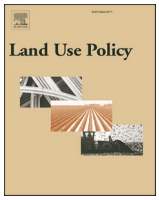
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Spatial transition dynamics of urbanization and Rohingya refugees' settlements in Bangladesh

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ABSTRACT

Urbanization needs to conceptualize land use policy beyond the city boundaries. It might be explained by exploring complex and interconnected interdependencies in regional key driving factors that can have telecoupling effects during sudden shocks. Over one million Rohingya have settled in the rural/forest area in Cox's Bazar for locational proximity and comparatively easy escape from Myanmar after domestic conflicts. This study aims to explore the spatial dimension of urbanization in a regional transition context focusing on the newly built refugee settlements in the south-eastern coastal area of Bangladesh. Additional, we also identify further research scopes and gaps in the context of the case study. Analysis of openly available global data products from historical built-up expansion from 1975 to 2021 suggests that refugee settlements impact spatial development intensity (annual rate ~2.55 ha/year) and population density (annual rate ~9431 person/year) dimensions, which have a transition (rural-to-urban) of a greater regional scale than local urbanization. Our results from the expert-based key informant interviews have a broad agreement with the quantitative findings; however, the environmental: deforestation, economic: increasing business and employment opportunities and daily living expenses; and socio-cultural impacts: increasing conflict between host and refugee communities due to prostitution, drug dealing, and insecurity, are more local than findings from the geospatial analysis. Therefore, the local development policies need an urgent adjustment to comply with the local and regional balances in the above factors, along with that international development actors may also need attentive measures in the policy formulation. Further investigations in scenario-based urbanization dynamics are required to avoid an urban desert initiated in the absence or relocation of refugee settlement. Similar kinds of studies may also be replicated even in prosperous global North countries in order to conceptualize the spatial transformative process of rapid migration influx on urbanization with innovative open data in the absence of up-to-date official datasets and adoptions of mixed methods approaches with related actors including policymakers.

1. Introduction

Urbanization needs to conceptualize land use policy beyond the city boundaries by exploring complex and interconnected interdependencies in regional key driving factors that can have telecoupling effects during sudden shocks (e.g., Al-Nammari, 2014; Liang and Li, 2020; McPhearson et al., 2021; Nam and Yen, 2021; Naumann and Nadler, 2022; Unruh, 1993; Zhang et al., 2022). Spatial dynamics and population increase are the two significant indications of urbanization and residential built-up settlement structure (e.g., de Castro Mazarro et al., 2022; Li et al., 2020; Pham et al., 2019; Zhang et al., 2022). Refugee migration and their settlement increase both populations and a spatial dimension. Urbanization has both positive and negative impacts depending on the scale of urbanization (Jehling and Hecht, 2021; Li et al., 2020; Martínez

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et al., 2020; Pham et al., 2019; Vaz et al., 2018). However, the question remains unanswered: how do pocket-based (camps) settlement and their numbers impact urbanization and vice-versa?

United Nations High Commissioner for Refugees (UNHCR) reported that "every minute in 2018, 25 people were forced to flee" (UNHCR, 2018) and 90% of refugees are hosted in low- and middle-income countries (World Bank, 2018), experiencing economic, environmental, social and development difficulties (Leiterer et al., 2018; Potter et al., 2009; Thulstrup and Henry, 2015). However, the massive refugee population is becoming one of the recent challenges even in many high-income prosperous countries mostly in Europe like Germany (e.g., Asadzadeh et al., 2022), Sweden (Vogiazides and Mondani, 2021), the Netherlands (e.g., de Hoon et al., 2021) due to manifold regional and international crisis. Therefore, it is urgent to share the burden and responsibility for hosting countries and supporting the growing number of refugees equitably (McConnell, 2019). The resettlement scheme adopted by UNHCR is only for those refugees who are highly at risk in terms of life, liberty, safety, health, and fundamental human rights, and resettle to third countries (UNHCR, 2019). As a result, less than 1% of 20.7 million refugees worldwide are under UNHCR's recognition for resettlement (UNHCR, 2021). Therefore, land use and spatial planning policy, and refugee governing system of the host countries need to be analyzed and adjusted for both national and international development (Asadzadeh et al., 2022; de Hoon et al., 2021; Vogiazides and Mondani, 2021).

Rohingya is a minority ethnic group living in the Rakhine State (named Arakan before 1990) in the Union of Myanmar (changed from the Union of Burma in 1989) (Grundy-Warr and Wong, 1997; Islam et al., 2021a). By 2021, Bangladesh holds more than one million Rohingya refugees who are not eligible for UNHCR's resettlement scheme. They are living in 36 camps in Cox's Bazar (a South Eastern coastal area in Bangladesh) in inhuman conditions; however, they share some common spaces, e.g., the marketplace and natural resources, e.g., land and forest products, with the host communities in Bangladesh.

Since the 8th and 9th centuries, Islam began to spread at the eastern bank of the Meghna River to Rakhine (currently in Myanmar). Culturally, the Rohingya are Muslims. There was 500,000 Muslim population registered in Myanmar out of 13 million in 1921. However, due to the geopolitical importance, Muslim migration from India, conversion to Islam, and Muslim birthrates, the concentration of Rohingya in Rakhine increased. After independence from the British Empire on 4th January 1948, with the development of the military regime in 1962 inter and intra-community hatred increased (Grundy-Warr and Wong, 1997). Since the late 1970 s, the Rohingya population has been forced to cross the Myanmar-Bangladesh border with the intention of ethnic cleansing, via brutal military and civilian actions (Grundy-Warr and Wong, 1997), similar to Bosnia-Herzegovina in the 1990 s (Black, 2002), and what is an opposite direction (economic opportunity as pull factor) of migration scenarios across the border to the USA from Mexico (Rodríguez-Pose and von Berlepsch, 2020). As the proximity to the potential shelter, they migrate mainly to Cox's Bazar coast in Bangladesh (Fig. 1). There were 3500 Rohingya in 1975, and 222,000 in 1978 emigrated to Cox's Bazar, and a more sporadic Rohingya population continued to cross the border due to civic conflict-related insecurity (Grundy-Warr and Wong, 1997). Some of them have returned to Myanmar due to intergovernmental negotiation between Bangladesh and Myanmar, push-back action, and misconduct in refugee camps in Bangladesh (Grundy-Warr and Wong, 1997). Many of them mingled with the host community and migrated to third countries. In Bangladesh, nearly half a million Rohingya population registered in refugee camps till 2016, but a massive migration of 742,000 people happened in September-November 2017 (Islam et al., 2021a). More than one million Rohingya refugees live in 36 camps in Bangladesh.

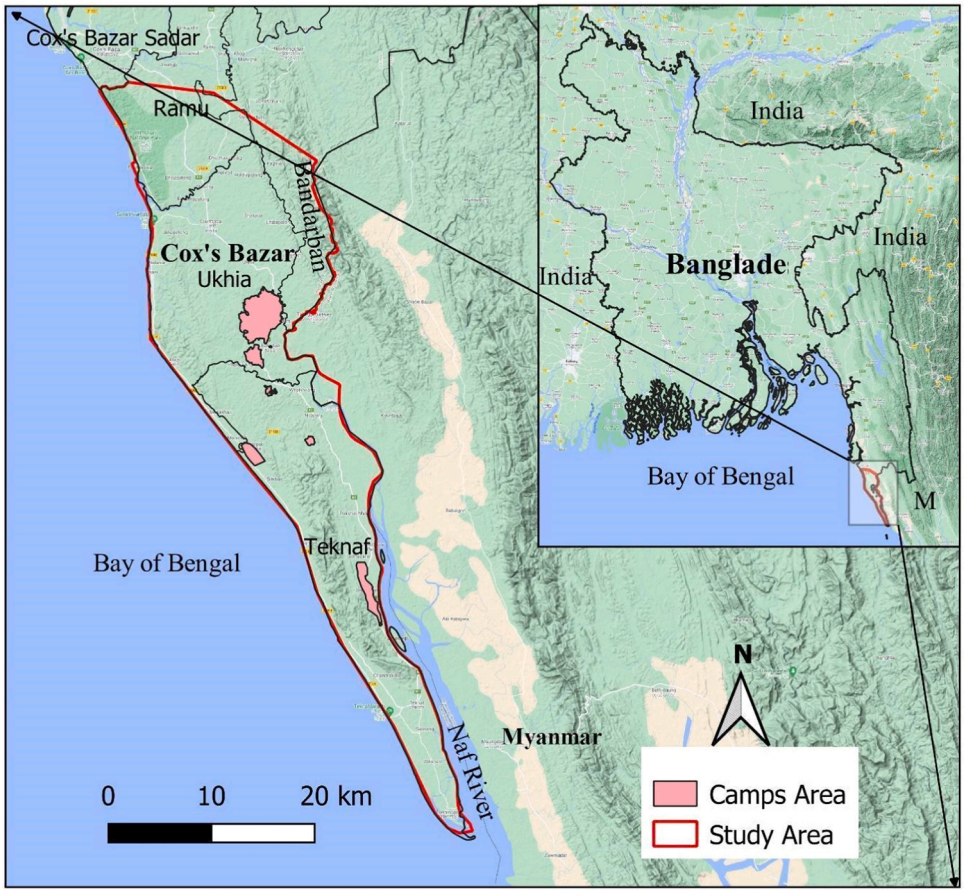


Fig. 1. Cox's Bazar, the location of the study area (Google map in the background, Map data @2021 Google).

Much literature can be found on Rohingya refugees and their multiple challenges to the impoverished host communities. Some significant studies discuss refugee camp's dependency on forest resources, Teknaf Wildlife Sanctuary, Himchari Nation Park and land-use change (e.g., Alam et al., 2015; Hassan et al., 2018; Imtiaz, 2018; Moslehuddin et al., 2017; Sakamoto and Tani, 2013), conversion and degradation, and socio-economic impacts (Khan et al., 2012; Rahman et al., 2014; Uddin and Khan, 2007) in this area. However, almost no literature can be found that has investigated the effect on urbanization. In contrast, more than one million refugees, their settlements, and socio-economic activities should significantly impact spatial dimensions on a local and regional scale.

This study explores on – what are the spatial extent of urbanization in a regional level transition context? It is focusing on the newly built Rohingya refugee camp in the eastern part of Bangladesh. This study aims to explore the spatial extent of urbanization in a regional level transition context, focusing on the newly built refugee camp in the eastern part of Bangladesh. The scope of the research is to (i) quantify the changes of the built-up area from 1985 to 2021, (ii) identify the population density over the study period using freely available open-source data sets, and (iii) qualify socio-economic impacts, particularly in the housing, local business and some social sectors. Even though access to migration-related big data for robust research is challenging (Franklinos et al., 2020), an attempt to explore the relationship between refugee migration and urbanization is initiated.

Our paper commences here with a brief review of the literature. Section 2 presents the global discussion on refugee settlements in relation to urbanization. Section 3 described the methodology, data sources, data processing and analytical approaches. Afterwards, the key findings are presented in support of graphical and statistical facts. The final two sections discuss and summarize the key contributions of this study, including the policy implications.

2. Refugees' settlements and urbanization: a global agenda

Refugees are immigrants forcefully entering a state/country without an official visa (Fábos and Kibreab, 2007). In developing countries, refugees are often welcomed as temporary guests with almost no social support (as recommended in international refugee conventions) until the conditions of the home country become relaxed and they are expected to return home regardless of the duration of exile (Akar and Erdoğdu, 2019; Fábos and Kibreab, 2007). It is equally expected that refugees in many developed countries should return to their homes, for example, Bosnian refugees in European countries (Black, 2002). In developing countries, refugees often go to urban areas/cities and settle after finding essential living support and economic opportunities. This was the case in the sub-Saharan African refugees in Sudan for better income and to hide their identity to avoid discrimination (Fábos and Kibreab, 2007). However, states typically see this as competition with the host communities, e.g., for employment, healthcare, education, sanitation, and other services, and impose restrictions on the refugees not to go outside predefined camps areas without permission nor allowing ownership of properties. This is typically justified by claiming security reasons and the control of criminal offences (Fábos and Kibreab, 2007).

The Government of Bangladesh (GoB) adopted similar measures for the case of Rohingya. They are neither allowed to go outside the camp area nor have the right to be property owners and cannot marry the citizens in the host county (BBC, 2018). However, it would benefit both the refugees and the host country if they were trained and allowed to work in the host country with some regulation (Akar and Erdoğdu, 2019; Fábos and Kibreab, 2007). This is found in some developed countries (Fábos and Kibreab, 2007). The lead author visited several Syrian refugee camps in Sweden during 2015–2017, whose occupants migrated since 2011 following the Arab Spring and conducted a reconnaissance survey and an open-ended discussion. Three-, and four-star hotels, and summer resorts were converted to camps where Syrian refugees lived at the beginning of their stay (Refugees' camps visit in Sweden). The refugees have been educated and trained and entered the job market. Simultaneously, the central government distributed the refugees among different municipalities with an expectation of integration. The local authorities made a massive investment in the housing sector to accommodate them with strategies of proportional mixing with the host communities for social integration (Bevelander and Luik, 2020; Bucken-Knapp et al., 2019). This leads to a considerable expansion of urbanization and related land use change for commercial and industrial activities (Jehling and Hecht, 2021). Similar processes occurred in other developed nations, e.g., European countries, the USA, and Canada (Bevelander and Luik, 2020; Bucken-Knapp et al., 2019).

On the other hand, ~95% out of 3.5 million Syrian refugees live in unprotected shelters in urban and peri-urban areas in Turkey with limited access to essential services (Akar and Erdoğdu, 2019). This puts pressure on the housing and health sector, and therefore house rent has increased greatly. Refugees' settlement or camps development poses a regional urbanization process, grows population movement locally, regionally, and even globally, and develops the transnational space (Fábos and Kibreab, 2007). This is experienced in particularly developing host countries, e.g., Turkey and Bangladesh. UN agencies and more than 130 local, national and international NGOs are working and supporting the GoB to provide essential support for the survival of about one million Rohingya refugees (OCHA, 2020). Their dwellings are part of the urban landscape.

It is also seen that some refugees never make a return or have an opportunity for repatriation. Such phenomena are observed for Afghan refugees in Pakistan after escaping the Soviet Union invasion and impacting urbanization (Kronenfeld, 2008). Due to similar religious and cultural practices, refugees can easily escape the camps, mingle with the host community, and marry and settle there. This has also been found in Rohingya refugees in Bangladesh since the 1970 s; many mingle with the host community (filed observation by the author in August 2018; Islam et al., 2022).

On the other hand, the Palestine refugees in Shu'fat in Northeast Jerusalem and the Kufr Aqab/Qalandia area between Jerusalem and Ramallah exhibit a complex power struggle between formal and informal states, freedom and colliding between them. However, it still plays a focal point in expanding urbanization in these areas and surroundings (Alkhalili, 2019). In fact, the refugees' settlements or camps in the global north and south countries impact ongoing urbanization, both in spatial and socio-economic dimensions.

3. Method and data

This study has adopted a mixed methods approach in a combination of quantitative and qualitative approaches to investigate the ongoing dynamics of spatial and population dimensions as the prime indicator of urbanization and socio-economic impacts in refugees' settlements (Tashakkori and Creswell, 2007). The models of mixing have been adopted considering embedding, connection, and integration (Halcomb and Hickman, 2014). The following section describes the detailed methodology, including a brief overview of the case study area.

3.1. Brief descriptions of the case study area – refugees' camps in Cox's Bazar

Cox's Bazar is the most south-easterly district of Bangladesh (Fig. 1). The area of this district is ~2 492 km^2. However, the study area consists of Teknaf, Ukhia, and part of Ramu sub-districts out of eight sub-districts (*Upazilla*) of Cox's Bazar District, extending ~92°8′30″ E to 92°17′53″ E and ~20°51′58″ N to 21°6′45″ N (Fig. 1). The study area also contains a small part of the Bandarban District, mainly a non-populated place (Fig. 1). The Naf River demarks the southern part of Cox's Bazar District and Myanmar, and a long coastline of the Bay of Bengal exists at the

south part of this district. The study area is predominantly covered by forest, named Himchari National Park with ~17.29 km^2 and Teknaf Wildlife Sanctuary of ~116.15 km^2. (Nishorgo, n.d.a, n.d.b). It is a hilly area with a tropical climate. The elevation ranges from − 30 m (below sea level) to 369 m with a gentle slope. The average rainfall is 349.4 mm/month, and the average temperature is 15 °C in the winter and 32 °C in the summer (Alam et al., 2015; Islam et al., 2019; Khan et al., 2012).

3.2. Quantification of spatial growth and population density dynamics

Utilization of remotely sensed data to estimate spatial expansion, as an indicator of urbanization is commonly practiced worldwide (Amoateng et al., 2018; Pham et al., 2019; Su et al., 2011). The spatial expansion of this study was quantified using built-up area and population data (Fig. 2), open-source and freely available from Global Human Settlement Layers (GHSL) also shown in Table 1 (Florczyk et al., 2019) using Geographic Information System (GIS). The temporal coverage and interval of the data used are from 1975, 1990, 2000, and 2015. It is a grid-based data with particulars; spatial resolution: 250 m, and reference system: 540,09 – World_Mollweide. However, it was projected and converted to World Geodetic System 1984/ Universal Transverse Mercator Zone 46 North (WGS 84/ UTM zone 46 N) for better comparison with other data sets. The built-up grid is presented by 0–100, indicating no to 100% built-up area. The population data set provides the total population in each grid in a specified period. However, this data has a limitation on temporal resolution. The massive migration in this area occurred in September-December 2017, not covered by the GHSL's data set. To understand the effect of this massive migration, the most recent Built-up area in January 2020 (the footprint of buildings) was collected from OpenStreetMap (OSM) Foundation (2018) (Fig. 2; Table 1).

A layer masked the data set, predominantly the Cox's Bazar District, Bangladesh, excluding the Cox's Bazar municipality using open-source GIS software QGIS (QGIS.org, 2021). The basic statistics of the data used are presented in Table 2.

From percentage to the actual value for the built-up area of GHSL's data was calculated by applying a Raster Calculator (pixel's value times pixel's resolution divided by 100). Further, the year-specific total built-up area and population in the study area were calculated (Table 3), and linear trends were estimated using the Linear Regression method using Microsoft Excel (Fig. 3). 1975 was set to a base year, 0 (zero) in regression analysis (Fig. 3). Finally, the GHSL in the study area were classified into different categories, calculated their general statistics, and presented in tabular and mapping formats (Fig. 4; Table 4).

The built-up area in 2021 was calculated from geometry (building footprint) calculation in the study area. The total built-up area in 2021 was obtained by summarizing the layer table (Table 3). The calculated built-up area layer was further aggregated and overlaid by the similar geometry of GHSL data (250 m X 250 m) to estimate the percentage of built-up (pixel-specific aggregated value divided by pixel's resolution times 100), similar to GHSL data. The built-up area in 2015 (GHSL's data) was re-scaled to identical in 2021, and both were classified on the same scale and presented side-by-side for better comparison (Fig. 5).

3.3. Qualitative data collection and analysis

The expert interviews were conducted in the form of semi-structured open discussions with the expert on the community relationship, population behavior their impact on physical development, e.g., urban development and/or urban growth. The following two major steps were involved in data collection and interpretation to identify the impact of refugee settlements on urbanization dynamics.

3.3.1. Selection of key respondents for an expert interview

The respondents in expert interviews were considered urban development practitioners at international and national levels, local

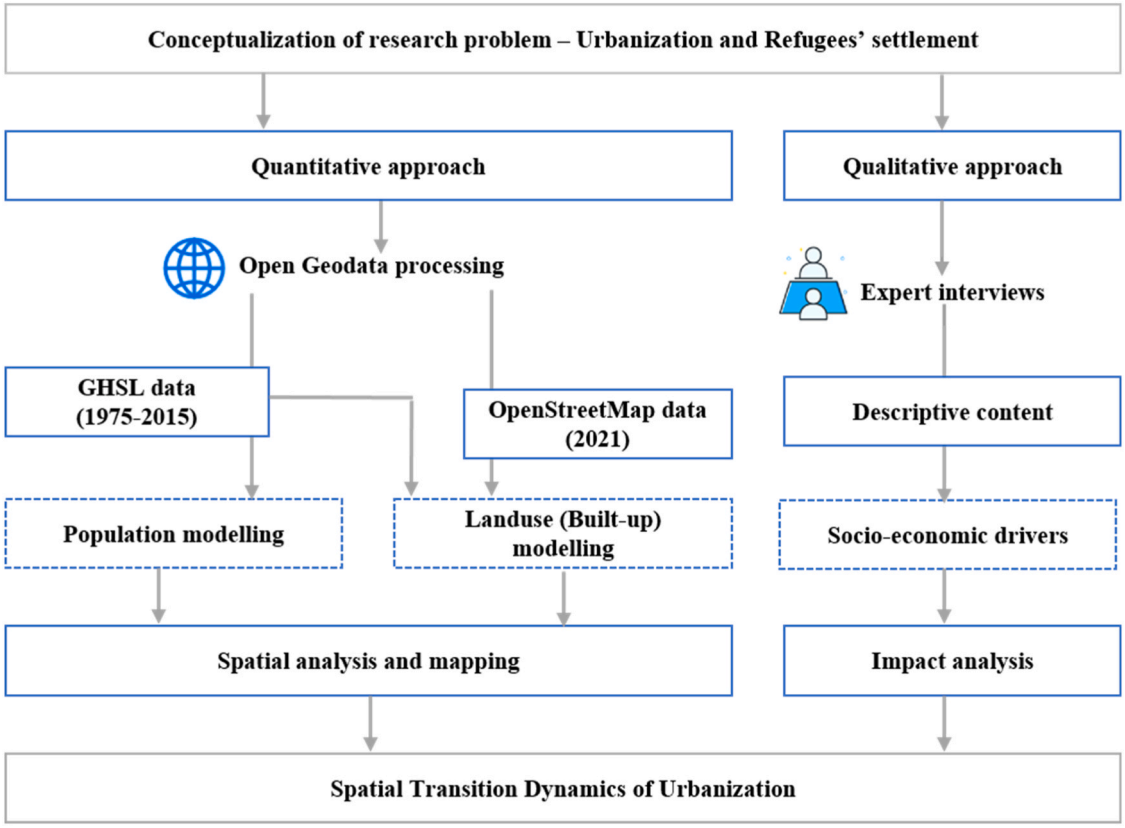


Fig. 2. Methodological flow diagram.

Table 1
The description of datasets used in this study.

Items	Data format	Spatial resolution	Spatial Reference	Temporal reference	Source
Population	Raster (Grid)	250 m	54009 – World_Mollweide	1975, 1990, 2000, 2015	GHSL Data catalogue, described in Florczyk et al. (2019)
Built-up					
Built-up (building)	Vector	-	WGS 84	19 Jan 2020	OpenStreetMap Foundation (2018)

Table 2
General statistics of the built-up area and population in the study area.

Items	Year	Minimum	Maximum	Mean	Std. Deviation
Built-up area (in %)	1975	0	69.1	0.3607	2.741
	1990	0	69.1	0.3858	2.873
	2000	0	76.8	0.4475	3.241
	2015	0	80.6	0.4889	3.347
Population (in number)	1975	0	3082.3	13.846	106.009
	1990	0	5178.4	25.009	187.491
	2000	0	7121.7	35.298	258.054
	2015	0	10432.8	50.841	358.995

Table 3
Total built-up area and population density in different years in the study area.

Year	Built-up area (ha)	Total population	Density (person/ha)
1975	271.72	149864	551.5
1990	290.61	270753	931.7
2000	337.10	378104	1121.6
2015	368.33	550188	1493.7
2021	898.08	564011 * , 2392631 * *	628 * , 2664 * *

* No data available – Population estimation based on time-population relationship in Fig. 3b
* *No data available – Population estimation based on the built-up area-population relationship in Fig. 3

government officials, regional development authorities, aid agency representatives, researchers at universities and research organizations, civil administrations, non-government organizations, and residents in local areas (study area). Appendix-A: Table A presents all detailed information of the expert respondents.

In expert interviews, the local and regional respondents were considered based on their direct knowledge and working experiences on the Rohingya refugees' issues in Cox's Bazar. The national-level respondents were considered based on their prior knowledge directly linked with the refugee migration in the study area and refugees' impact on urban development and host communities. However, the foreign respondents were considered because of their expertise on international refugees' aspects and problems and prospects in the local areas and host communities in general.

3.3.2. *Semi-structured interview (online interview), documentation, and content analysis*

As mentioned earlier, the interviews were conducted in a manner of open discussion following a semi-structured questionnaire (Appendix B). The discussion parameters were spatial dimensions, socio-economic and environmental issues regarding the mass migration and settlement in refugees' camps in Cox's Bazar. The interviews were conducted by the lead author through mobile communication using freely available mobile apps, namely, WhatsApp, imo, Viber and Skype. These apps' audio/video conferences provide the feeling of face-to-face discussion (Jianling, 2018; PytlikZillig et al., 2011). Specific issues such as "what are the impacts of refugees' settlement in physical infrastructure, particularly housing development in the nearby local area?", "what are the interactive relation between refugees and host communities?", "what are the impacts of the refugees' settlement on the local business sector?", "where do the aid agencies/NGOs workers live to serve the refugees?" were raised to start the discussion. During the discussions, many secondary issues were discovered, such as "security issues of both refugees

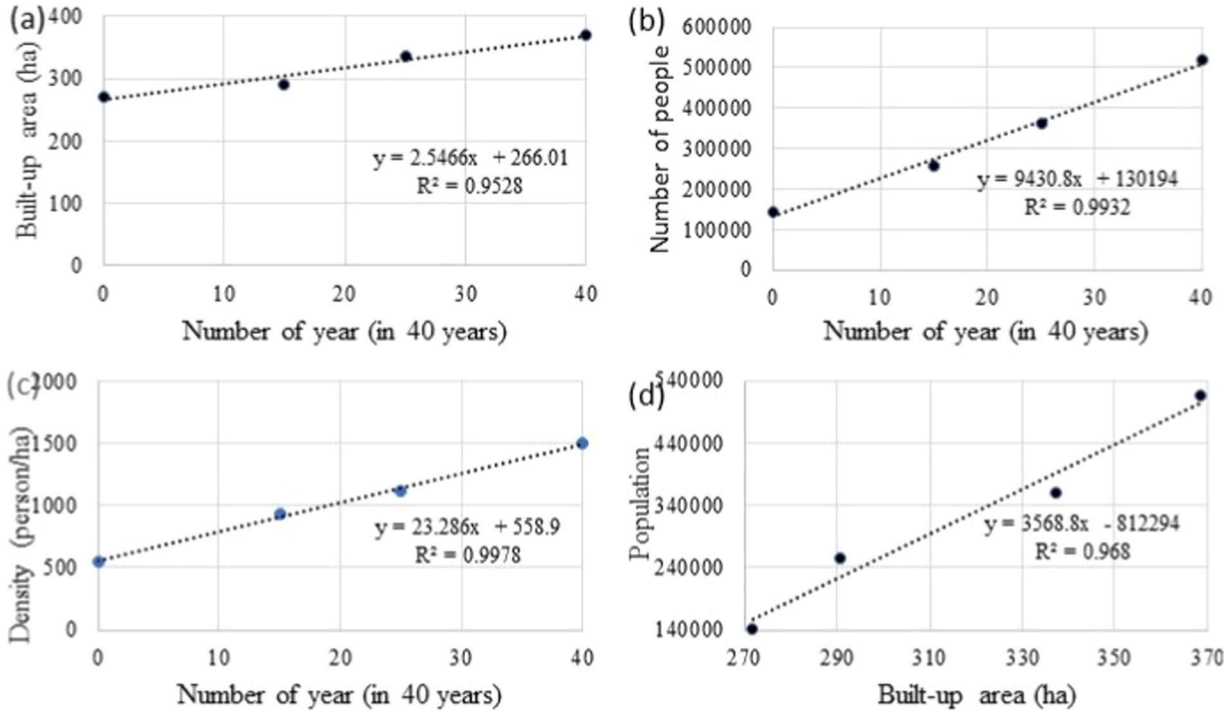


Fig. 3. Built-up area and total population in the study area.

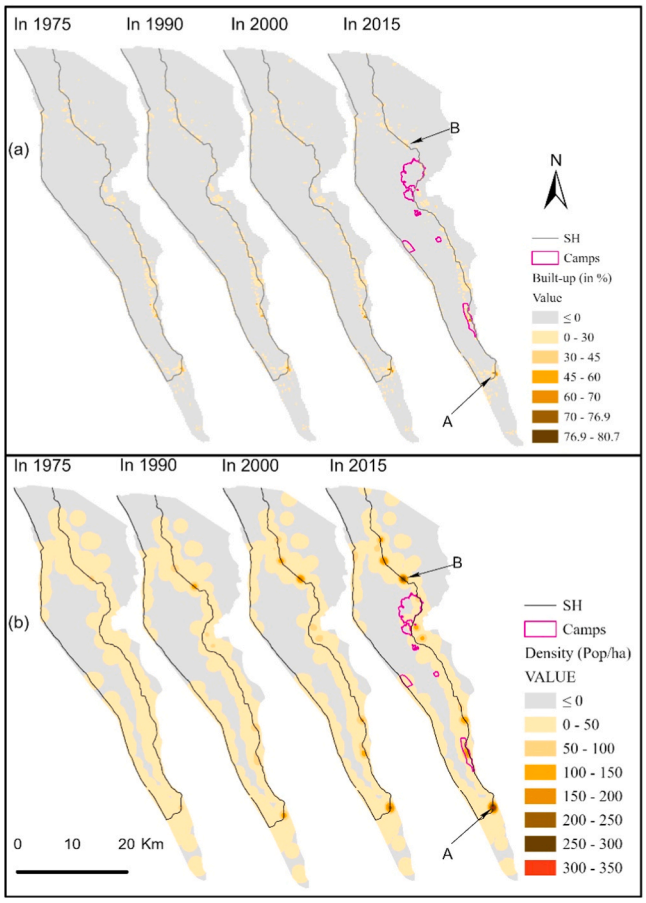


Fig. 4. Built-up area (a) and density (number of population/hectare) map (b) with secondary highway and camps area (in 2015) in the study area.

and host community", "long term self-reliance system for survival", "social mingling of refugees with the host communities".

The discussions of expert interviews were archived in a written text format and/or voice recording system individually. Responses of each respondent were documented as a single case. Later on, the information is retrieved from the archive and summarized. Finally, the summary of the findings was written in a narrative format as a content-based analysis (e.g., Archibald et al., 2017; Forman and Damschroder, 2007).

The positive and negative impacts of refugees' settlement were considered to bring benefits and harm, respectively, to the refugees' and host communities. Since the primary goal of this study was to investigate urbanization due to refugees' settlement, we prioritized physical infrastructure development and population growth and, secondarily, socio-economic issues under investigation. Fig. 2 shows a methodological flow diagram that includes data collection, processing, and analytical workflow.

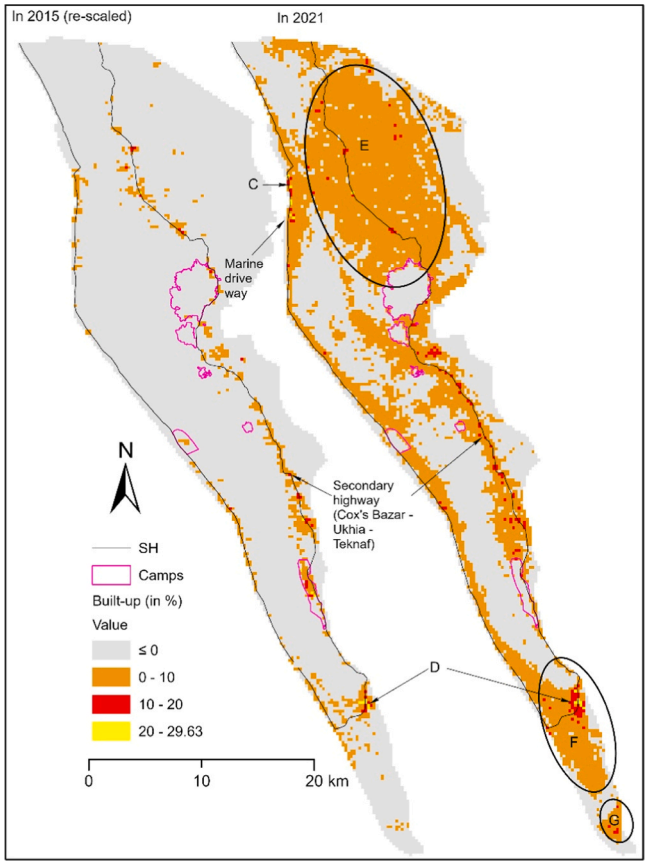


Fig. 5. Built-up area in 2021 and 2015 (re-scaled to similar in 2021) in the study area.

Table 4
Categorized built-up (in %) area (in ha) and population density (person/ha) in the study area.

Built-up (in %)	In 1975		In 1990		In 2000		In 2015	
	In ha	In %	In ha	In %	In ha	In %	In ha	In %
below 30	3818.7	96.07	4006.25	95.96	4293.75	95.55	4581.25	95.69
30 – 45	87.5	2.2	87.5	2.10	100	2.23	100	2.09
45 – 60	50	1.3	56.25	1.35	43.75	0.97	50	1.04
60 – 70	18.7	0.5	25	0.60	25	0.56	25	0.52
70 – 76.9	0	0	0	0	31.25	0.70	25	0.52
Above 76.9	0	0	0	0	0	0	6.25	0.13
Total	3975	100	4175	100	4493.75	100	4787.5	100
Density (person/ha)	**In ha**	**In %**	**In ha**	**In %**	**In ha**	**In %**	**In ha**	**In %**
below 50	36038.79	99.55	33065.82	96.42	32642.28	94.19	30927.96	90.59
50 – 100	163.44	0.45	1079.37	3.15	1452.51	4.19	2037.96	5.97
100 – 150	0	0	150.03	0.44	390.78	1.13	689.94	2.02
150 – 200	0	0	0	0	142.11	0.41	269.82	0.79
200 – 250	0	0	0	0	28.53	0.08	116.37	0.34
250 – 300	0	0	0	0	0.18	0	76.68	0.22
Above 300	0	0	0	0	0	0	22.5	0.07
Total	36202.23	100	34295.22	100	34656.39	100	34141.23	100

4. Results and findings

4.1. Spatial and population dimension: linear rapid increase

The total area of the study area is ~753 km^2 (~75 300 ha). The built-up area in 1975 was 271 ha, which is increasing linearly with a rate of ~2.55 ha/year, and in 2015, it was 368 ha (Fig. 3). The footprint of the building from the OSM provides ~898 ha in 2021 (Table 3). Similarly, the population in the study area was 149,864 people in 1975 that corresponds to 551 person/ha density (Table 2). The number of people in this area also increased linearly with a rate of ~9431 person/year, and in 2015, this number was 550,188 persons (Fig. 3; Table 3). However, the population in 2021 can be calculated using previous years' (1975–2015) population and built-up areas relation. Considering the time-population relationship in Fig. 3b, the population in 2021 can be projected to 564,011 persons, whereas based on the built-up area-population relationship in Fig. 3d, it can be projected to 2,392,631 persons (Table 3).

Table 4 presents categorized built-up area (in %) and population density (person/ha) in the study area. About 96% of the built-up area is categorized as up to 30% built-up from 1975 to 2015 (Fig. 4a; Table 4). During the study period (1975–2015), ~2% and ~1% built-up area were categorized to 30%– 45% and 45%– 60%, respectively. During 1975–1990, higher intensity of the built-up regions (70–80%) was absent. After that, the intensity of built-up areas increased even though that percentage was not that significant (~0.7%) (Fig. 4a; Table 4). However, the rate of low-density areas (up to 50 person/ha) decreased during 1975–2015 (Fig. 4b; Table 4). During 1975–1990, the study area was dominated by primarily low-density regions (up to 100 person/ha). After 1990, density increased where ~2% - ~4% area was dense up to 350 person/ha (Fig. 4b; Table 3). The high built-up and dense areas are located at Teknaf Upazila (location A in Fig. 4) and Ukhia Upazila (location B in Fig. 4), the urban centers.

The footprint of buildings in 2021 (derived using the OSM building data) suggests that the highest percentage of built-up area is ~30% that is located at Teknaf Upazila (location D in Fig. 5) and SonaPara Bazar (location C in Fig. 5). The Marine driveway construction and hotel development for tourism attractions might encourage rapid, intensive growth of built-up area at SonaPara Bazar (Fig. 5). A massive area in Ukhia Upazila (location E in Fig. 5) and Teknaf Upazila (locations F and G in Fig. 5) are low built-up density areas, only 10% built-up (Fig. 5). Otherwise, built-up areas have developed along the secondary highway of Cox's Bazar District, Ukhia Upazila and Teknaf Upazila (Fig. 5). Built-up area in 2021, particularly in locations E, F and G in Fig. 5 may not indicate the massive development during 2015–2021. It raises the issue of uncertainty in the precise quantification of built-up intensity due to the unknown data quality. Therefore, it is difficult to quantify and compare the built-up information from two data sources, e.g., remote sensing product: GHS (in 2015) and vector type volunteered geo-information: OSM (in 2021). To identify the driving force behind the development at the upazila headquarters (Ukhia Upzila and Teknaf Upazila) and along the secondary highway, qualitative measures were conducted (see Sections 3.3 and 4.2). However, the visualization of spatial expansion patterns can serve as initial information for strategic decision-making and intensive data collection for detailed investigation.

4.2. Qualitative results: tele-coupling effect at the local level

From the expert interviews, it was found that the spatial dimension and population increased (excluding refugees) at the local level outside of refugees' settlement. However, the local population numbers have not changed dramatically due to the mass refugees migration in the study area. A national UN expert said, "among the refugees, a major number are registered in the UNHCR". However, a researcher mentioned, "many refugees are not registered at UNHCR and, some but not the significant number is mingled with the host community". It is also noted that many early and new refugees made their passports as Bangladeshi and migrated to third countries e.g., Malaysia and Saudi Arabia, for mainly job purposes.

Most of the local level/field employees of the different national and international aid agencies and NGOs serving the refugees in the camps in Cox's Bazar have mainly been working from Teknaf, the thana headquarters and Cox's Bazar, the district headquarters. The district headquarters of Cox's Bazar District or Cox's Bazar Pourashava (local municipality) is outside this study area, which may be a limitation of this study in spatial contexts. However, high-level executives of prominent NGOs and aid agencies are working from the Cox's Bazar District office. National and international level executives of those NGOs and aid agencies visit the camp area from the local station in Cox's Bazar district, and at Upazila headquarters (Ukhia Upzila and Teknaf Upazila). It increases significant housing demand in Cox's Bazar Pourashava. Before the mass migration of the refugees in this area, a massive development occurred due to tourism development. Many three to five-star hotels and road infrastructures were developed to support tourism development. Part of such infrastructure has been used for humanitarian service to the refugees in the camps. However, such impact as housing demand might impact regional headquarters in the capital city. Similarly, most of the aid workers in the camps in Cox's Bazar stay overnight, not in the vicinity of the camps area. Therefore, the movement of the people, both national and international, increases dramatically, but that does not increase the total population in the study area, as an indication of urban expansion.

Population increases from both infrastructure projects and mass migration affected the local economy. Mass migration of refugees and their settlement in the camps in Cox's Bazar plays a role in improving local businesses. A local level NGO worker responded, "supply-chain system of daily-life needs such as consumer products, fuelwood, vegetable, fish, increases the business opportunities locally which provides little opportunity for income generation activities both for the refugees and host community".

However, refugees in Bangladesh are frustrated and do not see any future for themselves and their children. A respondent at the local madrasa said, "we live in the camps, we do not have a job, our children do not have proper education, we do not know when we shall go back to our land". Most aid agencies and NGOs provide services on an ad-hoc basis to keep refugees alive. On top of that, the geopolitical situation between Bangladesh and Myanmar is very complex. A small number of migrants who arrived before the mass migration in 2017 returned home to Myanmar. Eventually, the military intervention and taking power in Myanmar made the refugees' peaceful return to their homeland more complex. Therefore, it may be better to make a long-term plan along with the ad-hoc ones. Refugees may be trained for garments and handicraft sectors, poultry development as self-reliance. However, such action can appear as a conflicting issue with the host communities. It seems that many of the host community citizens would look at the refugees as opponents in this competition.

In fact, the host community has already taken a stand against refugees. Some refugees escape the camps and work as daily labors illegally, angering the local host community. One key informant – an experienced local academician (University Professor) mentioned, "many refugees are committing different types of crimes, particularly the drug sector, i.e., Yaba transportation and distribution". He also said, "young women and girls are often involved in prostitution". Such activities may have a solid link to socio-economic vulnerabilities like acute poverty. The refugees have almost no additional earning sources other than a limited ration for buying mostly daily food items (rice, vegetables, fish, meat), mobile communication expenses, and a few everyday consumer products.

5. Discussion

This study has addressed the spatial transition dynamics of urbanization from 1975 to 2021 in the area where the most recent (in 2017)

massive refugee influx has settled in Bangladesh. The key results were synthesized for strategic public policymaking on a sustainable spatial development basis, considering limited data resources of built-up area and population density from GHS and OSM together with expert interviews. The built-up area increased linearly during 1975–2015 (Fig. 3a). It suggests that the expected built-up area in 2021 would become 383 ha (the relationship in Fig. 3a). This number is almost 2.3 times less than what is found from the building footprint from the OSM that provides ~898 ha (Table 3). Similarly, if the population increased linearly that would estimate 564 011 persons in 2021 by the time-population, and 2 392 631 persons by the built-up-population relationship (Table 3, Figs. 4b, 3d). The high population (2 392 631 people) is estimated by the built-up population as affected by the high volume of the built-up area observed from OSM (Table 3). Note that the refugee settlement clusters and the number of refugees were excluded in the estimation of built-up area and population density.

The massive refugee migration and settlement may have a multidimensional impact at the regional level more than the local population (excluding refugee number and settlement). However, it was very complex to evaluate such dimensions with full resolution using limited data sources in this study (Vaz et al., 2018). But the analysis from the experts' interviews suggests a multi-dimensional impact in different scales (Section 4.2). The refugees' settlements/camps have been developed on a contained basis that is well protected by boundary fences and security forces. Unlike in the global north, e.g., Sweden, Italy, Poland, and the Netherlands (Czischke and van Bortel, 2018), they do not have the ownership right to real estate, a similar measure to African refugees in Sudan (Fábos and Kibreab, 2007).

Refugee migration and settlement in the global south welcomes humanitarian aid from the global north, leading to transnational space that leads to local development or urbanization. Today, nearly 130 NGOs, including 22 international humanitarian organizations, their 600 full-time response staff, and 1100 field workers, provide humanitarian support to the refugees in Cox's Bazar's camps. Most field-level workers serve from the district city, Cox's Bazar and upazila headquarters (Ukhia Upzila and Teknaf Upazila) (Section 4.2). However, their footprints are active all day long in the camps area. International organizations, including states and NGOs' staff, serve beyond the district city Cox's Bazar to the divisional city Chittagong and even the capital city Dhaka. It leads to predominantly housing demand in Cox's Bazar city rather than the local area near camps, similar to the case of Syrian refugees in Turkey and other European countries (Adam et al., 2019; Akar and Erdoğdu, 2019; Fábos and Kibreab, 2007; Valenta and Bunar, 2010). However, it impacts daily household items and transportation locally (Section 4.2; Ansar, Md. Khaled, 2021).

Due to the religious and cultural similarities, many early refugees mingled with the host communities, similar to Afghan refugees in Pakistan (Kronenfeld, 2008). The poor refugees were involved in drug transportation from Myanmar to Bangladesh, prostitution, and other crimes in the local area. To protect the host communities and for security reasons, GoB restricts the movement of refugees to avoid the mingling and marital relations between refugees and host communities, similar to sub-Saharan African refugees in Sudan (Fábos and Kibreab, 2007).

Geopolitical practice in this area is very complex, particularly between Bangladesh and Myanmar (Banerjee, 2020; Islam et al., 2021a). Rohingya refugees experienced forced migration to Bangladesh in the early 1970 s (Grundy-Warr and Wong, 1997). The success of the international effort and diplomatic relations between Bangladesh and Myanmar is negligible in terms of refugee repatriation. Even though this issue is considered an ad-hoc phenomenon, there is no guarantee of peaceful and safe repatriation in the near future. It has become more complicated by the shifting governmental system in Myanmar from democracy to military rule in February 2021. It could be helpful for both refugees and the Bangladesh economy if Bangladesh trains the refugees in garments, handicrafts, and other industrial sectors, similar to some practices in Europe and the USA (Adam et al., 2019; Bevelander and Luik, 2020; Bucken-Knapp et al., 2019; Valenta and Bunar, 2010). In contrast, the capacity of Bangladesh on this issue is minimal and may not be comparable with European and USA cases. The training program for Rohingya refugees in Bhasan *Char* is being run on an almost negligible scale. Instead, the host community in Bangladesh took it as an income generation competition, similar to African refugees in Sudan (Fábos and Kibreab, 2007). Therefore, this development program introduced socio-economic conflict between host and refugees' communities. In addition, the refugees work illegally as day labor which increases the tensions with the ultra-poor in this area (Ansar, Md. Khaled, 2021).

GoB initiated the relocation of 100 thousand refugee families from the camps area in Cox's Bazar to Bhasan Char. Bhasan Char is two blocks of islands with about 35 sq km area in the Bay of Bengal, between Hatiya Char and Sandwip (Fig. 1; Islam et al., 2021a). It is a temporary housing project with 120 cyclone shelters. The primary transportation system between Bhasan Char and the inland area of Bangladesh is a waterway, and a Navy ship takes approximately three hours from the nearest seaport, Chittagong. By 3rd March 2021, 12 276 refugees were relocated willingly and/or unwillingly (Islam et al., 2021a). With complete phase relocation, the refugees may reduce the spatial and population dimensions in Cox's Bazar region. However, an additional group of people will be in vulnerable coastal communities in Bangladesh as it is very vulnerable living in terms of geographically, socio-economic, culturally, and climate change impacts, particularly severe flood and tropical cyclones (Banerjee, 2020; Islam, et al., 2021a, 2021b).

The data for the built-up area and population in the study area after refugee settlement (after 2017) are not available in the GHSL data source (Florczyk et al., 2019), a primary data source for spatial and population dimensions in this study. Therefore, it was challenging to make robust concluding remarks on this issue by comparing the built-up area derived from the building's footprint in 2021 from OSM, which requires qualitative measures, termed to a mixed method consider both quantitative and qualitative investigation (Jain et al., 2023). That might be one of the significant limitations for making evidence-based detailed public policy and planning without the effort of extensive primary data collected at the field level. Indeed, big data to research refugee migration is a great challenge (Franklinos et al., 2020). However, it is expected that qualitative measures from expert interviews addresses this enough to draw tentative conclusions. Therefore, the ranking of the issues considered could not be made, which is a limitation of this study.

6. Conclusions and policy impact

This study investigated the spatial dynamics of urbanization due to the refugees' settlement. With the limited research resources, this study found some positive impacts for Bangladesh such that:

(1) it's impact on urbanization (both spatial and population dimensions) appears more at the regional than local level, such that infrastructure development has occurred in housing and hotel sectors to support the workers and visitors for the refugees;
(2) it led local 'places' to become transnational 'places' (Cf. Cresswell, 2015);
(3) impacts on the economic sector are suggested by the data at the local, regional, and national levels; (a) employment opportunities have increased at a local, regional and national level, and (b) local business sector has also increased.

However, the evidence suggests some negative consequences specifically;.

(1) most of the adverse effects have been felt locally;.
(2) daily living expenses have increased;.
(3) social and cultural conflicts are increased with the host communities by prostitution and drug dealing, which further increases security issues.

It might be concluded that all positive impacts are observed at the

regional and national scale due to the refugee settlement. Still, the local host communities face several social, economic, and cultural vulnerabilities.

The discussion above has a wide range of potential policy impacts many of which would be subtle, multi-faceted and dispersed. Some specifics can be noted though. (1) International assistance to refugees should consider the impacts of staff on local communities especially if assistance will be provided in the long term – consultation with various levels of government in countries receiving the refugees will be key to maximizing benefits from this and minimizing harm. (2) If well managed the long-term impact of refugee settlements can be quite small. (3) Adequate amounts of international assistance are key to minimizing the impacts of refugees on host communities.

A sudden boom of activities concerning refugee camps is already posing multiple uncertainties in the spatial development system on the local and regional scale. Therefore, there remains an urgent need to adjust local development plans and strategic policy after understanding the critical factors of the transformation process due to Rohingya refugee camps settlements. According to current government policy, the Rohingya camps were constructed temporarily. They may be relocated or disappear from the existing location. In that case, will it lead this unplanned spatial development to an urban desert? Therefore, further in-depth research should investigate, to understand the spatial impact and scenario of urbanization dynamics in the absence of Rohingya. Similar kinds of investigations may also be replicated even in prosperous global north countries (particularly EU countries) in order to conceptualize spatial transformative process of rapid migration influx on urbanization; with innovative open data in the absence of up-to-date official datasets (Tjia and Coetzee, 2022) and adoptions of mixed methods approach including related actors and policymakers. This study did not use any quantitative metric to investigate the socio-economic impacts, which remains as future research scope.

The study could only identify spatial growth and population density by using two-dimensional gridded data primarily available from global remote sensing and open data product. Therefore, it is not enough to interpret and detect the changes in high resolution. Often, the Rohingya refugee housing does not appear in freely available satellite data, e.g., Landsat (https://earthexplorer.usgs.gov/), Sentinel (https://scihub.copernicus.eu/) without more high-resolution commercial satellite or field-level data collection. Because their housing area is ~16–22 m^2 (Islam et al., 2022) which is much lower than the pixel resolution of e.g., Landsat (30 ×30 m^2) and Sentinel (10 x10 m^2). So far, high-resolution data collection remains out of the research scope due to the limitation of resources for data collection. However, the finding of this study might be helpful to stimulate the discussion of strategic planning for spatial transition management even in the context of prosperous countries in absence of up-to-date official data.

CRediT authorship contribution statement

Md. Tariqul Islam: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Sujit Kumar Sikder:** Supervision, Conceptualization, Methodology, Writing - review & editing. **Mark Charlesworth:** Writing – review & editing. **Atta Rabbi:** Data curation.

Declaration of Competing Interest

None.

Data Availability

We used open source spatial data set processed data are available at: https://doi.org/10.5281/zenodo.8286515.

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Appendix A

Table A.1
General Characteristics of the respondents in expert interviews.

Categories	Organization	Level	Number
Teacher/researcher	University/Research	National	4
Teacher/researcher	University/Research	International	4
Expert	Development agency	International	2
Expert	UN	National	1
Expert	NGO	Local	1
Teacher	Madrasa (Islamic education institute)	Local	2

Appendix B

Semi-structured questionnaire for an expert interview

Part 1: Basic Information and professional profile.
Respondent Name:
Age:
Sex:
Highest academic degree:
Name of the Organization:
Job title and major responsibility:
Total Years of professional experience after completing academic education:
The number of years of working experience in your current role and working location:
How do your current work/experiences relates to the spatial development topics:

Part 2: Thematic discussion on urbanization and refugees' settlements.

1. What are the involvements of your organization and your every work with the Rohingya refugee's settlement issues in Bangladesh – specifically related to new camps in Cox's Bazar?
2. How often and at what level are your interactions with the stakeholders involved in managing refugee camps?
3. What information on refugee crisis management policy and planning are accessible to you?
4. Do you think there is a significant impact on urbanization, land use change, construction, and spatial development due to the new refugees' settlements? If yes, Can you describe some sectors and examples of those issues considered by your organization and other related partners?
5. How do local infrastructure and service sectors respond to this sudden emergence of large new settlements? For example, the housing sector, shopping, and health services may need to serve more people than before.
6. Do you know – how local administration, municipality, and development agency are adopting their local spatial development policy due to the new refugee camps and their local dynamics? Is there an indirect effect on the local area due to refugee-related government residence representatives/aid agencies/NGOs in the town? Do they find their office space and housing in the local town – if not, where do they prefer to live and run the activities in the camp area?
7. Is there any economic impact (alternative business opportunities) that affects the host community's livelihood for settling in refugee camps nearby? How? What are they?
8. What is the level of interaction between refugees and host community people? Is there any evidence or discussion about the social mingling of refugees with the host community? Do you observe or experience any socio-cultural integration and diversion after the new establishment of these refugees in the region? Can you describe some positive and negative aspects of that?
9. Are any security issues reported that indicated an alarming trend for the local authority for sensitive conflict management strategies targeting the refugees and local residents? How does it impact refugees and the host community – if you think of different sectors – social, economic, and environmental?
10. Are the local authority and aid agencies concerned about the ecological and environmental dimensions and their management in relation to the new camps establishment and supporting live hood of settlers? What is your own opinion and assessment? What will be your suggestion to adopt these new dynamics with the local development policy, and what role you and your organization may promote in supporting the local sustainable spatial development agenda for this region?

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