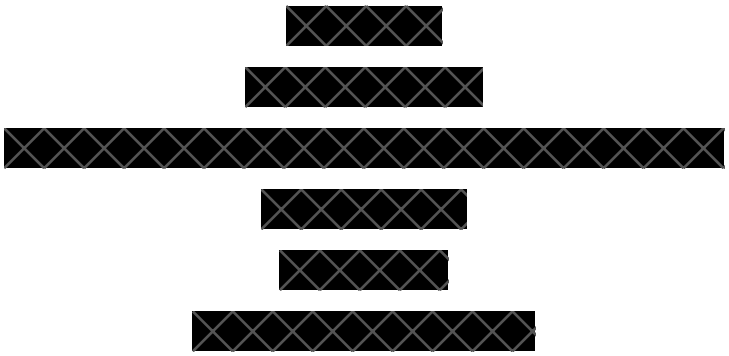
Ulster University

The anthropogenic impact of the climate change-environmental migration nexus in Bangladesh.



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Abstract:

The climate change-environmental migration nexus is increasingly apparent in climate change literature. The anthropogenic impacts of climate change disproportionately affect socio-economically vulnerable developing countries. Populations must adapt to the effects of climate change by altering their livelihoods. Rural-to-urban migration and relocation to slums are becoming common adaptation strategies. These strategies are prevalent in Bangladesh, a country whose susceptibility to climate change is well documented. The climate change-migration relationship in Bangladesh requires further examination. This correlation can be investigated through the temporal analysis of Bangladeshi satellite imagery, night-time satellite imagery demonstrating urbanisation in Bangladesh and analysis of precipitation and normalised difference vegetation index data. Quantitative surveys and focus group discussions indicate public awareness and perceptions of the anthropogenic impacts of climate change. Climate-induced migration is increasing in Bangladesh. Slum populations have grown exponentially in the last two decades in conjunction with climate phenomena. While migration is not solely triggered by climate change, evidence suggests it is a primary motivating factor. Environmental migration is a legitimate adaptation strategy. However, populations often migrate to unsustainable dwellings, further contributing to environmental degradation. Thus, migration is increasing due to climate change, although this is not necessarily a sustainable adaptation strategy.

1. Introduction:

In climate change and environmental migration literature, Bangladesh is recognised as a socio-economically vulnerable country that is adversely impacted by the threat of climate change (Call *et al*. 2017). Research indicates that a positive correlation exists between climate stresses and environmental migration (Martin 2014; Sinthia 2014; Davis *et al.* 2018). Investigating the climate change-environmental migration nexus in Bangladesh will demonstrate the anthropogenic impact of climate change (Martin 2014; Ji 2018). In Bangladesh, environmental migration primarily results in relocation to slums, thus, exacerbating existing environmental issues in slum areas and compounding deprivation among environmental refugees (Sinthia 2014; Mallick and Etzold 2015). Climate change induced drought, flooding, and temperature increases motivate migration as they compromise food supplies, destroy homes, and threaten livelihoods (Naser *et al*. 2019; Eriksen 2020). An examination of the correlation between climate change and migration facilitates a deeper understanding of the human impact of climate change in socio-economically vulnerable areas (Naser *et al*. 2019; Eriksen *et al.* 2020; Haque *et al.* 2020).

Bangladesh is a South Asian country located in the Bay of Bengal, characterized by its subtropical monsoon climate and the Ganges, Brahmaputra and Meghna rivers (Ayeb-Karlsson 2016). Due to its low-lying, deltaic topography, Bangladesh is exposed to sea-level rise and is susceptible to flooding, particularly throughout the rainy season (Call *et al.* 2017; Goes *et al*. 2021). During extreme precipitation events, cyclones, and tidal surges originating

from the Bay of Bengal, mass displacement of the population occurs (Ayeb-Karlsson 2016; Call *et al*. 2017; Naser *et al.* 2019). With an estimated population of 164.7 million in 2020 and a landmass of 147,570km² (United Nations Population Fund 2020; United Nations Data: Bangladesh 2020), Bangladesh is overpopulated. Bangladesh is socially and economically vulnerable, with an estimated 39 million people living below the poverty line, this vulnerability is aggravated by the threat of climate change (Naser *et al*. 2019; The World Bank 2020). It is anticipated that temperature extremes in Bangladesh will intensify in the future; the monsoon season is expected to become wetter and the dry season will be exacerbated (Mallick and Etzold 2015; Abedin *et al*. 2019). According to IFAD (2014), "pre-monsoon rainfall is coinciding with the paddy rice pre-harvest period" severely compromising food production (Martin 2014). The Long-Term Climate Risk Index in the period 1999-2018 ranked Bangladesh the 7th most affected country in the world, while the Natural Hazards Risk Atlas named Dhaka the 35th most exposed key manufacturing and logistics hub in the world in 2015 (NHRA 2015; Germanwatch Global Climate Index 2020).

Dhaka, Bangladesh's capital, is a primary recipient of environmental migrants with its slums hosting a significant proportion of displaced peoples (Sinthia 2013). The Bangladesh Bureau of Statistics (2014, p.5.) describes a slum as:

"a cluster of compact settlements of 5 or more households which generally grow very unsystematically and haphazardly in an unhealthy condition and atmosphere."

Dhaka is home to an estimated 6489 slums, thus, is one of the most densely populated cities in the world with estimates placing the 2020 population at over 21 million, despite a declining fertility rate (Sinthia 2013; Census of Slum Areas and Floating Population 2014; World Population Review 2020). The Korail Slum, located in central Dhaka, is thought to be one of the largest slums in Bangladesh, with an estimated population of 59,516 inhabiting an area of just 100 acres (BRAC 2017). The Korail Slum has grown exponentially, in part due to its gradual expansion "across the (Banani) lake by land reclamation and through the dumping of waste and soil" (Shiree-DSK 2012, p.7.). Surya *et al*. (2020, p.279.) suggest that informal housing built on reclaimed land causes "excessive groundwater use, soil pollution, and surface water quality pollution." Therefore, worsening the environmental impacts on the Korail slum's inhabitants, highlighting the unsustainable nature of rural-to-urban environmental migration in Bangladesh.

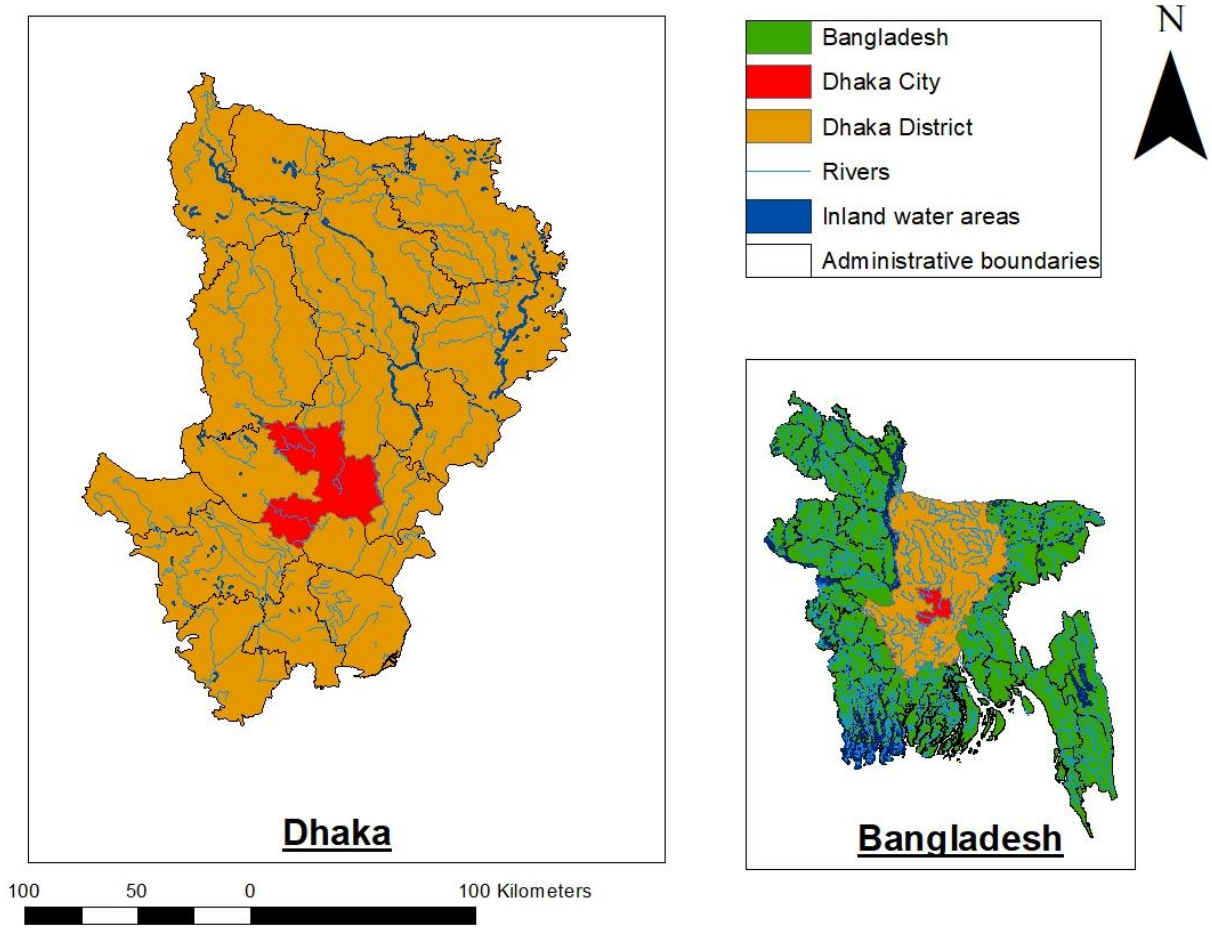

Figure 1: A map of Bangladesh and Dhaka the capital city and this investigation's study area (DIVA-GIS 2021.)

Ji (2018) suggests there are two main adaptation strategies to climate shocks. The first being in-situ adaptation; whereby the population in an affected area develop strategies to adapt to fluctuations in the climate and landscape without resorting to "human mobility" or migration (Ji 2018). These adaptations often take the form of altering farming practices or livelihood changes from subsistence farming to fishing, however, these coping mechanisms are strained (Mallick and Etzold 2015; Ayeb-Karlsson *et al*. 2016). When these practices fail, the second approach is ex-situ adaptation, this is migration to avoid environmental threats. Often, ex-situ adaptation can be seasonal or temporary (Mallick and Etzold 2015; Ayeb-Karlsson *et al*. 2016; Davis *et al.* 2016). However, in Bangladesh, rising sea levels often render involuntary environmental migration permanent as residents' original homes are submerged and uninhabitable (Black *et al*. 2013; Davis *et al*. 2018). An estimated 300,000-400,000 rural migrants arrive in cities in Bangladesh annually as an adaptation strategy to natural disasters, land degradation and resource strain (Ahmed 2014). However, it should not be assumed that all migration is forced and motivated by environmental factors (Martin 2014). As the United

Nations International Children's Emergency Fund (UNICEF) (2010, p.10.) state, “Migration is (also) fuelled by extreme rural poverty, landlessness and large urban-rural wage” gaps.

Displacement in Bangladesh is often internal (Black *et al.* 2013; Martin 2014). Refugees relocate to local areas due to financial constraints, travel restrictions, or a desire to remain in their home country (Martin 2014). Migration is a legitimate adaptation to climate shocks; however, migrants are often exposed to poor living conditions in their new settlements, clearly demonstrating the Bangladeshi population’s socio-economic vulnerability (Mallick and Etzold 2015; Ayeb-Karlsson *et al*. 2016). Furthermore, “the psychosocial coping capacity of refugees and climate migrants whose numbers are growing” (Eriksen 2020, p.34.) is negatively impacted by their continued impoverishment in new settlements. Therefore, socio-economic deprivation compounds the human impact of climate change.

As Haque *et al*. (2020, p.791.) argue, “low-income communities face unique challenges in accessing basic services.” These communities' poor socio-economic status is exacerbated by the impacts of climate change (Sinthia 2014; Eriksen 2020). Furthermore, Bangladesh’s susceptibility to rising sea levels, flooding, over population and rapid unplanned urbanisation has resulted in significant landmasses becoming waterlogged due to inadequate drainage facilities (Rahman and Hossain 2019). Flooding is, therefore, a common and extremely hazardous occurrence (Black *et al*. 2015; Rahman and Hossain 2019). Water supplies can become contaminated as water-borne diseases thrive in standing water, thus water for drinking, farming, and bathing are compromised (Abedin *et al.* 2019; Rahman and Hossain 2019; Haque *et al.* 2020). This raises the question, is environmental migration to Bangladesh’s slums an adequate and sustainable response to climate change?

Martin (2014, p.104.) states that environmental migration “works as an effective adaptation strategy to offset the impact of climatic stresses and shocks (and to) diversify livelihoods.” However, concern exists regarding the vicious cycle of rural-to-urban migration which results in informal settlements, unemployment, and resource strain. Eriksen (2020, p.27.) argues that “if we manage to increase the material wealth of an individual, community or nation, an increase in resilience (to climate change) will necessarily follow.” Thus, theoretically, it is feasible to reduce the vulnerability of slum settlements such as the Korail Slum; although the threat of displacement remains without extensive investment and intervention from the Bangladeshi government or perhaps wealthy countries, who have greater responsibility for climate change (Black *et al*. 2013; Mizan *et al*. 2020). Clear climate mitigation strategies must be implemented to alleviate the pressure of climate change on Bangladeshi citizens and halt forced environmental migration.

To conclude, Bangladesh’s vulnerability to climate shocks is well documented in the existing literature, while the country’s socio-economic vulnerability is understood and has been quantified (Sinthia 2013; Ayeb-Karlsson *et al.* 2016; Naser *et al*. 2019). It is evident that most

environmental migration is forced. Environmental migrants often lack financial stability, due to disastrous climate events, thus, they are forced to adapt and migrate to slum dwellings (Davis *et al.* 2018). Socio-economic deprivation is fuelled in these slum environments, further contributing to climate degradation (Sinthia 2013; Surya *et al*. 2020; Haque *et al.* 2020). Research on climate change as a driving force for migration in Bangladesh is limited. Furthermore, a large proportion of migration in Bangladesh is undocumented thus, accurate migration data is unavailable (Black *et al.* 2013). Therefore, this paper aims to critically assess the human impact of climate change in Bangladesh and how it has given rise to environmental migration as an adaptation strategy.

1.1 Aim and Objectives:

Hypotheses: A correlation exists between climate change and increased environmental migration in Bangladesh.

Aim: This study aims to critically assess the human impact of climate change in Bangladesh and how it has given rise to environmental migration as an adaptation strategy.

Objectives:

1. To briefly examine the physical impact of climate change in Bangladesh and discuss the country's vulnerability to future climate shocks (Mallick and Etzold 2015; Naser *et al*. 2019; Abedin *et al*. 2019).
2. To assess the human impacts of climate change, land degradation and resource stress and investigate how these lead to environmental migration to slums (Sinthia 2014; Davis *et al.* 2018; Eriksen 2020).
3. To discuss how vulnerability to climate change, and extreme weather events is exacerbated by deprivation and poor socio-economic status (Abedin *et al*. 2019; Eriksen *et al.* 2020; Haque *et al.* 2020).
4. To study the current adaptation strategies to climate change in Bangladesh (Martin 2014; McNamara 2015; Ayeb-Karlsson *et al*. 2016).

2. Materials and Methods:

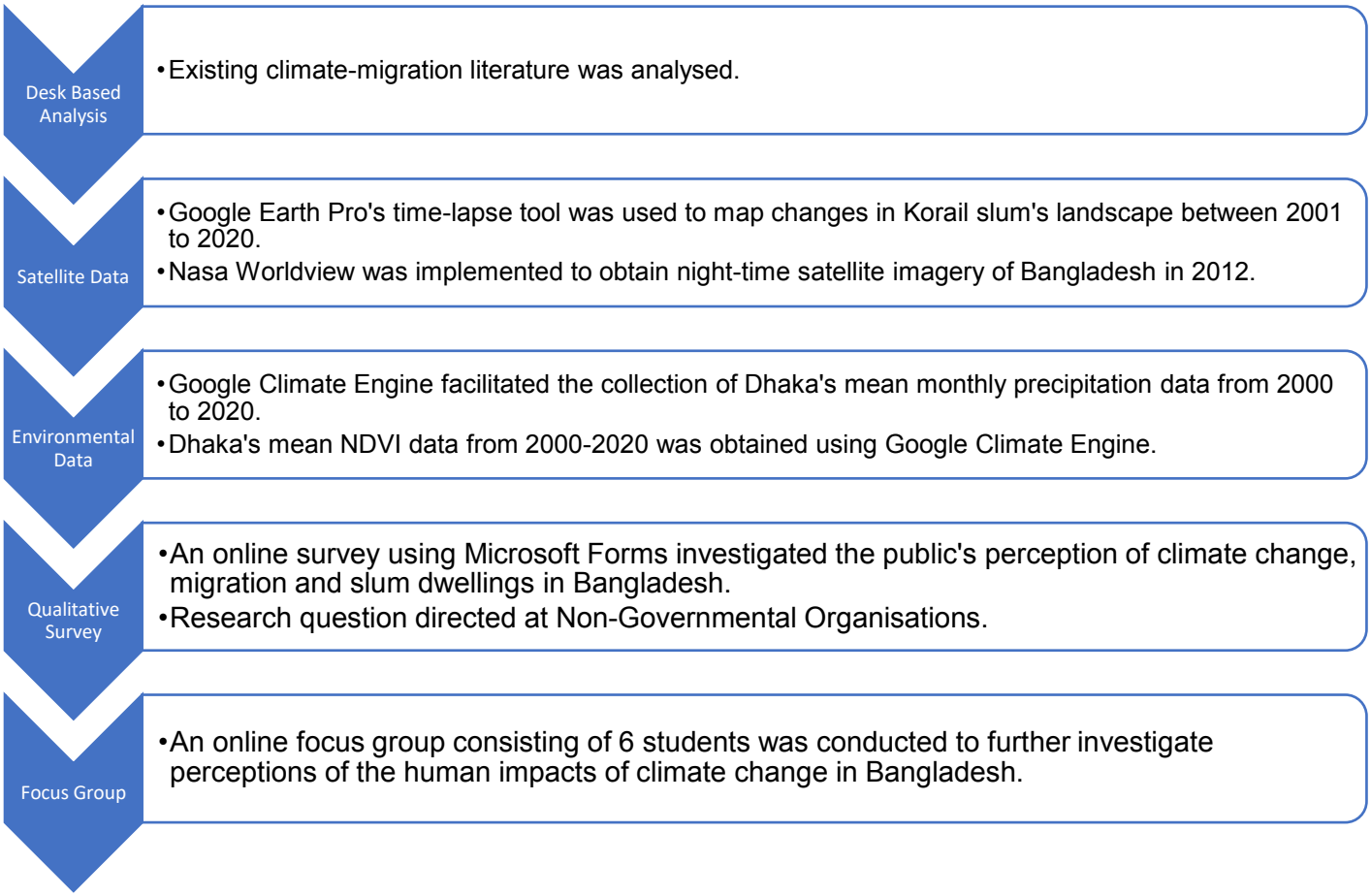

Figure 2: The flow chart above details the methods implemented to conduct the qualitative and quantitative research necessary to satisfy the aims of this investigation.

2.1 Study Area:

A case study will form the basis of this research to demonstrate how climate change has shaped the Bangladeshi landscape, directly resulting in the displacement of Bangladesh's vulnerable population (Ahsan *et al*. 2014; McNamara 2015; Ayeb-Karlsson *et al*. 2016). Dhaka, the capital of Bangladesh (figure 1), has a population of 14.5 million, approximately 6 million of whom inhabit urban slums (Yeasmin 2020). Korail Slum is one of the most densely populated slums in Dhaka, with an estimated population of 59,516 people, inhabiting an area of 100 acres, a large portion of which is legally owned by the Bangladeshi Government (BRAC 2017; Yeasmin 2020). The slum is in "wards 19 and 20 of Dhaka North City Corporation," (Shiree-DSV 2012, p.7.) bordering Banani and Gulshan, two of Dhaka's most affluent areas (BRAC 2017). The Korail slum has grown exponentially in the last twenty years due to rapid rural-to-urban migration (Figures 3 and 4). Overcrowding and insufficient service provision in

Korail have resulted in the residents constructing settlements on reclaimed land from Banani Lake. Thus, contributing to decreased environmental quality (Surya *et al*. 2020). This case study illustrates the correlation between climate change and increased environmental migration in Bangladesh.

2.2 Data Collection:

To test the hypothesis and satisfy the aims and objectives of this investigation, quantitative and qualitative methods were implemented. This approach facilitated an examination of how the Bangladeshi landscape has been altered by climate change, thus influencing the environmental migration of susceptible populations. The qualitative approach took the form of systematic research of contemporary academic literature on climate change and environmental migration (Black *et al*. 2013). Carefully selected sources including official governmental documents and non-official sources from international organisations (IO's) and non-governmental organisations (NGO's) proved invaluable (UNICEF 2010; Bangladesh Bureau of Statistics 2014; NHRA 2015; BRAC 2017; Ji 2017). Additionally, The International Fund for Agricultural Development (IFAD), UNICEF and The Bangladesh Rural Advancement Committee (BRAC) were contacted asking the research question:

"Is changing climate and environment leading to migration to the slums of Dhaka in Bangladesh?"

This research question sought to understand the organisations perception of the climate crisis in Bangladesh. However, no responses were received. A broad understanding of how the socio-economic landscape in Bangladesh impacts environmental migrants was established through extensive qualitative analysis of existing academic literature (Parsons and Knight 2015; Eriksen 2020). Furthermore, an online survey examining public awareness of climate change, environmental migration, and perception of slum dwellings in Bangladesh was conducted using Microsoft Forms (Zhao *et al*. 2019; Rahimi 2020). This survey consisted of five closed questions with multiple-choice style answers (McGuirk and O'Neill 2016). A sample population of 101 (n=101) voluntary self-selected participants comprised this survey (McGuirk and O'Neill 2016). A focus group consisting of 6 participants was conducted using Microsoft teams due to Coronavirus restrictions. The focus group provided an informed commentary from students on their perceptions of climate change and a critique of the temporal satellite imagery of the Korail slum (figure 4) (Hossain *et al*. 2018; Rahimi 2020). Respondent's names were omitted from the paper to preserve anonymity, with participants identifiable through numerical pseudonyms (eg: Participant 1). Respondent's observations are not proof of the climate change-migration nexus and the opinions expressed cannot be regarded as representative of the whole population (Martin *et al*. 2014).

To fulfil the aim of the investigation, quantitative research was essential to obtain satellite imagery and environmental data demonstrative of the climate change and migration processes. A geographic information systems (GIS) approach facilitated the collection of data for this investigation. Secondary data was obtained from Google Earth, a vast data set that is quickly accessible and readily available (Parsons and Knight 2015). Google Earth is a digital cartography tool that uses composite imagery to form 2D and 3D interactive maps of the Earth by stitching together billions of cloud-free Landsat satellite and aerial images (Davis 2019; Miyazaki 2019). This satellite data mapped the topography of the Korail Slum over 20-years from 2001 to 2020 using Google Earth's time-lapse tool, at a scale of 500 meters (Figure 4). These high-resolution satellite images were implemented to map urban slum expansion and land reclamation in Korail, thus facilitating the analysis of temporal landscape changes (Warnasuriya 2020). The influx of rural environmental migrants to the Korail slum illustrates the extensive environmental migration occurring in Bangladeshi slums in response to climate change (Sinthia 2013). Night-time satellite imagery was obtained from Nasa's Earth Observatory to display the extent of the anthropogenic influence on Bangladesh's landscape (figure 3). According to Bennett and Smith (2017), a correlation exists between night-time satellite imagery and socio-economic processes such as urbanisation and population migration. Thus, night satellite imagery is an effective tool, particularly in countries lacking official demographic statistics. NASA/NOAA's Suomi National Polar-orbiting Partnership satellite was launched in 2011 using a Visible Infrared Imaging Radiometer Suite (VIRS) sensor to capture Earth's radiance at night, proving to be an effective source for this investigation (Bennett and Smith 2017; NASA 2021)

Figure 3: This satellite image of Bangladesh was obtained from the NASA Earth Observatory. Bright gold areas on the map represent visible light and anthropogenic influence including city lights. This map was generated from VIRS data captured by the Suomi NPP satellite in 2012 at a resolution of 750m (NASA 2021.)

Meteorological data obtained from Google's 'Climate Engine' provided insight into specific weather phenomena. Climate Engine technology effectively facilitated customisable spatial and temporal analysis of weather phenomena (Google Climate Engine 2020). The average annual rate of precipitation in millimetres, and the Normalised Difference Vegetation Index (NDVI), were measured. These variables provided insight into the impacts of Bangladesh's variable and changing climate. The NDVI measures "photosynthetic activity by a combination of Red and Near-Infrared bands that are generally conditioned by the presence of chlorophyll." (Spadoni *et al*. 2020, p.2.).

The index is scaled between -1 and +1, with +1 representing the highest amount of green vegetation land cover. According to Mlenga *et al.* (2019, p.2.), NDVI has been utilised for "vegetation monitoring, crop yield assessment and estimation, (and) early warning systems" in previous research. NDVI data (Figure 5a) is indicative of the land's ability to cope with extreme precipitation events, the potential for infiltration, and the overall health and abundance of green space in Dhaka. Furthermore, significant precipitation events (Figure 5b)

can indicate flooding events that are likely to promote environmental migration. Precipitation data for Dhaka city from 2000-2020 was obtained from the Climate Hazards Group InfraRed Precipitation with Station data set (CHIRPS) using Google Climate engine. Satellite images of the Korail slum were analysed in conjunction with environmental data to determine if extreme climate events coincide with increased environmental migration to slum areas.

A gap exists in the current literature surrounding the environmental migration and climate change nexus due to a distinct lack of research and communication of findings (Mallick and Etzold 2015; Davis *et al.* 2018). The physical impacts of climate change are evident in academic literature; however, limited research exists regarding the anthropogenic impacts of climate change while public awareness of climate change is insufficient (Mallick and Etzold 2015; Rahimi 2020.) Although “the rate of urban poor is increasing inevitably in every sphere of Dhaka,” (Sinthia 2013, p.701.) a distinct lack of urban planning and government intervention means population growth is not effectively monitored and cannot be accurately quantified. Black (2015) argues that it is difficult to calculate the number of people displaced by extreme environmental events, and it is even more difficult to estimate future displacement. Therefore, one cannot assume that the expansion of the Korail slum is solely the result of environmental displacement. Despite migration potentially being motivated by other socio-economic factors like poverty, unemployment, and food security, the quantitative methods implemented insinuate that environmental migration is the sole cause of slum expansion (Sinthia 2013; IFAD 2014; Haque *et al.* 2020). This oversight could be mitigated in future research by conducting a questionnaire in the Korail Slum to determine the population’s primary motivation for migration, a process demonstrated in Ahsan and Warner's 2014 study. The qualitative methods of this paper rely on a singular case study which according to Daly (2016), suggests “strong internal validity but poor external validity.” Thus, additional case studies would improve the validity of the qualitative element of this investigation.

3. Data Analysis

Time-lapse satellite imagery collected from Google Earth Pro reveals massive urban expansion across Banani Lake, which intersects the Korail slum. In 2001 (Figure 4) the Banani Lake was unobstructed (figure 4a), as dwellings were located solely on the riverbanks and inland areas. However, urbanisation is increasingly evident, satellite imagery of the lake in 2020 reveals exponential urban expansion across the lake (figure 4f). Bangladeshi environmental migrants have constructed makeshift homes on unsafe and unstable land reclaimed from the river (Surya *et al*. 2020). This satellite imagery reinforces evidence of increasing rural-urban migration and urban expansion in Bangladesh in the last two decades (Sinthia 2013). This urbanisation process has been rapid, urban sprawl across Banani lake is

particularly evident in the satellite imagery from 2014 (figure 4d) to 2020 (figure 4f). According to Rahman and Hossain (2019), this rapid urbanisation has directly resulted in a degraded aquatic environment. Dhaka City's lakes have become polluted swamp areas on the verge of ecological cataclysm (Rahman and Hossain 2019). Drainage systems have not been maintained and modernised in tandem with urbanisation. Thus, the disposal of untreated domestic and commercial wastewater and faecal matter into Dhaka's lakes has compromised water quality (Okubo *et al.* 2010; Rahman and Hossain 2019; Haque *et al.* 2020). Due to overpopulation and resource strain in the Korail slum, lake water is utilised by the homeless and slum inhabitants for bathing, drinking, fishing, cooking, and cleaning resulting in further degradation of the water quality (Hossain *et al*. 2018; Surya *et al*. 2020; Haque *et al.* 2020). Banani Lake is contaminated despite its widespread use. Dangerous pathogens, including diarrhoea, typhoid, skin diseases and dysentery can be transmitted through its use (*Abedin et al.* 2019; Rahman and Hossain 2019; Haque *et al.* 2020). The expansion of the Korail slum, evidenced in figure 4, has had massive environmental, anthropogenic, and socio-economic impacts.

Night-time satellite imagery of Bangladesh in 2012 (figure 3) obtained from NASA Earth Observatory reveals the extent of urbanisation. Visible night-time lights are indicative of urbanised areas including, cities, slum dwellings and settlements. High-resolution night-time satellite imagery is difficult to obtain, particularly for underdeveloped countries like Bangladesh. However, this night-time imagery provides an integral insight into the location of urban areas and their population densities (Bennett and Smith 2017). Night-lights are particularly prominent in Dhaka, revealing the extent of urbanisation in the city, insinuating a high population density and influx of migrants (Sinthia 2013). Access to additional contemporary night-time satellite imagery of Bangladesh would facilitate accurate temporal analysis of urban expansion. However, this data is not publicly accessible through NASA's Earth Observatory. Temporal satellite imagery of Bangladesh and the Korail slum reveals an exponential increase in urban population. Despite this evidence of urbanisation, the imagery does not prove that environmental migration and adaptation to climate stresses are the sole causes (Martin 2014; Naser *et al.* 2019). Therefore, analysis of satellite imagery in conjunction with environmental data is required to isolate climate change as the primary cause of migration in Bangladesh.

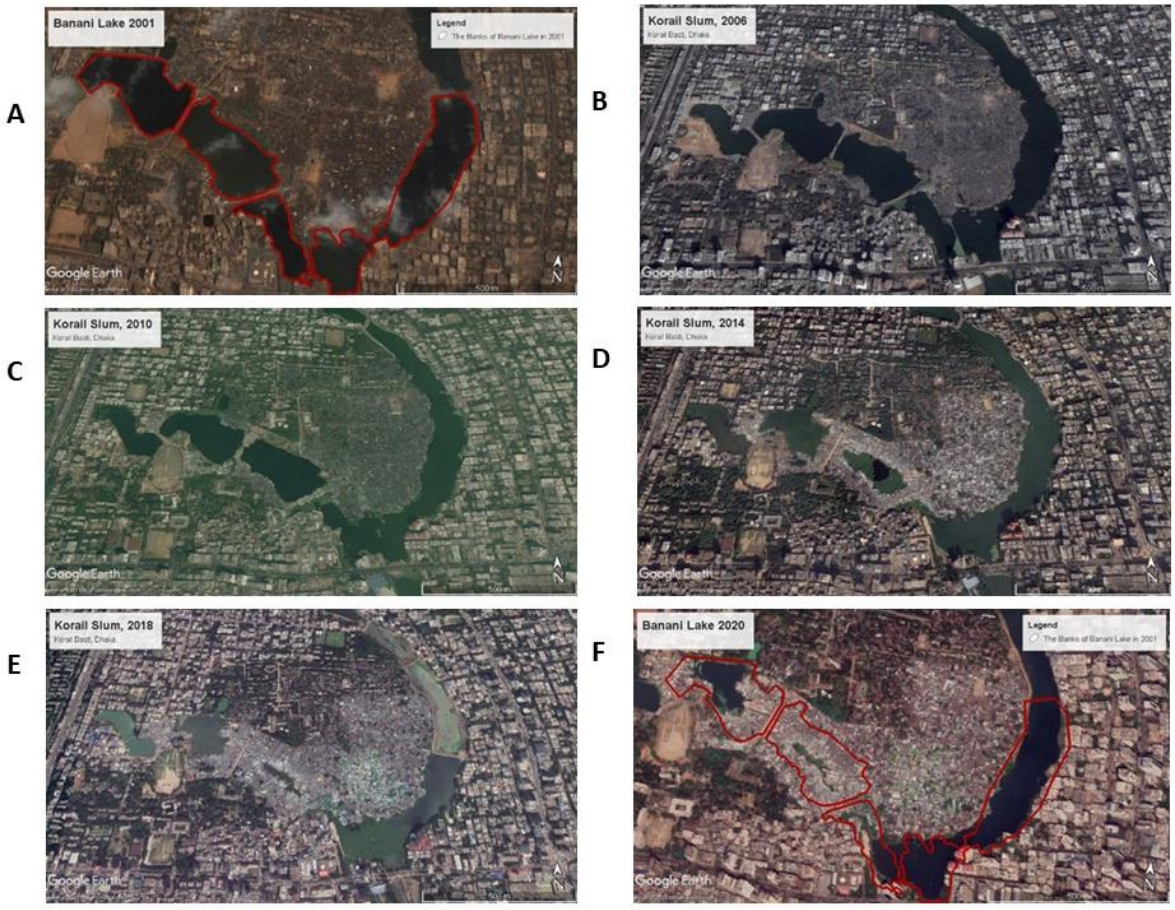

Figure 4: The satellite images above obtained from Google Earth (2020) reveal the extent of urban expansion which has occurred in the Korail slum, Dhaka from 2001 to 2020 at a scale of 500 metres.

An examination of the Normalised Difference Vegetation Index (NDVI) revealed a marginal decrease in Dhaka's visible vegetation from 2000 to 2020. However, significant fluctuation in NDVI is evident throughout the time period (Figure 5a). NDVI largely remained between 0 and 0.37 during the study period, excluding an anomalous result of -0.57 in 2004. This considerable decrease in NDVI can be associated with the significant period of flooding that occurred in 2004. This flooding affected Bangladesh from July to September, destroying an estimated two million acres of agricultural land across Bangladesh (The Asian Development Bank and The World Bank 2005). The highest NDVI was recorded in September 2016 at 0.37, although this dropped to 0.12 by September 2019, lower than the moderate NDVI value of 0.21 recorded in January 2000.

Precipitation data (figure 5b) for the recorded period 2000 to 2020 in Dhaka revealed similar annual patterns, with mean monthly precipitation peaking during the monsoon season between June and October (Goes *et al*. 2021). Troughs in the data typically occur during the pre-monsoon and dry seasons from November to May. The lowest recorded mean monthly precipitation rate occurred in January 2014 and again in 2019 at 0.4mm (Goes *et al*. 2021). The highest recorded mean monthly precipitation was 252mm, documented in September 2004, coinciding with the flood of 2004 (The Asian Development Bank and The World Bank 2005). The average monthly precipitation in Dhaka between 2000 and 2020 was 28.9mm.

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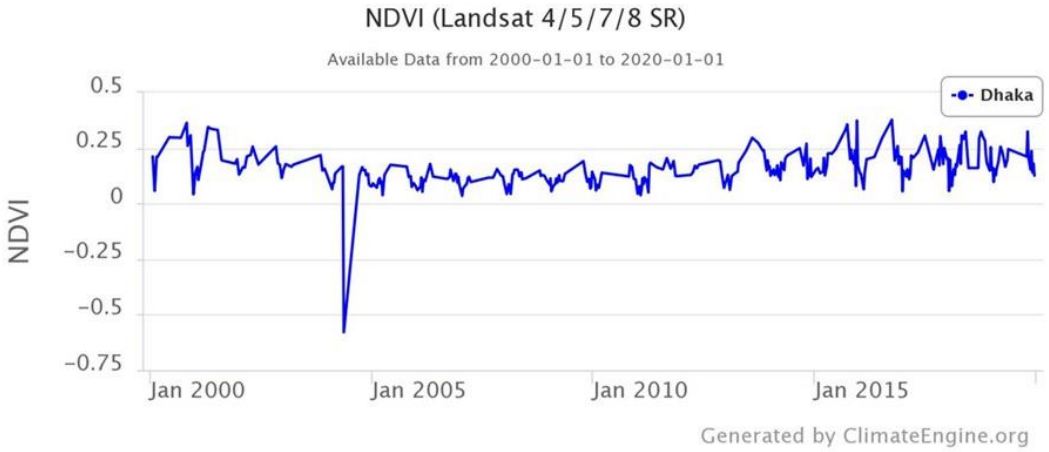

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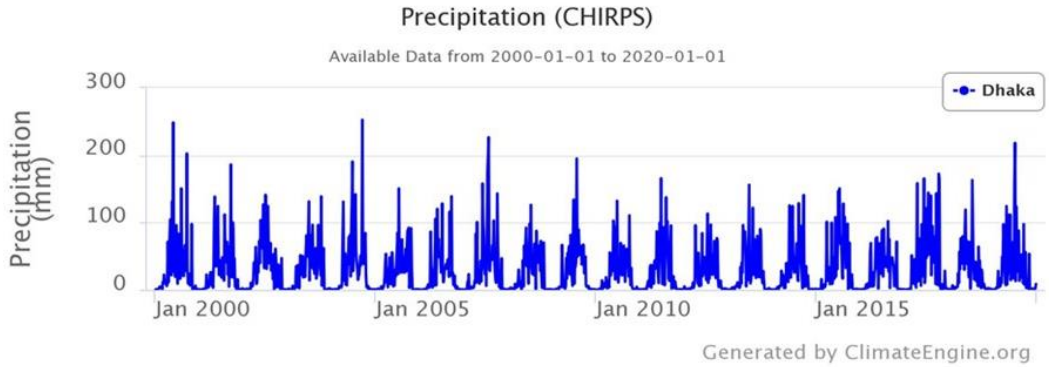

Figure 5a: The NDVI line plot above shows the mean Normalised Difference Vegetation Index (NDVI) in Dhaka from January 2000 to January 2020 at a computation resolution of 30m. This data was produced from the Landsat 4/5/7/8 Surface Reflectance dataset and obtained through Google Climate Engine (Google Climate Engine 2021.)

Figure 5b: The precipitation line graph above displays mean monthly precipitation rates measured in millimetres in Dhaka from January 2000 to January 2020. This CHIRPS pentad precipitation dataset was obtained using Google Climate Engine at a computation resolution of 4800m (Google Climate Engine 2021.)

Resources and reports from International Organisations (IOs) and Non-Governmental Organisations (NGOs) provided invaluable data for this investigation. Thus, a research question was proposed to gain insight into IO/NGO's perceptions of climate change and migration in Bangladesh (Ji 2017). Unfortunately, the IOs and NGOs did not respond to communication attempts. Thus, potential responses were inferred based on the organisations' published materials. The research question *"Is changing climate and environment leading to migration to the slums of Dhaka in Bangladesh?"* while unanswered, remains relevant to this study.

For almost 40 years, IFAD has been involved in helping the vulnerable Bangladeshi population adapt to climate change and empowering the country's socially marginalized populations (IFAD 2021). The organisation's projects have produced invaluable literature on the anthropogenic impacts of climate change in Bangladesh. IFAD state:

"With two-thirds of its territory less than five metres above sea level, Bangladesh is particularly vulnerable to climate change. Poor people are hit hardest as they often live in poorly constructed housing and on land that is vulnerable to extreme weather." (IFAD 2021).

IFAD acknowledge the impact of climate change on the Bangladeshi population which is compounded by their reliance on slum dwellings due to socio-economic deprivation and a growing population (Sinthia 2013). Thus, IFAD supports the view that climate change directly results in environmental migration to urban slums in Dhaka. Conversely, UNICEF's research on urban inequalities in Bangladesh generally focuses on economic migration rather than climate migration. UNICEF state that the influx of migrants to Dhaka's slums is a result of migrants seeking employment and improved social services. UNICEF report:

"Dhaka is one of the fastest growing mega-cities in the world, with slum populations seemingly outpacing the growth of other urban areas" (UNICEF 2010 pp6).

UNICEF cites economic migration as the driving force for rapid urbanisation and slum expansion in Dhaka (UNICEF 2010). Therefore, changing climate is not the only factor influencing migration to Dhaka's slums (Sinthia 2013; Haque *et al*. 2020.) The Bangladesh Rural Advancement Committee (BRAC) Bank is a Bangladeshi International Development Organisation, whose headquarters are based in Korail. Therefore, much of the organisation's research and development strategies are focused on slum living. BRAC is vocal about the climate change-migration nexus and its impact on Dhaka slums. BRAC states:

"Korail is one of 4,000 slums scattered across the capital, where every 1 in 3 people live in slums. They are predominantly migrants, accounting for 60% of Dhaka's total population growth." (Saleh and Khan 2020)

BRAC acknowledge the influx of migrants into Dhaka's slums and discuss the population expansion which Korail slum has experienced, reiterating that migrants often reside in overpopulated slum dwellings. Therefore, BRAC suggests that climate change is leading to

migration to Dhaka's slums. While not all NGOs and IOs cite adaptation to climate change as the primary motivation for migration, it is evident that migration is increasing in Bangladesh, resulting in overpopulation and environmental degradation. Migrants may choose to relocate due to environmental push factors. However, the population's socio-economic vulnerability results in economic migration. Changing climate is leading to environmental migration to Dhaka's slums, however, economic migration is also common.

The online survey conducted to assess public awareness of climate change, environmental migration, and the prevalence of slum dwellings in Bangladesh revealed limited knowledge of the anthropogenic effects of climate change in Bangladesh. 68% of respondents reported they were unaware of the impacts of climate change in Bangladesh. Conversely, 52% of participants were familiar with the term 'environmental migration', although just 38% of these respondents were familiar with environmental migration occurring in Bangladesh. Despite respondents reporting a lack of familiarity with climate issues and migration, 73% of participants were aware of the prevalence of slum dwellings in Bangladesh. Most respondents (80%) regarded slums as environmentally unsustainable while a small proportion (2%) reported that they perceive slums as environmentally sustainable dwellings. The survey's results overwhelmingly reveal that the public is largely unfamiliar with the challenges climate change presents to the Bangladeshi population (Rahimi 2020). However, participants are aware of the commonality of slum habitation in Bangladesh and generally regard these dwellings as environmentally unsustainable.

Finally, a focus group conducted in February 2021, concluded the qualitative element of this investigation. Participants overwhelmingly reported an understanding of the negative impacts of climate change on socio-economically vulnerable communities globally (Eriksen *et al.* 2020).

"The impacts of climate change are becoming obvious. Poorer countries seem to be suffering more than rich countries. There seem to be more natural disasters" Participant 5.

However, awareness of the processes associated with climate change in Bangladesh and its slums was limited.

"I haven't heard much about how climate change is impacting Bangladesh. I know there are a lot of slums in Bangladesh, but I didn't know this was related to climate change." Participant 2.

Despite this, the concept of environmental migration was understood by all participants.

"I think an environmental migrant is someone who has to migrate because of changes in the environment which have destroyed their homes or jobs." Participant 4.

Furthermore, slums were deemed environmentally unsustainable by the participants.

"No, I don't think slums are environmentally sustainable. They are makeshift homes constructed without planning permission, that, can't be good for the environment." Participant 1.

Despite their understanding of slum sustainability and environmental migration, respondents reported feeling shocked and angry while analysing the satellite imagery of the Korail Slum (figure 4).

"I find these images unbelievable. While I knew that slum populations were increasing, I didn't think it was happening so quickly. I am so shocked that people are forced to build their homes on rivers, it seems very dangerous." Participant 3.

The focus group session revealed that public awareness of climate change in Bangladesh is very limited (Rahimi 2020). Participants may have an awareness of slum habitation and the concept of environmental migration; however, this is very basic. Despite unfamiliarity with the topic, participants seemed very concerned about these issues, revealing the need for more education about the climate change-migration nexus.

4. Discussion

Urban expansion is evident in the Korail slum in the last 20 years (figure 4). However, this growth is not unique to the Korail slum. The prevalence of slum dwellings and urbanisation is increasingly common across Bangladesh due to environmental migration and socio-economic deprivation. Naser *et al*. (2019) claim climate change cannot be isolated as the primary motivation for migration in Bangladesh due to poor socio-economic status and resource scarcity. Populations may choose to migrate, seeking economic opportunities and employment; however, climatic change has rendered migration a requirement rather than a choice in Bangladesh (McNamara *et al*. 2016). Therefore, Bangladesh's vulnerability to climate change and environmental degradation is apparent. Evidently, a relationship exists between climate change and the surge in environmental migration as an adaptation strategy (Davis *et al*. 2018; Naser *et al*. 2019) Davis *et al*. (2018) and Mallick and Etzold (2015) cite migration as a legitimate adaptation strategy, however, this investigation revealed that environmental migration to the Korail Slum is ineffective. The Korail Slum's population has exceeded the land capacity; thus, slum inhabitants have reclaimed land from the Banani Lake, constructing residential areas on the water (Figure 4f). Land reclamation is an unsustainable practice, fuelled by inadequate housing and service provision, which undoubtedly will result in further environmental degradation (Surya *et al*. 2020). Environmental migration can be an effective adaptation strategy to climate change; however, the migration of displaced peoples to slums is unsustainable and promotes further environmental degradation. Thus, environmental migration to slums is a cyclical crisis.

Dhaka's climate influences the average annual NDVI, as demonstrated in figure 5a. In theory, a high NDVI is anticipated due to the abundance of farmland in Bangladesh. In reality, NDVI fluctuates, often becoming extremely low in the monsoon season due to climatic events that destroy agricultural land. Figure 5b emphasises the annual variation in precipitation due to the dry and monsoon seasons (Goes *et al*. 2021). The Bangladeshi landscape is shaped by extreme precipitation events that determine the success of the agriculture industry. Thus, a correlation between NDVI and precipitation is evident (figure 5). While Bangladesh is becoming increasingly urbanised, agriculture and the population's livelihoods remain intrinsically linked (Call *et al*. 2017). The farming industry is impacted disproportionately by climate change; despite this, informal agricultural employment is prevalent. Flooding, large-scale precipitation events, and drought are detrimental to the farming sector, compromising food supplies and livelihoods (Martin 2014; Naser *et al*. 2019). The destruction of farmland during extreme weather events motivates migration to urban areas as inhabitants must secure new employment and homes post-disaster (Call *et al*. 2017). Seasonality and climate variability in Bangladesh contribute to temporary migration as an adaptation strategy (Mallick and Etzold 2015; Ayeb-Karlsson *et al*. 2016). According to Call, *et al*. (2017, p.158.) "cyclical temporary migration" is a common adaptation strategy implemented to compensate for climate variability and the monsoon season when the land becomes flooded and precipitation peaks. Thus, not all environmental migration is permanent and is often motivated by the variable Bangladeshi climate.

Just 32% of questionnaire participants reported an awareness of the impact of climate change in Bangladesh. This response supports Rahimi's (2020) investigation that suggests there is limited public awareness of the effects of climate change. Thus, large-scale education campaigns and public acknowledgement of climate change are required to implement effective mitigation strategies (Rahimi 2020). Focus group discussions proved valuable in the Martin *et al*. (2014) investigation. However, the qualitative element of this investigation was impaired by Coronavirus restrictions. This study consisted of one online focus group session, including six demographically similar participants with comparable educational attainment levels. Thus, demographic bias compromised the validity of the investigation. Furthermore, the online questionnaire's small sample population (n=101) is not representative of the whole population (McGuirk and O'Neill 2016). Despite these weaknesses, the questionnaire and focus group session revealed poor public awareness of the anthropogenic impacts of climate change in Bangladesh and the role of migration as an adaptation strategy.

4.1 Conclusion

To conclude, the results of this investigation demonstrate the existence of the climate change-migration nexus in Bangladesh. The hypothesis 'a correlation exists between climate

change and increased environmental migration in Bangladesh' can be accepted. The physical impacts of climate change in underdeveloped countries including Bangladesh cannot be underestimated (Mallick and Etzold 2015; Naser *et al*. 2019; Abedin *et al*. 2019.) Socio-economic deprivation in Bangladesh is exacerbated by the country's vulnerability to climate change, land degradation and resource strain (Sinthia 2014; Davis *et al.* 2018; Eriksen 2020; Haque *et al*. 2020.) The population must adapt to extreme climatic events; however, poor socio-economic status limits their ability to choose sustainable adaptation strategies (Abedin *et al.* 2019; Eriksen *et al.* 2020; Haque *et al.* 2020.) Thus, environmental migration has emerged as a primary adaptation strategy to climate change (Martin 2014; McNamara 2015; Ayeb-Karlsson *et al.* 2016.) Despite its prevalence, environmental migration is unsustainable as migrants often relocate to overpopulated, unregulated slums. Environmental migration, while an effective adaptation strategy, is socially and environmentally unsustainable; therefore, more sustainable adaptation strategies must be implemented (Black *et al.* 2013; Mizan *et al.* 2020.) This investigation recognises the climate change-migration nexus as a cyclical crisis requiring significant intervention to preserve the landscape and the lives of the Bangladeshi population.

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