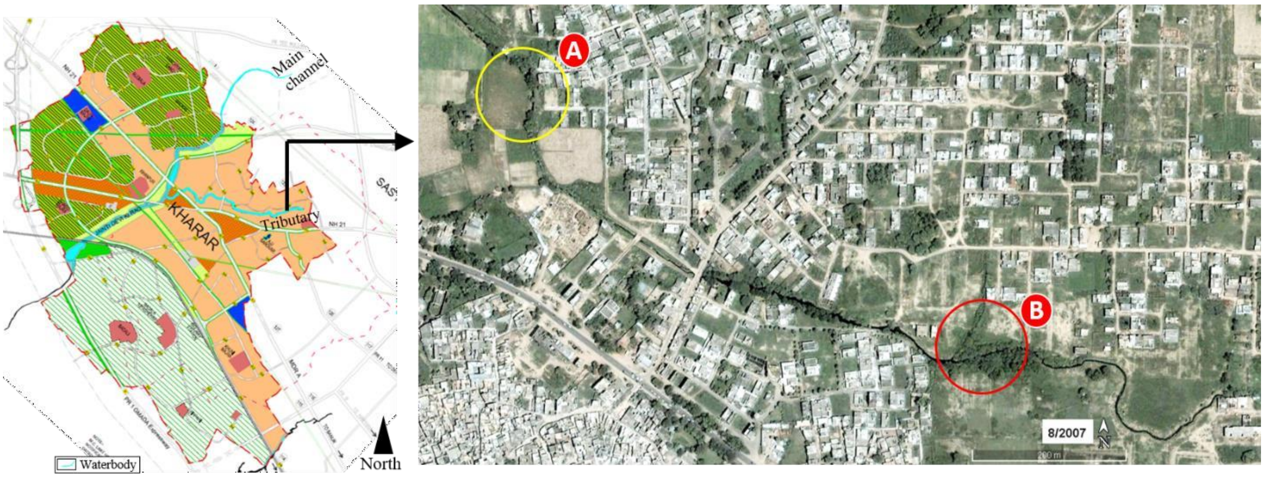

Figure 2: Master plan of Kharar LPA with waterbodies (left); Aeriel view of a waterbody in Kharar LPA with areas under consideration in circles (right)

Figure 2 (left) is the master plan 2031 of Kharar LPA that shows a perennial channel and its tributary in the area. No significant changes are observed in the path and width of the main channel after analysing the data from 2002 to 2020. However, the time-series analysis has revealed that the tributary originating in the Kharar area is on the verge of extinction. Figure 2 (right) is the google earth pro image showing the uninterrupted tributary path in 2007. Over the years, it has been filled at many places to reclaim new construction land. The observations from two such conflict points, marked as A and B in Figure 2 (right), are discussed further (Figure 3 and Figure 4).

Figure 3 shows the transformation of location A from 2007 to 2020. It is evident in Figure 3 (a) that one side of the channel is majorly agricultural land while the other side is a settlement. The channel is acting as a barrier between the two landuse. However, the channel has been filled by 2020, and the settlement is spreading onto the other side (figure 3 (b)).

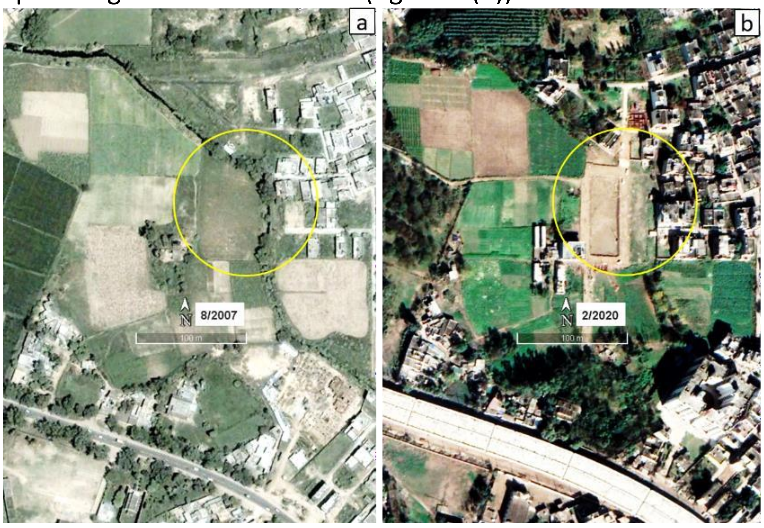

Figure 3: Time series analysis of location A showing the filling of natural channel

The section of the tributary at location B has seized to exist by 2018. The time-series analysis of this extinction is shown chronologically in Figure 4. In 2007, the floodplains of the channel had a dense spread of tree cover

(Figure 4(a)) which decreased substantially by 2009 (Figure 4(b)). It indicates a gradual preparation towards the encroachment of the channels' floodplain. Image from 2016 shows that the rampant building construction has wholly engulfed the branch jutting out of this tributary, though the fragmented channel is still there (Figure 4 (c)). The channel diminished entirely in 2018 because of filling, and now the high-rise residential buildings are standing tall in the area (Figure 4(d)). This visual demonstration also suggests that the Kharar village's rural character has also changed to urban in a decade. It is confirmed from the site visit that Kharar village has now amalgamated with the surrounding city sprawl.

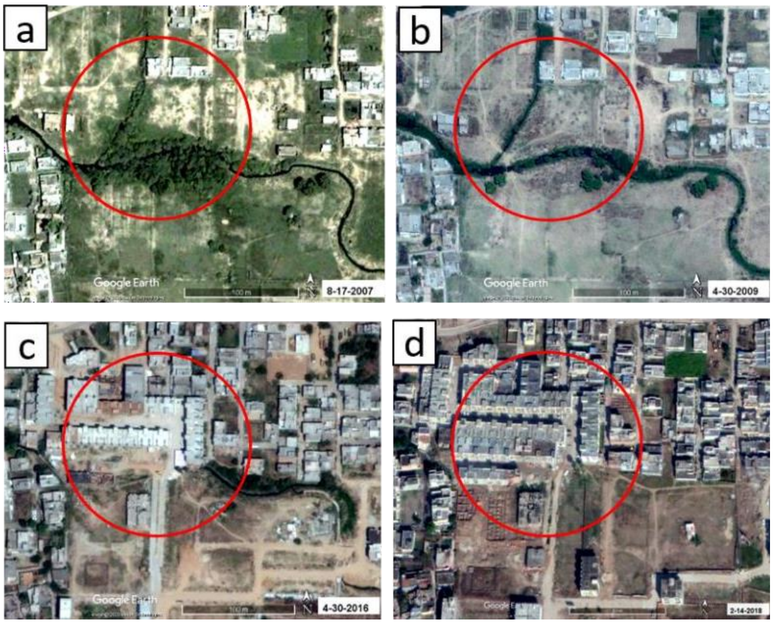

Figure 4: Chronology of the destruction of the natural channel at location B (from a to d)

Results and discussion

The google earth pro exploration has confirmed that the Greater Mohali Region is undergoing a development phase to meet the proposals planned in master plan 2031. The analytical observations from the time-series analysis of the land reclamation process are discussed below:

a) **Threat to natural channels:** A significant outcome of the analysis is knowing that a threat of extinction is looming over the ephemeral and intermittent channels. These channels are mainly originating in the LPA itself and have seasonal streamflow. In non-functional months, these channels are perceived as a wasteland and not a waterbody and therefore fall prey to land reclamation. The simplest way of reclamation is to fill the area with rocks, clay, construction debris, and excavated earth until the desired height is reached. The filling mainly takes place in the arid months when there is no streamflow. In this study, no threat of extinction to the perennial channels is observed. These channels have a large volume of water gathered from their tributaries, and the streamflow is continuous all year round. Therefore, the chances of land reclamation by filling such channels are bleak in small-scale projects.

b) **Floodplain reduction:** Many channels are facing the wrath of urban expansion by losing their crucial floodplains. It is mainly observed in the case of perennial channels. The settlements built on these floodplains are vulnerable to flooding.

c) **Trend of landuse change:** Channel extinction follows a series of landuse changes. It starts with the waterbody landuse, falls under the wasteland landuse category, and ultimately becomes residential, institutional, or any other constructed landuse. The process usually takes years and sometimes decades depending upon the pace of urbanization. Conversion to the wasteland is initiated by filling the channel at a drypoint, which breaks the flow continuity. For the lack of upstream water, the entire channel reach[1] dries out and turns into a wasteland. It paves the way for land reclamation to accommodate future construction. Also, when the channel is blocked, surface runoff from upstream areas does not find a way to drain off naturally. It causes waterlogging incidences in the rainy season.

In areas where the development stress is comparatively low, the landuse change is from the waterbody landuse to the agricultural landuse. It might be a case-specific outcome because the Punjab state is an agrarian-based economy. Studies from other areas may reveal a different trend of landuse change because of other local factors.

d) **Shortcomings in master plan implementation:** A concerning outcome from the analysis is the gap between master plans and their implementation. Some channels that have made their way to the master plan are on the verge of extinction and will entirely be vanished by 2031. It is a worrisome observation because, as per the master plans, the LPAs have a dependence upon these channels to drain off the stormwater. It reveals the shortcomings in the master plan implementation. Hence, there is a scope for periodic monitoring to ensure that the actual development trajectory is as per the planning proposals.

e) **Correlation between urbanisation and channel extinction:** Banur LPA is the least developed area in the GMR, primarily because it is not directly connected with Chandigarh city and has less urbanisation stress. The area also has the most natural channels in comparison to the other five LPAs. It indicates a correlation between urbanisation and natural channel extinction. It also suggests the possibility of many channels in other LPAs in the past that have been lost over the years. It can be confirmed from the historic survey sheets to establish a profound correlation.

f) **Unauthorised infilling:** Discrepancy between the infilling of channels and their presence in the master plan indicates that the filling process is unauthorised. The possible explanation is that the landowners and builders have been opportunists to grab hold of additional land, for they do not know the better ways of utilising the natural channels to their advantage. The practice can be curbed through appropriate legislative interventions and bylaws. There is also a need for awareness-building among landowners regarding the benefits of channels' preservation.

Conclusions and future work

The loss or dysfunction of natural channels is a proven cause of pluvial flooding. The need to preserve and restore natural channels in urban areas has emerged as a growing concern over the years to mitigate and manage the pluvial floods (EPA, 2010; Mujibor Rahman, M Akteruzzaman, H Khan, Jobber, & Rahman, 2009). As the cities may witness more extreme rainfalls in the future, the disregard of natural channels in the stormwater management system may prove self-sabotaging. Cities that have not considered the pluvial flooding in their hazard profiling have compromised the city's overall resilience[2]. A flood-resilient city has low flood consequences if and when the hazard strikes (Hammond et al., 2013). The underlying factor behind the concept of flood resilience is that the increased incidences of rainfall are inevitable, but strategic planning and management can prevent flood situations.

This study explores the land reclamation practices in one particular region, predominated by natural channels. The outputs are, therefore, case-specific. There is a scope for further research on other regions using the same methodology, which may yield different results based upon their topography, existing landuse, economy, and bylaws. A holistic guiding document for sustainable land reclamation practice can be prepared by combining the output of all the studies. This desk-based research method is suitable to funnel down the problematic locations where more in-depth studies can be conducted in the future. This approach

[1] A reach is the small section of a channel between two branches (tributaries).

[2] Resilience is the ability of a system, community, or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management (UNISDR, 2017).

relies on visual interpretation, limiting the results to the physical attributes of the channels. Other aspects such as the water quality, flow velocity, and channel bed depth could not be explored but might have been affected by land reclamation.

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