IJMS 2023 10(1): 35 - 57

International Journal of Multidisciplinary Studies (IJMS)
Volume 10, Issue I, 2023

Influence of Locational Characteristics on the Sustainability of Underserved Settlements in *Jaffna Municipality* and its Urban Fringe

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ABSTRACT

In developing countries, ineffective land-use planning and unplanned development have spread underserved settlements, particularly in Sri Lanka. These settlements have grown to be an important supplement to cities' insufficient formal housing supply, and they spontaneously formed spatial patterns that significantly impact sustainability. This study examines the locational characteristics of underserved settlements and their influence on their sustainability in the Jaffna Municipal area and its urban fringe. Primary data were collected through a questionnaire survey with 341 underserved settlements using a stratified random sampling technique; focus group discussions with representatives of community-based organizations and ground-level officers; interviews with administrative officers of government institutions, local authorities, academics, and social activists, while secondary data were obtained from Google Earth and government departments. The collected data were analyzed using spatial, descriptive statistics, and qualitative methods. SPSS statistical software was used to analyze the data collected via a questionnaire survey, and ArcGIS 10.4 mapping software was used to create maps. According to the results, underserved settlements' locational characteristics, specifically their location in flood-inundation areas, land reservations, and irregular road networks with poor accessibility, weaken the development potential and negatively impact the sustainability of underserved settlements as well as the urban environment. On the other hand, the current location is crucial for the livelihoods of the underserved settlements. As a result, this study emphasizes the importance of aligning underserved settlements with spatial development and sustainable development goals to reduce problems in underserved settlements and establish cities without underserved areas. Accordingly, this study is expected to be useful for developers, urban planners, and policymakers in prioritizing housing programs and livelihood asset development activities to control the emergence and growth of underserved settlements and minimize existing problems.

KEYWORDS: *Underserved settlements, Locational characteristics, Influence, Sustainability, Jaffna Municipality, Urban fringe*

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1 INTRODUCTION

1.1 Background

Underserved settlements (USSs) have become important in developing countries' urban housing sectors. In Sri Lanka, USSs refer to housing units that lack essential services, adequate living space, adequate structure, and tenure security (Ekanayake 2001; Gunetilleke, Cader & Fernando 2004; United Nations Human Settlements Programme [UN-HABITAT], Centre for Poverty Analysis [CEPA] & Sevanatha 2013). Geographic factors, rural-to-urban migration, poor urban governance, poverty, and low-income, contribute to the spread of USSs, which has positive and negative consequences (Mahabir et al. 2016; UN-HABITAT 2020; Zhang et al. 2020).

USSs have an environmental impact due to a lack of essential amenities (Birajdar 2014; Mahabir et al. 2016; Takyi et al. 2020). This results in a perpetuated cycle of decline for both the USSs and the environment, with the possibility of impacts extending to communities beyond the USSs (Ali & Sulaiman 2006; Mahabir et al. 2016). Consequently, USSs might threaten sustainable urban development on different levels (Patel 2012; Mahabir et al. 2016; Takyi et al. 2020).

Economically, the growth of the USSs can have both positive and negative effects on the national and regional economies. On the one hand, they reduce the efficiency of urban land and housing markets, discourage investment and labour force participation, and impose a financial burden on the government (Fox 2008; Marx, Stoker & Suri 2013; Mahabir et al. 2016). This could impact a country's or region's overall economic outlook in the global economy, making it less competitive (Gambo, Idowu & Anyakora, 2012; Mahabir et al. 2016). However, conversely, they provide a comparatively cheap labour force to urban areas and contribute significantly to the country's Gross Domestic Product through the informal sector (Banda 2007; Senanayake, Wimalaratana & Premaratne 2012); they are seen as a high-flying, cost-effective zone for poor communities (Malecki & Ewers 2007; Brugmann 2010; Mahabir et al. 2016). Underserved residents contribute significantly to the border economy by providing a wide range of essential goods and services to the formal economy. Economic experts from the informal sector, namely Hernando De Soto, claim that the poor have a significant amount of dead capital (Elrayies 2016).

Many initiatives have been undertaken to upgrade and relocate the USSs in Sri Lanka (Jagoda 2009; Dayaratne 2010; Samaratunga & Hare 2013). Despite the government's concerted efforts, the housing supply for underserved communities remains critical, and improvements in the quality and quantity of housing remain less than satisfactory (Jagoda 2009). Residents in USSs face various issues and challenges to sustain their lives; they are viewed as barriers to urban development (Sirueri 2015). Thus, if urban development is to be sustainable, the USSs must be transformed into sustainable ones (Chambers & Conway 1992; Soma, Sukhwani & Shaw 2021). For this, it is vital to comprehend the USSs' geographic context and how it influences both the positive and negative aspects of their sustainability.

Even though many scholars focused on the locational aspects of USSs in various ways (Ishtiyaq & Kumar 2011; Birajdar 2014; Sirueri 2015; Brata et al. 2018; Mahadeva & Chandrashekara 2018; Kolhe & Dhote 2019; Takyi et al. 2020; Zhang et al. 2021), most studies overlooked how USSs' location influences their sustainability. In Sri Lanka, literature on the geographical context of USSs has not been sufficiently developed. There have been few studies on USSs' locational characteristics in Sri Lanka, and they have only covered a few aspects (UN-HABITAT, CEPA & Sevanatha 2013). Thus, the purpose of this study is to fill that knowledge gap by addressing the research questions of what are the locational characteristics of USSs and how these characteristics influence their

sustainability, particularly in *Jaffna Municipality* and its urban fringe.

1.2 Research problem

There are 22622 USSs in the *Jaffna* district, of which 13.34% are within the *Jaffna Municipality* and its urban fringe (*Jaffna* District Secretariat [JDS] 2021). The USSs of *Jaffna* city is congested to a limited extent, starting from the *Columbuthurai* to *Navanthurai*, and the entire underserved area has developed into an imminent threat to the environment, health, and sanitation of not only that area but the entire city as well (United Nations Development Programme [UNDP] et al. 2006). The coastal population expanded as follows: 5692 in 2000, 31626 in 2010, 33402 in 2014, and 34007 in 2017 (JDS 2018). In 2004, *Reclamation East* and *West* had population densities of 4143 and 4256 people per square kilometer (km^2), respectively (UNDP et al. 2006). Still, within sixteen years, the population density of the divisions had increased to 22115 and 22580 people per km^2 (JDS 2020). It was also obvious that within *Jaffna Municipality* and its urban fringe, the severity of the issue of USSs varied across *Grama Niladhari* Divisions (GND). A preliminary survey conducted in the study area confirmed that the locational characteristics seemed to impede their sustainability. Hence, this paper aims to examine the locational characteristics of USSs and their influence on their sustainability.

2 MATERIALS, METHODS & TECHNIQUES

2.1 Study area

The *Jaffna Municipality* and its urban fringe were chosen as the study area. It is located in the *Jaffna* Peninsula's southern part, between 9^0 36' 30" N – 9^0 42' 90" N and 79^0 88' 10" E – 80^0 08' 20" E. It is 44.539 km^2 in size and is naturally bounded in the south by the *Jaffna* lagoon. It includes 68 GND, with a total population of 121,762 (JDS 2021). Figure 01 depicts the study area's location.

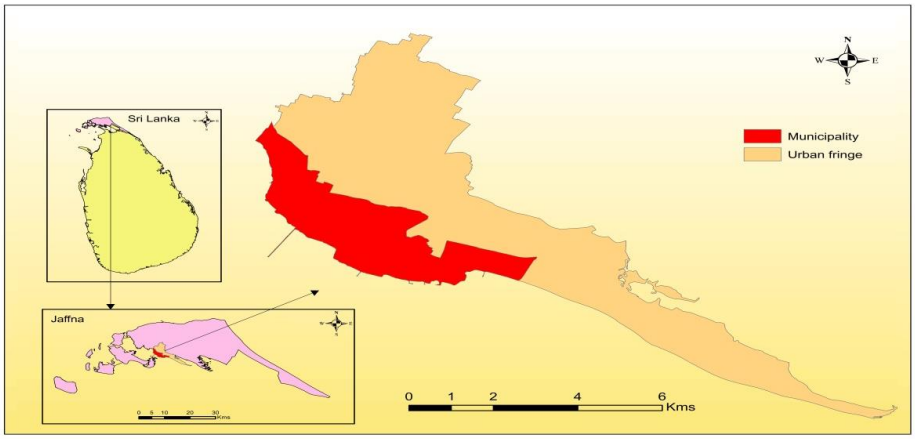

Figure 01: Location of the study area

Source: Prepared by the researcher based on Survey Department [SD], 2021

2.2 Conceptual framework

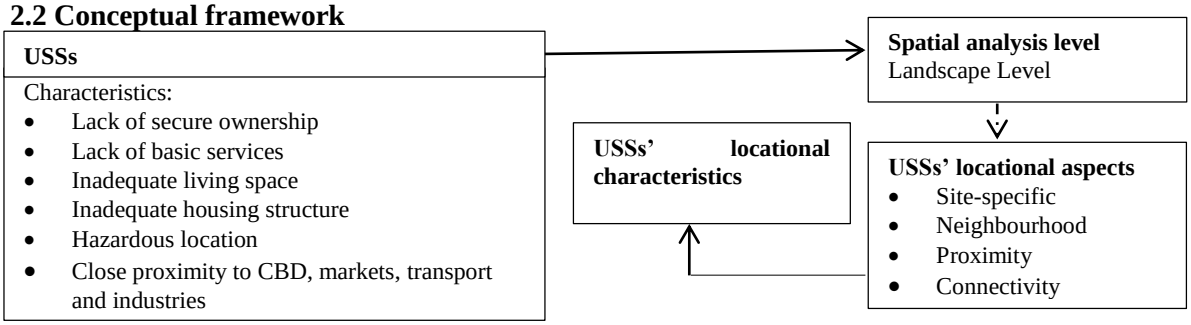

Figure 2: Conceptual frame work

Source: Developed by the researcher, 2021

2.3 Sampling

The total number of USSs is 3019 (Field survey 2020 & 2021), which is considered the study's total population. According to Morgan's table, 341 USSs were chosen as the study's sample. As shown in Table 1, a proportionately distributed stratified random sampling technique was used to select samples from the population. The random numbers were generated using the "RANDBETWEEN" formula in MS Excel.

Table 1: Distribution of Sample Underserved settlements

Housing condition (Strata)	Administrative divisions (Strata)			
	Jaffna Municipality (Urban)		*Nallur Pradeshiya Sabah* (Urban fringe)	
	Population	Sample	Population	Sample
Temporary settlements	348	39	128	14
Semi-Permanent settlements	289	33	113	13
Permanent settlements	2064	233	77	9
Total	2701	305	318	36

Source: Field survey, 2020 & 2021

2.4 Methods of data collection

This study used both primary and secondary data. Table 02 summarizes secondary data obtained from various sources.

Table 2: List of Secondary Data used in the Study

Type of Data	Year of Acquisition	Source
Raster data		
Satellite imagery	2021	Google Earth
Vector data		
GND boundary	2021	SD
Contour, land-use, pond & flood zone	2021	JDS
Road	2021	Urban Development Authority (UDA)
Statistics		
Statistical hand book	2021	JDS
Hazards	2021	JDS
Land	2021	JDS
Land reservation	2021	*Jaffna* Municipal Council (JMC), *Nallur Pradeshiya Sabah* (NPS), Road Development Authority (RDA), Road Development Department (RDD), Coastal Conservation Department (CCD), UDA

Source: Developed by the researcher, 2021

Direct field observation (DFO), transect walks, structured questionnaire surveys (SQS), key informant interviews (KIIs), and focus group discussions (FGDs) were used to collect primary data for this study. DFO was conducted from August 2020 to December 2021 to comprehend the location of the USSs. A SQS was carried out with 341 USSs from August 2021 to December 2021 to investigate the impact of locational factors on their livability. FGDs were conducted with representatives of community-based organizations (CBOs) and ground-level officers, as well as KIIs with officers of government institutions, local authorities, academics, and social activists, to obtain further information about the impact of USSs' location on their sustainability and measures to mitigate the impacts.

2.5 Locational analysis

Figure 3 depicts the study's methodological framework.

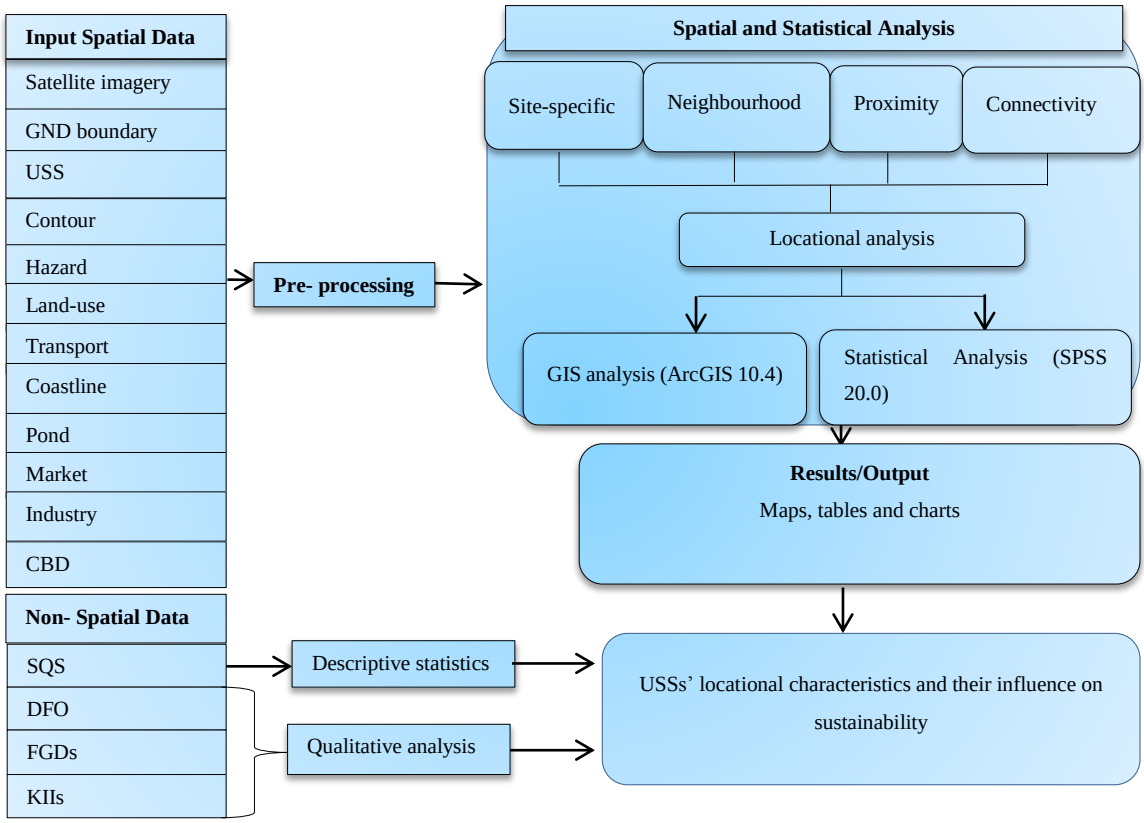

Figure 3: Flow chart of Methodology

Source: Developed by the researcher, 2021

2.5.1 Terrain

The steps below were taken to create a map depicting the terrain of the USSs. First, the contour shape file was imported into ArcGIS. The contour lines were then converted into points with an elevation attribute using a Data Management Tool for Generate Points Along Lines. The surface was then interpolated, and the terrain map was obtained using Kriging's Spatial Analyst Interpolation Tool. Finally, the terrain map was added with the USS shape file, and the terrain of USSs was identified.

2.5.2 Natural hazards' risk

The risk mapping was carried out to assess the level of risk for natural hazards. Floods, droughts, cyclones, and epidemics were chosen as risk factors. Based on the data set obtained from the Disaster Management Center (DMC), the risk value was calculated using the formula below (Sugathapala & Munasinghe 2010).

$$\text{Risk} = \frac{\text{Hazard} \times \text{Vulnerability}}{\text{Capacity}}$$

The risk maps for floods, droughts, cyclones, and epidemics were then created using ArcGIS, and the level of risk for each hazard was determined at the GND level. Following that, to identify flood-prone USSs, the USS shape file was combined with the flood-inundation shape file using ArcGIS, and a map displaying flood-prone USSs was obtained.

2.5.3 Underserved settlements in the land reservation

The major locational points of USSs were identified as coastline, ponds, roads and railways based on DFO and transact walk. Consequently, the ArcGIS was used to identify USSs located within reservations. First, the satellite map of the study area was downloaded from Google Earth, imported into ArcGIS, and georeferenced. Following that, the satellite

imagery's coastline, railway line, and ponds were digitized and saved as shape files. Thereafter, buffer zones were created for the features using the ArcGIS Geo Processing Tool of Buffer, based on the reservations specified by the respective organizations, and the land reservations were detected. Subsequently, USS shape file was added to the newly created reservations to identify the USSs within the reservations.

2.5.4 Proximity of underserved settlements to spatial features

The coast, markets, industries, and the CBD provide opportunities for USSs, which influences their spatial location. Consequently, proximity was used as a parameter to determine the distance between USSs and the above-mentioned spatial features. For the above purpose, Multiple Ring Buffers were used to find out the areas within a given distance of a set of features. Firstly, unavailable datasets were digitized from the satellite imagery and created as shape files. Following that, based on the literature and opinions of experts, buffer zones have been determined. Accordingly, buffer zones have been created as 250 m, 250-500 m, 500-750 m, 750-1000 m, 1000-1250 m, and 1250-1500 m radii from the *Jaffna* CBD; 100 m, 100-200 m, 200-300 m, and 300-400 m from the coastline; 500 m, 500-1000 m from industries; and 500 m, 500-1000 m from markets to find out the geographic accessibility in terms of distance.

2.5.5 Neighbourhoods of underserved settlements

First, land-use was reclassified into fourteen classes using the ArcGIS Spatial Analyst Reclassify function, and USS shape file was added to the land-use shape file. Following that, the proportion of land-use classes surrounding USSs was calculated. A buffer of 200 m was chosen as a feasible value in assessing the proportions of land-usage in the surrounding areas of USSs, and the buffer zone was created using the Geo Processing Tool of Buffer.

2.5.6 Road connectivity

To analyze the road connectivity, the number of edges, nodes, and total road lengths were used. First, the network data set was built from the street feature class in a geodatabase (gdb), and the road's nodes and edges were derived. Following that, various indices based on these variables were developed to characterize all aspects of the road network's connectivity. The following formulas were used to calculate Circuitry (α), complexity (β), and connectivity (γ).

α = ((L-V) +1)/ (2V-5)
β = L/V
γ =L/ (3*(V-2))
Where L is the number of links and V is the number of nodes.

The alpha (α) index measures the circuitry of a road network; that is, the number of complete cycles in a network (Sirueri 2015; Zhang et al. 2020). The index ranges from 0 (0%) to 1 (100%). The beta (β) index reflects a road network's complexity and completeness (Sirueri 2015; Zhang et al. 2020). This is done by expressing the ratio of links to nodes. When β <1 is present, it indicates that the network is disconnected; β =1 indicates a single circuit; β >1 indicates that the road network connectivity in an area is greater. The gamma (γ) index measures the extent to which the nodes are connected. It is also a ratio of links and nodes, and its value ranges from 0 -1 (Sirueri 2015; Zhang et al. 2020). Gamma is independent of the number of nodes within the road network. The value of 1 denotes a completely connected road network, whilst 0 indicates a lack of connectivity. These indices are crucial for understanding road connectivity (Sirueri 2015; Zhang et al. 2020).

3 RESULTS & DISCUSSSION

3.1 Site-specific characteristics of underserved settlements

3.1.1 Terrain

The study area's topography is almost flat; the highest elevation is 7.64 m above mean sea

level (MSL) in the northeast fringe, and no sharp gradients are noticeable. 87.67% of USSs are less than 2.5 m above MSL, 7.71% are between 2.5 and 5.0 m, 2.31% are between 5.0 and 7.5 m, and 2.28% are above 7.5 m. Figure 4 depicts the terrain of the USSs.

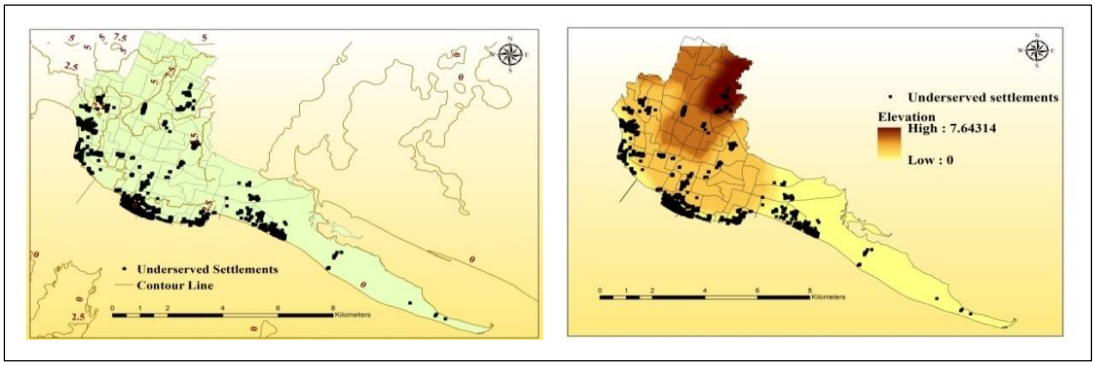

Figure 4: Terrain of Underserved settlements

Source: Prepared by the researcher based on JDS, 2021

3.1.2 Risk assessment

Figure 5 depicts the risk assessment of the study area for floods, droughts, cyclones, and epidemic hazards.

According to Figure 5, there is a very high risk of flooding in *Nedunkulam, Passaiyoor West, Fort, Navanthurai North, Navanthurai South,* and *Moor Street North*. Drought is imminent in *Columbuthurai East, Vannarpannai North,* and *Ariyalai Center North*. *Nedunkulam, Columbuthurai East, Small Bazzer, Jaffna Town East, Navanthurai North,* and *Ariyalai South East* are particularly vulnerable to cyclones. *Reclamation West, Sirampiady, Fort,* and *Moor Street North* are at high-risk of epidemics. Consequently, all the above hazards pose very high or high risk to *Nedunkulam* and *Navanthurai North.* Simultaneously, three types of hazards are prevalent on *New Moor Street, Ariyalai Center North, Columbuthurai East, Fort, Reclamation West,* and *Sirampiady.*

The severity of floods in *Jaffna* city and its urban fringe has increased recently. According to Piratheeparajah, Chan and Tan (2020), geographical factors, specifically low-lying terrain, soil type, collapsed natural and man-made drainage systems, unplanned road development, railway track construction, altered topographical characteristics and patterns, and pond siltation have contributed to flood hazards in *Jaffna*. Figure 6 depicts the USSs in a flood zone.

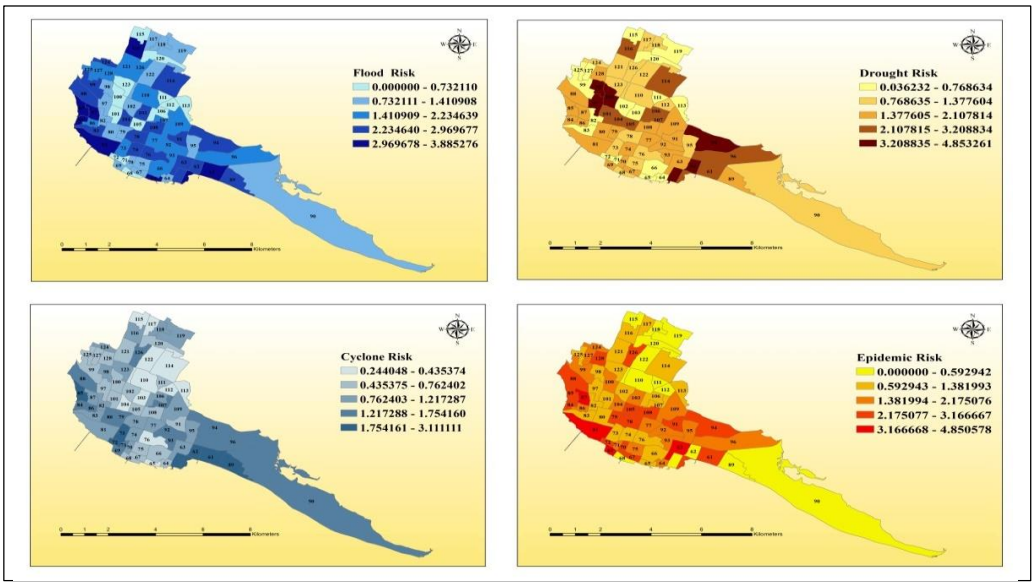

Figure 5: Risk Assessment for Flood, Drought, Cyclone and Epidemic Hazards.

Source: Prepared by the researcher based on JDS, 2021

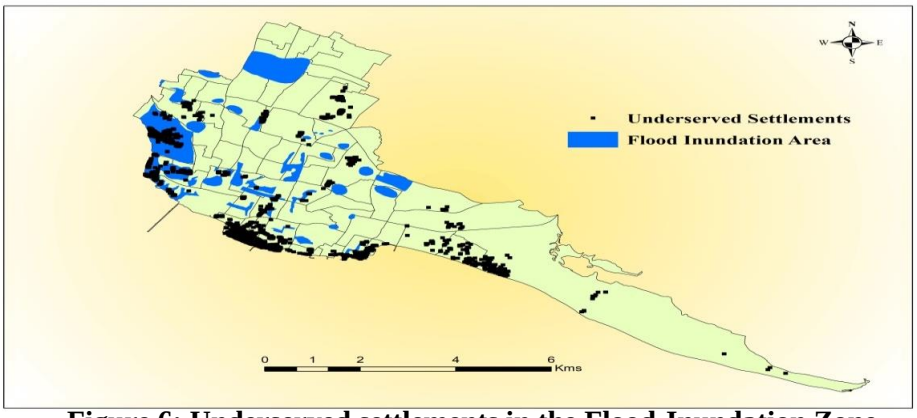

Figure 6: Underserved settlements in the Flood-Inundation Zone

Source: Prepared by the researcher based on JDS, 2021

Floods inundate 5.119 km^2 of the study area, and the flood-inundation zone encompasses 569 USSs. According to Figure 6, floods make the western coastal belt and pond catchments more likely to be inundated. 32% of the flood-inundated USSs are in *Navanthurai North*, 14% in *Moor Street South*, 12% in the *Fort*, 11% in *New Moor Street*, 10% in *Moor Street North*, 8% in *Navanthurai South*, and 3% in *Koddady*, accounting for 90% of the flood-inundated USSs. USSs in the catchments of *Kannathiddy* Pond, *Theverir* Pond, and *Cheddiyarthoodam* Pond are also in the flood-inundation zone.

According to administrative officials, numerous USSs are located in coastal belts, ponds, and low-lying areas unsuitable for residential development. Low-lying areas include *Sabinagar*, *Nithiyaolly*, and *Pommaivelly*. It is not surprising that these areas are prone to flooding. Academics also claimed that USSs encroached on many ponds and their catchments, obstructed main and sub-drainage, and altered the natural drainage system.

3.1.3 Underserved settlements in the reservations

The USSs encroached on reservations, specifically the coastal, railway, road, pond, and drainage sites.

The CCD established buffer zones that apply to the country's coastal areas to manage and conserve the coastal environment. The Coastal Conservation Act of 1981 defines the coastal zone as "the area lying within a boundary of 300m landward of the mean high water level and a limit of 2 km seaward of the mean low water level" (Koralagama 2008). Simultaneously, a setback area is a geographical strip or band within the coastal zone where certain development activities are prohibited or severely restricted (Koralagama 2008). Between the seaward and the landward reference lines of the particular coastline segment, the entire setback band is separated into segments, the reservation area and the restricted area. The area adjoining the coast is known as the "reserved area," whereas the area further to the coast is known as the "restricted area."

The minimum reservation for permanent structures is 50 m from the Permanent Vegetation Line (PVL), which includes 20 m of reservation area and 30 m of the restricted area, which is only applicable for fishing, national development, and tourism. The 300 m coastal zone encompasses 8.814 km^2 of land, 2.416 km^2 of which is included in the 50 m coastal setback. 2223 USSs encroached on the coastal zone, with 656 in the coastal setbacks. In other words, the USSs encroached on 0.245 km^2 of the coastal zone, of which 0.051 km^2 is subjected to coastal setbacks. Table 3 and Figure 7 depict USSs in coastal reservations.

Table 3: Coastal Reservation Underserved settlements

Zones		Frequency	Percent
Coastal Zone	300 m from the PVL	2223	73.63
Coastal setbacks (50 m from the PVL)	30 m (Restricted area)	460	15.23
	20 m (No built zone)	196	6.49

Source: Field Survey, 2021

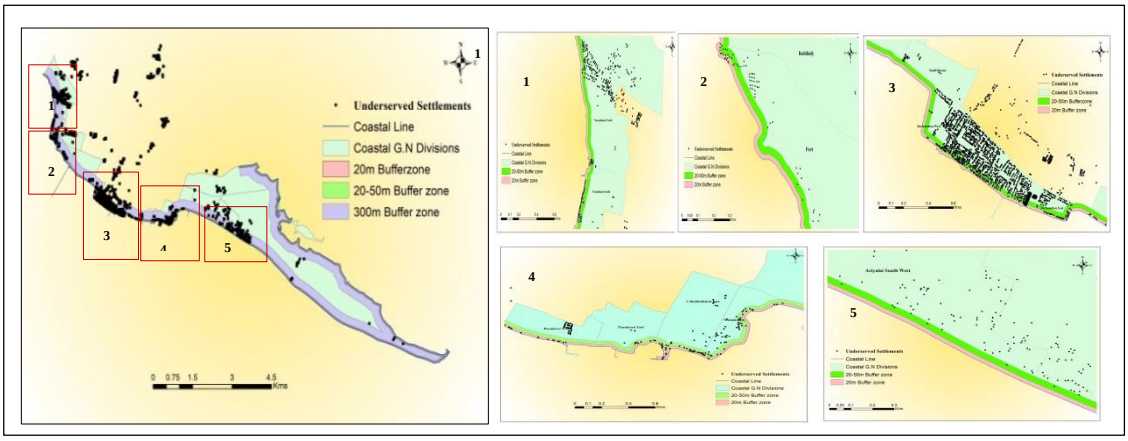

Figure 7: Coastal Reservation Underserved settlements

Source: Prepared by the researcher based on Google Earth, 2021

Figure 7 shows that the *Reclamation East* and *West* have a large number of USSs within the coastal setback of 50m, accounting for 57.31% of the total. Following that, the *Nedunkulam-Passaiyoor West* cluster has 20.12% of the USSs. The *Fort-Navanthurai North* cluster contains 21.34% of the USSs. Coastal encroachment USSs are found near prawn cultivation sites in *Gurunagar Flats, Muthamil, Manpiddy, Kannapuram, Mahendrapuram, Eliloor, Punithapuram, Passaiyoor Beach* Road**,** and *Reclamation* Road**.**

According to community leaders, landless households encroached on coastal reservations due to land scarcity and unaffordability. Following the tsunami, CCD focused on coastal reservations; however, USSs existed before the tsunami. USSs in the coastal reservations are depicted in Image 1.

Image 1: Underserved settlements in the Coastal Reservations

Source: Field Survey, 2021

The authorized agencies that maintain the roads determine their road reservations based on their class. The RDA maintains A and B-class roads; the RDD maintains C and D-class roads; and local governments, namely JMC and NPS, maintain other roads. The RDA maintains reservations of 15 m from the road centre line, whereas the RDD maintains 7.5 m from the road centre line. Furthermore, local governments retain 3 m, 4.5 m, 6 m, 7.5 m, 9 m, 10 m, and 15 m reservations from the centre line.

The survey found that 63 USSs encroached on RDA road reservations. The *Beach Road*, *Jaffna Ponnalai-Point Pedro Road* and *Navanthurai-Oddumadam Road* were encroached upon. Figure 8 shows that 65.07% of the RDA reserve's USSs are in *Reclamation East* and *West*, 28.57% are in *Navanthurai North*, and the remaining are in *Small Bazzer*. 677 USSs also encroached on the municipal government's road reservation. Figure 8 shows that *Reclamation East* and *West* account for 98.67% of the USSs in the JMC reservation, with the remainder located in *Chundikuli South* and *Thirunagar*. JMC's 7.5 m reservation was encroached upon by 138 USSs; its 6 m reservation was encroached upon by 289 USSs; and its 4.5 m reservation was encroached upon by the remaining USSs. All the roads in *Reclamation East* and *West*, as well as *Rajasingham Road*, are occupied by the USSs.

According to *Reclamation East and West*, community representatives, the inner roads were at the minimum standard. Residents encroached on this path over time, making it narrower and narrower. The path is now just wide enough for one person to walk in some locations. This caused difficulties in providing essential services. However, the reservation of RDD roads is not occupied by the USSs. USSs in the road reservations are depicted in Figure 8 and Image 2.

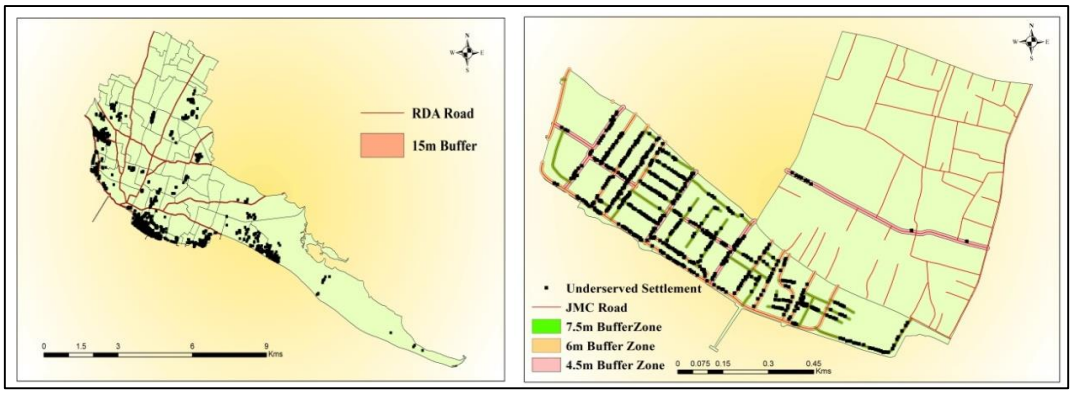

Figure 8: Underserved settlements in the Road Reservations

Source: Prepared by the researcher based on JDS, 2021

Image 2: Underserved settlements in the Road Reservations

Source: Field Survey, 2021

The Sri Lanka Railway (SLR) states that no land is to be subdivided within 40 m of a railway line, either for state or other purposes. There are 178 USSs on railway reservation land. In particular, the railway reservations from Rasavinthoddam to Alupanthi harbour contain 73.59% of the railway reserve's USSs, while the railway reserve in Kokkuvil has 24.71% of USSs. The study area's railway reservation encompasses 1.173 km2 of land, with 0.017 km2 encroached upon by the USSs. Community leaders noted that until the late 1980s, cargo train services were seen loading and unloading goods from the port of Alupanthi

harbour. Still, that service was interrupted due to political unrest. The landless population in the surrounding areas encroached on railway tracks and railway lands and built their settlements. In the 1990s, the railway service between the North and South was completely discontinued, resulting in the abandonment of railway lands. Consequently, the landless population occupied the railway reservation lands until 2014. Many USSs were evicted due to the reopening of railway services, and some of them remain in the reservation area in Kokkuvil. However, cargo rail transport has not yet returned, and the railway line is fully occupied. Most settlements are constructed using permanent materials; trees are planted; and residents use a portion of the railway line for access. The USSs within the railway reserve area is depicted in Figure 9 and Image 03.

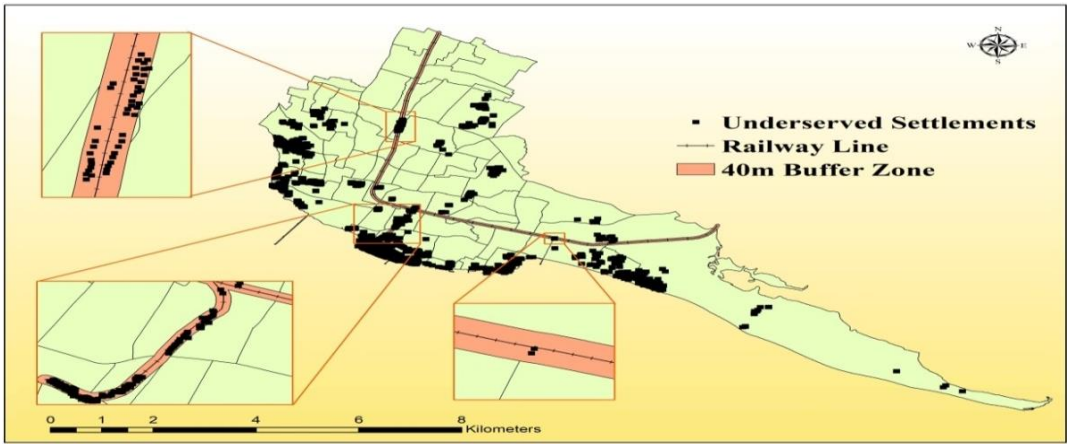

Figure 9: Underserved settlements in the Railway Reservations

Source: Prepared by the researcher based on JDS, 2021

Image 3: Underserved settlements in the Railway Reservations

Source: Field Survey 2021

According to JMC and NPS, a 3 m reservation area has to be maintained around the ponds. 23 USSs are located on the pond reservation. In particular, *Kannathiddy* pond reservations contain 47.82 % of the pond reserve's USSs, while the pond reserve of *Thevarir* pond has 34.78 % of USSs.

Kabilan (2016) claimed that between 1966 and 2011, the reservations of every single pond were reduced in size. Between 2005 and 2015, 21.51% of *Kannathiddy* pond reservation and 8.35% of *Thevarir* pond reservation were encroached. Moreover, drainage canals were encroached upon, and the main and sub-drainage canals were filled with solid waste. Figure 10 and Image 4 depict the USSs within the pond and drainage reservations.

Image 4: Underserved settlements in the Pond & Canal Reservations

Source: Field Survey, 2021

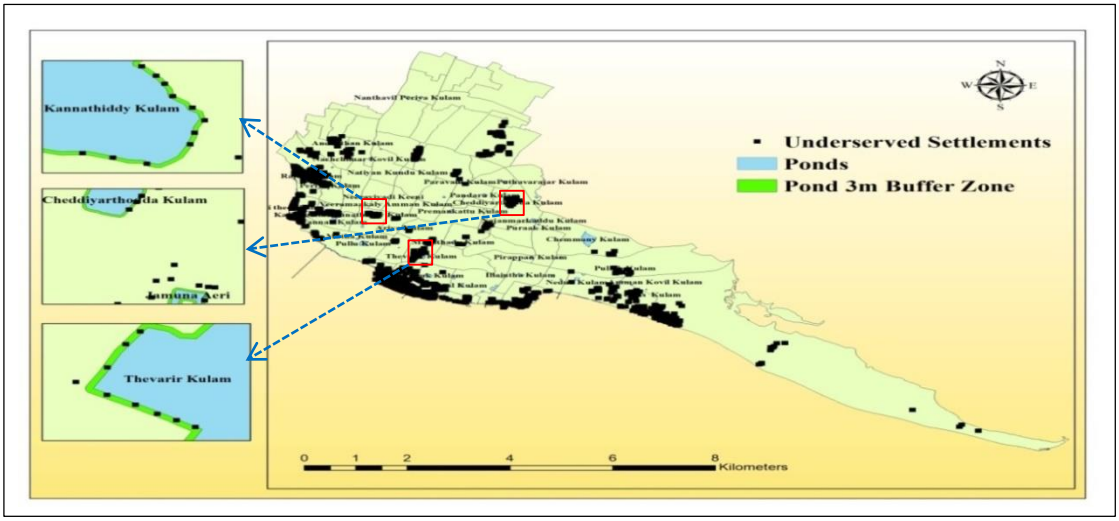

Figure 10: Underserved settlements in the Pond Reservations

Source: Prepared by the researcher based on JDS, 2021

3.2 Neighbourhood characteristics

The land is utilized for different purposes, and the USSs are associated with varing land-uses as shown in Figure 11.

Certain peculiarities were encountered while mapping residential land. The only densely built-up areas were *Reclamation East* and *West, Gurunagar East* and *West*, and *Small Bazaar*. Here, the average distance between dwellings was less than 9 m, and they were contiguous in several places. Homesteads, conversely, account for larger proportions of land use within the USS environment, accounting for 62% of USSs on parcels of land.

The proportion of the land use within 200 m of the USSs is depicted in Figure 11 and Table 4.

Table 4: Land-Use in Underserved settlements Environment

Land-use	Area (km^2)	Percent of USSS	Land-use	Area (km^2)	Percent of USSS
Homesteads	7.70	62.23	Marsh	0.12	0.79
Built-up area	0.68	24.14	Paddy	0.59	0.49
Barren land	0.90	4.04	Sand	0.17	0.13
Water bodies	0.32	3.87	Scrubs	0.49	0.79
Cropland	0.43	1.32	Other cultivations	0.30	0.56
Playground	0.12	1.95			

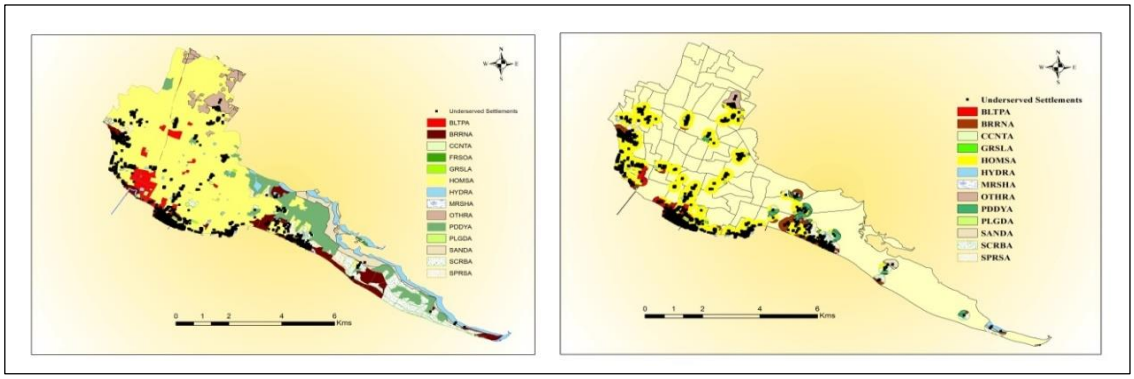

Figure 11: Land-Use in Underserved settlements Environment

Source: Prepared by the researcher based on JDS, 2021

During the FGD, community leaders remarked that these areas were once known as paddy and coconut cultivated land, or scrubland. However, they were converted into residences. The study area's built-up area contains 65.51% residential, with 9.55% USSs (JDS 2021).

3.3 Proximity of Underserved settlements to the spatial features

Using ArcGIS, proximity analysis was carried out by employing the criteria of distance from the CBD, industries, coastline, and markets.

3.3.1 Proximity to coastline

Jaffna City's coastal zone has grown far more crowded than the inland areas, with 33387 people crammed into 6 km^2. The importance of the site for the communities' livelihood is one of the main reasons for the population concentration in *Jaffna*'s coastal divisions. *Nedunkulam, Columbuthurai East, Passaiyoor East* and *West, Gurunagar East* and *West, Reclamation East* and *West, Small Bazzer, Fort, Koddady, Navanthurai North* and *South, Ariyalai South East* and *East* are fishing villages. 75.38% of the USSs are primarily involved in the fishing industry. Figure 12 depicts the USSs' proximity to the coastline.

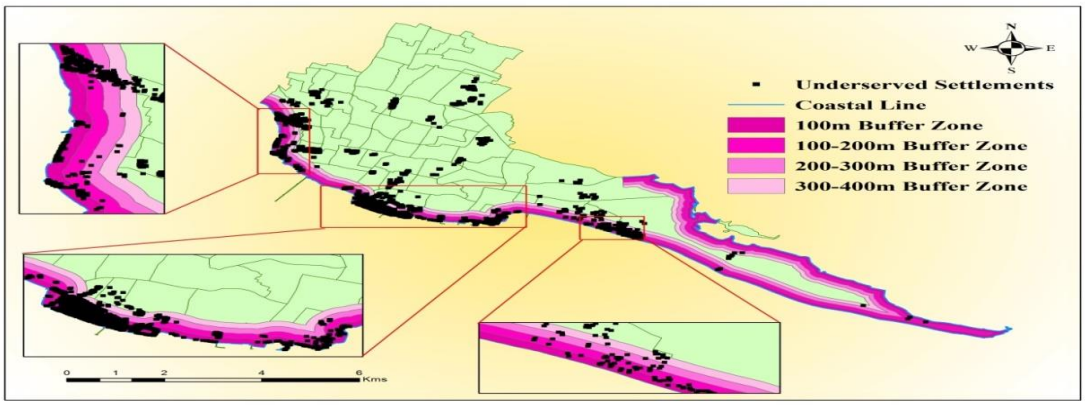

Figure 12: Underserved settlements' Proximity to the Coastline

Source: Prepared by the researcher based on Google Earth, 2021

According to Figure 12, the southern coast from *Nedunkulam* to *Small Bazzer* contains 77.27% fishing USSs within a 400 m buffer zone, with *Reclamation East* and *West* covering 67.77% and 61.98% of the labour force population dependent on fishing. The western coast, stretching from *Fort* to *Navanthurai North*, has 12.40% fishing USSs within 400 m buffer zone, while *Ariyalai South East* and *Ariyalai East* have 5.67%. *Navanthurai* has been a well-known fishing village since 1905, with fishing employing 50.67% of the labour force.

Furthermore, fishing USSs on the western coast are located within 400 m buffer zone of the shoreline; however, USSs in *Gurunagar East* and *West* have expanded to 1000 m from the shoreline in the southern coastal area.

3.3.2 Proximity to industries

Manufacturing is a significant occupational pattern in Jaffna. They employ a large number of low-income people. However, many industries were abandoned during the war.

Seafood processing industries, ice factories, and fishnet factories are currently functional near coastal areas. The area's residents benefit from the factories, which provide job opportunities and income, thereby supporting their way of life. 69.05% of USSs are located within 500 m of fishing-related industries. According to JDS (2021), 299 people are engaged in seafood processing activities, among them 68.56% from N*avanthurai,* where *Annai Sea Food* is located; 29.76% of them are from *Gurunagar* and *Passaiyoor*, where A*nnai Sea Food, Taprobane Sea Food, Reclamation Ice Factory,* and *Lanka North and East Ice Company* are located.

Furthermore, USSs have emerged in areas with access to raw materials and appropriate processing sites, namely *Nedunkulam, Columbuthura*i and *Ariyalai*, where coir and rope are manufactured. The *Jaffna* lagoon is especially suitable for retting because the buried husks can remain undisturbed for long periods. In Figure 13, the USSs' proximity to industries is depicted.

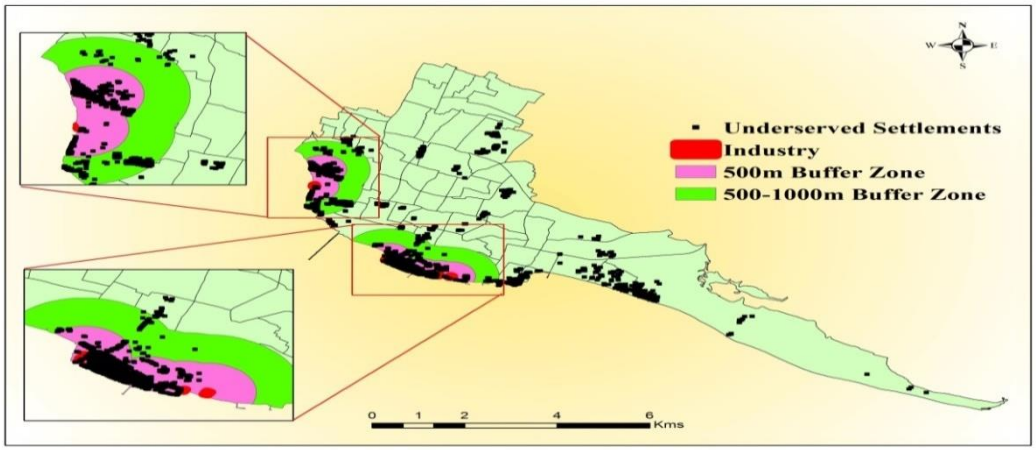

Figure 13: Underserved settlements' proximity to industries

Source: Prepared by the researcher based on Google Earth, 2021

3.3.3 Proximity to markets

Markets supply products and provide employment opportunities for USSs. There are fish markets in *Columbuthurai, Passaiyoor, Reclamation, Navanthurai, Kaakkai Theevu*, and *Pannai. Thirunelvely, Kalviyankadu*, and *Jaffna* have vegetable and fruit markets, while *Small Bazzer, Kokkuvil*, and *Ariyalai* have fish, meat, and vegetable markets. Within 500 m of t he markets, 37.86% of the USSs are located. Of that, 0.78% of the USSs are served by two markets. Furthermore, 55.64% of USSs are located 500-1000 m from markets. Of that, 56.54% of the USSs are served by two markets, while three markets serve 6.78%. Figure 14 depicts the USSs' proximity to markets. According to Figure 14, USSs in *Athiyady, Maruthady, Ariyalai South East* and *East, Ariyalai Centre South* and *North, Vannarpanni North* and *North West* are more than 1000 m away from markets.

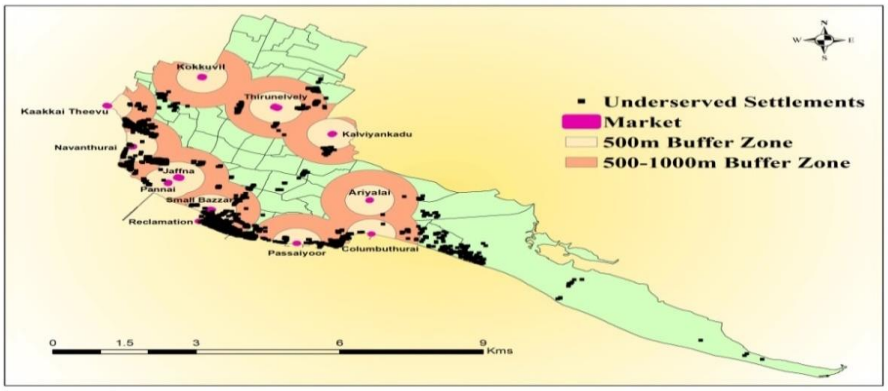

Figure 14: Underserved settlements' proximity to Markets

Source: Prepared by the researcher based on Google Earth, 2021

3.3.4 Proximity to Central Business District

Jaffna city is a high-order city centre that provides commodities, services, and job opportunities to residents of the *Jaffna* district. Consequently, communities prefer to live near the city centre and are hesitant to relocate even though they are in USSs. 62.60% of the USSs are within 1500 m of *Jaffna* CBD. Figure 15 depicts the USSs' proximity to *Jaffna* CBD.

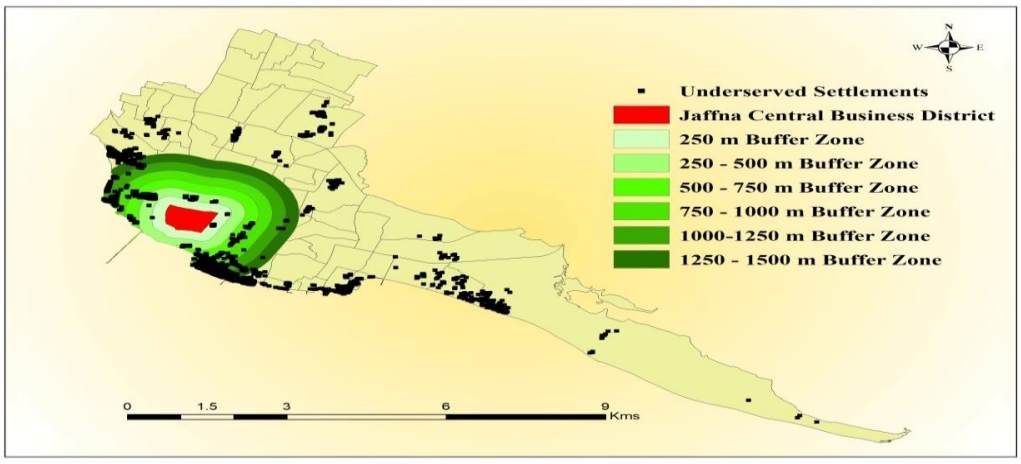

Figure 15: Underserved settlements' proximity to *Jaffna* Central Business District

Source: Prepared by the researcher based on Google Earth, 2021

According to Figure 15, USSs in *Nedunkulam, Columbuthurai East, Passaiyoor East* and *West, Thirunagar, Chundikuli South, New Moor Street, Ariyalai South East* and *East, Ariyalai Centre South* and *North, Vannarpanni North* and *North West, Sangiliyan Thoppu, Thirunelvely West* and *Centre North,* and *Kokkuvil East* are located more than 1500 m away from the *Jaffna* CBD.

3.4 Road network connectivity

A well-developed transportation network is crucial for the settlement area's social and economic development because it connects places and people. Figure 16 depicts the study area's road connectivity.

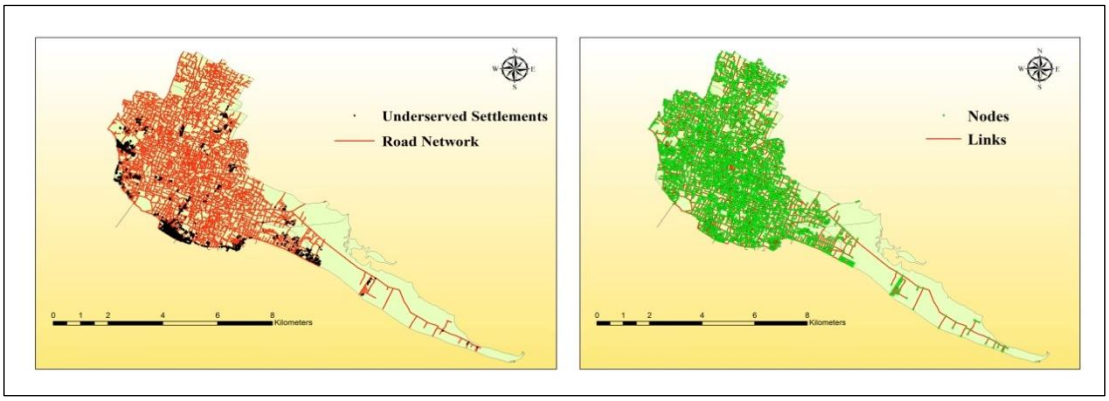

Figure 16: Road Network Connectivity

Source: Prepared by the researcher based on UDA, 2021

The road network of the selected divisions consists of 3161 nodes (V), 4748 links (L), and a total length of 305.35 km. The road connectivity indices were computed and tabulated, as shown in Table 5.

Table 5: Alpha, Beta, and Gamma indices

GND	L	V	α	β	γ	GND	L	V	α	β	γ
61	167	127	0.16	1.31	0.45	81	229	160	0.22	1.43	0.48
62	235	108	0.61	2.18	0.74	83	133	86	0.29	1.55	0.53
64	73	39	0.48	1.87	0.66	84	58	36	0.34	1.61	0.57
65	73	33	0.67	2.21	0.78	85	180	129	0.21	1.4	0.47
67	41	29	0.25	1.41	0.51	86	88	44	0.54	2	0.7
68	147	82	0.42	1.79	0.61	87	150	100	0.26	1.5	0.51
69	121	60	0.54	2.02	0.7	88	124	92	0.18	1.35	0.46
70	71	41	0.4	1.73	0.61	89	147	91	0.32	1.62	0.55
71	87	50	0.4	1.74	0.6	90	118	99	0.1	1.19	0.41
72	54	26	0.62	2.08	0.75	94	119	90	0.17	1.32	0.45
73	120	83	0.24	1.45	0.49	96	153	119	0.15	1.29	0.44
74	109	81	0.18	1.35	0.46	98	105	65	0.33	1.62	0.56
75	99	57	0.39	1.74	0.6	99	185	126	0.24	1.47	0.5
77	209	137	0.27	1.53	0.52	109	313	231	0.18	1.35	0.46
78	215	151	0.22	1.42	0.48	110	212	159	0.17	1.33	0.45
79	107	63	0.37	1.7	0.58	114	135	114	0.1	1.18	0.4
80	151	91	0.34	1.66	0.57	122	220	162	0.18	1.36	0.46

Source: Developed by the researcher, 2022

The average alpha index is 0.31, which equals 31%. The highest alpha value is assigned to the *Passaiyoor West*, indicating that the division has a very high degree of circuitry or that a more significant number of nodes are well connected. *Ariyalai East* and *Thirunelvely Centre North*, have very low levels and poorly connected nodes. On average, the beta index is 1.58. All the selected divisions have a value greater than one, indicating that the area's road network connection is better. *Passaiyoor West* has the highest beta value, while *Thirunelvely Centre North* has the lowest. The average gamma is 0.54. The *Passaiyoor West* has the highest gamma value, while *Thirunelvely Centre North* has the lowest.

3.8 The influence of Underserved settlements' locational characteristics on their sustainability

3.8.1 Hazard vulnerability and impact

Site-specific characteristics influence the sustainability of USSs (Sirueri 2015). The USSs in low-lying areas, pond catchments, and closer to canals are affected by floods annually, while others are not. Floods are more likely in *Navanthurai North* and *South, Moor Street North* and *South, New Moor Street* and *Fort* than in other areas, with 86.11% of reported annual floods. Due to its location, flood water takes more than a week to recede. 77.13% of residents left their homes during that time. For 70.96%, basic services were disrupted, with 12.90% reporting that the disruption lasted more than a week. As shown in Image 05, water, sanitation, housing, and transportation are major concerns for USSs during the floods.

Image 5: Flooding Impacts on Underserved settlements

Source: Field survey, 2020

The invasion of floods into homes and the surroundings impacts their health. When the toilets are flooded, they overflow and become unusable. Floodwater contaminates and defiles the wells. Consequently, 88.86% of respondents reported that their family members had become ill during the most severe flood. Overall, 29.91% of respondents sought medical treatment, but this figure was higher among those who experienced floods twice or more per year. The risk of dengue fever, diarrhoea, and skin disease is higher in flood-prone USSs (*Jaffna* Medical Officer of Health 2021).

Furthermore, floods have an impact on USSs' livelihoods and financial standards. During the severe flood, 87.10% of the affected USSs lost three or more working days, resulting in more than Rs 10,000 in earnings. Furthermore, 60.11% of respondents mentioned their property and belongings were damaged during the severe flooding.

Accordingly, USSs in flood-prone areas are extremely vulnerable to severe floods economic, environmental, infrastructure, and social vulnerability. Simultaneously, due to their lower capacity, they have a high risk of flooding. Thus, sustainability is very low in flood-inundated USSs. Previous studies support this finding. According to UN-HABITAT, CEPA and Sevanatha (2013), the most vulnerable communities in Colombo are flood-prone USSs. Furthermore, Mahabir et al. (2016) asserted that USSs that are physically threatened by disasters are vulnerable to risk than more formal communities due to their lower capacity for disaster recovery.

During a flood, communities were observed taking protective measures to prevent or minimize damage to their household items. To combat the threat of flooding, communities filled their plots with soil and raised their levels; dwellings were constructed at raised levels where water could seep through and a raised wall was constructed. Few houses were built with extra floors to protect against flooding. Important items are also placed at a higher level to reduce damage.

3.8.2 Proximity to hazardous or environmentally sensitive areas (ESAs).

As shown in Table 6 and Image 6, USSs are located near hazardous areas such as railway tracks, garbage dumping sites, and ESAs, specifically the coastal area and pond.

Table 6: Proximity to Hazardous/ Environmentally Sensitive Areas

Distance	Frequency	Percent
Less than 100 m	137	40.2
100 to 200 m	84	24.6
200 to 300 m	50	14.7
More than 300 m	70	20.5

Source: Questionnaire survey, 2021

Image 6: Location of Underserved settlements in the Garbage Dumping and Lagoon Sites

Source: Field Survey, 2020 & 2021

At various times, the availability of vacant and marginalized lands; proximity to employment opportunities, transportation networks, and urban centres; low commuting costs; access to goods and services; social ties; displacement; malfunctioning of institutional activities due to political unrest; lack of mechanisms to regulate development; and political influence contributed to the emergence and growth of USSs near hazardous and ESAs. These findings are consistent with previous research, which claimed USSs were developed in marginal lands, specifically coastal, road and railroad reservations, river banks, and disposal sites (Ishtiyaq & Kumar 2011; Birajdar 2014; Brata et al. 2018; Takyi et al. 2020). USS residents prefer these types of lands because they lack the purchasing power to compete for formally approved lands, which are relatively expensive. It is worth noting that the lower-income of USS residents influences their decision to occupy these marginal lands. The availability of marginal lands influences the location of USSs (Righa 2012; Mahabir et al. 2016).

Conversely, residents in hazardous and ESAs are threatened with eviction, affecting their housing quality and livelihood. Poor living conditions in USSs adversely affect dwellers' health status, leading to communicable (CDs) and non-communicable diseases (NCDs). According to the survey, 49.27% were impacted by CDs and 50.73% by NCDs. The underserved community could also negatively affect their environment due to a lack of basic services, leading to deterioration in Jaffna city's urban environmental quality. Previous studies support these findings. According to Takyi et al. (2020), USS activities, including indiscriminate waste disposal, raw sewage channelling, open defecation, building setbacks, and indiscriminate industrial waste dumping, contributed to high pollution levels along water bodies and wetlands. They had several implications for the city's environmental facets. According to Zhang et al. (2020), many buildings in underserved areas were built adjacent to environmentally hazardous areas, jeopardizing residents' lives and property. This indicated that when planning building layouts in underserved areas, low levels of local environmental conditions were taken into account. Simultaneously, safe drinking water was scarce due to garbage and faeces polluting water sources. Furthermore, most farmland and vegetated areas were transformed by buildings, resulting in a steady decline in the service function of ecological space in USSs and a generally fragmented landscape pattern. Because of the spatial

distribution of USSs in ecologically risky areas, it was not easy to manage and provide infrastructure centrally. Consequently, Zhang et al. (2020), underlined that the living conditions of USSs were harsh and threatened residents' health and the environment. Studies by UNDP et al. (2006); Birajdar (2014); and Mahabir et al. (2016) highlighted that the environmental impact of USSs extended to communities beyond them, which means that their growth and expansion could threaten sustainable urban development at all scales. Accordingly, locational factors impact the sustainability of USSs and the urban environment.

3.8.3 Location and livelihood

The proximity of CBDs, industries, markets, and the coast impacts the sustainability of USSs. These spatial features provide goods and services and informal job opportunities to the underserved population. The results indicated that 62.60% of USSs were located within 1500 m of the CBD, 69.05% were within 500 m of fishing-related industries, 78.81% were within 400 m of the coastal line, and 93.50% were within 1000 m of markets. All USSs indicate that their current location is crucial to their livelihood. The reasons given vary, but the proximity to the workplace is the most significant. Consequently, USSs tend to congregate in specific areas that support their livelihood. Tables 7 and 8 show the reasons for and the significance of the current location for earning income.

Table 7: Reasons for being in the Present Location

Reasons	Frequency	Percent
Work based on the present location	37	10.9
Close to workplace	181	53.1
Clients are from the locality	24	7.0
Informal job opportunities	68	19.9
Home-based	31	9.1

Table 8: The Current Location's Importance to the Income Source

Importance	Frequency	Percent
Less than 25%	10	2.9
25% to 50%	24	7.0
50% to 75%	126	37.0
Over 75%	181	53.1

Source: Questionnaire survey, 2021

53.08% of respondents mentioned that their workplaces are within walking distance of the settlements. Among them, 9.09% are engaged in home-based jobs, while 87.39% said they could get to work in an hour. Figure 17 depicts the mode of transportation to work, the distance from the workplace, and the time spent commuting, respectively.

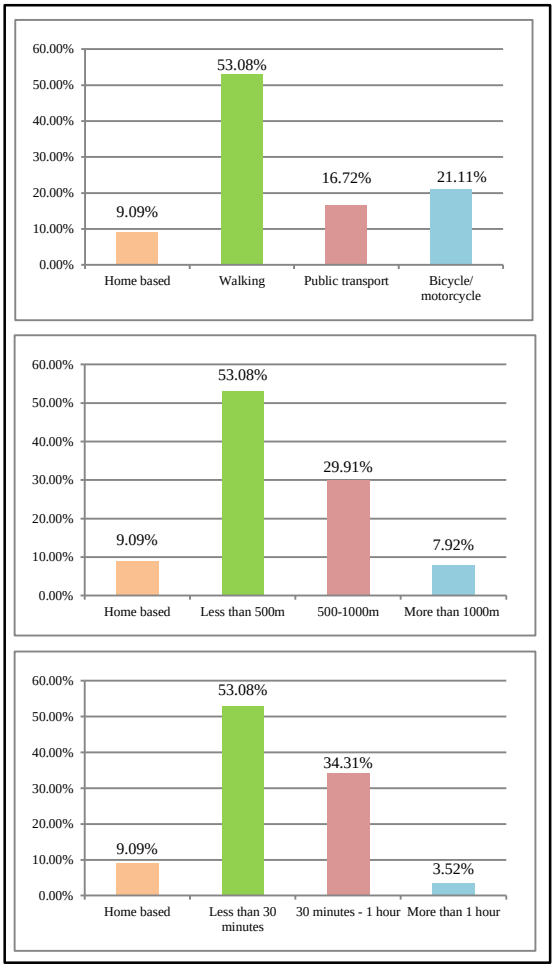

Figure 17: Transportation Mode to Work, Workplace Distance, and Commuting Time

Source: Questionnaire survey, 2021

Despite the inconvenience of living in congested USSs, the community appears to be motivated to stay in the surveyed locality due to lower or no rental costs, access to education and health facilities, and the convenience of being close to their workplaces and markets. These findings are supported by Takyi et al. (2020). They claimed that USSs are typically located closer to the CBD and market, lending support to the centralization theory of residence, demonstrating an inverse relationship with socioeconomic status. People with high incomes who work in the inner rings tend to travel further to work. Low income people, conversely, have shorter commutes to work and live close to the CBD, so their commuting costs are lower. Birajdar (2014) and Sirueri (2015) also asserted that USSs located near the aforementioned spatial features could access job opportunities, goods, and services at lower commuting costs than those located further away, influencing their sustainability through expenditure.

3.8.3 Road connectivity

The findings revealed that complexity, connectivity and circuitry varied across divisions. The *Passaiyoor West* road network had the most circuitry, complexity, and connectivity, accounting for α value of 0.67, β value of 2.21, and γ value of 0.78. Conversely, *Thirunelvely Centre North* and *Ariyalai* East had the lowest. Improved road network connectivity provides many alternative routes to destinations, reducing transportation time and costs (Sirueri 2015; Zhang et al. 2020). Consequently, road connectivity influences the sustainability of USSs. USSs in the more-connected areas can travel to their destinations via alternative routes that have the lowest time and cost. Conversely, USSs in less-connected areas don't have the opportunity to make choices. During the FGD, people from *Ariyalai East* mentioned that they faced difficulties due to the poor road network. They had to spend more than 2 hours getting to Jaffna city centre. These findings are supported by previous studies. Sirueri (2015) and Zhang et al. (2020) also noted that good roads and road connectivity influence the sustainable development of USSs, because people use the roads to access places of opportunity.

4 CONCLUSION & RECOMMENDATIONS

The study's findings provided two possible contributions. First, the locational characteristics of USSs were examined, and the results indicated that action should be taken promptly to prevent the formation and expansion of USSs. The study focused on the potential link between the locational characteristics of USSs and their sustainability. According to the study, the locational characteristics of USSs, specifically their location in flood-prone areas, land reservations, irregular road networks and poor accessibility, impede development potential and have negatively impact on the sustainability of USSs and the urban environment. Furthermore, to reduce problems with USSs and establish cities without USSs, the development of USSs must be aligned with spatial and sustainable development. Preserving land reservations, environmental protection, flood control, allotment of government lands to people in alternative locations, road planning and infrastructure development in other parts of the district, enhancing the livelihood assets of USSs, developing coordination among multiple stakeholders, and strengthening existing laws and regulations are some of the strategies that can be used to promote sustainable development of USSs and the urban environment.

Urban sustainable development emphasizes people-orientation and capacity-building as a three-dimensional coordinated development of society, economy and ecology. The city's spatial organisation at different scales can influence all three dimensions. A hot topic in urban sustainable development research is determining how to guide a city to form a reasonable spatial form while promoting sustainability (Zhang et al. 2020). More

comprehensive research is needed at this time to investigate the mechanisms underlying the relationship between the locational elements of USSs and their functional development to make more innovative recommendations to promote USSs' sustainable development.

REFERENCES

Ali, MH & Sulaiman, MS 2006, 'The Causes and Consequences of the Informal Settlements in Zanzibar', *XX111 Congress of the International Federation of Surveyors,* pp.1-17.

Banda, OG 2007, *Informal Trade in Sri Lanka.* Project Report for Legal Empowerment of Poor, Path Finder Foundation, Colombo.

Birajdar, RT 2015, *Geographical Assessment of Slums and its Effect on Urban Environment*, PhD thesis, Tilak Maharashtra Vidyapeeth. Available from: Shodhganga Digital Repository. [15 May 2020].

Brata, JT, Bariun, LO, Djauhar, A & Tantu, AG 2019, 'Poverty Alleviation through the Program Slums in the City of Kendari, Indonesia', *Journal of Environment and Ecology*, vol. 9, no. 2, pp. 35-42.

Brugmann, J 2010, *Welcome to the Urban Revolution: How Cities are changing the World*, Bloomsbury Publishing, USA.

Chambers, R & Conway, G 1992, *Sustainable Rural Livelihoods: Practical Concepts for the 21st Century*, Discussions Paper 296, Institute of Development Studies, UK.

Dayaratne, R 2010, *Creating Sustainable Habitats for the Urban Poor: Redesigning Slums into Condominium High-Rises in Colombo*. Nova Publishers, New York.

Ekanayake, M 2001, *Redevelopment of Underserved Settlements in the City of Colombo, Sri Lanka*, MSc thesis, University of Twente. Available from: University of Twente Digital Repository. [15 May 2020].

Elrayies, GM 2016, 'Rethinking Slums: An Approach for Slums Development towards Sustainability', *Journal of Sustainable Development*, vol. 9, no. 6, pp. 225-244.

Fox, S 2008, *On the Origins and Consequences of Slums*, Center for the Study of African Economies, Oxford.

Gambo, YL, Idowu, OB & Anyakora, IM 2012, 'Impact of Poor Housing Condition on the Economy of the Urban Poor: Makoko, Lagos State in View', *Journal of Emerging Trends in Economics and Management Sciences*, vol.3, no. 4, pp. 302-307.

Gunetilleke, N, Cader, AA & Fernando, M 2004, /*Understanding the Dimensions and Dynamics of Poverty in Underserved Settlements in Colombo*, Centre for Poverty Analysis, Colombo.

Ishtiyaq, M & Kumar, S 2011, 'Typology of Informal Settlements and Distribution of Slums in the NCT, Delhi', *Journal of Contemporary India Studies: Space and Society*, vol.1, no.21, pp. 37-46.

Jagoda, D 2009, *Sustainable Housing Development for Urban Poor in Sri Lanka*. Available from: https://www.lth.se/fileadmin/hdm/alumni/papers/ad2000/ad2000-14.pdf [1 June 2020].

Kabilan, S 2016, *Spaces of Conflict: Emerging Built Environment in Post War Era Urban Development in the City of Jaffna, Sri Lanka*, MSc thesis, University of Moratuwa. Available from: University of Moratuwa Digital Repository. [12 April 2020].

Kolhe, NP & Dhote, KK 2019, 'Spatial Assessment of Rurban Slums: a New Perspective of Urban Villages', *International Journal of Recent Technology and Engineering (IJRTE)*, vol. 8, no.3, pp. 8688-8693.

Koralagama, D 2008, 'Community Perception Towards A Set Back Area: A Case Study In Galle District, Sri Lanka', *Fourteenth Biennial*

Conference of the International Institute of Fisheries Economics & Trade, pp. 1-11.

Mahabir, R, Crooks, A, Croitoru, A & Agouris, P 2016, 'The Study of Slums as Social and Physical Constructs: Challenges and Emerging Research Opportunities', *Regional Studies, Regional Science*, vol. 3, no. 1, pp. 399–419.

Mahadeva & Chandrashekara, B 2018, 'Spatial Distribution of Slums and its Locational Characteristics in Mysuru City', *Review of Research*, vol. 8, no.1, pp. 1-14.

Malecki, EJ & Ewers, MC 2007, 'Labour Migration to World Cities: With A Research Agenda for the Arab Gulf ', *Progress in Human Geography*, vol. 31, no. 4, pp. 467-484.

Marx, B, Stoker, T & Suri, T 2013, 'The Economics of Slums in the Developing World', *Journal of Economic perspectives*, vol.27, no. 4, pp. 187-210.

Patel, A 2012, *Slumulation: An Integrated Simulation Framework to Explore Spatio-Temporal Dynamics of Slum Formation in Ahmedabad, India*, PhD thesis, George Mason University. Available from: George Mason University Digital Repository. [14 July 2020].

Piratheeparajah, N, Chan, N & Tan, ML 2020, 'Identifying Flood Hazard Potentials Based on Geographical Characteristics in the Jaffna District, Sri Lanka', *Geografi*, vol. 8, no. 2, pp. 92-109.

Righa, EM 2012, *Factors Influencing Growth of Informal Settlements: A Case of Bangladeshi Slum, Changamwe Constituency, Mombasa County, Kenya*, Master's thesis, University of Nairobi. Available from: University of Nairobi Research Archive. [14 July 2020].

Samaratunga, T & O'Hare, D 2013, 'Reflections on Over 100 Years of Urban Housing Policies in Sri Lanka', *Social Sciences*, vol.2, no. 1, pp.14-21.

Senanayake, SMP, Wimalaratana, W & Premaratne, SP 2012, 'Informal Sector and the Economy in Sri Lanka', *Sri Lanka Economic Journal*, vol. *12*, no. 2, pp. 1-20.

Sirueri, FO 2015, *Comparing Spatial Patterns of Informal Settlements between Nairobi and Dar es Salaam*, MSc thesis, University of Twente. Available from: University of Twente Digital Repository. [10 July 2020].

Soma, H, Sukhwani, V & Shaw, R 2022, 'An Approach to Determining the Linkage between Livelihood Assets and the Housing Conditions in Urban Slums of Dhaka', *Journal of Urban Management*, vol.11, no. 1, pp. 23-36.

Sugathapala, KC & Munasinghe, DS 2019, 'Risk Mapping As a Tool for Disaster Risk Reduction in Urban Areas of Sri Lanka'. Available from: https://nbro.gov.lk/images/content image/ publications/ symposia/2010/risk_mapping.pdf. [10 May 2020].

Takyi, SA, Amponsah, O, Yeboah, AS & Mantey, E 2021, 'Locational analysis of slums and the effects of slum dweller's activities on the social, economic and ecological facets of the city: insights from Kumasi in Ghana', *GeoJournal*, vol. 86, no. 6, pp. 2467-2481.

UN-HABITAT, CEPA & Sevanatha 2013, *Colombo City – Livelihood Assessment of Flood-Prone Low-Income Settlements*, pp.1-76. Available from: https://pubdocs.worldbank.org/en/482241460466145516/Output-Colombo-City-Livelihood-Assessment-of-Flood-Prone-Low-Income-Settlements.pdf.[10 May 2020].

United Nations Development Programme, United Nations Human Settlements Programme, Jaffna Municipal Council & Ministry of Urban Development & Water Supply 2006, *Jaffna City Profile*, pp. 1-64. Available from: https://unhabitat.lk/wp-

content/uploads/2015/01/Jaffna.pdf .[10 May 2021].

United Nations Human Settlements Programme 2020, *World Cities Report: The Value of Sustainable Urbanization*. pp. 1-377. Available from: https://unhabitat.org/World%20Cities%20Report%202020 [15 June 2021].

Zhang, J, Chen, S, Gao, Q, Shen, Q, Kimirei, IA & Mapunda, DW 2020, 'Morphological characteristics of informal settlements and strategic suggestions for urban sustainable development in Tanzania: Dar es Salaam, Mwanza, and Kigoma', *Sustainability*, vol. 12, no. 9, pp.1-21.