Identification of Irregular Settlements Using Remote Sensing Technique and Calculating their Carbon Footprint: A Case Study of Islamabad

By

Imran Ahmad

(2018-NUST-MS-URP)

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Urban Planning

Department of Urban & Regional Planning
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THESIS ACCEPTANCE CERTIFICATE

Certified that final copy of the thesis titled ―Evacuation Decision Making and Behavior in Flood-Prone Rural Areas: A Case Study of Dera Ismail Khan‖ written by Mr. Imran Ahmed (Registration No. 00000275952), of Urban and Regional Planning (NIT-SCEE) has been vetted by the undersigned, found complete in all respects as per NUST Statutes/Regulations, is free of Plagiarism, errors and mistakes and is accepted as partial fulfillment for the award of MS degree. It is further certified that necessary amendments as pointed out by GEC members of the scholar have also been incorporated in the said thesis.

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Date: _______________________________________

DEDICATION

This work is a humble dedication to Almighty Allah our Creator and Lord and to our dearly loved Homeland Pakistan. I proudly dedicate my work to my beloved parents and my wife who have always been a constant source of encouragement for me. They have given me the drive and discipline to tackle any task with enthusiasm and determination. Without their love and support this project would not have been made possible.

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Imran Ahmad

ABSTRACT

Islamabad is a planned city of Pakistan. Over the years, due to economic growth it has been a hub for immigrants. Since it is a capital of country so most of the people came here for Government jobs. In recent years, the population of the area rises significantly as more than double in last decade. Despite of being a planned city due to high population many irregular settlements, slums and likewise areas were created in urban area of Islamabad including settled and unsettled areas. Government must provide them the basic health facilities and eradicate their poor habitat. But official managers were unable to do so because they were unaware of exact population, area, and size of these types of localities. As a result, the epidemic cases were increasing in the area. For instance, the micro plans that are developed for the easy access and approach of settlers in the areas totally neglect the communities in the irregular settlements and likewise localities because of them being not considered for any resource allocation. Communities in these types of irregular settlements are both unregistered and registered with the Capital Development Authority (CDA) as CDA by itself has assigned them an identification code. Most of the localities have no record of their need and issues, health hygiene, sanitation, clean drinking water are other main problem of these types of areas. Government and semi government organizations cannot show any progress as they are not included in any of their plans.

This study was aimed at devising a fast and low-cost methodology to identify and delineate these kinds of irregular settlements in the urban sectors of Islamabad by using remote sensing techniques and digital technologies with a view to help them improve their habitat and access to socio-economic and basic health services. The satellite imagery was used to classify the boundary of these irregular settlements, their spread from 2004 to 2019 and through ground truthing the availability of basic facilities in these types of irregular settlements were validated. Moreover, the information about availability of basic amenities like refrigerators, air conditioners, mass communication, types of structures, owned transport and access to public transport were all collected through Focus Group Discussions (FGDs) held with communities. Significant increase was noticed in the focused irregular localities during past 02 decades. This increase in the spread clearly shows that as population size was increased and the irregular settlements were expanded. So, using the technology we can gather the information of area and its sprawl to take decisions accordingly. This study can also help to the health sector to provide basic health facilities in the area and any type of vaccination program can be planned and managed effectively.

Another assumption regarding irregular settlements is the production of greenhouse gas emission and an increase in the overall carbon footprint of the cities. So, to establish a supplementary comparative study as part of this research was held and overall carbon footprint resulting from greenhouse gas emission both by the irregular settlement and planned sector was calculated. The objective of this supplementary study is to sensitize the urban planners, environmental engineers, and city administrators to take their decisions based on appropriate factors and their subsequent analysis and the findings of this study will help the planners to concentrate their efforts on appropriate unit by devising customized environmental improvement strategies but in a holistic context.

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Chapter 1

Introduction

Human migrations from one place to another in search for better economic opportunities or security play a determining role in sprawling up of informal settlements in urban cities. According to United Nation estimates, about half of the world's population currently lives in urban slums. The figure is expected to rise by 6.5 billion in 2050, thus making urban migrants two-thirds of the population. In the last couple of decades, rapid urbanization was experienced in the developing world. While the cities in the developing world were not prepared to meet the needs of the expanding and growing population and consequently in many cities' slums emerged. There have been various types of interventions to deal with the problem of the spread of slums worldwide i.e., from relocation of slum dwellers to integral interventions, consisting of each infrastructure works, and social services targeted to poor neighborhoods. However, the interventions were either ad hoc or created a confusion between slums and *katchi abadis* due to which they were not pursued. Another associated aspect with urbanization and irregular settlements is the increase in carbon footprint which goes unnoticed by the authorities. It must be noted that carbon emission has significantly increased directly because of household energy consumption in Pakistan. This is visible in the country's rank among climate vulnerable nations. Another factor that has led to the urban carbon footprint is the unsustainable use of energy. To understand the spike in carbon footprint, a study into household carbon footprint is important. Combining these factors and introducing methodological nuance, this study makes a pioneering contribution by providing deeper insights into the expansion of slums/ irregular settlements and increase in carbon footprint.

In general, slums are perceived to be the settlements that are largely devoid of most basic social services in terms of health, education, water supply, public transportation, electricity, or sewerage. A more operational definition provided by UN-Habitat is as follows: "Areas characterized by inadequate access to safe water, sanitation, poor quality of housing, overcrowding and insecure residential status" (Habitat, 2007). The most pressing concern concerning the spread of slums is poverty. Poverty can be gauged by the measurable indicators for deprivation of social service delivery, and by the lack of urban city plans and policies dealing with it (Nolan, 2015). To make matters worse, there appears to be a lack of policy that can address a myriad of urban issues pertaining to the economic demands, migrations from rural to urban, or from within the cities, availability of basic services and infrastructure for health and education.

In local context, the slums are commonly recognized as *katchi abadis*, which literally translate to ‘temporary dwellings. The inhabitants of such communities live in vernacular structures consisting of concrete, semi-concrete, mud, or makeshift structures made of cloths, thatch or sticks, straw, mud, etc. In indigenous terms, their houses are termed either as *katcha* (non-concrete or semi-concrete structures) or *pakka* (housing structures made from concrete materials). The *katchi abadi* settlements have their origin in initial mass migrations to Pakistan from India during 1947. In a matter of just three years since its independence, the populations swelled from initial four hundred thousand to one million. With a huge influx of population and a lack of administrative control, the new Government of Pakistan gave the refugees permission to settle in any vacant land, thus giving rise to the trend of informal trading which remains prevalent in many parts of Pakistan even today (Abbas et al., 2019).

Currently, owing to conflicts, population dynamics, employment trends and changing economic conditions, rapid rural-urban migrations are occurring throughout the country, mainly in the 10 mega-cities. Even within the pockets of rural areas, population density threshold has reached 400 per kilometer in sprawled-up settlements, thus giving them the characteristics of urbanized locality, which are also known as “desakota”, which bring their own set of challenges in terms of service delivery to the poor (Kohli et al., 2012).

While the local term for slums has a universal appeal, the scope of it is, however, limited in terms of governance. For the administration, a katchi abadi is defined under Katchi Abadi Act, 1992, which is in place for all the four provinces of Pakistan. In Punjab, the Act technically defines a Katchi Abadi as (Fernandes, 1994): “Any area or part thereof which was occupied unauthorized before (31st December 2006) and continues to be so occupied and has at least forty dwelling units on it”.

Administratively, the development authority of a city requires a katchi abadi to have houses built of concrete material to be regularized. A notified katchi abadi is eligible to receive basic services, whereas the unregistered settlements remain largely neglected. The residents of a katchi abadi can have ownership rights of the land only if they fulfilled all criteria defined by the development authority, as costly process which discourages many poor. Owing to their unrecognized status, the authorities generally do not attend to their equitable demands in terms of bringing improvements in their quality of life and living standards (Mustafa, 2019). It is also noteworthy that the Katchi Abadi Act is applicable only for those lands that belong to the government. The sprawled-up communities on the private lands have no jurisdiction of the Katchi Abadi Directorates, thus, their inhabitants often face the risk of evictions during anti-encroachment drives. In Punjab province, it is estimated that the identified Katchi Abadis on government lands are 1287, out of which 900 have been notified. Whereas, Sindh has 1300 notified settlements, Baluchistan has 55 and Khyber Pakhtunkhwa has 65 notified katchi abadis. It is noteworthy here that Punjab has the least share of settlement span on private lands, whereas it is the highest in KP province. The Table 1.1 shows province-wise notified katchi abadis and their sprawl on government and private lands.

Table 1: Province-wise Katchi Abadis

Province	**Katchi Abadis (Notified. Acres)**	**Govt. Land (acres)**	**Private Land (acres)**
Baluchistan	55	2,826	0
KPK	65	1,509	3,434
Punjab	902	8,875	501
Sindh	1300	24,300	1,700
Total	2322	37,510	5,636

While the slum dwellers remain largely unrecognized, it is often forgotten that they remain major contributors to the economic development as they are the prime sources for instant and easily available labor. Slums are formed because of massive and rapid urbanization which poses a great burden on city's available resources. Through urbanization, Punjab is fast transitioning into manufacturing-based economy from agriculture. According to a research, Punjab at present is hiring nearly 60% of its labor for industries. However, there appears to be a lack of policy that can address a myriad of urban issues pertaining to the economic demands, migrations from rural to urban, or from within the cities, availability of basic services and infrastructure for health and education. Simply, this paper tries to establish a methodology to delineate the irregular settlements taking place or being established at different point in time. Likewise, for planners, city managers, health care service providers and for the responsible people to provide municipal services, the methodology is useful.

The researcher conducted this research on identifying and delineating irregular settlements for the reasons, which are as under:

- To help administrators and managers from non-governmental organizations to have a decision support system to declare an area as a slum and make them able to differentiate slums from squatter settlements.

- To help planners both from development authorities and non-governmental sector to have a realistic equation to be applied for the population estimation.
- Development authorities in Pakistan are meant to develop both rehabilitation cum improvement and resettlement plans for the slum's dwellers. The use of technological intervention to identify slums and likewise areas in Capital Development Authority Islamabad for the planning and improvement purposes will help them to identify the needs being fast while being in their office premises and they can plan whatever they want to improve upon.
- The environmental impact of the houses of the irregular settlements is to be determined by calculating overall carbon footprint in comparison with the planned sector for a better and holistic planning by the city developers, administrators, and urban planners.

Keeping this in view, this research has used remote sensing and in-situ techniques to gather information about the urban slums and their sprawl in Islamabad. This study contributes by providing helpful insights to the health sector to give access of basic health facilities in the slum areas where government-led vaccination programs can also be conducted effectively. Overall, using the techniques used in this research, more timely and informed decisions about planning of settled areas can be taken.

1.1 Problem Statement

Thus, it is extremely important to develop a methodology for the delineation of the irregular settlements comprising both slums or katchi abadis (Câmara et al., 1996), demarcation and identification which is quite fast with a view to help governments to develop plans for the improvement of living conditions of the dwellers of these irregular settlements (Gruebner et al., 2014). While speaking or talking about improved living conditions, for the houses and inhabitants of the irregular settlements may it be the slum or katchi abadi, the overall carbon foot print the existing one and greenhouse gas emission in terms of the metric tonnes is to be known by the urban planners. Their solutions in terms of the location, rehabilitation and improvement of irregular settlements are not sensitive of the production of overall carbon footprint.

In this view, this research thesis explores the use of satellite images that can help in ensuring the availability of data on the establishment of irregular settlements and likewise areas more readily available for their inclusion in development planning (Chen et al., 2000). Profiling of unidentified in fact undocumented sections of urban poor by mapping unlisted and hidden slum clusters, temporary settlements with poor or no infrastructure is an important strategy to help development authorities and municipal corporations for developing resettlement plans, compact city development improving existing slums (Hoalst-Pullen & Patterson, 2011). It is important to note that having a consistent definition of slum in a consistent manner geographical targeting within slum intervention programs on global as well as local scales (UN-HABITAT 2018). The potential of using satellite imagery in producing data/ information related to slums is being realized by the global community, whereas, adequate robust methodologies do not exist. The major difficulties include the lack of generalised definitions across different contexts and the high variability in the characteristics of slums. Additionally, an assumption usually exists in the development managers arena is about the increased carbon footprint due to establishment of these types of irregular settlements. So, the study indirectly tried to establish a finding regarding contribution towards increased carbon footprint by the residents of these irregular settlements as well calculated based on calculation of production of greenhouse gas emission.

1.2 Objectives

- To help administrators and managers from non-government organizations to have a decision support system to declare an area as a slum and make them able to differentiate slums from squatter settlements.
- To help planners both from development authorities and non-government sector to have a realistic equation to be applied for the population estimation.
- Development authorities in Pakistan are meant to develop both rehabilitation cum improvement and resettlement plans for the slum's dwellers. The use of technological intervention to identify slums and likewise areas in Capital Development Authority Islamabad for the planning and improvement purposes will help them to identify the needs being fast while being in their office premises and they can plan whatever they want to improve upon.

Overall carbon footprint of the irregular settlements calculated based on greenhouse gas emission is known, calculated, and used by the development authorities while planning the rehabilitation and improvement plans both for the planned sectors and irregular settlements. The objective of the study was to determine those irregular settlements are producing and contributing more greenhouse emission leading to increased carbon footprint in urban areas of Islamabad when compared with planner or settled areas.

Chapter 2

Literature Review

2.1 REVIEW OF LITERATURE

This section provides a brief overview of the existing literature about urban slums, the living conditions in irregular settlements and the overall impact of such dwellings on the environment. Furthermore, the literature clearly elucidates that the study of slums is significant to devise a sustainable solution to hamper their spread. Adding to this, this research explores the use of satellite images that can help in making the provision of data and information on slums more readily available for their inclusion in development planning as also illustrated by Chen et al. (2000). It must be noted that the profiling of unidentified in fact undocumented sections of urban poor by mapping unlisted and hidden slum clusters, temporary settlements with poor or no infrastructure is an important strategy to help development authorities and municipal corporations for developing resettlement plans, compact city development improving existing slums (Hoalst-Pullen & Patterson, 2011).

In light of this, to integrate more thorough approaches to urban city planning, inclusive of urban informal settlements, a policy agenda, better known as New Urban Agenda, was adopted during a UN Habitat-III Conference on Housing and Sustainable Urban Settlements, held in Quito, Ecuador in 2016 (Organization, 2016). This agenda was then duly endorsed by the UN General Assembly which provides workable guidelines to be considered by the governments across the globe. This policy document is important as it calls for meaningful inclusion of the slum dwellers into the economic mainstream. It must be noted that while the slum dwellers remain largely un-recognized, it is often forgotten that they remain major contributors to the economic development as they are the prime sources for instant and easily available labor.

To define the slums, Doshi (2015) contends that slums are situated where there are drains and lack of facilities like lavatories, roads, schools and public and health services and where houses are in the form of huts and made from waste materials, tin and sheets of asphalts, plastic bags, waste tires, old bamboos sticks, tree leaves and mud. This indicates that the homes in slums are in urgent need of mending. As a building they are usually in bad condition with lack of facilities and full of people. Whereas, in the works of Percival and Homer-Dixon (1998) they define dense settlements comprising of communities housed in self-constructed shelters under conditions of informal or traditional land tenure. The study reveals that the areas cover most of the urban areas which causes many routine disruptions and harms to all the area.

In this vein, the work by Faiza et al., (2019) found that the slums that belonged to "non-transferred areas", where inhabitants did not have ownership rights, and were vulnerable to poverty than those slums belonging to "transferred areas". The study also revealed that 48.3% of the people living in slums in Vehari, Pakistan, did not have basic socio-economic facilities. Similarly, Katukiza et al., (2010) through their studies shared that the sanitation solutions for urban slums were extremely challenging for space, access, and sense of ownership. In another study, by Huchzermeyer and Karam (2006) explained the challenges and health issues which they observed in slums. They also identified several settlements that were not planned and did not have formal permission to settle from the government. While many studies and intervention programs for urban development discuss the problems and issues pertaining to slums, ample of focus has been given to research which have also identified the spread of slum dwellings.

For instance, Khan (1994) discussed the case of Bangkok, Thailand, in 1993, where an estimated 18% to 20% of the population were living in "slums", or under-serviced settlements. Most of these dwellers were tenants while some of them were had been living illegal on the land. Whereas, the case of Dhaka, Bangladesh suggests that 50% of the population lived in slums while in Manila, the Philippines, this figure stood at 40%. In the case of Indonesia, these estimates stood at 55% as the urban population lived in settlements without water supply, and 70% lived in areas with no sanitation network (Meyer et al., 1995). The data also provides insights about the spread of slums around the world. The studies and literature mentioned above presents a discussion on slums, their spread, and the lack of basic life necessities. However, urban and development studies have taken a turn to include satellite imagery to study the spread of slums, especially in the surrounding of planned areas. This research also sets out to make a similar contribution, particular to the context of Islamabad, Pakistan. And established that remote sensing of high and very high-resolution calibre has proven to be a significant source of data in this matter. In a similar vein, Mahabir et al. (2018) also contend that slums are a worldwide problematic phenomenon with underdeveloped countries being specifically affected. They further contend that to be able to geographically plot them out, extensive information is needed about their whereabouts, spatial extent, and gradual progression. Their research aimed at overviewing the data used in research to detect and map slums. They contended that that although the use of remote sensing to map slums have been increasing over time, their focus tends to be on a limited locality and they usually employ a single approach, thus restricting the generalisability of the findings to be applied in a global context to understand the slums and their population. Mahabir et al. proposed that geospatial data along with new trends and technological developments should be used to detect and map slums under a holistic framework. Through this integrative approach, the most adequate methodology for mapping slums can be singled out and used to confront this challenge.

Building further on this, Kit et al., (2012) have made the identification of informal settlements possible through high resolution satellite imagery using lacunarity. They used high resolution binary representation of Hyderabad, India by using principal component analysis and line detection algorithms. In their research, a number of grounds truthing areas were used to classify the resulting datasets and to identify lacunarity ranges which were typical for settlement types that combined high density housing and small dwelling size features characteristic for urban slums in India. The findings of their research proposed that the emergent slum location maps could assist in pinpointing the overcrowded areas of the city and help in the vulnerability and resilience assessments conducted afterwards. Their study also suggested that the developing urban agglomerations globally can benefit from the application of rapid analysis and comparison of multi-temporal data.

According to Kohli et al., (2016) the variations in slum categorizations and descriptions make the detection of slums through satellite imagery difficult. This research put forth a proposal for slum detection studying the morphology of the 'built environment'. Their methodology comprised of segmentation and then classification in a hierarchical order, using object-oriented image analysis and incorporating expert knowledge of local slum ontology. Furthermore, their work used the size of segments and portions of vegetation as special metrics for slum detection. The agreement percentage between slum classification and the reference layer was 60 percent, which was lower than the land cover classification (80.8 percent), caused by huge variations. Kohli et al. concluded that the methodology achieved beneficial results and possessed the capacity to be useful in situations with similar morphology.

In similar vein, Kuffer et al., (2016) found that the availability of very-high-resolution (VHR) sensors has increased the dependency of slum mapping scientific literature bodies on remote sensing methods. This contributes towards information gathering for pro-poor policy development and building means for systematic global slum monitoring, which in turn helps international policy development, for instance the Sustainable Development Goals. The overview provides remote sensing publications related to slum mapping, covering the span of 2000-2015, across four dimensions of contextual factors, physical slum characteristics, data requirements and slum extraction methods. Their results exhibited the limitations of knowledge about the global diversity of slums and the lack of appropriate imagery of slum dynamics. Furthermore, they proposed that a thorough investigation into the physical features of the slums is needed to produce concrete image-based proxies. They also contended that despite the latest commercial sensor technologies providing image data of less than 0.5 m spatial resolution with improved object recognition in slums, the complex and variable morphology of slums makes extraction through usual methods difficult. Moreover, the extracted information, implemented indicator sets and employed methods exhibit the diversity of the successful approaches. Within the global slum inventory, texture-based methods provide firm results across cities and imagery. Kuffer et al. concluded that to enable global slum monitoring, the algorithms need to be trained through developing a methodised relationship between elements of higher-level images and slum features, to fully understand variations in slum morphologies.

Whereas Liu and Yang (2015) state that observing land changes can help in managing resources and planning landscapes. Using satellite imagery, geographic information system, and landscape metrics, urban land changes in Atlanta metropolitan are evaluated in their study. The study site was a rapidly increasing network in the United States, comprising of complex landscape types. The methodology and process adopted by them comprised of remote sensing-based land classification and GIS-based land change analysis. They also employed a strategy of stratified image classification combined with a GIS-based spatial reclassification to map land classes from Landsat Thematic Mapper (TM) which were obtained in two different years in their research. They also adopted post classification change detection and a variety of GIS-based operations to gauge the spatial fluctuations and spread of urban land variations across the city zones. They also used landscape metrics to study the size, pattern, and nature of land changes. Just as in this research, the remote sensing combined with GIS and landscape metrics enabled them to take note of spatial patterns and examine the hidden causal processes of urban land changes. However, they concluded that despite the overarching suburbanization process, the results depict a shift of urbanization patterns towards a limited outward expansion.

According to Verma et al., (2019) slums provide affordable labour and casual services which significantly contribute towards Gross Domestic Product (GDP). However, such localities are urban risks due to overpopulation and unsuitable living standards. The socio-physical health of such communities has been halted due to negligence from urban management and poor legislation. They argue in their work that one of the contributing factors towards negligence is the lack of geographical and evolutionary documentation of the slums. And while multiple remote sensing techniques have been employed to address the problem, but no global solution has emerged so far. They suggested that recently Deep Learning Techniques with remote sensing have proven to be successful in analysing the underlying mechanics of physical characteristics present in the satellite imageries. Verma et al. utilized the pre-trained convolutional networks of DL technique for slum detection through VHR and MR satellite imagery. As a result, they developed training datasets of four classes consisting of slums, built, green and water. The models were further trained to detect these classes in the city. Their findings resulted in a comprehensive technique for the detection of informal settlements which could be edited for suitable implementation to detect different landforms.

Another aspect associated with urbanization and expansion of irregular settlements is the increase in carbon emissions. In this view, this study makes another contribution by providing supplementary findings in the shape of comparative analysis of the production of carbon emissions between planned and irregular settlements. In the context of Pakistan, various anthropogenic activities such as the production of energy through the utilization of fossil fuels has contributed to the increased concentration of greenhouse gases, especially carbon dioxide emission which has the greatest share at 60% in all of the greenhouse gases (Khan & Jamil, 2015). It must be noted that the increase in carbon emissions is directly associated to the ascended consumption of the fossil fuels. This correlation has emerged as a requirement to attend to the increased urbanization and growing population in Pakistan and the world at large. However, studies and research have also established that the increasing carbon footprint is also directly associated with the rise in income, especially in the global south, which is directly proportional to increase in car/ vehicle ownership while their usage greatly adds to the increase in carbon dioxide emissions (Timilsina & Shrestha, 2009).

The phenomenon of carbon footprint is related to the measurement of carbon dioxide and other carbon compounds which are released into the environment through the utilization of petroleum products by individuals or groups, etc. However, these emissions may be direct or indirect. This further means that primary carbon footprints include emission estimations from direct carbon dioxide because of domestic use and also transportation (cars, plans, etc.) since they are using non-renewable sources of energy (Adnan et at., 2018). Various studies have been conducted to analyze the carbon footprint at the level of houses or industrial levels at different areas around the world (Shirley, Jones, & Kammen, 2012). However, they establish a clear differentiation between primary and secondary carbon footprint.

For instance, Kerkhof et al. (2009) argue that release of carbon at household-level includes emissions from sources such as cars, bikes (automobiles) used in the houses which contribute to direct production of emissions while indirect sources include household products for instance televisions, furniture until they are disposed (Kerkhof et al., 2009). The link between urbanization and increasing carbon footprint has directed interest towards the exploration at household consumption. In this view, Bendewald & Zhai (2013) argue that investigation carbon footprint at housing sector provides a baseline assessment and information in identifying the leading contributors of carbon dioxide emissions in the urban settlements (see also Gardezi et al., 2016). However, it must be kept in mind that this area of research is relatively new and unexplored and the lack of data constraints basic understanding into the phenomena. Furthermore, the uncertainties or lack of data on the carbon footprint in Pakistan has directly impact the formulation of effective climate change policies. Despite these limitations, some studies have clubbed urbanization, irregular settlements, and the increase in carbon footprint to provide depth and understanding to this area of study.

The study by Adnan et al. (2018) reiterates that carbon emission, urbanization and climate change are closely associated. The objective of their study was to draw a comparison between the carbon footprint of the urban slum (Kachi Abadi, Khayaban-e-Sir Syed) and non-slum areas (Bahria Town, Gulraiz Colony) of Rawalpindi city. This contrast reflected the negative impact on the environment which the household energy usage has. The results of their study indicated that the carbon footprint of non-slum locations was higher than urban slum areas. Their findings also indicated that the increase in monthly income of the inhabitants of the households directly impacted the carbon footprint of the non-slum areas. Further analysis revealed that personal transports exponentially increased the carbon footprint of non-slum areas. Adnan et al. argued through their conclusions that the main household parameters which depict the energy usage patterns associated with carbon emission should be regulated. Irresponsible usage in households leads to an increase in carbon footprint at domestic level which could be decreased by using less carbon intensive items.

Based on ‘multiple fuels-multiple choice’ framework, Jan et al. (2012) examined the present-day sources of energy and the deciding factors for a household in their choice of that specific source of energy. The data for this research was gathered through random selection of households from two villages of northwest Pakistan. The results showed that rural settlements consistently relied on biomass fuels for household energy use while having other energy sources available to them. According to the socioeconomic standing of the study groups, they switched between their sources of fuel. The study found that the monetary background was not the only factor in deciding upon either a conventional or modern source of energy. Factors such as availability of alternative energy sources and personal preferences also contributed towards the domestic energy choice.

According to Bano et al., (2018) reducing carbons emissions is a pressing concern universally. They contend that the progression of human resources can assist in decreasing the carbon emissions. The long- and short-term impacts of human capital on carbon emissions in Pakistan were perused within this paper, spanning the duration from 1971 to 2014. For analysis of the assimilation and direction of casualties between human capital and carbon emissions, autoregressive distributed lag model and the vector error correction model was used. The findings indicated that a long-term association exists between human capital and carbon emissions. Furthermore, betterment of human capital should decrease carbon emissions without stunting economic growth. An improvement in human capital through awareness and education can reduce the carbon emissions in the long term. The findings from their work can help lawmakers strategize to reduce carbon emissions through the responsible use of human capital.

According to Colenbrander et al., (2016) climate change alleviation gravely depends on the rapidly increasing cities in the global South. However, they argue that governments in the global south are more occupied with the city's socioeconomic needs, such as poverty. The authors used the case of Kolkata in India as an economic case for low-carbon urban progress. They argued that by 2025, Kolkata is estimated to reduce its energy bill and greenhouse gas emission by 8.5 and 20.7 per cent respectively, through the employment of affordable mitigation prospects. And in this case, some of these prospects had great societal benefits, especially public health. However, Colenbrander et al. argued that others disrupt the low-income urban residents' lifestyle, limiting their affordable benefits. The results of their study found that the municipal mitigation methods had to be strategized in accordance with the affected communities so that their social costs could be reduced, bringing about an overall change.

In another case exploring 'green housing', Dewi et al., (2016) studied the housing policy of Tangerang's local government which stated that the residential area had to be revitalized through the 'green housing' process. For urban planning, carbon footprint had to be factored in as an indicator of sustainability. In their work, studies reviewed policies from the socio-economic perspective rather than carbon emission footprint per capita. Dewi et al. used carbon metric, GIS and system dynamic methods, and an approximation of carbon footprint per-capita was made in relation to the green housing process. The study explored the entire life cycle of building: construction phase, operational phase and demolition phase. The settlements incompatible with RTRW (urban land use planning) were demolished. The results indicated that the construction and demolition processes contributed to higher carbon footprint in the early policy implementation duration. However, over the long run the carbon footprint per capita was reduced due to the practice of green housing.

Whereas McGee et al. (2017) studied the relationship between urbanization and carbon intensity of well-being (CIWB) in countries from 1960±2013. In their study, the ups and downs in this equation were impacted by the economic background and whereabouts of the nation’s urban population. The UN definition of slum households was used to recognize developing countries that have a significant number of slum populations. The results indicated that the rate of increase in CIWB for nations without significant slum populations slowed down when urbanization levels increased. However, the link between CIWB and urbanization is relatively insignificant in countries with large slum settlements. While urbanization is linked with an increase in CIWB, their correlation marks a stark difference in developed countries without slums than in under-developed countries with slum populations.

Wismansyah et al. (2019) used the concept of land re-adjustment (LR) to Tangerang City to put forth their arguments about slum management and reducing carbon footprint. Additionally, LR is considered a practical model managing land development in the urban development process. The authors argued that one of the most important and complex issues managing the improvement of slums is associated with ownership of the land by multiple individuals/ parties. In most developing states, this issue is resolved through by relocating or by providing apartments to the inhabitants of the slum areas. The authors proposed the development of slum areas by considering three aspects: social acceptability, affordability, and environmental sustainability. The findings by the authors suggested that in the management of the slums, the LR model can help reduce carbon emissions to about 40 % in comparison to other models. Keeping in view these debates, the next section outlines the methodology followed by data, results, and discussion.

2.2 LANDSAT DATA

The Landsat software is the longest-operating corporation for capturing of satellite images of the Earth. The Landsat Program is a series of Earth-observing satellite missions together managed through NASA and the U.S. Geological Survey. In cooperation with NASA, on July 23, 1972, the Earth Resources Technology Satellite (ERTS-1) was set in motion. Moreover, Landsat 8 has been one of the recent most launched satellites for collection data. The contraptions on board the Landsat satellites have taken hundreds of thousands of pictures via the direction of the missions, and the facts are a treasured useful resource for global change lookup and purposes in farming, forestry, geology, regional planning, and training.

The pictures, archived in the United States and at Landsat receiving stations around the globe, are a singular resource for international exchange lookup and functions in nearly all difficulty areas, and can be viewed via the U.S. Geological Survey (USGS) 'Earth Explorer' website. Landsat 7 records has eight spectral bands with spatial resolutions ranging from 15 to 60 meters; the temporal resolution is sixteen days. Landsat pics are typically cut up into scenes for handy downloading. Each Landsat scene is round 115 mils lengthy and one hundred fifteen miles broad. The Landsat application affords the longest non-stop world document of the Earth’s surface; it goes ahead to supply visually attractive and scientifically valuable photographs of our planet. In 1975, NASA administrator Dr. James Fletcher expected that if one area age improvement would store the globe, it would be Landsat and its successor satellites. Since the former 1970s, Landsat has always and constantly archived images of Earth; this unparalleled statistics archive offers scientists the strength to measure changes in Earth’s landscape. For over forty years, the Landsat program has amassed spectral data from Earth’s surface, making a historic archive unmatched in character, detail, coverage, and duration.

Chapter 3

Materials and Methods

3.1 Study Area

For this research, the Federal Capital of Pakistan, Islamabad, was chosen. Islamabad covers an area of 906 square kilometers and is situated between the Margalla Hills and Rawalpindi city, while geologically, Islamabad lies on the Potohowar Plateau (Sheikh, 2007). Being the federal capital, it also forms a cross-road between Punjab and Khyber Pakhtunkhwa (Figure 1.1). Administratively, Islamabad is divided into eight zones; for instance, administrative zone, commercial district, diplomatic enclave, educational sector, green areas, industrial sector, residential areas and rural area.

In terms of population, according to the World Population Review, the total population of Islamabad is estimated around 1,095,06460. Moreover, the trend analysis of the capital city has indicated that by 2025, the population would swell up to 2 million and would further reach 2.9 million by the year 2030 (Review, 2019). In the same way, the population in the irregular settlements has been expanding exponentially in the last two decades. This can be illustrated by the fact that almost twenty years ago, there were only twelve slums in and around Islamabad, however this number has now increased to 44 slums. Particularly, the areas in and around Sihala, Tarnol, Rawal Dam, Bani Gala, Barakahu, Bari Imam and Golra have witnessed the increase in the expansion of the population and number of slums.

Moreover, the analysis of the rapid urban development in Islamabad has indicated surge and expansion of slums and irregular settlements in new areas along with the aforementioned old ones. These areas include the sectors like I-9, I-10, I-11, I-12, and I-14. This is problematic since these expansions threaten the availability of the already scare natural resources in the city. The population estimates in these areas are also worrisome; for instance, it has been recorded that more than 0.2 million people reside in more than two dozen slums/ irregular settlements in the sectors such as G-7, H-9, F-6, F-7. To further corroborate this, a study by Leadership for Environment and Development (LEAD) has stated that three irregular settlements in Islamabad comprising of Chora Stop Locality, Akram Gill Colony, and Merajaffar area have an estimated population of 5,000, 2,000 and 1,000 respectively.

It is also noteworthy that more than a dozen of these slums or irregular settlements are legally occupied by their dwellers. These occupants are often given ‘ownership’ rights by the courts. However, basic necessities of life such as clean drinking water, sanitation facilities, supply of electricity and gas remain unavailable to many of these areas. Resultantly, the lack of basic amenities has contributed in poor health conditions, social and economic hardships for the dwellers of these irregular settlements.

The indicators contributing towards production of greenhouse gas emission or increasing carbon footprint i.e., air conditioners, vehicle ownership, gas connection availability and consumption, per capita mileage for the vehicle, bills of utilities etc. all are studied and used for calculating the carbon footprint of the irregular settlements and regularized settlements for sector G-7 of Islamabad.

3.2 Rationale for the Area Selection

The researcher intended to identify and delineate the irregular settlements and likewise areas and localities in the urbanized city of Islamabad. Islamabad was selected based on easy access for the researcher and limited number of research have been conducted to identify and delineate irregular settlements. Thus, an area of 24 Kms starting from 26 Number to Lake Blue Area in Islamabad was selected. Secondly, different non-government organizations are working in development sectors to improve the utilities and services in these irregular settlements. But the understanding of the non-government sectors and even administrators regarding slums and squatter settlements is quite limited and overlapping. Thus, researcher tried to develop a standardized and working definition of these irregular settlements and help them in classifying either as slums or squatter settlements and their differences from each other for a better planning.

The ground truthing for land use land cover analysis provided researcher opportunity to conduct a sample based scientific household study for data collection regarding greenhouse gas emission for the calculation of carbon footprint of the inhabitants of the irregular settlements.

3.3 Study Sample

Study sample for the land use land cover and image analysis was the 26 kilometers of the Kashmir highway and localities and sectors located surrounding the sectors located along Kashmir Highway. For the data collection regarding greenhouse gas emission for carbon footprint, two sectors i.e., G - 7 and F-7 are the areas for research study selected after the proper consultation of research advisor at department of Urban and Regional Planning at National University of Science and Technology (NUST). Transect walk of the irregular settlements in G – 7 sector and France colony of F-7 sector was conducted to get an idea about the types of utilities available in the area. Household visits of the irregular settlements were conducted to collect information about the greenhouse gas emission producing amenities i.e. Air conditioners, vehicles, refrigerators, monthly utility bills, daily milage and fuel usage, average monthly bills for the electrification or energy consuming products etc.

3.4 Study Tool

A simple questionnaire subject to the ground truthing of the irregular settlements identified through image analysis of satellite image for Islamabad was developed. The details of the areas studied for producing greenhouse gases and contributing towards increased carbon footprint in urban areas of Islamabad are as under: -

Table 2: Details of the Irregular Settlements Studied

S#	Irregular Settlements	Settled Areas	Number of houses visit
1	Faisal colony	G - 7/1	57
2	100 Quarters	F - 6/2	30
3	66 Quarters	G - 7/2	25
4	Allama Iqbal colony	G – 7	50
5	France colony	F – 7	75

3.5 Studied Variables in the Tool and Rationale for Carbon Footprint

1. Average annual travel distance on personal vehicle; both travel distance and personal vehicle ownership are required to calculate the fuel or fossil fuels consumption by the individual household weather in irregular settlement or planned areas.
2. Average annual Electricity usage: both for winter and summer the electricity usage is determined based on electricity bills i.e., usage of air conditioners and humidifiers in summer and winter and using electric geezers in winter etc.
3. Average annual Natural gas/ LPG usage i.e., natural gas connection in case of planned areas and LPG usage by residents of irregular settlements and their usage from utility bills and LPG cylinder costs are required to calculate greenhouse gas emission contributing to increased carbon footprint in Islamabad.
4. Average Vehicle efficiency i.e., per liter milage based on the type of vehicle i.e., Japan assembly line or Pakistan assembly line are to determine to calculate the contributing factor for increased carbon footprint.
5. Average annual travel distance on motorbike along with average motorbike efficiency are to be asked from the respondents to determine and estimate the fossil fuels contribution by the motorbike owners.
6. Average annual travel distance on bus in case of need are to be asked both from the respondents from irregular and planned areas residents because their fossil fuel is

contributing heavily towards increased carbon footprint and vehicle ownership is usually observed less in the irregular settlements most of the times either residents are travelling on bus or on their motorbikes.

7. Average annual spending on food is to be asked because while cooking food the utility bills and LPG costs are to be validated and these food cost comes under direct consumption of the fuel.
8. Average annual spending on medicine again comes under the production cost of the medicines and is a kind of indirect measure contributing towards increased carbon footprint of the city.
9. Average annual spending on paper items like stationary for children studying in schools because indirectly the country is producing paper like products and contributing towards increased carbon footprint nationally.
10. Average annual spending on computer/IT equipment was asked as they are also contributing both directly when are being used or indirectly when are being repaired, fixed, and made.
11. Average annual spending on TV, radio/phone etc. again comes under indirect cost contributing greenhouse gas emission.
12. Average annual spending on furniture was asked as their production requires cutting, burning, molding etc. thus contributing increased carbon footprint in the cities.
13. Average annual spending on hotels/restaurants, Average annual spending on mobile/phone calls, Average annual spending on maintenance of vehicle, Average annual spending on education, Average annual spending on recreation/sports, Average annual spending on clothes, textile/shoes were asked as all these costs comes under indirect costs require for survival and their production costs a lot in terms of producing fossil fuels at the time of their preparation in the factories.

3.6 REMOTE SENSING DATA

The data was obtained from Google earth engine and earth explorer and Landsat 8 tiles were downloaded. The data were further preprocessed to be used for analysis.

3.7 DIGITAL IMAGE PROCESSING AND ANALYSIS

Below (Figure 1) explains the process flow and steps taken in the overall model.

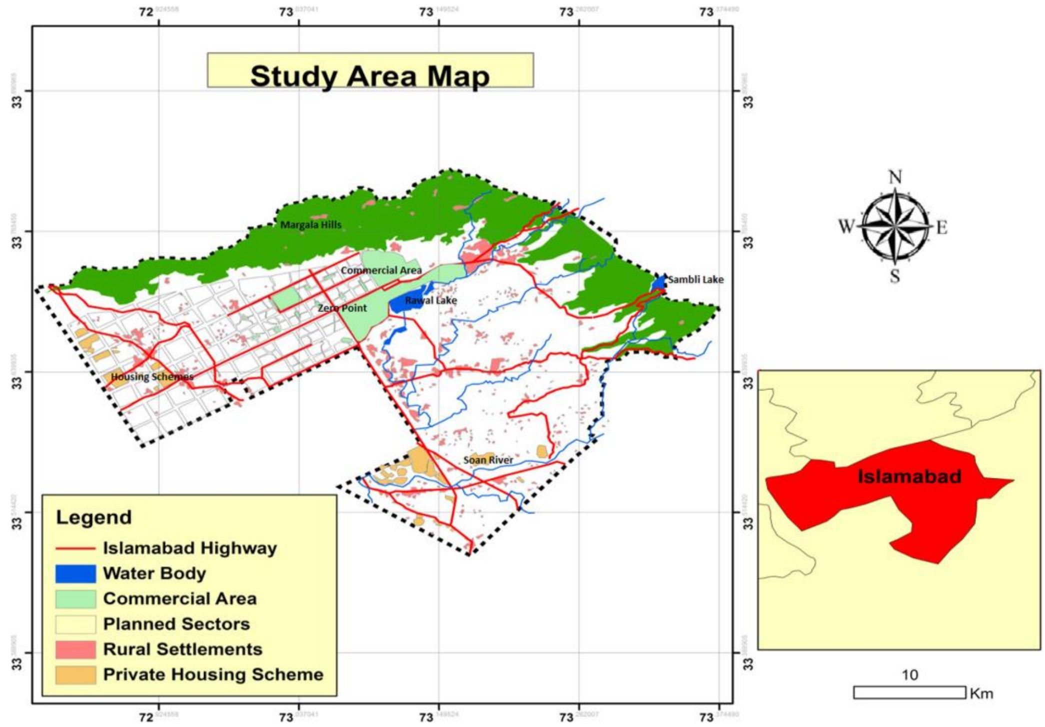


Figure 1: The location of study area.

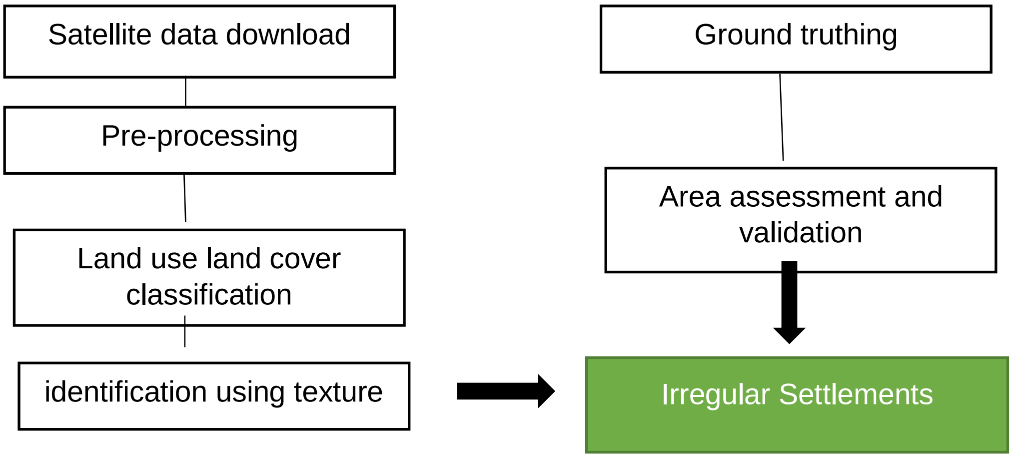


Figure 2: Flow Diagram for Methodology.

Area Classification Tool, August 2019											
	Housing	**Land Ownership**	**Size of House - Average**	**Persons Living Per Household**	**Own Water Connection i.e. Tank**	**Sewers/ Drains**	**Toilets**	**Streets**	**Density – Built up Area**	**Location**	**Utilities**
A Grade	Tented	Occupied	½ marla Tent	2 – 6	No Water Connection	In Streets	No Toilet	No street patters	Low	In Near Urban Centers	No
B Grade	Brick	Occupied but Registered	2 Marla	4 – 6	No Water Connection	In Streets	Simple Pit toilet without sewer	Streets un paved with out car size	Low to high i.e. 1 to 2.	Near Urban Centers	Electricity shared i.e. a link from one house to other/
C Grade	Plastered	Owned	5 Marla	4 – 8	Water Connection personalized	Open Drains	Simple pit toilet connected with open drain	Mixed streets with half paved and half un paved	Moderate to High i.e. mixed with 1 to 3 and irregular.	Urban Peripheral area	Sui gas, electricity, mixed land use, telephone
D Grade	Plastered	Owned	7 Marla	4 – 6	Water Connection personalized and tank/ supply	Semi covered and semi opened drains	Partially having drain and partially not having drains	Paved streets but irregular pattern i.e. front levelled and broad and rare irregular	Moderate to High i.e. mixed with 1 to 3 and irregular.	Urban Peripheral area	Planned land use, sui gas, electricity, telephone
A Category is the type of irregular settlement having tented houses i.e. katchi abadi both registered and un registered.											
B Category is the type of irregular settlement having bricks but un-plastered i.e. Paki Abadi or regularized katchi abadi.											
C Category is the type having paved houses but irregular circulation and street pattern i.e. semi plan having quarters in between houses.											
D Category is the type of slum which is planned but may deteriorate in future i.e. extension of existing towns whose first phase was planned.											

Table 3: Area/ Settlement Classification Tool.

3.8 PRE-PROCESSING

After downloading the data, pre-processing was carried out. During pre-processing, we primarily tried to eliminate or reduce the errors of satellite images, while Geo-rectification was done as well. These steps were essential. With the aim for further analysis, other pre-processing steps and procedures may be used. These can be used to emphasize the images' important information. The latter include, for instance, image enhancement.

- Series of consultations were held with representatives from Rawalpindi and Capital Development Authorities to decide a decision support system using definitions from National Planning Reference Manual.
- Series of consultations were held with instructors and specialist from IGIS at Nust University to decide about methodologies and tools i.e., ERDAS Imagine, ArcGIS, Google Earth Code Editor etc.
- Series of meetings were held with representatives from non-government organizations working in slums and squatter settlements to document their expectations of technology-based interventions while identifying, delineating, and deciding upon slums and squatter settlements.
- Based on consultations held objectives of the research were set and the objectives decided upon are as under: -

1. Design a decision support system to identify slums and differentiate them from squatter settlements.
2. Using Image based analysis and technology and its application for identification and delineating slums.
3. Derive, apply and test field-based population calculator to be used for the estimation of population.

    - Literature available from three perspectives i.e.

1. image analysis, land use land cover classification using google earth engine's code editor, ERDAS Imagine, ArcGIS.
2. definitions of slums and squatter settlements from other Asian countries and
3. population estimations were studied and reviewed to identify the gaps and determine a focus for the study.

- Image of the Islamabad was downloaded using google earth engine.
- Land use land cover classification of the Islamabad image was conducted using google earth engine's code editor, ERDAS Imagine and ArcGIS.

- Based on standardized definition of slums agreed upon with the research advisor the slums and squatter settlements were delineated.
- By synchronizing the two i.e., google earth and land use land cover classification, the slums and squatter settlements were identified, and their areas were calculated.
- Number of structures per slum were counted and standard sized quadrants of 100 sqft. were made, and house structures were counted in specified quadrants.
- The slums and squatter settlements marked were confirmed by ground truthing.
- Basic profile of the slums and squatter settlements during ground truthing were prepared and number of rooms in a house and number of stories were counted.

The other pre-processing techniques employed to improve the satellite imaging are as under: -

3.8.1 Layer Stacking and Mosaic

Satellite imagery is composed of several bands having different spectral and reflectance values. To view satellite image as real world we need stack of those layers which have same resolution. Layer stacking was done by using Erdas for band 2,3,4,5,6-7 for Landsat 8. To cover study area, two images were used to extract study area these two images were mosaic based on geometric lines. The mosaic combine two images into single image and study area is extracted from mosaic image to perform further analysis.

3.8.2 Validation of the Land Use Land Cover Analysis

Google earth-based code editor was used to download Islamabad image and develop machine-based language for the land use land cover classification for Islamabad. Samples from planned residences in sectors of Islamabad, water bodies from Rawal lake and unplanned localities were cut and applied to the image analysis for land use land cover classification.

Satellite technology to download image of Islamabad was used and applied. Image Analysis and land use land cover classification was learnt and applied. Landsat 8 images, image analysis using ERDAS, ArcGIS and then validation by synchronizing ERDAS based land use land cover classification with Google Earth was applied. From comparison perspectives, the results produced both by google code editor and the ERDAS image analysis of Landsat Images were compared and validated.

Subject to identification of the irregular settlements based on agreed upon definition, population of these localities was not known and presents in itself another challenge for the planners both from development authorities and non-government organizations. So, FGDs during ground truthing were held with the residents of these irregular settlements to have an idea about the total number of people residing there.

3.9 Methodology for Carbon Footprint Calculation

3.9.1 Methodology

This study was conducted in the urbanized sector G-7 and France colony of F-7 sectors of Islamabad. However, the selected study areas differ in the local conditions of living. The household survey was conducted at five different locations of sector G-7 and France colony of F-7 sector. Same number of houses was selected randomly both from the irregular settlements and planned areas.

3.9.2 Sampling Methodology

Total houses of the irregular settlements were probed through focus group discussions with the residents of the irregular settlements. 10% of total houses were selected for the interviews and conduct of the questionnaires. Nth number of the sample under study was determined by dividing the total houses with the date i.e., 700 houses in France colony and 10% comes to 70 and so 70 houses from the France colony are to be surveyed. The nth number for France colony was 3 and calculated following the practice mentioned underneath.

- Date of study 25th April
- Total sample comes to 150
- Nth number is 70/25 = 3

So, every 3rd household from France colony was studies and visited to collect the data for the variables mentioned above contributing for increased greenhouse gas emission and increased carbon footprint. From the planned houses in street 48 and 46, 44, 42 similarly number of houses were visited.

3.9.3 Calculating Averages for the Data Analysis Using Carbon Footprint Calculator

Carbon footprint for each of the irregular settlements and settled area was calculated for all the locations using online carbon footprint calculator (https://www.carbonfootprint.com/calculator.aspx). Household surveys were conducted to estimate the following variables: The details of the analysis of the variables for carbon footprint calculation are to be appeared later in findings section. Average unit for electricity bills i.e., from the residents of irregular settlements was determined by adding all the electricity bills values with the total number of respondents and then that average value of electricity bill was put in the carbon footprint calculator to find and establish the per kwh consumption of the electricity for one household. The value was later multiplied with the total number of households studied in the irregular settlements to reach to the cumulative kwh used by the households in the irregular settlements. Same practice was followed by the other variables. The details of the findings of the carbon footprint calculation are mentioned in findings section.

3.10 Data Compilation and Analysis

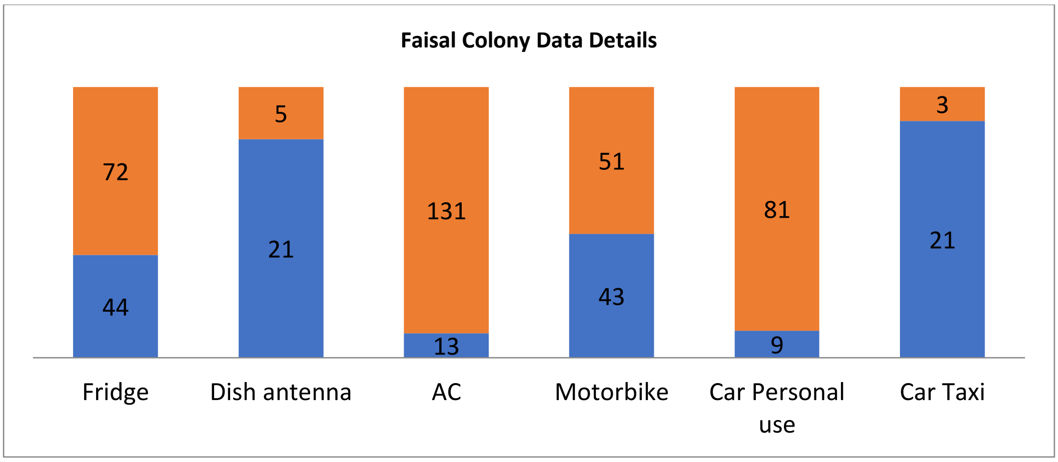
3.10.1 Data Compilation and Analysis – Image Analysis

Field teams were trained for ground truthing to validate the images while being in field. Though first level validation of the images was already conducted and ensured by the researcher by linking down the ERDAS Imagine with the google earth pro. But the first level validation by synchronizing both ERDAS Imagine, and Google earth pro did not provide an in-depth information about the population, facilities and amenities thus establishing the need for the further investigation by sending in the teams for the ground truthing. So, the teams were trained in holding Focus Group Discussions with the local communities residing there and information about following variables was collected from the residents of irregular settlements i.e., number of houses, average number of floors in the structures, average number of people residing in every structure, availability of refrigerator, air conditioner, motor ownership, motor bike ownership and ways of mass communication in every community. Subject to collection of the information regarding these variables, the information was entered into SPSS for the further analysis. The validation of the irregular settlement, collection of the information about basic utilities and amenities then was used to establish results and conclusion for the research.

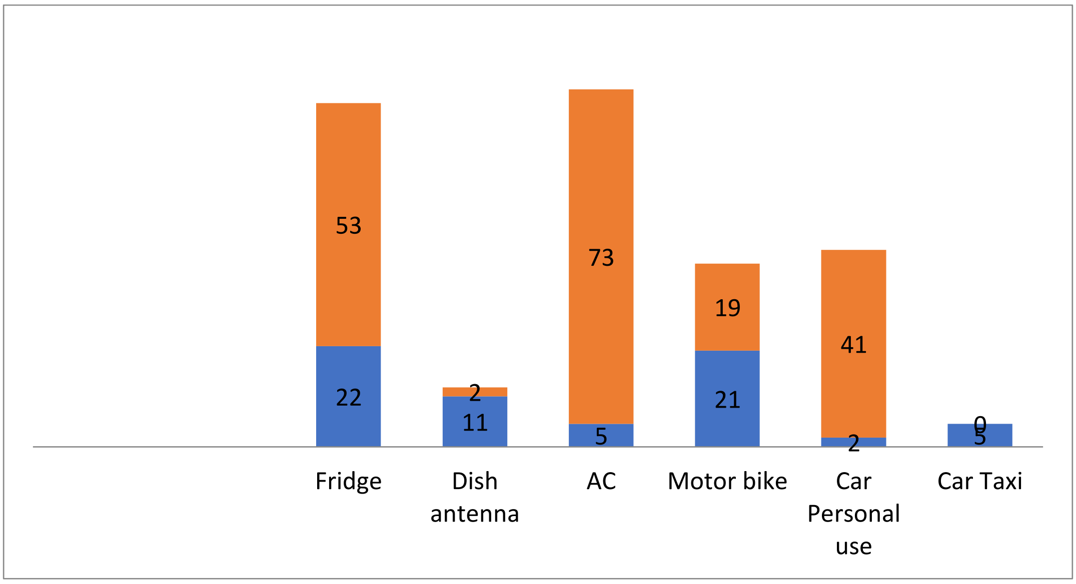
3.11 Data Compilation and Analysis (Calculation of Carbon Footprint)

Faisal colony: Air conditioner a very few people can afford in the Faisal colony as they could not even afford the bill of the electricity and during the study it was found that out of 57 houses only 13 have ACs while on the other side in the settled area the number of ACs were in similar 57 houses was 131 with quite a big difference. On the same time in the Faisal colony the number of refrigerators was 44 and in the settled areas the number was 72. The number of Dish antenna in the settled areas were low and only 5 houses have had the dish antenna and mostly use cable networks. Whereas in Faisal colony the use of Dish antenna was found comparatively high as 21 of total 57 houses were using dish antenna. Motor bikes use in the Faisal colony was found and responded in 43 out of 57 households and the number of motorbikes in the settled areas was 51. The ratio of car use in the Faisal colony was reported as only 9 out of 57. Most of these vehicles are being used as taxi. Whereas in the settled area studies around Faisal colony, the 81 cars are available in the houses with three households responded using careen or uber

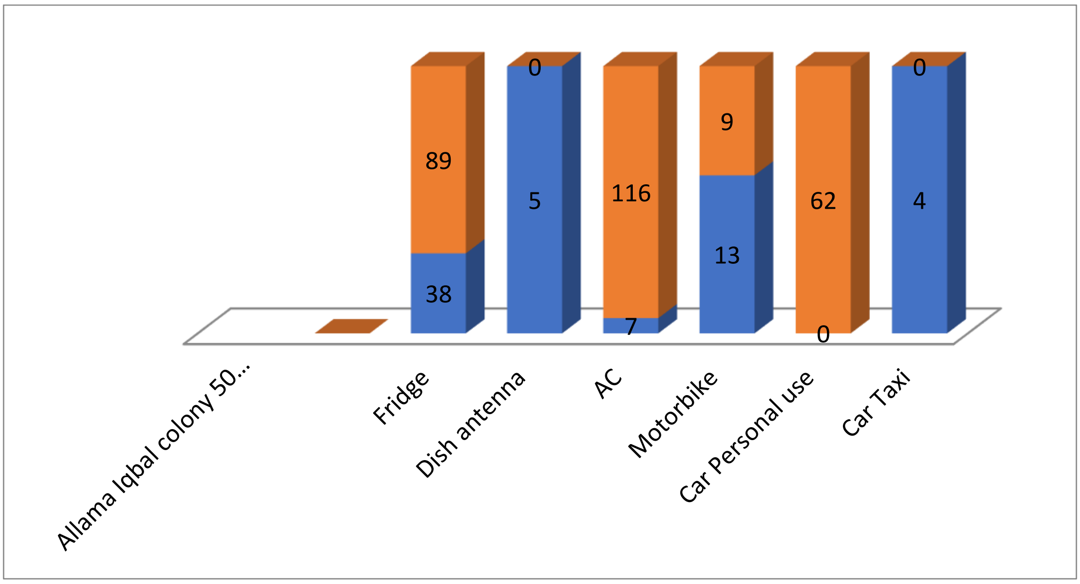
cars for their family trips.



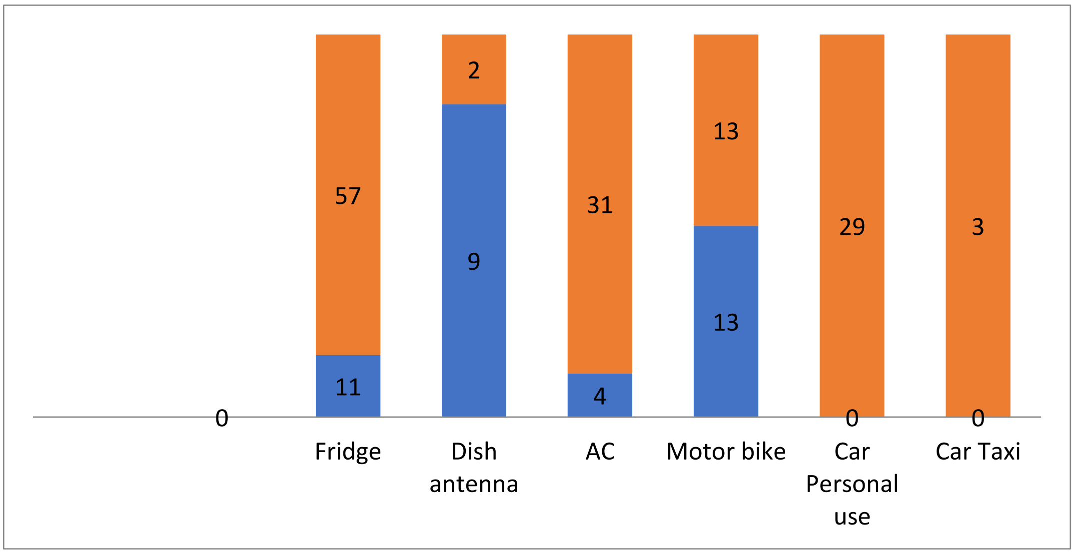
100 Quarters Is the second area studied and selected for the data collection located in the vicinity of F-6/2. Most of the houses have had same religion and economic background. The total number of the basic indictors that were set for comparison are the same as in the case of Faisal colony. Out of 30 houses in 100 Quarters, only 22 reported having refrigerators with 53 people of the F-6/2 residents of the planned areas having refrigerator available for their households. Dish antenna was reported from 11 households of total 30 from 100 Quarters in comparison with only 02 houses in F-6/2 having dish antenna for a sample of randomly selected 30 households. 100 percent households in the planned settlements are also having cable network connections. Air conditioner in entire 100 quarter study sample are observed to be 05 in comparison to 73 air conditioners available in the same number of houses in sector F-6/2. The number of motorbikes in the 100 Quarters was found to be 21 and 02 people responded using vehicles as taxis. Whereas in F-6/2, 41 vehicles are being owned by the residents of similar number of houses.



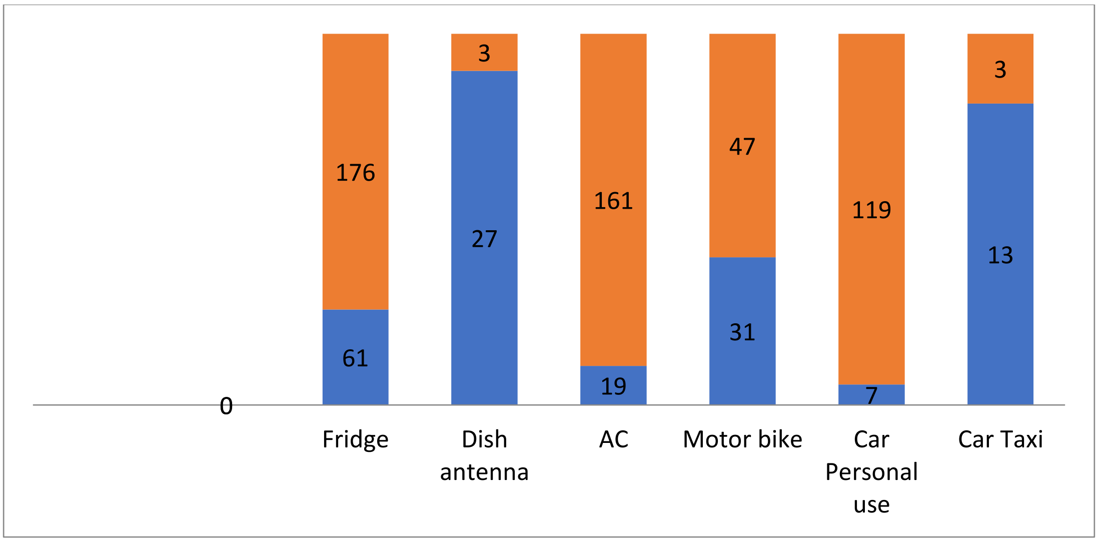
Allam Iqbal Colony is the third area visited for the data collection by the local team. 50 houses from Allama Iqbal Colony were visited for the data collection purposes. The 38 houses of total 50 from Allama Iqbal Colony reported having and using refrigerators in comparison 89 refrigerators available in similar number of houses in the planned area. On the other side the number of dish antenna in the Allama Iqbal Colony in total 50 houses surveyed was only 5 and in the settled area it was zero because almost all the houses use cable network. The number of air conditioners in the Allama Iqbal Colony was found to be 7 and in settled area it was 116. The number of bikes in the Allama Iqbal Colony was found to be 13 and in the settled area it was 13 too. 09 vehicles are being used by the houses studied from Allam Iqbal Colony as taxis whereas in the settled area 62 cars are being owned and used by the residents.



66 Quarters are located near G -7/2 and here the number of houses studied comes to 25. Out of total 25 houses, 11 households in 66 Quarters have had refrigerators in comparison with 57 refrigerators and deep freezers availability in 25 houses of G-7/2. Air conditioners are available in 4 houses of 66 quarters whereby 57 air conditioners are being used by the residents of G-7/2. 13 houses in the planned area reported owning and using car whereas none of the household in the 66 Quarters reporting owing or using car.



France colony is the most populated irregular settlement of the study area in the Islamabad and total 75 houses are studied in this area. 61 out of total 75 households reported using and having refrigerators as opposed to 176 refrigerators availability in similar number of houses in F-7/1. The number of dish antennas in France colony are 27 and in settled area only three household reporting using dish antennas beside having cable connections as well. 19 houses interesting of total 75 reported having air conditioners when compared with similar 75 houses of F-7/1 having 161 air conditioners under use. 07 houses of total 75 reported using and having personal vehicle being used for taxi etc. as opposed to 119 cars available in 75 houses of that planned sector located nearby.



Chapter 4

Results and Discussion

4.1 LULC Classification

To determine the land-use/land-cover (LULC), the satellite image was classified by using maximum likelihood supervise method in Erdas Imagine. The training samples were drawn from all classes. After image classification, four major classes were obtained which included water, barren land, built-up and vegetation along with classification of roads. Though the forest area of Islamabad was also delineated by using supervisory classification technique.

Figure 3: LULC Map of Islamabad.

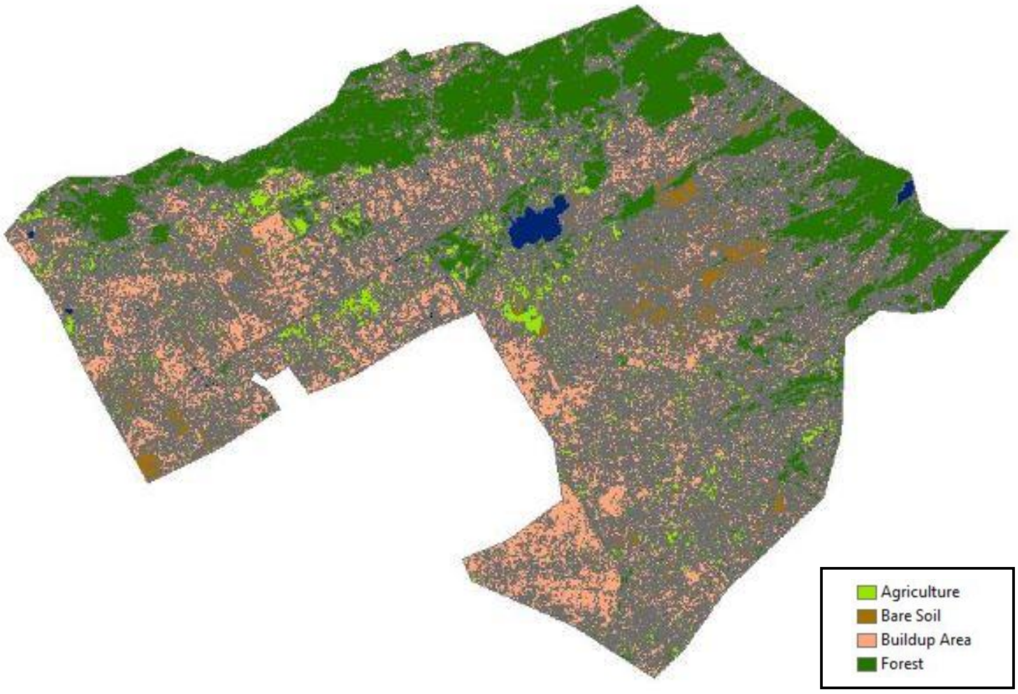


Table 4: Class Wise Area and Percentages.

Class Name	Area (Percent%)	Area (Hectares)
Agriculture	19%	17251.53
Buildup Area	43%	38761.29
Forest	26%	24155.44
Roads	3%	1112.67
Bare Soil	8%	7819.26
Water	1%	668.65

The overall results of this research from the satellite image classification indicate that 19% of area of Islamabad is used for agriculture, whereas 26% area accounts for forests. In a total, they report that impervious surfaces in Islamabad have increased by 11.9% at the cost of declining forest land, agriculture land and water bodies. While the results from this research of irregular settlements using the satellite image analysis expedite that the build-up area in Islamabad expands over 43% of the total area and bare soil is spread over 8% land. Moreover, the roads cover 3% of the area and water contributes 1%.

A comparison was made with a previous article published by Arif Rehman back in 2003. “The overall results of this research from the satellite image classification indicate that 28% of area of Islamabad was used for agriculture as opposed to 19% being used for agriculture during current and recent years. Whereas 26% area accounts for forests now was 37% back in 2003. So, during 1993 to 2018, forest land has decreased annually by 0.056% at the cost of increasing impervious surfaces. Similarly, the research has observed that due to the spread of urbanization, the city landscape has changed with massive LULC changes.

4.2 Subset of Focus Area

To generate the scale to focus on a specific area of study, keeping in view the financial constraints and to prevent the over-generalization of findings by taking a comparatively large area, the focus area was clipped after classification. In that, Figure 1.4 highlights the 24 kilometers focus area of the study. This focus area has been used as a base map for image analysis and LULC analysis for field research and to draw analyses about the presence of irregular settlements. In this process, the LULC techniques for the identification of built-up areas and their segregation from green areas and water bodies resulted in the demarcation of the area requiring to be studied. Moreover, three types of analysis were applied to validate the findings of the LULC analysis i.e., once the Landsat 8 imagery was used for the LULC analysis. Secondly, the sentinel 2 imagery was used to study the land use and further classify it down to classes like built up, water, forest, vegetation etc. and thirdly the good code editor was used to download the image of Islamabad for land use land cover classification. The results of the three types of the analysis on the similar subset of the study area slightly varied and the best of the results were obtained on the Landsat imagery.

Furthermore, the study area was validated through using software such as Google Earth Pro and Erdas Imagine (Figure 4). This was undertaken to ensure that the subset of area contains settlements and residential area and provide a more comprehensive view. In each of the sector along the Srinagar Highway, 24 irregular settlements, slums, and likewise areas are found to be existing. The cloud cover of the image downloaded plays an extremely important role to determine the areas; whether they are irregular settlements, slums or different from others planned areas or sectors of Islamabad.

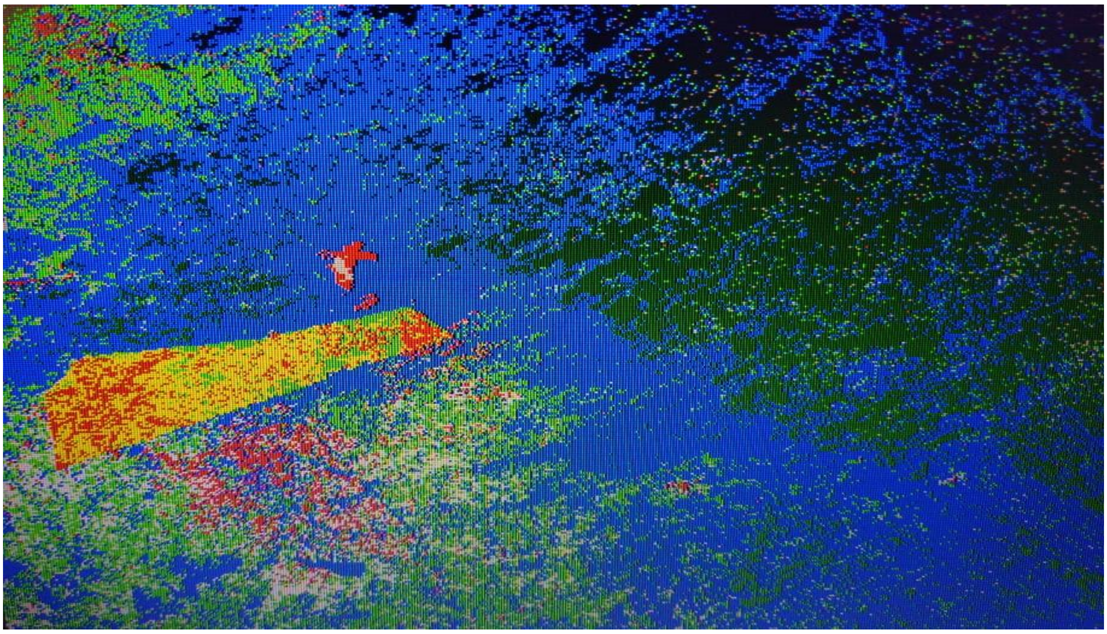


Figure 4: Subset of focus area.

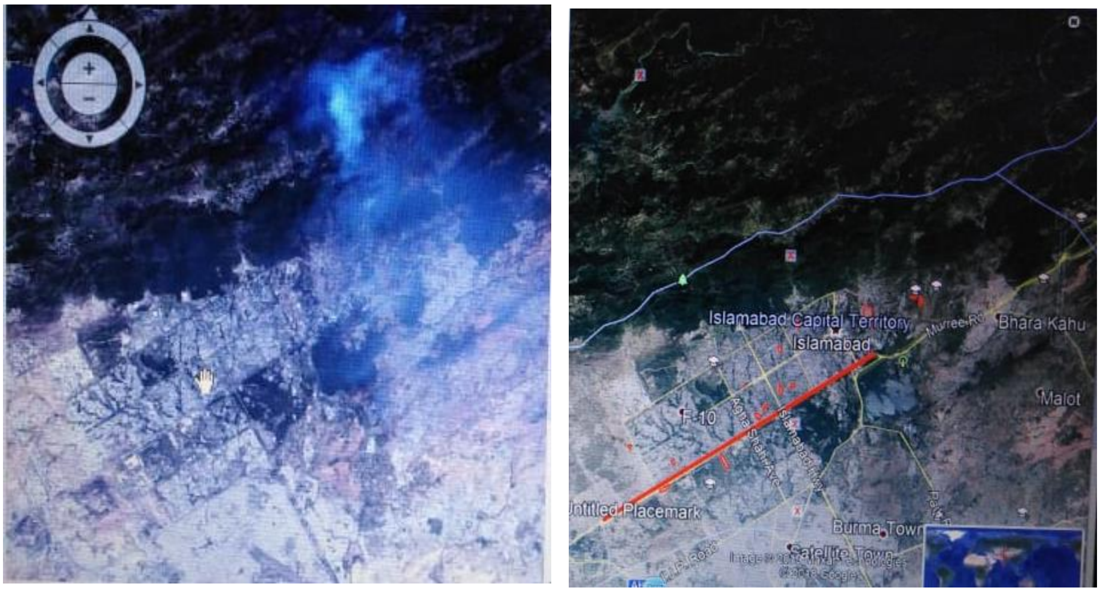


Figure 5: Linked with google earth and Validation of the Focus Area.

4.3 Slum Area Calculation

Number of structures per irregular settlement or likewise area was counted and standard sized quadrants of 100 sqft (Figure 5) were made and house structures were counted in specified quadrants. The slums and squatter settlements marked were confirmed by ground truthing and basic profile of the slums and squatter settlements during ground truthing were prepared and number of rooms in a house and number of stories were counted for a purpose to ensure the calculation of carbon footprint comparison of irregular settlements with the planned sector in Islamabad.

4.4 Slum Area Calculation

The slum area calculation is important to determine the spread of the slum or irregular settlement, the population density, housing structures, availability of facilities, etc. For this research, the number of structures per location were counted and standard-sized quadrants of 100 sqft were made and house structures were counted in all the specified quadrants. The marked slums and squatter settlements were confirmed by ground-truthing. In that, the basic profile of the slums and squatter settlements during ground-truthing were prepared and the number of rooms in a house and number of stories were counted. The preparation of basic profile is significant to identify the services that are inadequate in the slums, such as health services, municipal services, sewage, drainage, etc.

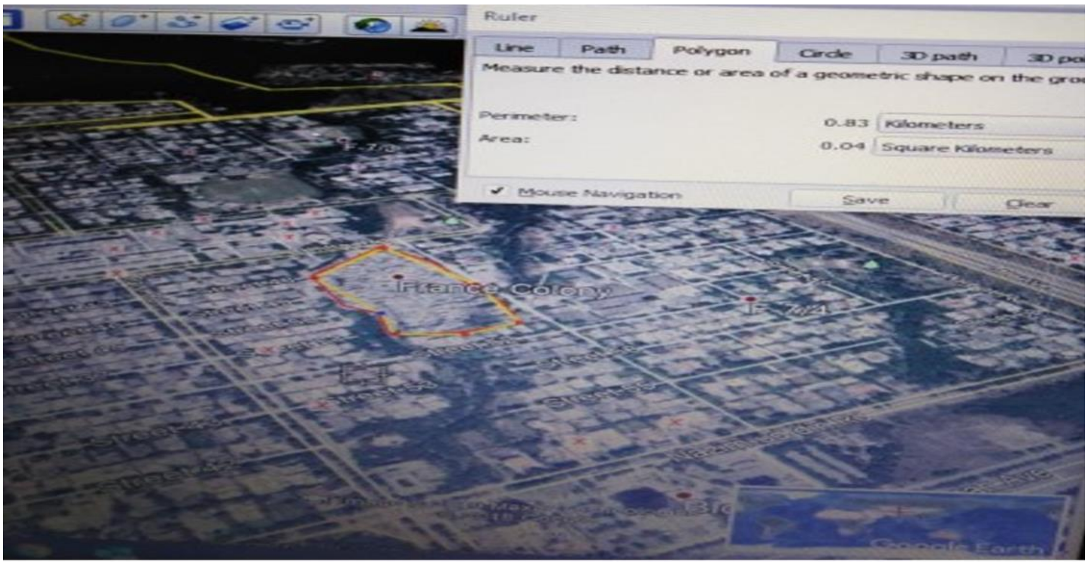


Figure 6: Calculation of the Area.

Figure 7: Slum area calculation.

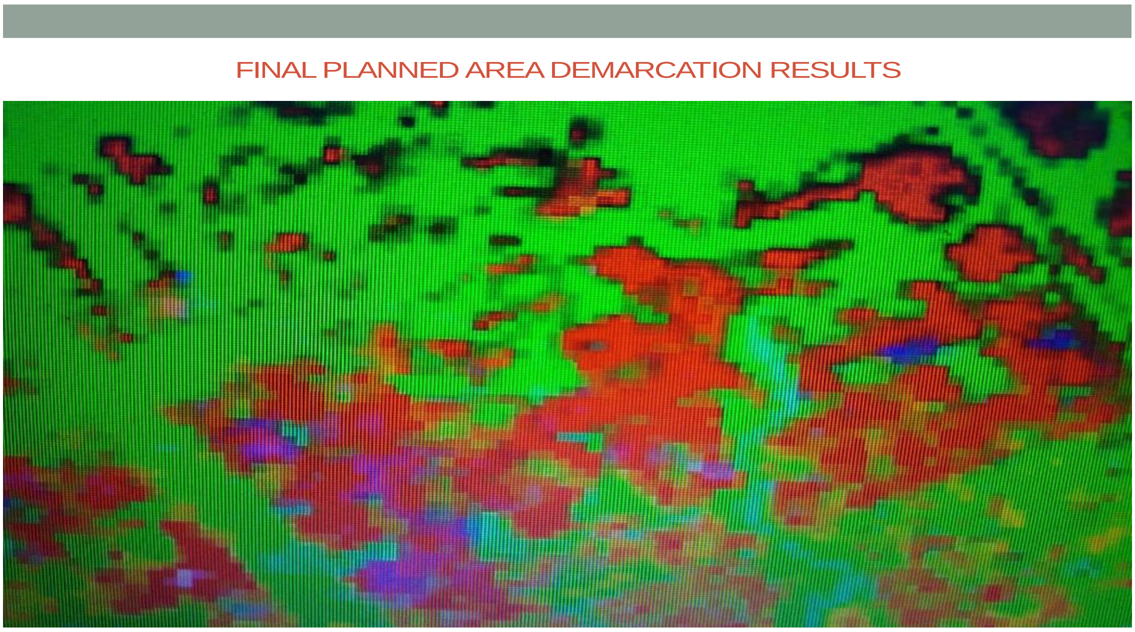


Figure 8: Planned area.

4.5 Slum Spread Identification

To draw assessment over the spread of the slum, irregular settlement overtime, a historical view of the study area was taken from 2004 (Figure 6) using Google Earth and compared with the image of the settlement in 2019 (Figure 7). The comparison of the two images of the same settlement and area indicate that the irregular settlement has almost doubled in size from 2004 to 2019. Based on this, it can be contended that the spread of the settlement was not hampered and as population in the settlement grew, it covered more area. Thus, putting on more pressure on the open land near water bodies in Islamabad. If the settlement dwellers were rehabilitated in 2004 then the State would have to be bear less cost as compared to the current circumstances. It must also be noted (in the Figure 8) that the slum is spread around the green belt and blue channels i.e., water bodies. This is significant because the forests and water bodies provide breathing spaces to the city and the increasing spread of the irregular settlements around such areas is further jeopardizing the environment of Islamabad.

Furthermore, to determine the population density in the study area, the housing structures were marked in the Figure 9 and the total structures were multiplied with average family size to determine the total population residing in a settlement. Therefore, the area, perimeter, number of structures in the study area was determined to calculate the estimate of the total population of the settlement.

Figure 9: Slum spread in 2004.

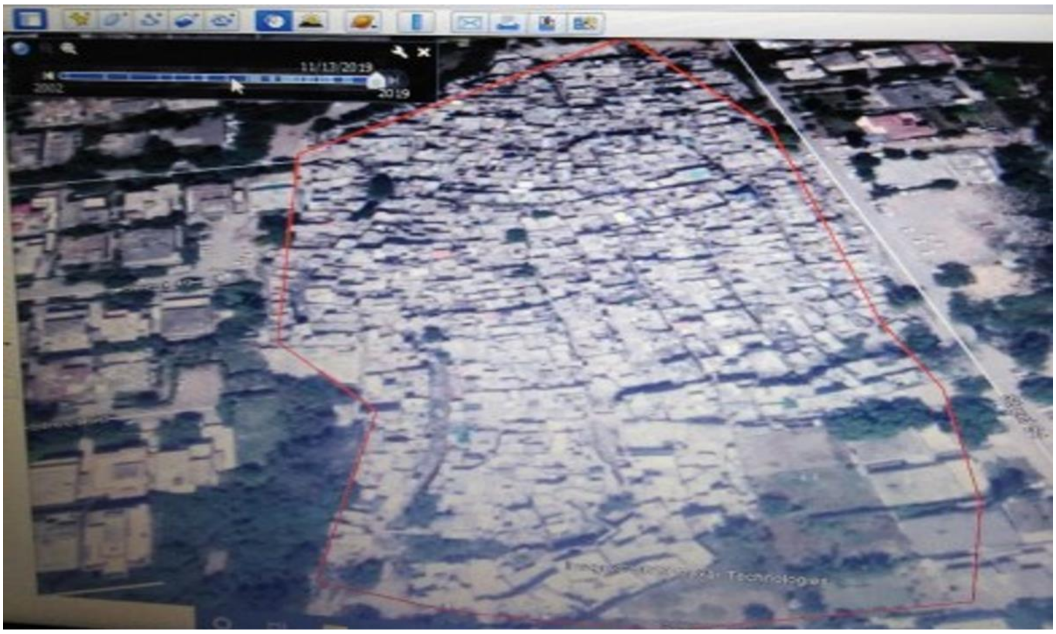


Figure 10: Slum spread in 2019.

4.6 Results and Findings for Carbon Footprint Calculations

4.6.1 CARBON Footprint Definition

Carbon footprint considers the activities, appliances and lifestyle that results in emission of greenhouse gases i.e., Cos, N2O, Methane etc., with the results presented in metric tons of CO2 equivalent. In the case of Pakistan, industry, living style like using vehicles, having non efficient fuel buses, type of electricity, type of fuel for cooking etc., having and owning refrigerators, air conditioners, motor bikes, stationary consumption, clothing and buying shoes etc. all contributes directly or indirectly to the emission of greenhouses gases increasing carbon footprint for the cities and country wholistically.

Carbon footprint for each of the irregular settlement and settled area was calculated for all five locations using online carbon footprint calculator (https://www.carbonfootprint.com/calculator.aspx). Household surveys were conducted to estimate the following variables: The findings of the calculations are as under: -

Table 5: Carbon footprint estimation data.

Indicator per household	Irregular Settlement	Settled area
Average annual travel distance on personal vehicle	45625 Km	14600 Km
Average annual Electricity usage	2325 KWh	10850 KWh
Average annual Natural gas/LPG usage	$482	$417
Average Vehicle efficiency	10 Ltr/100km	4.76 Ltr/100km
Average annual travel distance on motorbike	11000 Km	11000 Km
Average Motorbike efficiency	1.42 Ltr/100km	1.66 Ltr/100km
Average annual travel distance on bus	9125 Km	9125 Km
Average annual spending on food	$787	$1770
Average annual spending on medicine	$118	$590
Average annual spending on paper items	$20	$79
Average annual spending on computer/IT equipment	$79	$197
Average annual spending on TV, radio/phone etc.	$79	$236
Average annual spending on furniture/other manufactured goods	$787	$1574
Average annual spending on hotels/restaurants	$79	$551
Average annual spending on mobile/phone calls	$79	$197
Average annual spending on banking/finance	$100	$1170
Average annual spending on maintenance of vehicle	$394	$630
Average annual spending on insurance	$0	$314
Average annual spending on education	$95	$945
Average annual spending on recreation/sports	$40	$79
Average annual spending on clothes, textile/shoes	$394	$630

Carbon Footprint Calculation: (One Household in Irregular Settlement VS One Household in Planned Settlement)

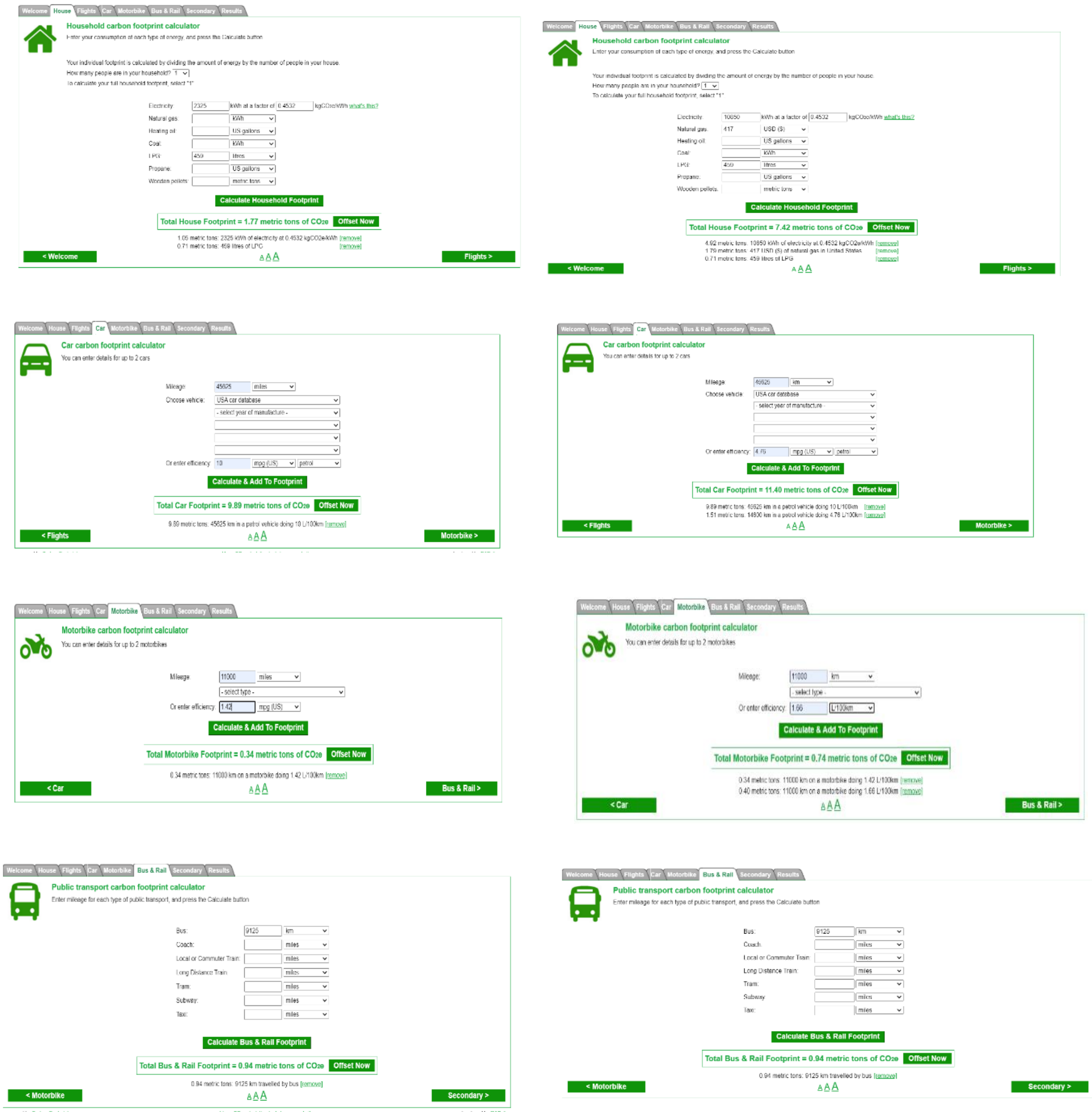
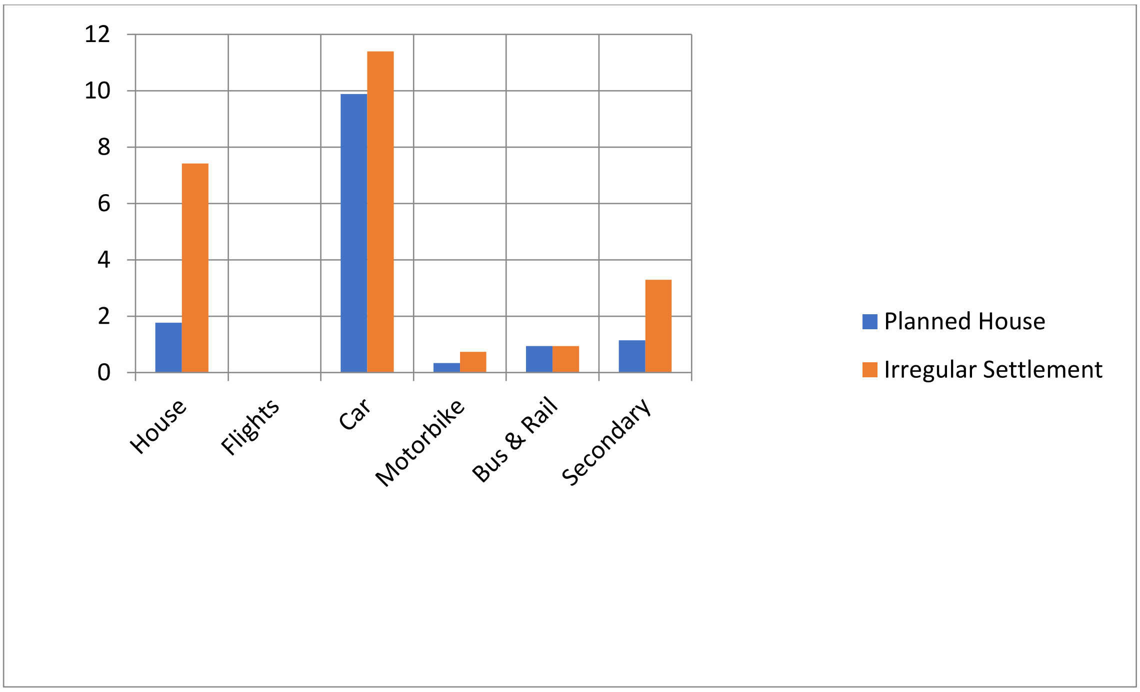


Figure 11: Carbon footprint of household in Irregular Settlement and Planned House

Table 6: Carbon footprint statistical analysis.

Category	Irregular settlement	Planned House		
	Metric Tons of CO2		t-Test: Two-Sample Assuming Equal Variances	
House	1.77	7.42	P(T<=t) one-tail	0.258354
Flights	0	0	P(T<=t) two-tail	0.496708
Car	9.89	11.4		
Motorbike	0.34	0.73		
Bus & Rail	0.94	0.94		
Secondary	1.15	3.29		



(Comparison between Planned House and Irregular Settlement in Metric tons of annual CO2 emissions)

Chapter 5

Conclusion

The research detailed herein aimed to provide a robust methodology that investigated and explored the ‘invisible’ settlements, such as slums and irregular settlement areas, within a brief timeframe, limited resources and urgent decision making on numerous socio-economic interventions to improve the services in the aforementioned areas. It is also important to note that while Islamabad is the Federal Capital of Pakistan, but the excavation of information and data collection posed significant hurdles due to lack of development of appropriate systems and mechanism. In this view, the use of appropriate methodologies developed despite lack of financial resources and scare urban environment hold importance for making informed decisions at the local-level.

In this conclusion section, the main findings of the research are elucidated. In this regard, the first and second sections focus on describing the results derived in view of the research problem and questions and also the lessons learnt in the context of the research. Additionally, the third and fourth sections provide reflections on both the methodologies used to fulfill the research objectives i.e., identification of irregular development beside planned sectors in Islamabad and delineating them using appropriate research methodology. Following this, the fourth section identifies the conclusions drawn which helps to answer the research questions in chapter one. In the end, the last section provides recommendations to signal further research on the topic and help identify new avenues to address the increasing areas of irregular settlements in urban areas in Pakistan.

In this section, it is also important to illustrate the significance of the Millennium Development Goals (MDGs) since these goals outlined the need for interventions to improve the lives of the swelling numbers of slum dwellers by 2020. However, in the case of MDGs, the urgent need dictates the availability of thorough, reliable, robust, timely and policy-relevant data to that complementary policies and interventions can be implemented in the slums. But, this issue is further problematized since most of these irregular settlements are swelling-up in developing countries which do not have the revenant and updated information. Pakistan is not an exception to this case. In this view, the main research problem can be described as the absence of localized and context-specific appropriate methodological design which can help investigate the three following aspects: lack of sufficient data, incomplete understanding of the basic characteristics of the slums where resources to conduct data collection and analysis are limited. During the data collection process for this research, it became evident through the analysis of local documents and focus group discussions that the absence of detailed information on irregular settlements has been a primary reason which has prevented adequate policy interventions to improve the lives of slum dwellers and limit their unchecked expansion. Therefore, due to lack of sufficient data, ad hoc intervention programs are being implemented which result in rather wastage of resources and responses which do not address the basic problems of the irregular settlements.

In addition to this, the tools for data collection for this research (interview forms, surveys, focus group discussion guidelines) ensured that the diversity of the socio-economic conditions of Islamabad, the unique characteristics of the areas within the city and the context-specificity of the slums was captured adequately. This was increasingly important to ensure that comprehensive information was collected to support sustainable interventions in order to improve the lives of the people living in these irregular settlements. Therefore, efforts were taken to ensure that an appropriate methodological design was outlined to gain an in-depth assessment of the information. By employing the methodology designed for this research, the term 'slum' was defined in the local context while keeping in view the definition provided by the UN-Habitat for 'slum' and resultantly the data was collected and assessed in the similar fashion. The methodology established that:

Landsat image downloading was easier as far as the image downloading, its analysis for the land use land cover changes is concerned when compared with sentinel 2 image downloading and analysis. The details of the objects in sentinel 2 was more than Landsat 8 images but the processing and analysis of the images using ERDAS imagine, and image stacking was relatively easier and fast with the Landsat images.

Google code editor and its use for image downloading was much faster and image was quite clear but the machine language for the planners would be an issue and hindrance to do the image stacking and analysis in google code editor was a kind of challenge. Image downloaded from paths of satellite while using google code editor was difficult and time consuming thus the research established that Landsat 8 images are best to be processed by urban planners for the planning purposes and delivery of the services.

Structures visibility after validation exercise is quite clear but the built-up density of the irregular settlements was not achieved through image analysis techniques. Thus, requiring the built-up density calculation using the field teams during ground truthing.

In G-7 sector of Islamabad, 05 irregular settlements were observed and studied using the ground truthing technique after land use land cover analysis. In 05 settlements, more than 4000 houses are existing with varied sizes i.e., ranging between 02 Marla to 07 Marla with none of the houses in France Colony having any air conditioner and mostly having refrigerators in their houses and using dish antenna for the mass media purposes. Vehicle ownership was less and most the houses having vehicles were using as local taxi or transport in comparison to the houses in the sectors of G-7, with each house having at least one car for their mobility. But the motor bike ownership in the houses of the irregular settlements was relatively high if compared with the houses in the planner sector of the G-7, Islamabad. Stoves being used in the irregular settlements of Islamabad relate to LPG cylinders whereas 100% houses of the planned sector of Islamabad have SNGPL connections mostly 02 in each house. Each of the single house in planned sector of G-7, Islamabad have had at least one air conditioner with mostly having 02 in each house. Similarly, the solid waste collection indicated that average waster production from the houses in France Colony was ranging between 0.75 Kg to 1.25

kg whereas each of the house in G-7 sector of Islamabad was producing a waster ranging between 01 to 02 Kilograms. So, the definition used for the calculation of carbon footprint contributed by irregular settlements i.e., 05 in G-7 sector seems relatively low than the planned sector and houses in planned sector of G-7.

Disaster management authority and development authorities shall have an in-built mechanism for the processing of the images using satellite image analysis technique as most of these irregular settlements irrespective of them being a slum, katchi abadi or squatter settlements are located either near green area or blue channels. For instance, heavy rains and water flow in the blue channels of Islamabad may be destructive for these irregular settlements.

Similarly, the urban planning department shall need to integrate the technological subjects like digital monitoring using satellite technology etc. for the development planning and monitoring at their departmental levels.

Following the definition of the carbon footprint and its contribution from greenhouse gas emission i.e., CO2, N2O and methane etc. resulted from the activities of daily living, consuming patterns, lifestyle, and state responsiveness a comparison both for the house in an irregular settlement of Islamabad and planned sector is made. The variable wise findings of the study are as under: -

1. The total carbon footprint for the electricity usage for one household in an irregular settlement of Islamabad was calculated to be at 1.77 metric tons of CO2e whereas when compared with the one household each having two floors the total electricity usage carbon footprint is calculated at 7.42 metric tons of CO2e. The fundamental reasons established from the study are the number of floors in each of the house in the settled area are usually 02 as opposed to the houses of irregular settlements being mostly single floor houses. Secondly, the electricity appliances like availability of air conditioners, refrigerators, cooking ovens, cooking ranges, electricity and natural gas geezers all contribute to the immense amount of CO2, N2O and methane etc. Whereas the availability of similar appliances in the houses of irregular settlements are either very few or unavailable.
2. The total carbon footprint for the car usage for one household in an irregular settlement and planned sector is compared and calculated at 9.89 metric tons of CO2e whereas when compared with the one household each having two floors the total car usage carbon footprint is calculated at 11.40. The car usage carbon footprint for the house of irregular settlement is appeared to be high when compared with their lifestyle and seen in their context because 99% of the houses in the irregular settlements having cars were using them as Taxis. The mileage for the Taxis is usually high than those of the household vehicles being used only for the offices or education purposes. If, we exclude the vehicle usage as Taxi by the inhabitants of the irregular settlements the carbon footprint for the vehicle usage would come to 1.40 as opposed to 9.89 currently.

3. The total motor bike carbon footprint for the motor bike usage for one household in an irregular settlement and planned sector is compared and calculated. The total motor bike carbon footprint for one house of an irregular settlements is calculated at 0.34 metric tons of CO2e whereas when compared with one house of the settled area the similar carbon footprint for the motor bike usage for one household is calculated at 0.74. The reason behind increased value of carbon footprint for the house of the irregular settlement is the availability of only one type of the transport i.e., motor bike. Whereas in the houses of the settled area the motor bike is termed to be the secondary source of transport available in a house. If we club both the values for the total carbon footprint of motor bike and car for a house in a settled area the value for the carbon footprint will go much higher and per household contribution of the household would be way too high.
4. The total carbon footprint for the users of public transport in Islamabad is also calculated and that appeared to be at 0.94 metric tons of CO2e both for one household of the irregular settlement and the planned sector. The reason for the similar values both for the inhabitants of the irregular settlements and planned sectors may be the availability of only one type of transport i.e., metro in Islamabad and the number of trips or usage for both types of respondents are found to be same. Mostly, non-local people are using this public transport and they are not part of this study. So, the carbon footprint of the public transport usage is shared by the non-local residents coming in and going out from Islamabad.
5. The total carbon footprint of one household from an irregular settlement, the cumulative and determined based on all the above variables is appeared to be at 14.09 metric tons of CO2e. Whereby, the total carbon footprint of one household from a planned sector, the cumulative and determined based on all the above variables is appeared to be at 23.79 metric tons of CO2e.
6. The objective of the study was to compare the carbon footprint of the houses of the irregular settlements with those of the planned sectors. Usually, the planners in a society assume may be based on the myth that irregular settlements in the urban areas are producing high greenhouse gas emission i.e., CO2, N2O and methane etc. and are a constant source of increased carbon footprint for the cities and countries. The same myth, study papers and interaction with urban planners and teachers at Department of Urban and Regional Planning, National University of Science and Technology was turned into a hypothesis that slums are rich in producing greenhouse gas emissions and increasing the carbon footprints of the cities and urban areas. But from the data collected from the inhabitants of 05 irregular settlements, and their subsequent analysis using carbon footprint calculator this has been established that the houses in the planned areas are rich in contributing greenhouse gas emission and increasing carbon footprint of the cities and country holistically. The fundamental reason behind this difference if the lifestyles of the people residing in both types of the communities.

7. The urban planners while planning the sectors, cities and urban centers need to calculate the probable contribution by the planned houses as far as the greenhouse gas emission and carbon footprint are concerned. Similarly, while designing and devising the rehabilitation cum improvement plans for the irregular settlements, the features contributing the greenhouse gas emissions thus leading to increased carbon footprint are never to be neglected. May be the similar lifestyle but with improved living conditions i.e., of house structures, streets, drains, fuel being used by the residents of irregular settlements are to be a kind of solution for the people residing in irregular settlements.

Chapter 6

Recommendation and Literature Cited

6.1 Recommendations

1. The planners at development authorities particularly at Capital Development Authority, Metropolitan Corporation Islamabad are recommended to be vigilant regarding development of irregular settlements for their control or in fact regularized control evolvement and learning and using satellite image analysis for that purpose is highly recommended.

2. The planners at development authorities particularly at Capital Development Authority, Metropolitan Corporation Islamabad may plan the rehabilitation and resettlement of the irregular settlements using land cover land use analysis using satellite image analysis for the planned cities, particularly, proposing the low-income housing for the support services providers alongside planned sectors of the city.

3. Review of the land use, its changes in terms of percentages etc. shall be held on quarterly or at least bi yearly basis to help the planning bye laws aligned with the current context.

4. Carbon footprint calculation for the irregular settlements is seemed to be low when compared with planned city sectors but that does not mean that irregular settlements are recommended for the environment. But a potential with very little effect into carbon footprints of the cities, the irregular settlements can be improved following the bye laws and are to be discouraged due to other irregularities like decreasing green and blue channels in cities.

5. Green energy is a solution for the countries and cities in times to come when it comes to the consumption of fossil fuels as the fossil fuels may it be for the motor bikes or vehicles are all adding a lot to the emission of greenhouse gases and thus increasing carbon footprint of the cities.

6. Planners at the development authorities and metropolitan corporation of city, shall devised the land use practices promoting the heating and cooling systems naturally and reducing an increase in using air conditioners as the study established that air conditioners are one of the highly producing sources for the greenhouse gases.

7. Beside the planners at the development authorities and metropolitan corporation of city, shall propose the bye laws providing an ease for the green building standards and tax exemptions for the green buildings and for the people practicing and adopting them.

8. The master plan of the city shall be inclusive of the transport planning for the city and its natives as thus in the longer run shall be discouraging the personal car ownership and use. As both the motor bikes and personal cars ownerships was found high in irregular settlements and planned sectors respectively. The public transport, an efficient one and holistically connected and covering the urban areas and its peripheral territories is another recommendation.

9. Car and motor bike taxation policy shall be quite strict not allowing the household to get more than one vehicle registered. Similar principal shall be followed and is being recommended for the registration of motor bikes.

10. Advocacy and sensitization of the planners and designers shall be organized to design windows and room settings of the houses following the designs not allowing the heated air to allow entering the houses directly. Angular designs for the grills of the windows are another recommendation for the housing and the room settings and directions of the plots shall be adjusted using the sun and air directions etc.

11. Two plants in a house must be mandatory and the none of the plans and submission drawings for the houses shall be approved without any provision of plants. The positions of the plants again directly be linked with the sun and air direction as well. None of the houses shall be issued completion certificate without plantation etc.

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Tools

Annex 1 Studied Variables in the Tool and Rationale

14. Average annual travel distance on personal vehicle; both travel distance and personal vehicle ownership are required to calculate the fuel or fossil fuels consumption by the individual household weather in irregular settlement or planned areas;
15. Average annual Electricity usage; both for winter and summer the electricity usage is determined on the basis of electricity bills i.e. usage of air conditioners and humidifiers in summer and winter and using electric geezers in winter etc;
16. Average annual Natural gas/ LPG usage i.e. natural gas connection in case of planned areas and LPG usage by residents of irregular settlements and their usage from utility bills and LPG cylinder costs are required to calculate green house gas emission contributing to increased carbon footprint in Islamabad;
17. Average Vehicle efficiency i.e. per liter milage based on the type of vehicle i.e. Japan assembly line or Pakistan assembly line are to determined to calculate the contributing factor for increased carbon footprint;
18. Average annual travel distance on motorbike along with average motorbike efficiency are to be asked from the respondents to determine and estimate the fossil fuels contribution by the motorbike owners;
19. Average annual travel distance on bus in case of need are to be asked both from the respondents from irregular and planned areas residents because their fossil fuel is contributing heavily towards increased carbon footprint and vehicle ownership is usually observed less in the irregular settlements most of the times either residents are travelling on bus or on their motorbikes;
20. Average annual spending on food is to be asked because while cooking food the utility bills and LPG costs are to be validated and these food cost comes under direct consumption of the fuel;
21. Average annual spending on medicine again comes under the production cost of the medicines and is a kind of indirect measure contributing towards increased carbon footprint of the city;
22. Average annual spending on paper items like stationary for children studying in schools because indirectly the country is producing paper like products and contributing towards increased carbon footprint nationally;
23. Average annual spending on computer/IT equipment was asked as they are also contributing both directly when are being used or indirectly when are being repaired, fixed and made;
24. Average annual spending on TV, radio/phone etc. again comes under indirect cost contributing green house gas emission;
25. Average annual spending on furniture was asked as their production requires cutting, burning, moulding etc. thus contributing increased carbon footprint in the cities;
26. Average annual spending on hotels/restaurants, Average annual spending on mobile/phone calls, Average annual spending on maintenance of vehicle, Average annual spending on education, Average annual spending on recreation/sports, Average annual spending on clothes, textile/shoes were asked as all these costs comes under indirect costs require for survival and their production costs a lot in terms of producing fossil fuels at the time of their preparation in the factories.

Annex 2 Slum Classification Tool, August 2019

	Housing	Land Ownership	Size of House - Average	Persons Living Per Household	Own Water Connection i.e. Tank	Sewers/ Drains	Toilets	Streets	Density – Built up Area	Location	Utilities
A Grade	Tented	Occupied	½ marla Tent	2 – 6	No Water Connection	In Streets	No Toilet	No street patters	Low	In Near Urban Centers	No
B Grade	Brick	Occupied but Registered	2 Marla	4 – 6	No Water Connection	In Streets	Simple Pit toilet without sewer	Streets un paved with out car size	Low to high i.e. 1 to 2.	Near Urban Centers	Electricity shared i.e. a link from one house to other/
C Grade	Plastered	Owned	5 Marla	4 – 8	Water Connection personalized	Open Drains	Simple pit toilet connected with open drain	Mixed streets with half paved and half un paved	Moderate to High i.e. mixed with 1 to 3 and irregular.	Urban Peripheral area	Sui gas, electricity, mixed land use, telephone
D Grade	Plastered	Owned	7 Marla	4 - 6	Water Connection personalized and tank/ supply	Semi covered and semi opened drains	Partially having drain and partially not having drains	Paved streets but irregular pattern i.e. front levelled and broad and rare irregular	Moderate to High i.e. mixed with 1 to 3 and irregular.	Urban Peripheral area	Planned land use, sui gas, electricity, telephone

A Category is the type of slum having tented houses i.e. katchi abadi both registered and un registered.

B Category is the type of slum having bricks but un-plastered i.e. Paki Abadi or regularized katchi abadi.

C Category is the type having paved houses but irregular circulation and street pattern i.e. semi plan having quarters in between houses.

D Category is the type of slum which is planned but may deteriorate in future i.e. extension of existing towns whose first phase was planned.