

GEOSPATIAL ANALYSIS OF LAND ENCROACHMENT IN KARACHI CITY: A CASE STUDY OF SONGAL NALA

MUHAMMAD YASEEN¹ • SALMAN ZUBAIR¹ • NOSHEEN RAZA²

¹Department of Geography, University of Karachi, Pakistan

²Department of Sociology, University of Karachi, Pakistan

Corresponding author's e-mail: yaseen.khan.geographer@gmail.com

ABSTRACT

The development of built-up areas without proper planning encourages encroachment over urban land, which has now become a major problem for developing countries. Following research paper is about encroachment over Songal Nala territory, and this study based upon geospatial data and ground truthing which observed during survey. It was found that during past few years the Songal Nala territory heavily encroached. The main aim of this research paper is to calculate the land encroachment area which has been encroached between 1989-2023 and the social and economic conditions of the people who were living around Songal Nala territory. The work is based on GIS mapping along with field visits and questionnaire responses collected from residents. By using Normalized Difference Built-Up Index (NDBI) it has been found that 38.2862% area from 1989 to 2023 which was occupied by Songal Nala has been converted into built-up area during past few years, which increased occurrence of flood. The research revealed that the major reason for water occupied area encroachment was poor economic conditions of people and the migration of people from other rural areas who seek better employment opportunities which increased population of surrounding area as well as encroachment. These findings can help local departments plan better, and more work can be done in the future with new satellite data and community surveys.

KEYWORDS: Urbanization, Normalized Difference Built-Up Index, Normalized Difference Water Index, Reverse Osmosis, Digitization

1. INTRODUCTION

Urban growth has been increasing all over the world, and many natural areas are being used for housing and construction. This has also caused problems like flooding and loss of open land (Amjad et al., 2024). The same situation can be seen in Pakistan, where large cities, especially Karachi, have expanded very fast in recent decades (Maitlo et al., 2023; Afzal et al., 2023). Because of this expansion, many natural drains and open lands have been encroached upon, creating serious environmental and social issues for local communities (Iftikhar & Iqbal, 2023).

Karachi is Pakistan's most populated city with population around 3 Crores (Rehman et al., 2018). One of the main reasons behind this massive population is migration of people from rural areas to seek better employment opportunities (Mukta et al., 2022). The city experienced rapid

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urbanization that led to increase in its built-up land, industrialized area, number of motorized vehicles, and decreased its vegetation cover and water occupied area e.g., rivers and nala's (Mukta et al., 2022). Scarcity of water, mismanagement in urban planning and rapid increase in rural to urban migration became dangerous for the health of locals and ecosystem of the city as well (Mukta et al., 2022).

Karachi is considered as the economic heart of Pakistan (Khan, 2016). Around fifty percent of Sindh's total population and sixty-three percent of its urban population living in Karachi. The climate of Karachi is arid with precipitation of 250 mm per year (Arsalan, 2017). The unprecedented growth of Karachi's population became a challenge because of unrecorded in-migration and mismanagement in some of its government and private sectors. In Karachi around 4600 people are living 1 square kilometer, they have different languages and belong to different castes (Arif Hasan, 2022).

Songal Nala is one of the natural drains located in the east district of Karachi. Over the years, its surroundings have changed due to population increase and unplanned construction. Although many studies have been carried out on urban growth and land-use changes in Karachi, no previous research has specifically focused on Songal Nala. The present study therefore tries to analyze the temporal land encroachment using GIS techniques and to understand the socio-economic conditions of residents through field surveys and questionnaires.

1.1. Study area

Songal Nala is one of the tributaries of Liyari river. In East of it lies University of Karachi and in North-West and South-East Sohrab Goth and Safari Park exist. I was born here. I have seen with my own eyes how the width of the nala has become smaller with time. Earlier its width was several meters, but now at many places it is hardly one meter or even less. I have also seen how the nala, which once had cleaned and clear water, has now turned into a dirty and bad-smelling drain. I have also seen how fast the population has increased and how the floodwater spreads and damages house when the nala overflows. I know very well about the people living here their education level, their way of living, the languages they speak, and how they earn their income. Because of this close connection and personal experience, I chose Songal Nala as my study area.

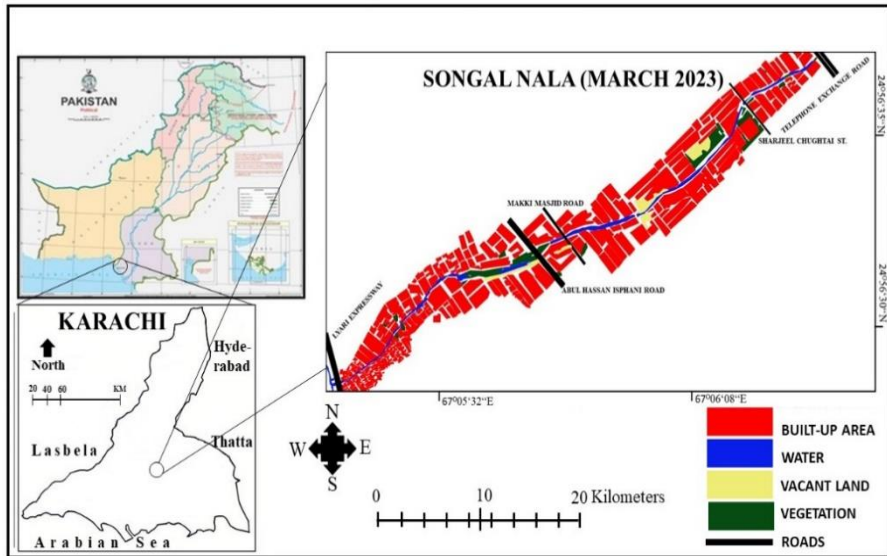


Fig. 1: Map Showing Study Area Songal Nala

2. MATERIAL AND METHODS

Landsat images downloaded from United States Geological Survey (USGS) earth explorer website with 30m spatial resolution. The study area includes the Songal Nala, Karachi, which falls under Path 152, Rows 42–43 of the Landsat grid. These datasets were later used to calculate NDBI and to study built-up areas. The study area map created with the help of several shape files, one shape file is used for each land feature e.g., road, parks, airport, river etc. Normalized Difference Built-Up (NDBI) Index of year 1989 and 2023 calculated using Near Infra-red and short wave infra-red bands. I have been living in the Songal Nala area for about thirty years, and during this time, I have personally seen many changes in land use, construction, and water flow, especially during the monsoon season when floods often damage nearby houses, including my own. Because of this close connection with the area, I developed a questionnaire based on my observations and discussions with local people. The aim was to record how families have been affected socially and economically by these physical changes. The questionnaire survey was carried out among local families living close to the Songal Nala. In total, 210 people were interviewed, each belonging to a different family. The families were selected randomly, but I mainly included those whose houses are affected during floods. These households have directly experienced the changes in land, water, and living conditions over time, so their views were important for this study. The questions covered topics such as education, income, land value, power sources, water use, and other social issues to understand how physical changes in the area have influenced the community.

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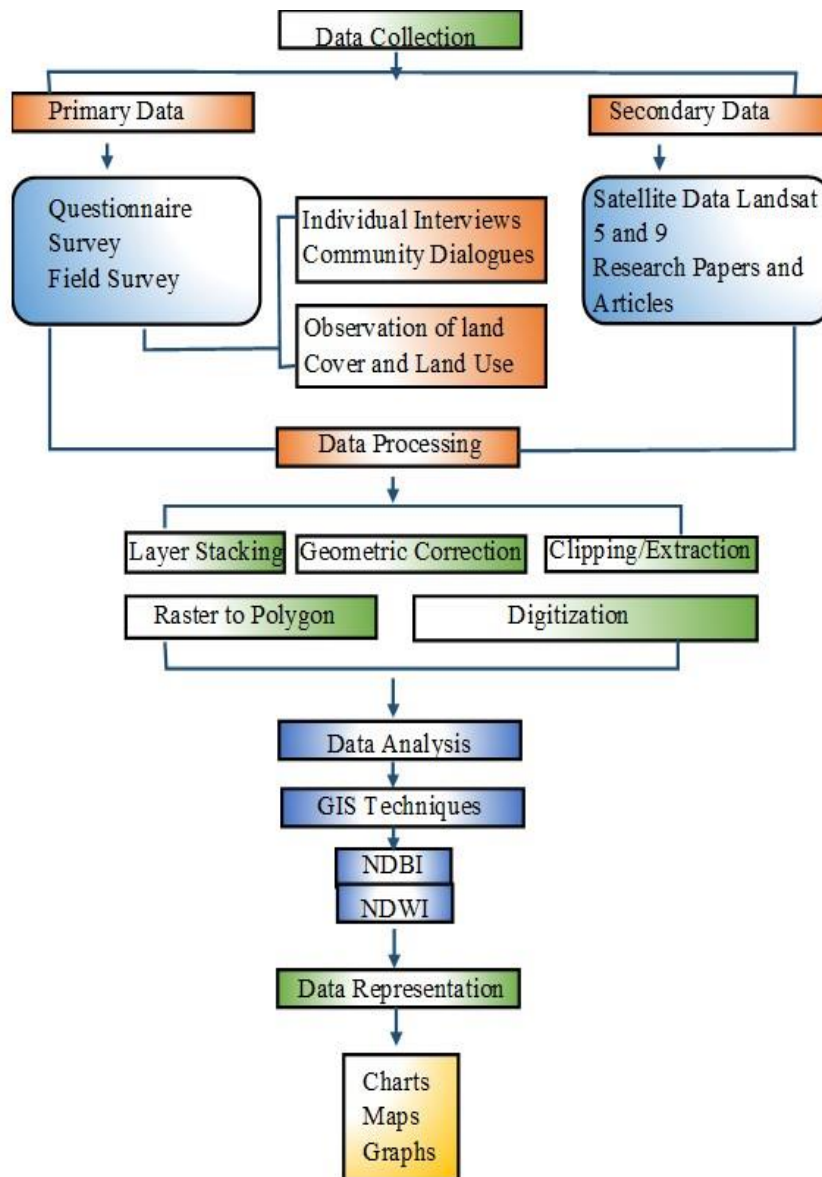


Fig. 2: Flow diagram of methodology

In this research paper field surveys were conducted in which questions were asked from different family individuals. Reasons of Songal Nala land encroachment were identified.

The questionnaire was designed to collect information about the social, economic, and environmental aspects of the residents living near Songal Nala. It covered topics such as education, income, land value, water use, energy sources, and social habits.

Table 1: The main variables included in the questionnaire and their response categories are shown

Sr. No.	Variable / Topic	Example of Questions	Response Options / Categories
1	Reasons for Leaving Education	Why did you stop getting education?	To get a job, to learn a skill, to do Alim course, to do work
2	Male Literacy Rate	What is your education level?	Illiterate, Middle, Matric, Intermediate, Graduation
3	Sources of Power Generation	What source of power do you use at home?	Solar panels, Generators, UPS, Nothing
4	Land Values in Study Area	What is the value or ownership status of your house?	On rent, 10–25 lac, 25–40 lac, 40–70 lac, 70–100 lac
5	Marriages Outside Community	Do you allow or practice marriages outside your community?	Yes, we do / No, we don't
6	Number of Male Children per Family	How many male members are there in your family?	1–3, 4–6, 7–9, 10 and more
7	Monthly Family Income	What is your family's monthly income range?	20–30 thousand, 30–60 thousand, 60–90 thousand, Above 90 thousand
8	Sources of Income	What is your or your family's main source of income?	Tailor, Dubai worker, Home driver, Gardener, Shopkeeper, Broker, Junkyard worker, House painter, Factory worker, Rickshaw driver, Water loader, Fruit/vegetable seller, Mechanic, Security guard, Crane/dumper driver, Plumber, Sindh police employee, Doctor, Bricklayer
9	Sources of Fresh Water	What is your main source of fresh water?	Line water, From loader
10	Use of Drugs / Addictive Substances	Which of the following substances do you use?	Tea, Cigarette, Ghutka, Mawa, Wine, Charas, Tobacco

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Research reports, articles, Landsat satellite images of 30m spatial resolution used. The main reason behind using Landsat images was to identify change in built-up land or Songal Nala land encroachment, and ArcGIS software used to process and analyze data.

Landsat satellite images contain several bands, so after downloading these images, composite band tool in data management arc tool box used to combine these bands (Layer Stacking), to create multi-band raster image. In this research Normalized Difference Built-Up (NDBI) Index was calculated to find changes in concrete land. By using NIR (Near Infra-Red) and SWIR (Short Wave Infra-Red) bands of Landsat images.

$$NDBI = \frac{(SWIR - NIR)}{(SWIR + NIR)} \rightarrow (1)$$

The equation was originally proposed by Zha et al. (2003) to effectively extract built-up areas from satellite images.

The main purpose of using Normalized Difference Built-Up Index (NDBI) in this research paper is to analyze and calculate change which occurred in built-up area along Songal Nala from 1989 to 2023. Besides using NDBI for 1989 and 2023, the data for the years 2004 and 2014 were prepared manually through digitization. Satellite images of these years were digitized in ArcGIS to outline the built-up area and the boundary of Songal Nala. Calculation of area was done by converting raster images into vector using raster to polygon tool of ArcGIS software, then to assign them coordinate system ArcGIS dissolve tool used, then using calculate geometry tool area of vector shape files calculated. To evaluate change in built-up land, images of 1989 and 2023 digitized. The process of digitization involved creating many shape files one for each land feature e.g., roads, parks, rivers etc.

3. RESULT AND DISCUSSION

During survey seventy-five questions asked from 210 families. The aim of questionnaire was to find their socio-economic profile. The responses of the respondents are presented through figures. Less than thirty percent families were living along Songal Nala from past 30 years, and remaining seventy percent families arrived during last 30-year period.

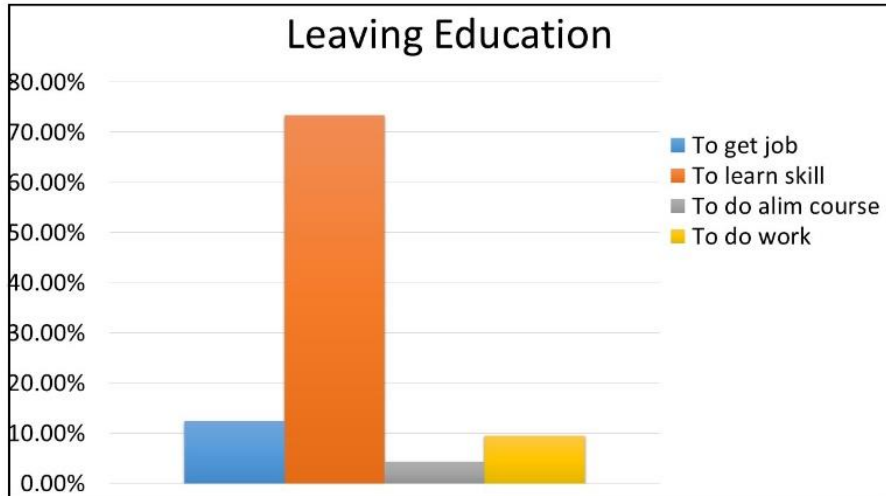


Fig. 3: Reasons behind leaving education

Many people left schools because they want to learn skill to open their own shops. Few of them were interested in getting religious education, and females started earning as housemaid.

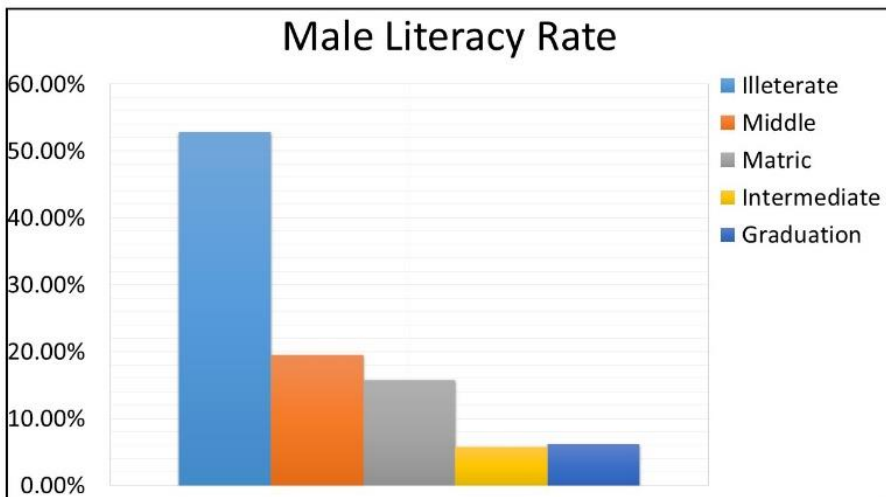


Fig. 4: Male literacy rate

In study area less than five percent male just attended universities. During research it was found that fifty-one percent of male members were illiterate.

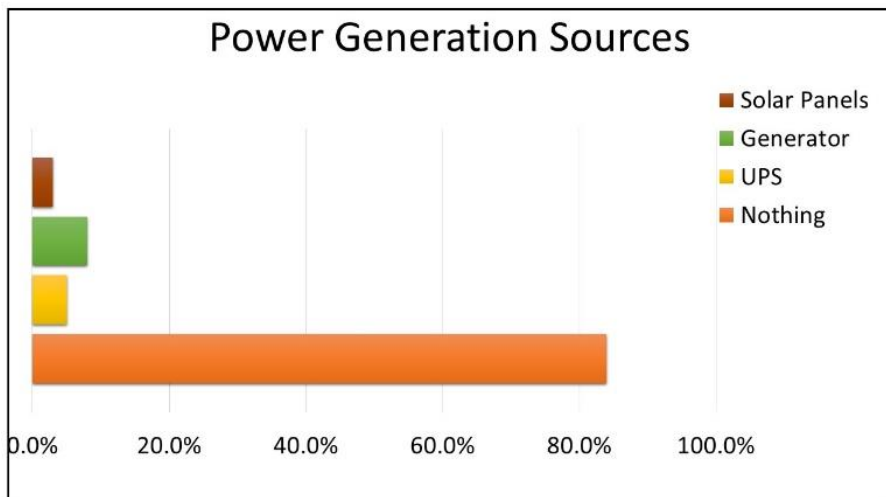


Fig. 5: Sources of power generation

In a day Six-hour load-shedding occurred in present study area (survey month: March and April 2023), eighty-three percent families had neither generator nor UPS.

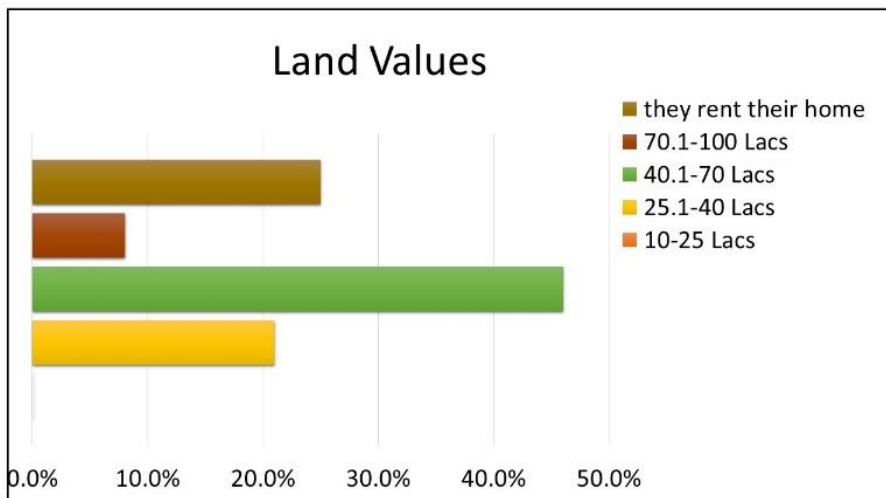


Fig. 6: Land values in present study area

The rent rates in the study area (Figure 6) of one room were ten thousand rupees per month. The price of 80 sq. yard plot had 25-35 lac rupee, and 120 sq. yard plot price were 40-70 lac rupees. It was observed that land prices increased with the width of the street and number of streets which met with that plot.

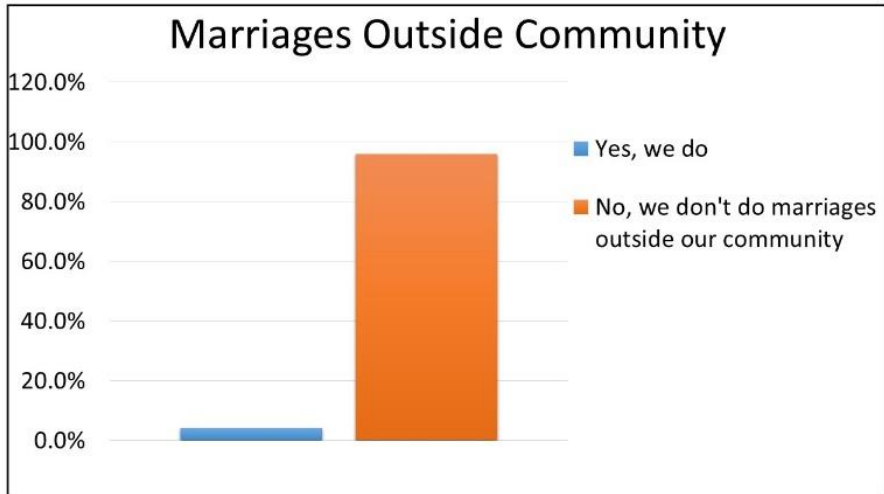


Fig. 7: Outside community marriages

It was found that ninety-three percent families were not interested in outside community marriages, it was observed in survey that nineteen percent families out of them just restricted their girls, they allowed their boys to marriage outside of their caste.

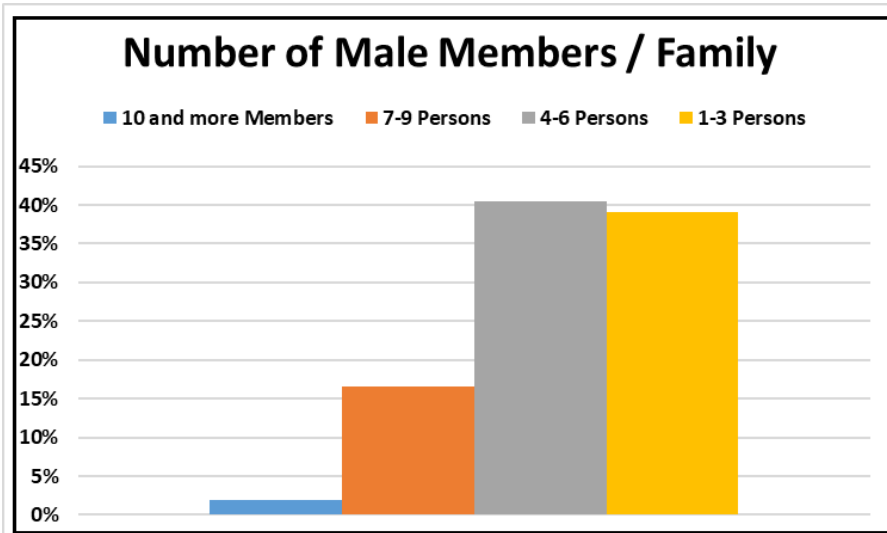


Fig. 8: Male children in each family

They preferred male birth and bigger family size, thirty-six percent families who had 9-10 members in their family had 6 male members per family.

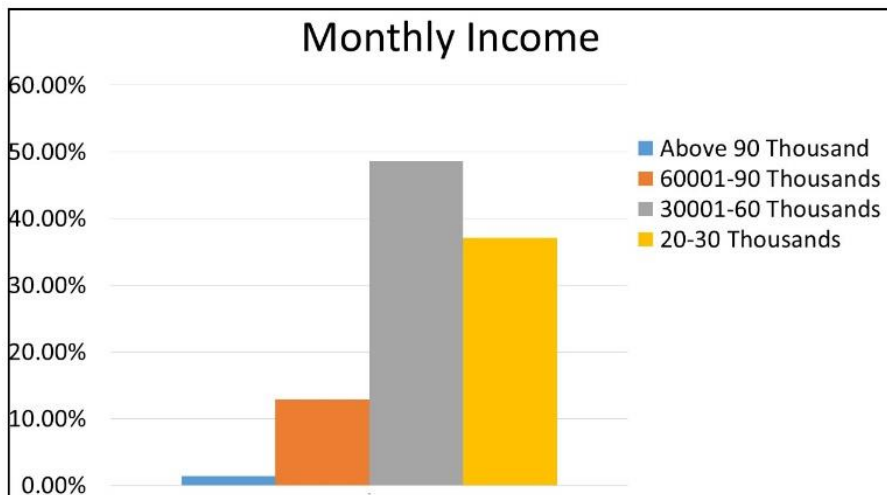


Fig. 9: Monthly income of families in study area

Just four percent families earned around 1 lac rupees each month, they had transport or construction business. Forty-four percent were rickshaw drivers and masons they earned around 45 thousand rupees.

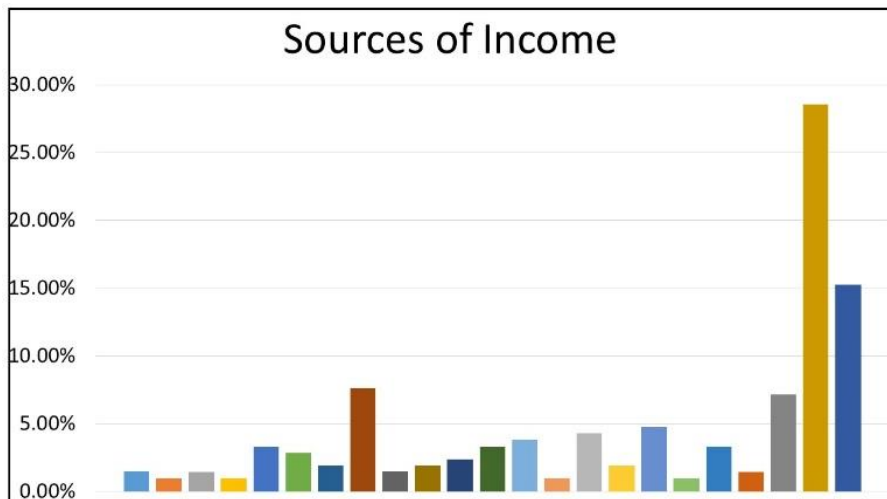


Fig. 10.1: Families Sources of Income



Fig. 10.2: Families sources of income

Male members of seven percent families had government employment, they belong to Sindhi caste, and twenty-nine percent were masons, the third largest occupation were rickshaw drivers, and Baloch male members went to Dubai to earn their livelihood.

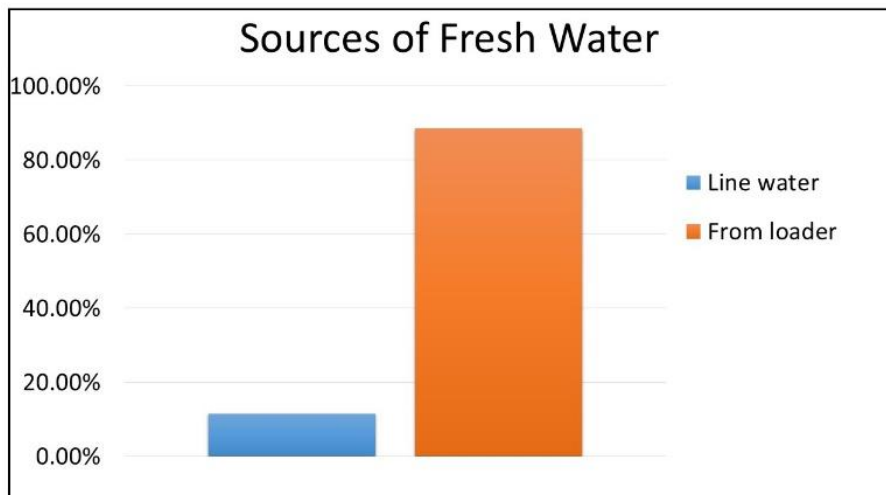


Fig. 11: Usages of different sources of fresh water

Just seventeen percent families had fresh water line connections from KW&SB (Karachi Water & Sewerage Board), other purchased drinking water from RO (Reverse Osmosis) plants. It was found during survey that eighty-three percent houses had their own bore-wells (boring depth varies from 110 feet to 130 feet) irrespective of their house size.

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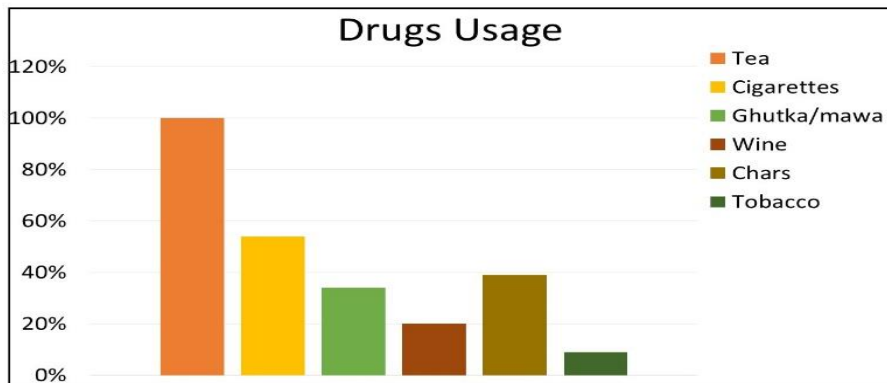


Fig.12: Usages of different types of drugs

During survey it found that fifty-two percent were Cigarette smokers, Gutka-mawa were also prevalent in thirty-four percent families, and twenty percent people occasionally drink alcohol/wine, and thirty-nine percent took drug, and five percent used Tobacco in different forms.

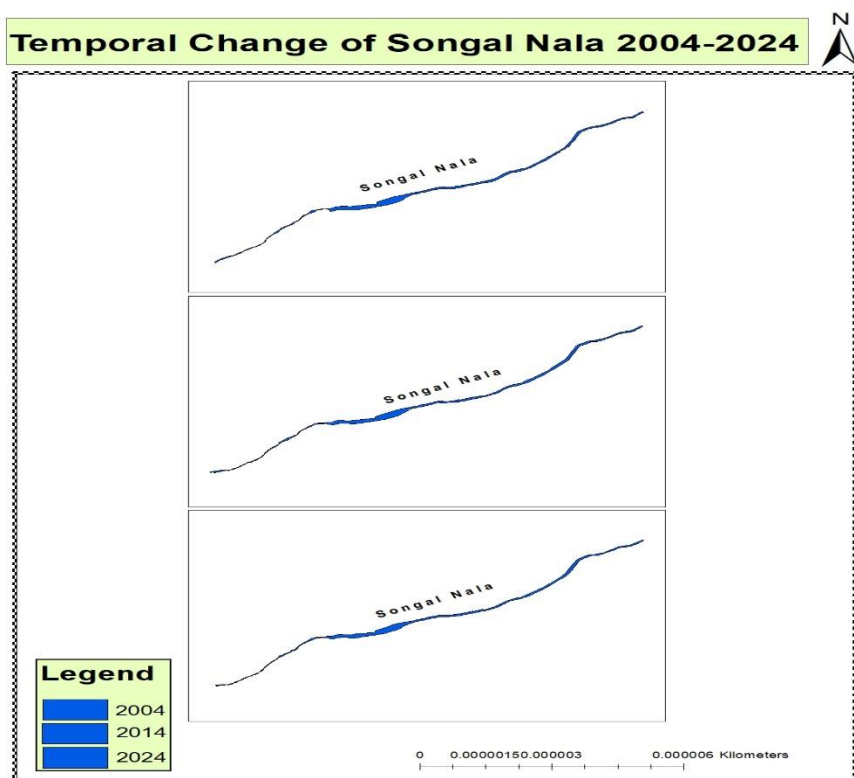


Fig. 13: Comparative digitized maps of the Songal Nala region (2004–2024) illustrating temporal changes in land use

Using NDBI data for 1989 and 2023 together with the digitized maps of 2004 and 2014, the total built-up area and the extent of encroachment were calculated. The summary of these results is presented in the following tables.

Table 2: Land encroachment upon Songal Nala

Period	Total Built-Up Land in Study area	Total Songal Nala area
	m ²	m ²
1989	67775700	75963.7
2004	72214593	64478.5
2014	77236592	57256.1
2023	78621070	54932.2

Source: Author

Table 3: Land encroachment upon Songal Nala

Period	Percentage change in Built-Up area	Percentage change in Songal Nala area
	%	%
1989-2004	6.1468%	15.1193%
2004-2014	6.502%	11.2014%
2014-2023	1.7609%	4.0586%

Source: Author

Table 4: land encroachment upon Songal Nala

Period	Percentage change in Built-Up area	Percentage change in Songal Nala area
	%	%
1989-2023	13.79448%	38.286287%

Source: Author

It is evident from above table that Songal Nala thirty-eight percent width reduced from 1989 to 2023. In which fifteen percent width reduced during 1989 to 2004 and eleven percent from 2004 to 2014. It is found in present study that Saraiki families came from Punjab to get better employment opportunities, they were living on rent along Songal Nala because of cheap rental price of land. Saraiki family twenty seven percent males were working in textile factories, forty seven percent were masons and painters, and twenty six percent were rickshaw drivers, and ninety three percent of their women were working as housemaid. Width of Songal Nala reduced because of urban land encroachment resulted occurrence of flood once a year. During survey twenty-seven percent families said that whenever flood occurred flood water entered their homes caused high damage of

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property, and they were not yet able to overcome this problem due to lack of available income resources.

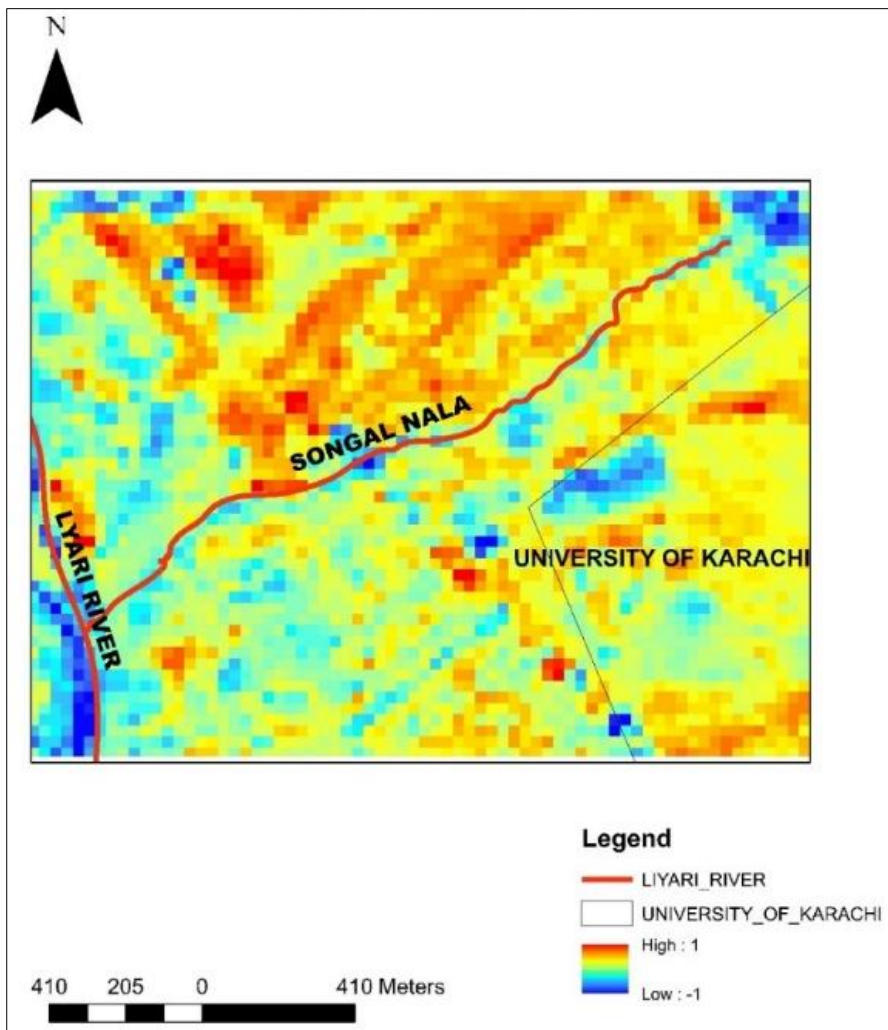


Fig. 14: Map of NDBI showing Built-Up area in study area (1989)

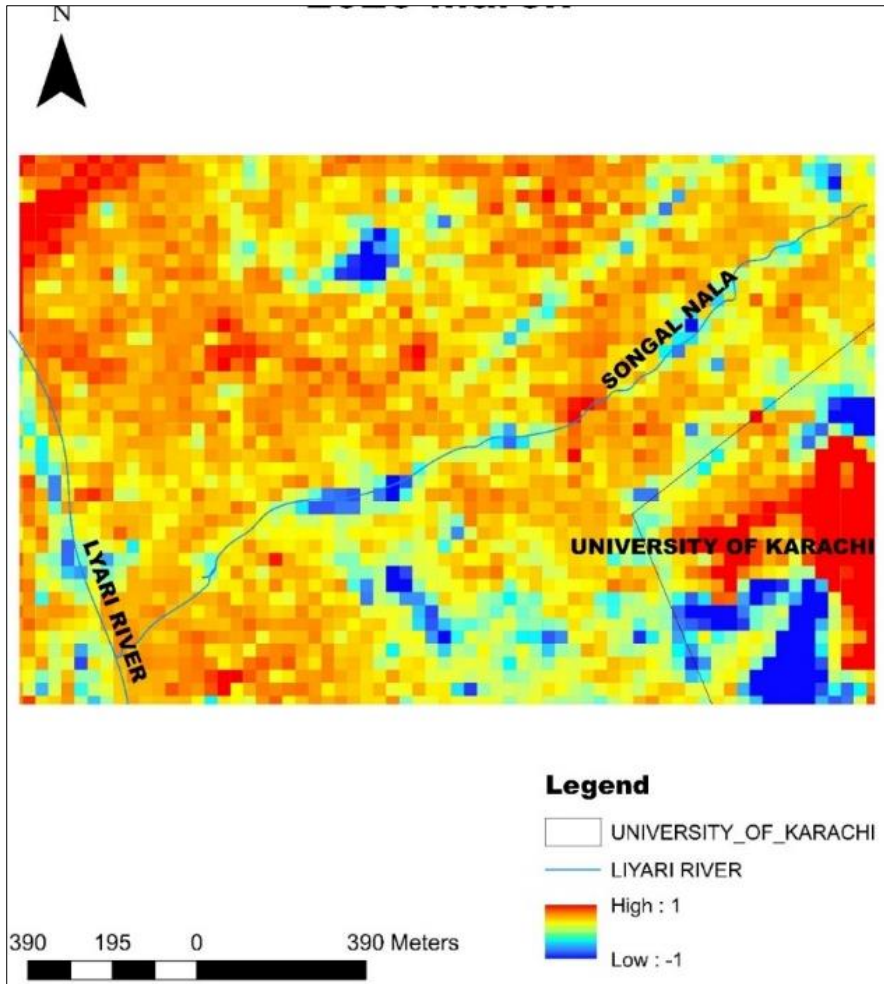


Fig. 15: Map of NDBI showing Built-Up area in study area (2023)

On a map higher values or positive values represented by red color indicating concrete land or urban built-up areas while the lower values represented by blue color highlighting land which were not made up of concrete. NDBI had sensitivity that it overestimates concrete land and include bedrock in it which are without vegetation into built-up area (Basnet et al., 2020).

CONCLUSION

The research has been focused on the application of Geographical Information System (GIS) in analysis of land encroachment on Nala's which had adverse effects on overall lives of nearest living families. This research is based upon Songal Nala which is in Karachi. Songal Nala area decreased thirty-eight percent from past three decades because of encroachment, and it had negative effect upon Songal Nala residents' social life. The

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current study will draw the attention of key stakeholders to regional development in general and local development, in particular, to mitigate or at least minimize these problems, which are putting adverse effects on the social and physical environment through these encroachments. It could also be helpful to researchers, students, and persons to identify other research questions and recommendations for future research studies in this field. Geo-spatial software, particularly ArcGIS 10.9, was used for data processing and analysis in this research. I also conducted field surveys and filled questionnaires to support the findings. Using geo-spatial tools helped make the work quicker and easier to manage, while field observations added reliability to the results. The objectives of this research achieved by using GIS tools and ground survey. Ground survey composed upon seventy-five socio-economic questions. Landsat images of year 1989 and 2023 downloaded from United State Geological Survey (USGS) website, which then digitized by using ArcGIS software. To found encroachment, calculate geometry tool used in arc tool box of ArcGIS software. The results show that land encroachment and blockage of the natural drainage along Songal Nala have increased over time. These findings are important because they explain many local flooding issues and can help in planning better drainage management. This study is a bit different as it used both satellite images and field checks together to show these changes clearly. In future work, I plan to focus on flood risk mapping and regular monitoring of drainage areas using updated satellite data.

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Author's contribution

Muhammad Yaseen conceived and designed the research, conducted data collection, performed analysis, and drafted the manuscript. Dr. Salman Zubair provided critical review and valuable suggestions that significantly improved the manuscript. Both authors have read and approved the final version of the manuscript.

Conflict of interests

The authors declare no conflict of interest regarding the publication of this manuscript.

Ethical considerations

I prioritized several ethical considerations to ensure the integrity and sensitivity of my study. Firstly, I obtained informed consent from all participants involved in interviews and surveys, explaining the purpose of the research. Confidentiality was strictly maintained to protect the identities and privacy of participants. Transparency was upheld by clearly communicating my research objectives, methodologies, and findings.

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