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Research Master Planning and Sustainability: Environmental Implications of Peri- urban Sprawl and the Urbanization of Secondary Cities in Latin America

Urban-sprawl

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ABSTRACT

South America is a standout amongst the most urbanized landmasses on the planet, where practically 84% of the absolute populace lives in urban areas, more urbanized than North America (82%) and Europe (73%). The eventual fate of the landmass will be commanded by urban advancement and driven by urban frameworks. In any case, the spatial conduct of most Latin American urban communities, their structure, main impetuses, primary highlights, likeness and others remain for the most part obscure. To measure and survey urban spread and discontinuity we address certain examples for 10 Latin American urban communities over a time of 23 years. Utilizing satellite symbolism we measure the fundamental parameters of extension and discontinuity, land utilization rates, spatial game plan and densities, distinguishing key elements driving the procedure and spatial approaches to portray urban improvement and rambling highlights under certain files, utilizing European urban advancement as an examination. The point is to address pertinent spatial measurements, all deliberate with GIS apparatuses, to accomplish strategy applicable files of urban structure. By distinguishing proof of those components, together with the evaluation of the spread as a device for observing advancement designs, we go for adding to better understanding urban structure in Latin America, towards an improved spatial urban improvement and land strategy. In an unavoidable urban development setting, Latin American urban communities are more conservative and less divided than in Europe. There are likewise significant contrasts in the rates, densities and degrees of discontinuity. The need to rethink the job of Latin American urban arranging shows up in a situation where urban extension is absurd to expect to control, and where patterns of spread, fracture and brokenness may result strengthened by the cooperation of affordable activities.

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CHAPTER 1

INTRODUCTION

1.1 Background

Achieving the United Nation's Millennium Development Goals (MDGs), the international community's unprecedented agreement on targets towards the eradication of extreme poverty and hunger, will depend to a large extent on how well developing country governments manage their cities. Urban communities are right now home to almost 50% of the total populace and throughout the following 30 years the vast majority of the two-billion or more individual increment in worldwide populace is relied upon to happen in urban territories in the creating scene. This speaks to a noteworthy take off from the spatial conveyance of populace development in the creating scene that happened in the course of recent years, which was considerably more uniformly isolated among urban and country zones. The dimension of world urbanization today and the number and size of the world's biggest urban communities are uncommon. Toward the start of the twentieth century, only 16 urban communities on the planet most by far in cutting edge modern nations contained a million people or more. Today, right around 400 urban areas contain a million people or more, and around 70% of them are found in the creating scene. By 2007, without precedent for mankind's history, more individuals on the planet will live in urban areas and towns than will live in provincial territories and by 2017 the creating scene is probably going to have turned out to be more urban in character than rural[1].

On the off chance that all around oversaw, urban areas offer significant open doors for financial and social advancement. Urban communities have dependably been central focuses for financial development, advancement, and work. In fact, numerous urban areas became generally out of some common bit of leeway in transport or crude material supply. Urban areas, especially capital urban communities, are the place by far most of present day beneficial exercises are gathered in the creating scene and where by far most of paid business openings are found. Urban areas are likewise focuses of current living, where female work power cooperation is most noteworthy and where markers of general wellbeing and prosperity, proficiency, ladies' status, and social versatility are ordinarily most astounding. At long last, urban areas are additionally significant social and social focuses that house exhibition halls,

workmanship displays, film ventures, theaters, design houses, and other significant social focuses.

High populace thickness may likewise be useful for limiting the impact of man on nearby biological systems. High populace thickness regularly infers lower per capita expense of giving foundation and fundamental administrations. Furthermore, notwithstanding the high rates of urban neediness that are found in numerous urban communities, urban occupants, by and large, appreciate better access to instruction and social insurance, just as other essential open administrations, for example, power, water, and sanitation than individuals in country territories. All things considered, as urban areas develop, overseeing them turns out to be progressively mind boggling. The speed and sheer size of the urban change of the creating scene presents impressive difficulties. Of specific concern are the dangers to the quick and encompassing condition, to common assets, to wellbeing conditions, to social attachment, and to individual rights.

1.1.1 Urbanization

Urbanization in the present and prospected form is one of the most drastic global changes that mankind has ever faced. It will touch most humans in coming decades, in developing countries in particular. The basic amenities of life such as water and food are and will be subject to escalating pressures. and meeting these demands is a great challenge. The growth rate of water and land resource problems is very rapid. As Frederiksen (1996) points out:

“Perhaps the most important constraint on solving the water resources crisis is time. There is very little time to do all that needs to be done to accommodate the 1 billion new people to be born in the next 10 yean. Very few actions of the magnitude needed can be completed in this period.”

What these actions and their magnitude should be, is an urgent and important issue. GroWing cities need rapidly escalating quantities of food and water. Mounting aspirations related to urban lifestyles typically mean more water use than in rural communities. Rural areas must

produce more and more food and other biotic products to meet the urban demand. Yet, food production on our planet does not appear to grow any longer (Worldwatch 1996). Priorities taken in water allocation policies are among key factors behind rural push and urban pull forces that lie behind congestion of people. Urban water infrastructure issues. safe drinking water for urban dwellers, proper sanitation, and waste management are concrete issues to any individual, and major challenges to societies.

Urbanization refers to the population shift from rural areas to urban areas, the gradual increase in the proportion of people living in urban areas(showed in **Fig 1.1**), and the ways in which each society adapts to this change[2]. It is predominantly the process by which towns and cities are formed and become larger as more people begin living and working in central areas[3]. Although the two concepts are sometimes used interchangeably, urbanization should be distinguished from urban growth: urbanization is

"*The proportion of the total national population living in areas classed as urban*",

while urban growth refers to

"*The absolute number of people living in areas classed as urban*".

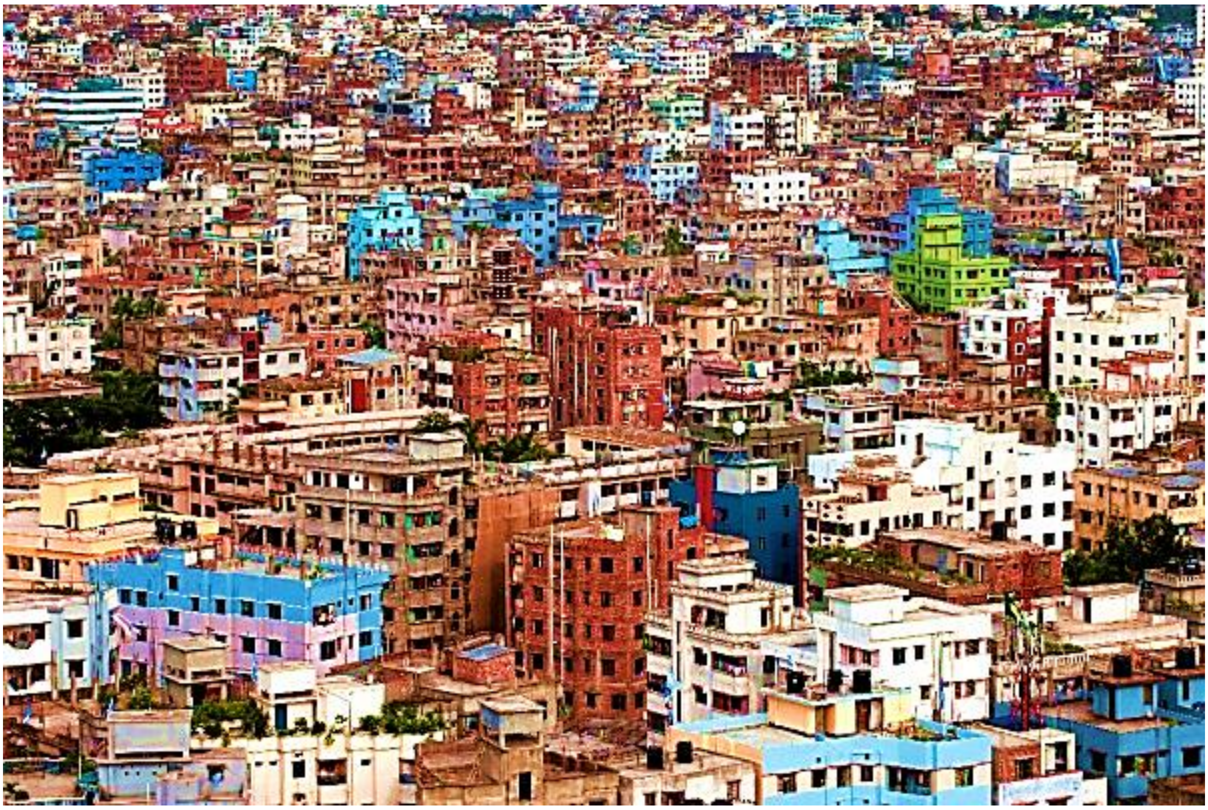

Fig.1.1 Urbanization in Latin America

Latin America has a very diverse population with many ethnic groups and different ancestries. Only in three countries, do the Amerindians make up the majority of the population. This is the case of Peru, Guatemala and Bolivia. In the rest of the continents, most of the Amerindian descendants are of mixed-race ancestry.

When measured by extent and intensity, urbanization is one of the most homogenizing of all major human activities. Cities homogenize the physical environment because they are built to meet the relatively narrow needs of just one species, our own. Also, cities are maintained for centuries in a disequilibrium state from the local natural environment by the importation of vast resources of energy and materials. Consequently, as cities expand across the planet, biological homogenization increases because the same "urban-adaptable" species become increasingly widespread and locally abundant in cities across the planet. As urbanization often produces a local gradient of disturbance, one can also observe a gradient of homogenization. Synanthropic species adapted to intensely modified built habitats at the urban core are "global homogenizers", found in cities worldwide. However, many suburban and urban fringe habitats are occupied by native species that become regionally widespread. These

suburban adapters typically consist of early successional plants and "edge" animal species such as macropredator mammals, and ground-foraging, omnivorous and frugivorous birds that can utilize gardens, forest fragments and many other habitats available in the suburbs. A basic conservation challenge is that urban biota is often quite diverse and very abundant. The intentional and unintentional importation of species adapted to urban habitats, combined with many food resources imported for human use, often produces local species diversity and abundance that is often equal to or greater than the surrounding landscape. With the important exception of low-income areas, urban human populations often inhabit richly cultivated suburban habitats with a relatively high local floral and faunal diversity and/or abundance without awareness of the global impoverishment caused by urbanization. Equally challenging is that, because so many urban species are immigrants adapting to city habitats, urbanites of all income levels become increasingly disconnected from local indigenous species and their natural ecosystems. Urban conservation should therefore focus on promoting preservation and restoration of local indigenous species.

Urbanization also creates opportunities for women that are not available in rural areas. This creates a gender-related transformation where women are engaged in paid employment and have access to education. This may cause fertility to decline [4]. However, women are sometimes still at a disadvantage due to their unequal position in the labour market, their inability to secure assets independently from male relatives and exposure to violence.

A consequence of this difference in the timing of urbanization is that the location of "mega-cities" - the largest urban agglomerations in a given time period - has changed demonstrably over time. From 1500 to the mid-20th century the largest mega-cities in the world tended to be in countries that were relatively rich and developing rapidly (e.g. London and New York). From that point until today increased urbanization rates, combined with large population bases, mean that the largest mega-cities now tend to be located in poor countries (e.g. Dhaka and Lagos).Measurement errors are a particular issue for the earliest time periods, precisely the ones in which one would hope to use urbanization rates to proxy for non-existent GDP per capita data. In years such as 1500, the sources of data for both urbanization and GDP per capita are subject to much uncertainty, and thus the estimated correlation between them may be spurious. If measurement errors in GDP per capita are simply noise, then we will be under-estimating the slope of the relationship. On the other hand, if the measurement errors are

endogenous to the urbanization rate, then we are likely over-estimating the slope, which would be however less of an issue for our analysis.

Regarding the urbanization data itself, this also is subject to issues with measurement. There are issues in defining what constitutes a city, and in making accurate estimates of the population of those cities. However, Bairoch (1988); Malanima&Volckart (2007) both use a threshold of 5,000 inhabitants to define a city in their historical data. While we use several additional sources to supplement their data sets, it is fortunate for us that many of them also use the standard threshold of 5,000 inhabitants, which should minimize exogenous measurement errors. But endogenous measurement errors could still create biases in the estimated relationship between urbanization and development. If, for example, it is in particularly poor countries that the population in cities of 5,000 is underestimated then true urbanization rates would be higher, and the estimated slope of the relationship lower

1.1.2 Suburbanization:

Suburbanization is a population shift from central urban areas into suburbs, resulting in the formation of (sub)urban sprawl showed in **Fig.1.2** (Sub-urbanization is inversely related to urbanization, which denotes a population shift from rural areas into urban centres.)

Many residents of metropolitan regions work within the central urban area, and choose to live in satellite communities called suburbs and commute to work via automobile or mass transit. Others have taken advantage of technological advances to work from their homes. These processes often occur in more economically developed countries, especially in the United States, which is believed to be the first country in which the majority of the population lives in the suburbs, rather than in the cities or in rural areas. Proponents of containing urban sprawl argue that sprawl leads to urban decay and a concentration of lower income residents in the inner city.

In the United States, suburbanization started to happen in mass sums after World War II, when officers returned home from war and needed to live in houses outside of the city. During this time America had a prosperous postwar economy, there was more leisure time available and an increased priority in creating a family unit. Throughout the years, the desire to separate work life and home life has increased, causing an increase in suburban populations.

Suburbs are built for particular groups of people and around certain industries like restaurants, shopping, and entertainment which allows suburban residents to travel less and interact more in the suburban area. Suburbs in the United States have also evolved by increases in technology, which allows residents to work from home rather than commute.

Fig.1.2 Suburbanization is Latin America

The suburbanization process is showed in **Fig.1.3**and **Fig.1.4**showed the re-urbanization process.

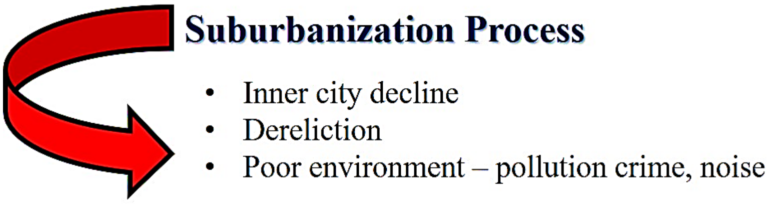

Fig.1.3 Suburbanization Process

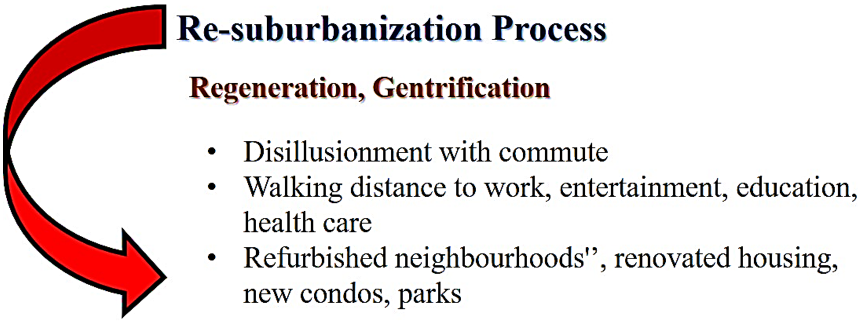

Fig.1.4 Re-suburbanization Process

Suburban Planet, explores the historical, conceptual, and thematic issues of modern global suburbanization which has become a massive and significant phenomenon in various regions of the world. Using a wide spectrum of academic literature in the field of urban and suburban studies, the author declares that the existing base of "western" and "centripetal-centrifugal" urban theory has to be re-thought. On the one hand, this statement builds on expanding the geography of suburban research in addition to an acquaintance with another trajectories of sub/urbanization in the regions of the Global South in post-socialist countries, and, on the other hand, is a criticism of the derivative significance of modern suburbs in relation to urban centres.

Sustainable landscape transformation as the consideration of both micro and macro-level structures in landscape management, where besides environmental and material organization, attention is paid to people's everyday attachment to place through community structures that resonate with a wider socio-cultural and historical background.s community creation in two suburban settlements in the Kiili municipality in the urban region of Tallinn through insights into how local history and environmental conditions influence community arrangements that have a socio-cultural effect on landscape patterns. In transforming communities, new homeowners need to adapt to their living environments by creating connections with places and people.

According to US Census data, 86 percent of all commuters drove to work in 2013 (McKenzie 2015). In addition to creating unwelcome road congestion, this massive automobile commute flow affects land-use in the CBD, with employee parking in the employment centres

of US cities consuming substantial amounts of land and other resources. Even though underground parking can limit the loss of land, parking in some CBDs covers more than 20 percent of the total land area. For example, in downtown Los Angeles, CA nearly 24% of land is allocated to industrial and commercial surface parking lots.1 This loss of land area hurts the city, reducing urban vitality and competitiveness by reducing the CBD's production potential.2 By contrast, public-transit usage does not create the same land demands as parking. Bus users require no land beyond the city streets on which buses travel, and while commuter rail users require a train station or subway stop, these facilities can be fairly compact and are often underground. Although a shift toward public transit would thus reduce parking's pressure on available CBD land, the choice between automobile and transit commuting is subject to a major distortion caused by the way parking is provided to workers. In particular, in attempting to attract and retain the best employees, nearly three-fourth of all firms in the U.S. provide free parking for their workers, offering an estimated 85 million free commuter parking spaces with a net worth of nearly $31.5 billion (EPA 2005).3 Since the practice is more common in large firms, 95 percent of all commuters who drive to work receive free parking. Even in the CBDs of large cities like New York and Los Angeles, where land is most scarce, over 50 percent of automobile commuters receive free parking paid for by their employer

1.1.3 Urban Sprawl:

Urban sprawl or suburban sprawl mainly refers to the unrestricted growth in many urban areas of housing, commercial development, and roads over large expanses of land, with little concern for urban planning in addition to describing a particular form of urbanization, the term also relates to the social and environmental consequences associated with this development. In Continental Europe the term "peri-urbanisation" is often used to denote similar dynamics and phenomena, although the term urban sprawl is currently being used by the European Environment Agency. There is widespread disagreement about what constitutes sprawl and how to quantify it. For example, some commentators measure sprawl only with the average number of residential units per acre in a given area. But others associate it with decentralization (spread of population without a well-defined centre), discontinuity (leapfrog development, as defined below), segregation of uses, and so forth.

The term urban sprawl is highly politicized, and almost always has negative connotations. It is criticized for causing environmental degradation, intensifying segregation

and undermining the vitality of existing urban areas and attacked on aesthetic grounds. Due to the pejorative meaning of the term, few openly support urban sprawl as such. The term has become a rallying cry for managing urban growth. It is showed in the **Fig. 1.5.**

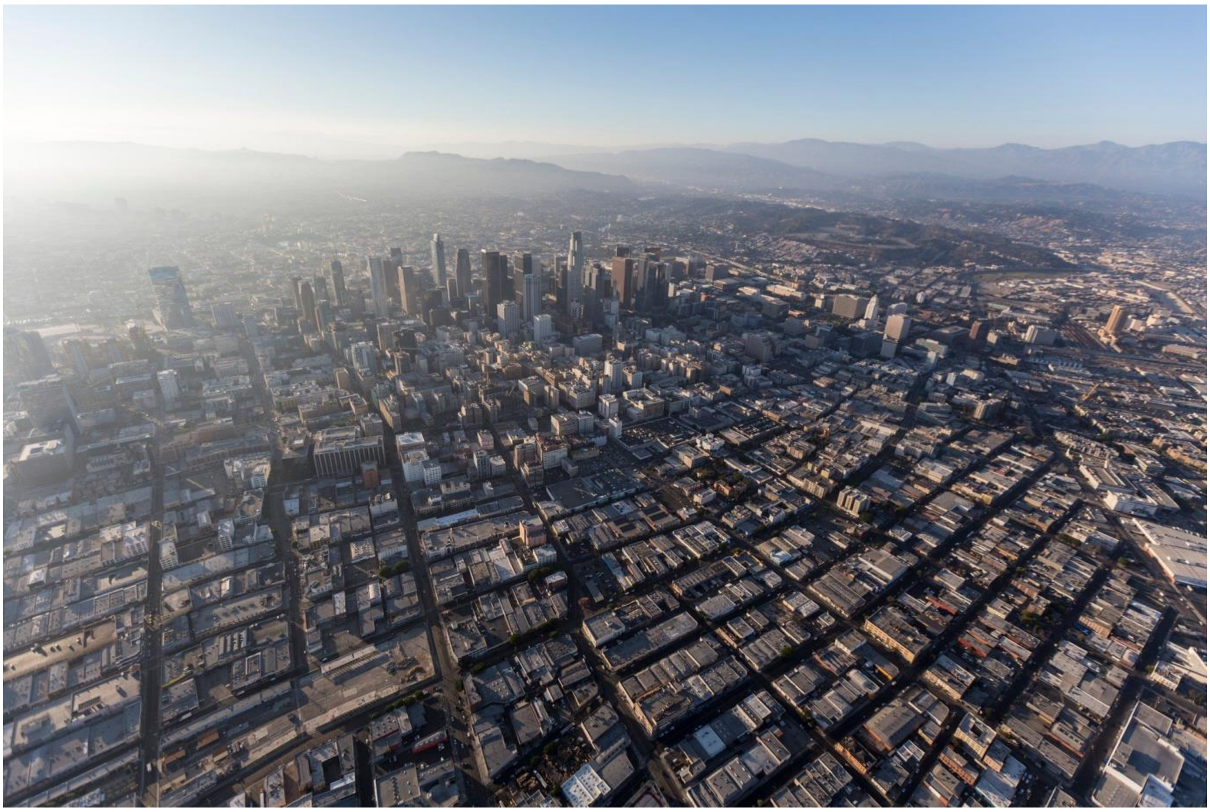

Fig.1.5 Picture of the Urban sprawl in Latin America

Urban sprawl has found widespread attention among scholars, planners, and policy makers. It has been defined and measured in various ways, and there is still no general agreement on how to measure and control urban sprawl and how to prevent its many harmful effects on the natural environment and its negative socio-economic consequences. Entropy has been one of the most often used metrics for the measurement of urban sprawl. However, its suitability in terms of requirements for measuring urban sprawl has not yet been examined systematically.Although urban sprawl has been a topic of great debate, there is still no commonly accepted definition of this phenomenon. For the past several decades, urban sprawl has been defined in various and often inconsistent ways in the academic literature. In most definitions, different sets of indicators of sprawl are used to define this phenomenonand several causes and consequences of sprawl have often been confused with the occurrence of sprawl itself. Urban sprawl is a phenomenon that can be visually perceived in the landscape. The term

denotes the extent of the area that is built-up, and its dispersion in the landscape, in relation to the utilization of built-up land for living and work.

Meanwhile, Latin America is the second most urbanized region after North America and has the highest urbanization rate in the developing world (well ahead of Asia). Nearly 80% of Latin America's people now live in cities; consequently, city dwellers provide the bulk of the region's demand for housing and social services. The region's 198 cities that each have populations of 200,000 or more currently host a total of 260 million people and have a combined gross domestic product (GDP) of $3.6 trillion (McKinsey 2011). By 2025, Latin American cities are expected to have 315 million inhabitants and to generate 65% of the region's GDP, which is estimated at $3.8 trillion (McKinsey 2011). Even though the region has already undergone the wave of urbanization that most other developing regions are expected to experience in the next 15 years, Latin America will experience important changes in income, population, and household formation patterns in the coming decades (Bouillon 2012).

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significant difficulties in their daily lives as a consequence of air quality deterioration, traffic congestion, noise pollution, and the unsustainable use of limited land resources. As a result, the increasing demands and outputs of human activities exceed environmental capacities (Donatiello 2001). The capacity of many urban areas is overstretched by the demands of human activity, increasing the need for and threatening the quality of basic services. These challenges are compounded by higher inequality, congestion, and expansion of slums (lower quality or informal housing). As a result of this lower quality of life, governments must, as a high priority, formulate policies that have environmental protection as an integral part of them.

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"The more area built-over in a given landscape (amount of built-up area), and the more dispersed this built-up area is on the landscape (spatial configuration), and the higher the uptake of built-up area per inhabitant or job (lower utilization intensity in the built-up area), the higher the degree of urban sprawl".

Accordingly, urban sprawl has three dimensions: the amount of land that is built-up, the dispersion of built-up areas over the landscape, and the density of people living or working in the urban areas. This definition is a refinement of the definition proposed earlier taking explicitly into account the land uptake per inhabitant or job (LUP) or, alternatively, the

utilization density (UD = number of inhabitants and jobs/ built-up area = 1/LUP). The refinement includes the understanding that densely populated places, like inner cities, do not count as urban sprawl.

Urbanization refers to the increase in the shares of urban populations over time. While Latin America took 2 centuries to achieve a 50% level of urbanization, the region took only 55 years more to have 80% of its population living in cities, a much faster urbanization rate than that of North America or Europe. Asia started urbanizing much later, but the speed and intensity of the process in Asia has also been remarkable. From 1980 to 2010, Asia added over a billion people to its cities—more than all other regions combined—with a further billion set to be city dwellers by 2030. The People's Republic of China (PRC) transitioned from 10% of its population in urban areas to 50% in just 60 years—a process that took 210 years in Latin America and the Caribbean. Moreover, Asia's urban population is projected to continue growing faster than that of other regions. Monitoring the degree of urban sprawl can greatly assist in controlling this phenomenon and its many negative effects, e.g., through a performance review for policies intended to counter sprawl. If the monitoring results are made available to responsible decision makers and the public, the results may serve as a strong incentive for planners and decisions makers to give urban sprawl more consideration and to increase their efforts to avoid sprawl. Many landscape metrics have been used for the quantification of urban sprawl, all of which have their particular strengths and weaknesses. It is important to choose the most reliable method for monitoring the state of a landscape and its changes over time (time series). Therefore, the behavior of every proposed metric needs to be carefully studied and compared with existing metrics before they are applied in monitoring systems. The methods for measuring urban sprawl cover a wide variety of aspects and their relation to urban sprawl is often not clear and sometimes relate instead to causes or consequences of this phenomenon rather than urban sprawl itself. Urban sprawl denotes expansion of human population away from the central urban areas into low-density areas that are mostly car dependent communities. The exact definition of urban sprawl differs among researchers as the term lacks precision and sometime have negative connotation. While urban sprawl appears to be inevitable phenomena, it is criticized for causing environmental degradation and undermining of existing urban areas as the margin expands. Batty andBesussidefines sprawl as,

"Uncoordinated growth: the expansion of community without concern for its consequences in short unplanned, incremental urban growth which is often regarded as unsustainable".

In India, the unprecedented population growth and migration results in urban sprawl where the urban fringe towns and cities cope up with changing land use along the highways and in the immediate vicinity of the city for better space. Due to which, the dispersed development takes place, outside the compact urban and village, along highways and rural countryside (Theobald, 2001) and this growth of built ups outside the urban margins are termed as urban sprawl. Bhatta et al. (2010) argues, despite the dispute over a precise definition of sprawl, the general consensus of urban sprawl is characterized by "unplanned and uneven pattern of growth, driven by multitude of processes and leading to inefficient resource utilization". Therefore, the methods of identifying urban sprawl is important in delineating the term from sub-urbanization using indicators (Ewing, 1997) rather than characteristics, as it is more flexible and less arbitrary.

In socialist cities the majority of urban land was owned by the state, property market was practically non-existent, urban policy and planning regulations fostered high-density developments. Residential or commercial sprawl could not evolve, at least that would have been comparable to the large-scale sprawls around cities in the United States or Western Europe. Consequently, one of the main differences between the physical appearance of socialist and capitalist cities was that the former was denser and more compact. Although the focus is on urban spatial character, attention will be paid to the wider historical, socio-economic and political conditions that have underpinned the process of suburbanization and sprawl around the Hungarian capital city.

As of 2010, Asia and Latin America were home to the densest cities in the world, with average city populations of 9.4 million in Asia and 4.6 million in Latin America (EIU 2012). The density of Asian cities, in particular, stands out, as is evident by the number of blue columns in Figure 5a. Nonetheless, Figures 5b and 5c show that urban density has declined and is projected to continue doing so in cities throughout the region, though this is primarily due to expansion of physical urban areas rather than a decline in the urban populations. The reduction in densities has been particularly striking in Ho Chi Minh City, Kolkata, and Manila. Countries in Asia and Latin America have experienced an increasing "metropolitanization"—the physical expansion of urban areas. Angel et al. (2005) observed that all Asian and Latin American cities

in their study increased their built-up area during 1990–2000. This massive expansion has resulted in new mega urban forms, with new externalities that arise from the networks of centres and urban systems that operate on different scales. The expanded metropolitanization reflects two separate processes: the expansion of big cities into adjacent areas and the interconnection of pre-existing towns. This implies that some of the biggest urban areas "are evolving from monocentric agglomerations to more complex systems made of integrated urban cores and subcenters. In other territories, a considerable number of cities and towns are increasingly linking up, forming polycentric integrated areas" Indeed, most cities have expanded horizontally faster than vertically, as technological capacities have reduced the barriers to interaction determined by distance. Glaeser and Kohlase (2003), for example, estimate that intercity transport costs in the United States declined by 90% during the 20th century. Other factors fuelling urban expansion in recent years include re-invigorated road-building activities, low-density suburban development, distant public housing projects, and squatter settlements at the urban fringe. An increasing number of industries, and hence settlements, also sprang up on the outskirts of cities as land prices in urban centers tend to be exponentially higher and

1.1.4 Pre-Urbanization

Peri-urbanisation relates to those processes of dispersive urban growth that creates hybrid landscapes of fragmented urban and rural characteristics. peri-urban areas (also called rurban space, outskirts or the hinterland) are defined by the structure resulting from the process of peri-urbanisation. It can be described as the landscape interface between town and country, or also as the rural—urban transition zone where urban and rural uses mix and often clash. It can thus be viewed as a landscape type in its own right, one forged from an interaction of urban and rural land use.

Its definition movements relying upon the worldwide area, however normally in Europe where urban regions are seriously figured out how to anticipate urban spread and ensure agrarian land, the urban periphery will be described by certain land utilizes which have either intentionally moved far from the urban region, or require a lot bigger tracts of land.As examples:

- Roads, especially motorways and bypasses

- Waste transfer stations, recycling facilities and landfill sites
- Park and ride sites
- Airports
- Large hospitals
- Power, water and sewerage facilities
- Factories
- Large out-of-town shopping facilities, e.g. large supermarkets

Despite these urban uses, the fringe remains largely open with the majority of the land agricultural, woodland or other rural use. However, the quality of the countryside around urban areas tends to be low with severance between areas of open land and badly maintained woodlands and hedgerows.

Apart from the structural definition dominating English-speaking literature, the concept is sometimes used to fill the gap between suburbanisation and ex-urbanisation, and thus relates moreover to the movement of people in space. In this case, peri-urbanisation is seen as the expansion of functional rural-urban linkages such as commuting. It is showed in the in the **Fig.1.6.**

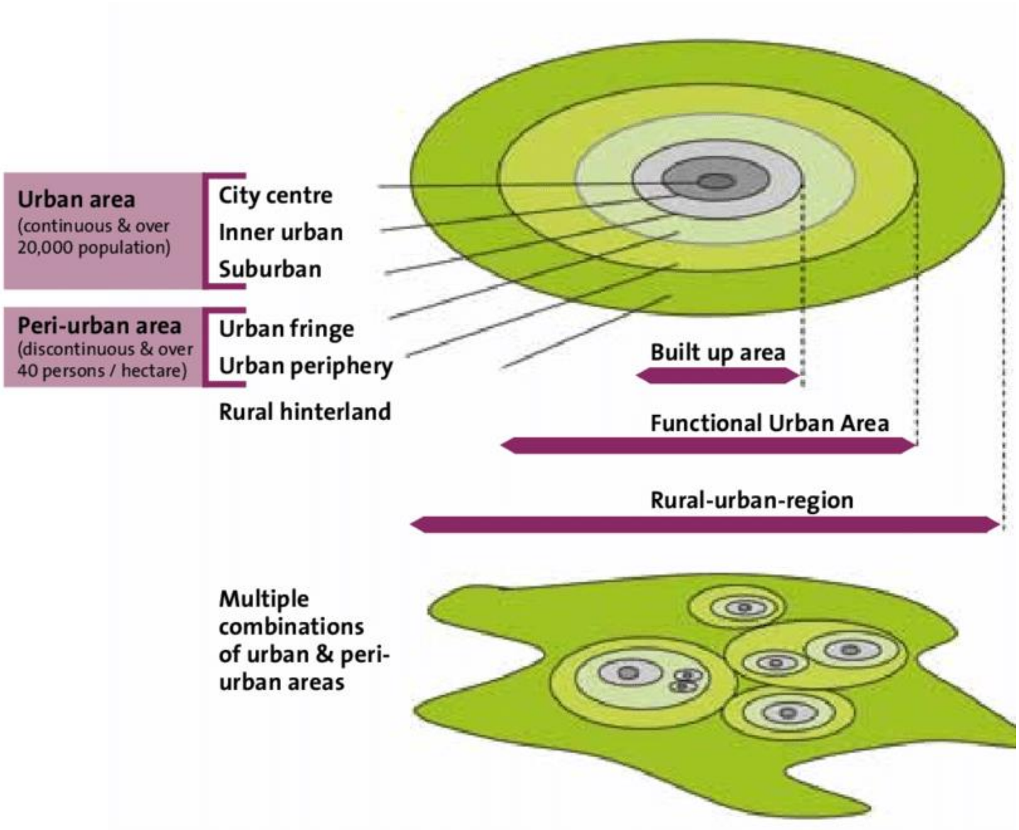

Fig.1.6 Peri-Urban Areas

In the mountain territories, the last decades have seen the expansion of urbanization towards the areas of contact between the plain and the slopes, places of multiple instabilities. Peri-urbanization in mountain basins with unstable slopes poses specific problems that local actors are trying to cope with. The Lavanchon basin (south-east of Grenoble), which combines a very rapid urban growth and particularly dynamic slopes, is representative of this rapprochement between hazards and activities. The diachronic study of the evolution of land use between 1956 and 2001 shows the densification of infrastructure in the valley and at the bottom of the slopes. In this context, a survey was conducted with a number of residents of the Lavanchon Basin to assess the degree of awareness that populations have natural hazards to which they are exposed. The results show that a little more than half of the surveyed population is aware of the problem of natural hazards in this territory, rather marked according to most inhabitants by the industrial and pollution risks. New residents ignore or obscure the reality of risks. The low frequency of significant natural events, the effectiveness of the protection works carried out, the lack of information from the public authorities and the fragmentation of the

basin between several managers seems to have generated a feeling of security in relation to natural phenomena.

The integration of rural areas surrounding cities into urban regions represents a common spatial development phenomenon in Europe in the recent decades. Physical conversion of open space – in particular agricultural land – for urban purposes and socio-cultural transitions in rural areas through adoption of urban life styles or in-migration of urban dwellers, leads to the establishment of a peri-urban space, and sets different forms of urban and rural living and working into close contact. However, it has been argued that, although under pressure and often marginalised, agriculture has responded to the peri-urban framework conditions by introducing post-productive, consumption-oriented adaptation of farming activities.

In the broadest sense, the configuration of cities is largely determined by geography and history. Cities traditionally emerged in areas that were easily accessible through waterways and had reliable supplies of basic needs such as water or fertile land. Hence, the cities tended to be located in the plains or near waterways, and from there, grew to their current size and form. But, since the industrial revolution, technology has played an increasing role in influencing urban form. An empirical investigation of 120 cities by Angel et al. (2005) identifies urban population, income, and linkages via air transport as primary drivers of urban land area expansion—a 100% increase in each of these factors can expand urban area by 66%, 50%, and 12%, respectively. As a result of increased access to information, policy tools (such as land and building taxes, zoning, and regulations; reconfiguration of infrastructure; and governance) also influence urban form, and therefore the efficiency of cities. Hong Kong, China; Singapore; and Tokyo all demonstrate how using these policies to engender an environment where human capital is harnessed to work collaboratively can make for successful as well as sustainable cities. Urban form and the spatial pattern of land use influence the way cities use and generate resources and waste, and ultimately the quality of life of city dwellers. Two general patterns of urban growth yield particularly favorable results—“satellite cities” and “compact concentric zones.” These patterns help preserve large patches and corridors of green space for ecosystems while at the same time providing for human development. Other patterns of urban growth, such as urban sprawl, produce less optimal results. This pattern, “which jumbles together fine-scale patches of people and nature on the land is one of the least attractive designs. In addition to conserving fewer large patches of land for ecosystems, sprawl tends to increase vehicle miles

driven by commuters, resulting GHG emissions, and infrastructure costs". The greater dispersion of population makes it difficult to concentrate enough demand to efficiently deliver public services. In Asia's dense cities, with critical masses of people in relatively small areas, supplying essential services such as piped water and sanitation is less complex and more cost effective than in dispersed settlements.

The integration of rural areas surrounding cities into urban regions represents a common spatial development phenomenon in Europe in the recent decades. Physical conversion of open space – in particular agricultural land – for urban purposes and socio-cultural transitions in rural areas through adoption of urban life styles or in-migration of urban dwellers, leads to the establishment of a peri-urban space, and sets different forms of urban and rural living and working into close contact. However, it has been argued that, although under pressure and often marginalised, agriculture has responded to the peri-urban framework conditions by introducing post-productive, consumption-oriented adaptation of farming activities. In-migration and socio-cultural changes represent relevant drivers for the development of agriculture in peri-urban areas around Copenhagen region. Although a distinct cause-effect relation might not exist, a mutual influence of peri-urbanisation and agriculture has been observed. The central research objective of this paper is to explore the relationship between the heterogeneous types of peri-urbanisation processes (ex-, displaced-, anti- and hidden-urbanisation) and effects on agricultural activity. More specifically, it aims at analysing the spatial co-existence of peri-urbanisation types and the extent of multifunctional farm adaptation, such as small-scale, high-value farming systems, the farmers' participation in landscape management and agri-environmental measures as well as the recreational and lifestyle orientation in peri-urban areas.

Chapter 2: Literature Review

Cohen [5] provided a broad overview of the recent patterns and trends of urban growth in developing countries. Over the last 20 years many urban areas have experienced dramatic growth, as a result of rapid population growth and as the world's economy has been transformed by a combination of rapid technological and political change. Around 3 billion people—virtually half of the world's total population-now live in urban settlements. And while cities command an increasingly dominant role in the global economy as centres of both production and consumption, rapid urban growth throughout the developing world is seriously outstripping the capacity of most cities to provide adequate services for their citizens. Over the next 30 years, virtually all of the world's population growth is expected to be concentrated in urban areas in the developing world. While much of the current sustainable cities debate focuses on the formidable problems for the world's largest urban agglomerations, the majority of all urban dwellers continue to reside in far smaller urban settlements. Many international agencies have yet to adequately recognize either the anticipated rapid growth of small and medium cities or the deteriorating living conditions of the urban poor. The challenges of achieving sustainable urban development will be particularly formidable in Africa.

Aithal et al. [6] studied an integrated approach of remote sensing and spatial metrics with gradient analysis was used to identify the trends of urban land changes with a minimum buffer of 3 km buffer from the city boundary has been studied (based on availability of data), which help in the implementation of location specific mitigation measures. Rapid irreversible urbanisation has haphazard and unplanned growth of towns and cities. Urbanisation process is driven by burgeoning population has resulted in the mismanagement of natural resources. Human-induced land use changes are the prime drivers of the global environmental changes. Urbanisation and associated sub growth patterns are characteristic of spatial temporal changes that take place at regional levels. Rapid urbanization subsequent to opening up of Indian markets in early ninety's show dominant changes in land use during the last two decades. Urban regions in India are experiencing the faster rates of urban dominance, while peri-urban areas are experiencing sprawl. Tier II cities in India are undergoing rapid changes in recent times and need to be planned to minimize the impacts of unplanned urbanisation. This communication focuses on seven tier II cities, chosen based on population. Mysore, Shimoga, Hubli, Dharwad, Raichur, Belgaum, Gulbarga and Bellary are the rapidly urbanizing regions of Karnataka, India. Results indicated a significant increase of urban built-up area during the

last four decades. Landscape metrics indicates the coalescence of urban areas has occurred in almost all these regions. Urban growth has been clumped at the center with the simple shapes and dispersed growth in the boundary region and the peri-urban regions with the convoluted shapes.

Mexico City, one of the heavily populated cities in Latin America, has likewise experienced de-densification of 60% during a span of 3 decades. The city’s population increased 40% between 1980 and 2010, while the metropolitan area expanded by 250% (SEDESOL 2011). Figures 10 and 11 demonstrate the physical evolution of Mexico City during 4 centuries, following a concentric pattern. The enlargement of the metropolitan area imposed major transformations in the surrounding rural and urban centers, generating growth and development in the region. The use of land surrounding small towns changed when it was acquired by industries established outside the city. The natural environment of the formerly sparsely populated areas became housing land and recreational space for increasing numbers of city dwellers and traditional land use changed with little deliberate or adequate planning. In effect, Mexico City’s growth promoted the urbanization of the municipalities of Cuernavaca, Pachuca, and Toluca, which are beyond Mexico City’s metropolitan area (Figure 10) and have traditionally provided environmental services to the city. These municipalities now have a predominantly urban character and a high urban density. They retain a strong level of functional relationships with Mexico City, such as having a significant number of residents commuting to work within the central municipalities of the metropolitan area and providing work to residents of the central municipalities. A high percentage of the three municipalities’ populations now work in industrial, commercial, and service activities.

Bhatta et al. [7] done an analysis of urban growth by using the historical and present data is an essentially performed operation in the urban geographic studies and for future planning. Urban growth is a spatial and demographic process and refers to the increased importance of towns and cities as a concentration of population within a particular economy and society. Urban growth can be mapped, measured and modelled by using remote sensing data and GIS techniques along with several statistical measures. In this study three temporal satellite images of 15 years interval (1975, 1990 and 2005) have been classified to determine the urban extent and growth of Kolkata-Howrah (West Bengal, India) in eight different directions within a circular region. Pearson's chi-square test and Shannon's entropy method have been applied to calculate the degree-of-freedom and degree-of-sprawl towards the

analysis of urban growth. A new measure, degree-of-goodness, has also been proposed for the analysis of urban growth. The result shows that the city of Kolkata-Howrah has a high degree-of-freedom, high sprawl, and a negative goodness in urban growth. Apart from the derived results, this study also shows the potentials of remote sensing data and effectiveness of demonstrated/proposed models in urban geographic studies. In physical terms, the last 60 years of urban growth in Medellin has resulted in the pattern of a dense central urban core with several minor centers north and south of Medellin, in the Aburra Valley. This urban form has been described as concentric and therefore of low spatial footprint. Connectivity in Medellin metropolis is achieved by a high capacity road system that also functions as a national road. Topographic conditions preclude building ring roads. Most urban facilities, services, and functions are located along the road system, as are the industry and the main mass transport system—an elevated metro system built in the 1990s that guarantees good accessibility to urban centers within the valley. Residential areas, both formal and informal, tend to occupy steeper zones. Nonetheless, the dynamics of city expansion implied the development of informal settlements in the city because the growing demand for housing generated by the exodus from rural areas was unmet. At first, the informal settlement process in Medellin focused on the steepest areas on the city's northern, central-east, and western hillsides, which had adverse conditions for human occupation and provision of public services. Conventional real estate and urbanization processes focused on the flattest areas of the valley, with better accessibility, topography, and location conditions.

Petrov et al. [8] present a range of future urban land use change scenarios and the implications of capacity-building/urban development and economy demand for the European tourist region. Using the MOLAND model, four future urban growth scenarios were created based on data and storylines for the Algarve region, Portugal case study. In all scenarios, urban growth arises from the increase in population particularly, due to tourism and economic change. However, the spatial patterns are different due to alternative assumptions about urban development processes/purposes. To conclude, the future urban development of the Algarve is mainly governed by two categories: the discontinuous urban and industrial & commercial classes. The general trend over 20-years shows that discontinuous residential area records the highest number of patches in all scenarios; however, it has the lowest number of patches and the highest mean area in the C scenario where environmentally friendly policies are applied. A similar result is shown for the industrial & commercial category. The different policy visions unfolded into potential scenarios presented in this study show that tourist areas are likely to

become an important issue for land use in Europe. The results of modelling are successfully illustrated in a spectrum of possible land use/land cover change scenarios for year 2020. They provide a very useful input for starting discussions on the “behaviour” and future urban development planning of European's tourist areas.

Luck et al. [9] research was designed to address four research questions: How do different land use types change with distance away from the urban center? Do different land use types have their own unique spatial signatures? Can urbanization gradients be detected using landscape pattern analysis? How do the urban gradients differ among landscape metrics? The answers to these questions were generally affirmative and informative. Urbanization is arguably the most dramatic form of land transformation that profoundly influences biological diversity and human life. Quantifying landscape pattern and its change is essential for the monitoring and assessment of ecological consequences of urbanization. Combining gradient analysis with landscape metrics, we attempted to quantify the spatial pattern of urbanization in the Phoenix metropolitan area, Arizona, USA. Several landscape metrics were computed along a 165 km long and 15 km wide transect with a moving window. The results showed that the spatial pattern of urbanization could be reliably quantified using landscape metrics with a gradient analysis approach, and the location of the urbanization center could be identified precisely and consistently with multiple indices. Different land use types exhibited distinctive, but not necessarily unique, spatial signatures that were dependent on specific landscape metrics. The changes in landscape pattern along the transect have important ecological implications, and quantifying the urbanization gradient, as illustrated in this paper, is an important first step to linking pattern with processes in urban ecological studies.

Allen et al. [10] created a dynamic model of urban growth presented by the authors in an earlier paper is further developed here, in order to take into account the possibility of daily travel between the point of residence and of employment. Model is done so that the parameters and levels in the system correspond to a particular urban hierarchy, then it should allow us to study the real, long-term effects of different possible strategies and decisions concerning its future. For example, a change in the transport network, or in the technology, or in the mobility of the population will lead to a redistribution of economic demand, which will modify the pattern of employment, and which will in turn cause a redistribution of the population, leading to a further modification of the economic demand, and so on, until the effects of the initial changes have been fully worked through the whole system. Only a model such as ours can ever permit the

estimation of the real cost/benefit of any particular decision that must be made, although the reader may disagree with the detailed choice of our particular set of equations. Another possibility that our model offers is to study the effect of a particular change in the urban hierarchy, induced perhaps from 'outside' the system of equations themselves, say a 'new town', introduced at a given point by specific government action. By studying the evolution of different sized 'new towns' using the model, it would be possible to find an optimum initial size such that the 'seed' would be self-sustaining, and indeed more than that would act as an economic motor for its surrounding area, but would not so divert growth from other areas that its success would be more than outweighed by the price exacted in other centres. With this modification the model leads to a more realistic description of the urbanization of a region, giving rise to successive phases of central growth, urban sprawl, central core decay and to counter urbanization.

Jat at al. [11] done a research on urban sprawl of the Ajmer city (situated in Rajasthan State of India) has been studied at a mid-scale level, over a period of 25 years (1977–2002), to extract the information related to sprawl, area of impervious surfaces and their spatial and temporal variability. Statistical classification approaches have been used for the classification of the remotely sensed images obtained from various sensors viz. Landsat MSS, TM, ETM+ and IRS LISS-III. Urban sprawl and its spatial and temporal characteristics have been derived from the classified satellite images. The Shannon's entropy and landscape metrics (patchiness and map density) have been computed in terms of spatial phenomenon, in order to quantify the urban form (impervious area). Further, multivariate statistical techniques have been used to establish the relationship between the urban sprawl and its causative factors. The concentration of people in densely populated urban areas, especially in developing countries, calls for the use of monitoring systems like remote sensing. Such systems along with spatial analysis techniques like digital image processing and geographical information system (GIS) can be used for the monitoring and planning purposes as these enable the reporting of overall sprawl at a detailed level. Results reveal that land development (160.8%) in Ajmer is more than three times the population growth (50.1%). Shannon's entropy and landscape metrics has revealed the spatial distribution of the urban sprawl over a period of last 25 years.

Garouani et al. [12] analyzed the relationship between urbanization and land use changes and their impact on cityscape in Fez and the importance of the increase in impervious surface areas. Fez is the most ancient of the imperial cities of Morocco. In Fez the rate of

population growth has been spectacular in recent times (484,300 inhabitants in 1982 and 1,129,768 in 2014). The accelerated rate of population growth has generated a large urban sprawl in all its forms and serious environmental problems. Satellite imageries and census data have been used to identify different patterns of land use change and growth of the city for the period 1984–2013. Classification and analysis of the satellite imageries were performed using Erdas imagine and ArcGIS Software. Urban sprawl in Fez was assessed over 29 years (1984–2013). The overall accuracy of land cover change maps, generated from post-classification change detection methods and evaluated using several approaches, ranged from 78% to 87%. The maps showed that between 1984 and 2013(**Fig. 2.1**) the amount of urban or developed land increased by about 121%, while rural cover by agriculture and forest decreased respectively by 11% and 3%.

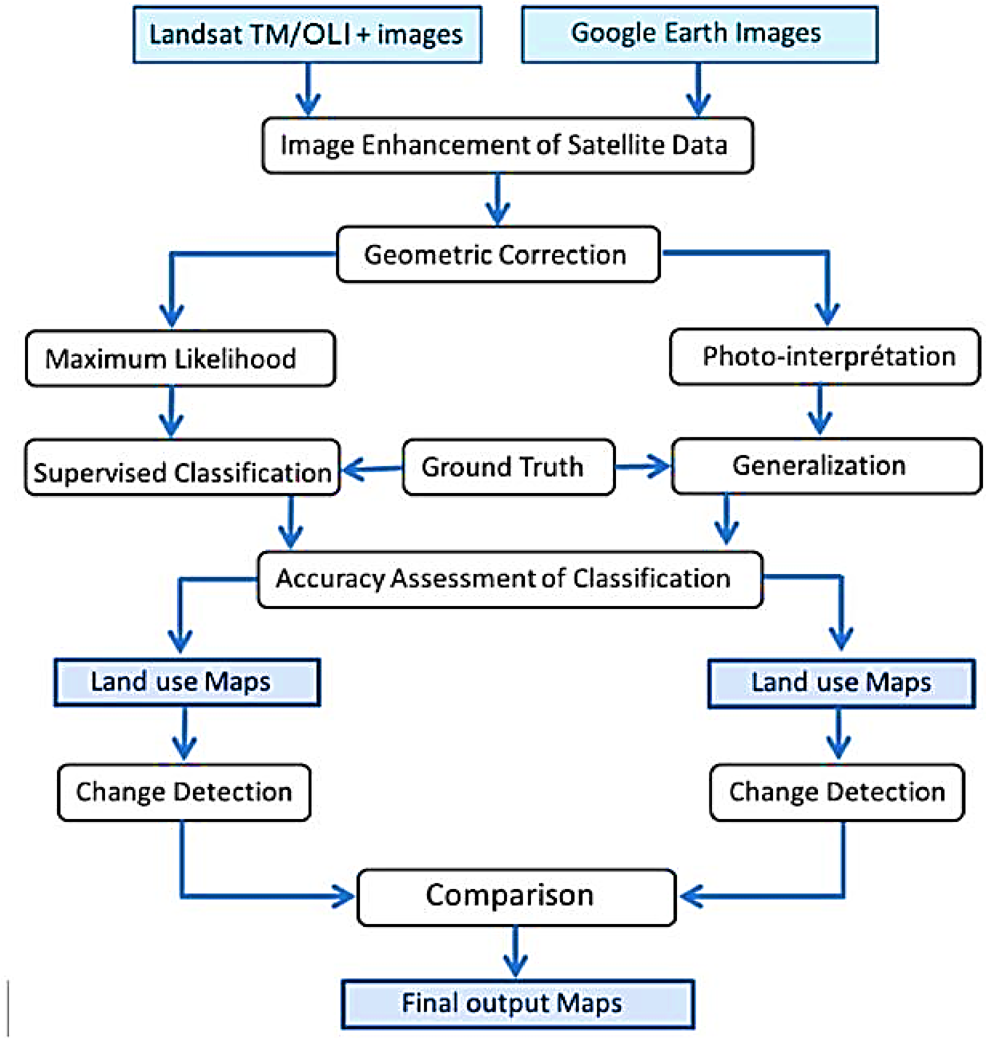

Fig.2.1 Flowchart of spatial and temporal changes in urban land cover.

Bhat et al. [13] did a study to understand and quantify the urban sprawl. In this study, an attempt has been made to monitor land use/land cover of part of Dehradun city over two periods of time i.e., from 2004 to 2014 for change detection analysis and to assess urban sprawl using IRS P-6 data and topographic sheets, in GIS environment for better decision making and sustainable urban growth. The world has seen the development and growth of urban areas at a faster pace. The rapid urban growth and development have resulted in the increase in the share of India's urban population from 79 million in 1961 that was about 17.92 percent of India's total population to 388 million in 2011 that is 31.30 percent of India's total population. This fast rate of increase in urban population is mainly due to large scale migration of people from rural and smaller towns to bigger cities in search of better employment opportunities and better quality of life. Urban sprawl has resulted in loss of productive agricultural lands, open green spaces and loss of surface water bodies. Therefore, rapid increases in both urban/built-up expansions led to dramatic changes in land use and land cover, which were witnessed by sharp decreases in agriculture, fallow, and vacant. Given an excessively dense population, massive resource consumption, and very scarce land resource, these adverse factors have greatly impaired the city's capacity to meet the challenges presented by modern growth and expansion for which planning policies needs to be devised for providing a sustainable environment. Thus, rational urban planning policy must be made to decrease the adverse effects of urbanization and enhance the sustainability of important urban center of North India.

Alphan[14] studied an analyses land-use/land-cover (LULC) changes in Adana city, Turkey, using satellite data of 1984 and 2000. Study of the expansion of the city over adjacent agricultural fields and semi-natural areas was the major focus. The satellite images were classified using supervised classification prior to comparison of LULC on two different dates. The change map was produced by pixel-to-pixel comparison of the classified images. Urban and built-up area increased by a factor of 2ċ07 during the 16 years; about 30 per cent on agricultural land and 70 per cent on previously semi-natural land. Permanent immigration and urban development strategies were the main driving forces. Identification of LULC trends is not difficult when pairwise comparison is performed. The time series of a particular urban area can be analysed to determine trends more accurately and depletion of agricultural and seminatural areas adjacent to city can be proven. Two Landsat datasets with 30 m ground resolution were classified and compared to detect LULC changes in the study area for a 16-year period. The frequency of change detection may be increased to decadal or half-decadal intervals depending upon the magnitude and extent of the changes. This study has shown that

this is an accurate, rapid and cost-effective method for detecting LULC changes in urban areas in a rapidly developing country, where areas of high economic and ecological importance around cities are subject to severe destruction due to an unprecedented increase of urban population. Provision of timely, consistent and reliable LULC information helps in achieving sustainable development of urban environments.

Wolff et al. [15] described an urban growth model, the Phoenix Urban Growth Model (PHX-UGM), illustrate a series of model calibration and evaluation methods, and present scenario-based simulation analyses of the future development patterns of the Phoenix metropolitan region. PHX-UGM is a spatially explicit urban landscape model and is a modified version of the Human-Induced Land Transformations (HILT) model originally developed for the San Francisco Bay Area. Using land use and other data collected for the Phoenix area, existing growth rules were selectively modified and new rules were added to help examine key ecological and social factors. We used multiple methods and a multi-scale approach for model calibration and evaluation. The results of the different evaluation methods showed that the model performed reasonably well at a certain range of spatial resolutions (120–480 m). When fine-scale data are available and when landscape structural details are desirable, the 120-m grain size should be used. However, at finer levels the noise and uncertainty in input data and the exponentially increased computational requirements would considerably reduce the usefulness and accuracy of the model. At the other extreme, model projections with too coarse a spatial resolution would be of little use at the local and regional scales. A series of scenario analyses suggest that the Metropolitan Phoenix area will soon be densely populated demographically and highly fragmented ecologically unless dramatic actions are to be taken soon to significantly slow down the population growth. Also, there will be an urban morphological threshold over which drastic changes in certain aspects of landscape pattern occur. Specifically, the scenarios indicate that, as large patches of open lands (including protected lands, parks and available desert lands) begin to break up, patch diversity declines due partly to the loss of agricultural lands, and the overall landscape shape complexity also decreases because of the predominance of urban lands. It seems that reaching such a threshold can be delayed, but not avoided, if the population in the Phoenix metropolitan region continues to grow. PHX-UGM can be used as a tool for exploring the outcome of different urban planning strategies, and the methods illustrated in this paper can be used for evaluating other urban models.

Batty [16] attempted to describe from three related perspectives the successes and failures characterising the short but turbulent history of urban modelling: from the broader perspectives of knowledge or scientific theory, and of action or design; and from the narrower perspective of the modelling activity itself. It is argued that modelling is concerned solely neither with science nor with design but with both; that is, it is concerned with the relationship between science and design and must be examined accordingly. Various arguments pertaining to these themes are elaborated in terms of the inadequacy of its theory and the dictates imposed by policy. Viewed from the individual perspectives of science or design, modelling is often judged a dismal failure but, in this essay, it is argued that as such views are necessarily incomplete, some compromise must be sought. In these terms, the field manifests a limited success. Much has been learned about the activity itself but, as in all situations involving immature science, the real value of these experiences may be in raising awareness of the conflicts and dilemmas which occur when uncertain knowledge is applied to problems whose perception is continually changing. Nevertheless, it does appear that a certain isolation from the dictates of policy is necessary before many of the scientific questions raised by this type of activity can be clarified; but as such activity is potentially costly and cannot be totally pursued on an individual basis, some public support for this activity is necessary. Herein lies the same dilemma which has confronted physical science, or at least 'Big' science, in the post-war period. Yet the conditions are quite different, for the physical sciences in a sense have 'proved themselves' or at least conveyed that impression: the social sciences have not, and thus the prospects for activities such as urban modelling are quite uncertain.

Jenerette et al. [17] To understand how urbanization has transformed the desert landscape in the central Arizona – Phoenix region of the United States, we conducted a series of spatial analyses of the land-use pattern from 1912–1995. The results of the spatial analysis show that the extent of urban area has increased exponentially for the past 83 years, and this urban expansion is correlated with the increase in population size for the same period of time. The accelerating urbanization process has increased the degree of fragmentation and structural complexity of the desert landscape. To simulate land-use change we developed a Markov-cellular automata model. Model parameters and neighborhood rules were obtained both empirically and with a modified genetic algorithm. Land-use maps for 1975 and 1995 were used to implement the model at two distinct spatial scales with a time step of one year. Model performance was evaluated using Monte-Carlo confidence interval estimation for selected landscape pattern indices. The coarse-scale model simulated the statistical patterns of the

landscape at a higher accuracy than the fine-scale model. The empirically derived parameter set poorly simulated land-use change as compared to the optimized parameter set. In summary, our results showed that landscape pattern metrics (patch density, edge density, fractal dimension, contagion) together were able to effectively capture the trend in land-use associated with urbanization for this region. The Markov-cellular automata parameterized by a modified genetic algorithm reasonably replicated the change in land-use pattern.

Kirtland et al. [18] investigated the ways that humans transform the land and the effects that changing the landscape may have on regional and global systems. Part of the US Geological Survey's Global Change Research Program involves studying the area from the Pacific Ocean to the Sierra foothills to enhance understanding of the role that human activities play in global change. To accomplish this research, scientists are compiling records of historical transformations in the region's land cover over the last 140 years, developing a simulation model to predict land cover change, and assembling a digital data set to analyze and describe land transformations. The historical data regarding urban growth focus attention on the significant change the region underwent from 1850 to 1990. The historical change is being used to calibrate a prototype cellular automata model, developed to predict changes in urban land cover 100 years into the future. These data aid in documenting and understanding human-induced land transformations from both historical and predictive perspectives. A descriptive analysis of the region is used to investigate the relationships among data characteristic of the region. These data consist of multilayer topography, climate, vegetation, and population data for a 256-km [sup 2] region of central California. A variety of multivariate analysis tools are used to integrate the data in raster format from map contours, interpolated climate observations, satellite observations, and population estimates.

Byomkesh et al. [19] attempt to dynamically map and monitor green spaces in Greater Dhaka of Bangladesh. Both primary and secondary data were acquired to document the spatial–temporal dynamics of green spaces in the study area. Green space is particularly indispensable for proper functioning of the ecosystem in an urban environment. Using a supervised classification algorithm, multi-temporal land use/cover data were extracted from a set of satellite images. A number of spatial metrics were employed to understand the landscape condition in a multi-temporal manner. In addition, 50 key informants along with focus group discussion and observation techniques were used to document existing management aspects of green spaces and their conservation policies. The analysis revealed that green spaces in Greater

Dhaka are rapidly disappearing over the course of time even though they provide a number of natural, economic and social benefits. The disappearance of green spaces was primarily attributed to a rapid increase in the urban population, mainly driven by rural–urban migration. As a result, the landscape became highly fragmented and less connected. A substantial reduction of green patches is also leading to deterioration of the ecological condition of the landscape. The drastic reduction of green spaces in Greater Dhaka has been attributed to a lack of policy, low political motivation, and poor management showed in the **Fig**.2.2 In order to ensure sustainability of green spaces and proper functioning of the city's ecosystem, there is an urgent need for strategic green space planning.

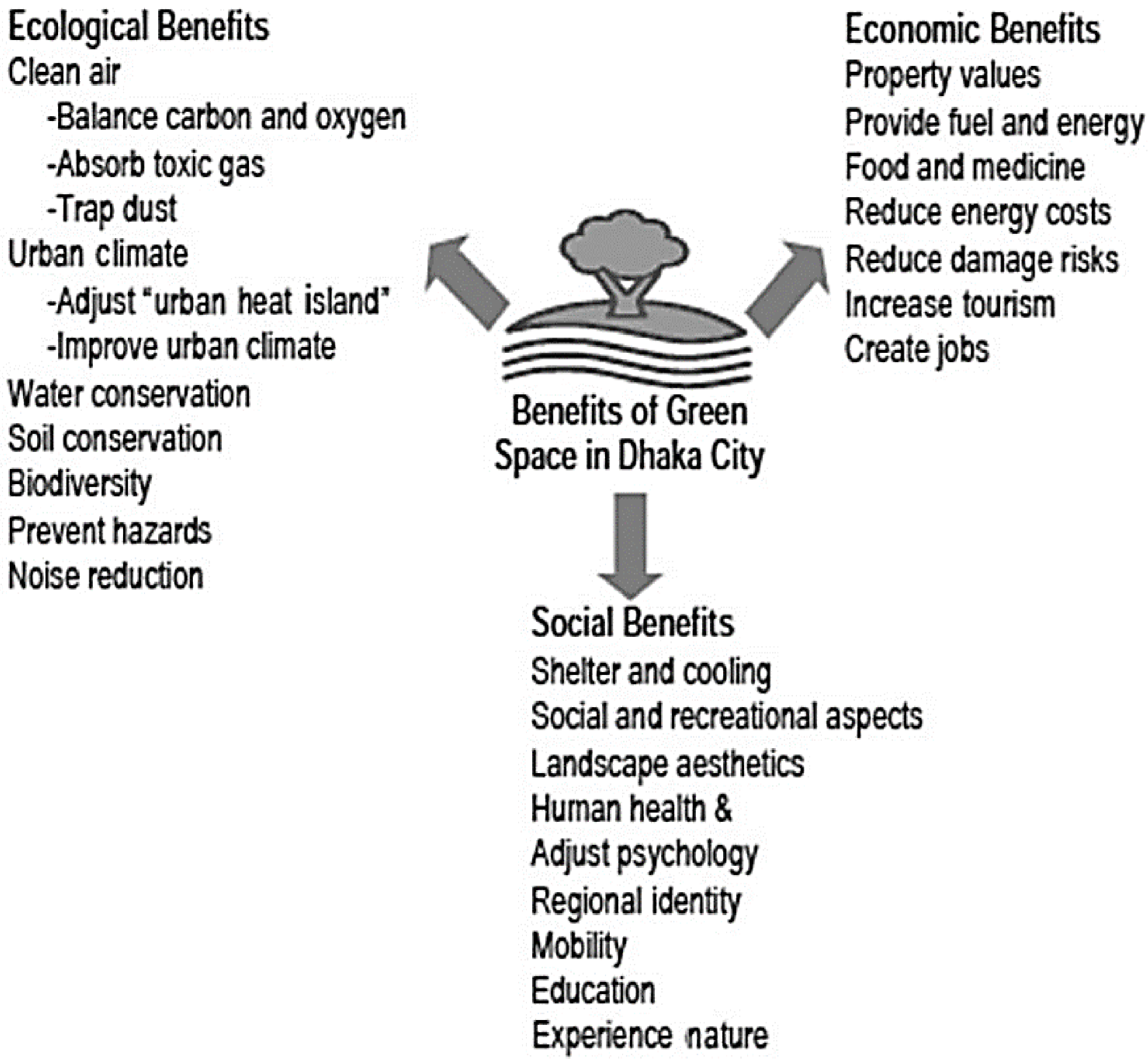

Fig.2.2 Conceptualization of the benefits of green spaces

Apan et al. [20] done a case study of the Lockyer Valley catchment in Queensland, Australia, was conducted to develop appropriate mapping and assessment techniques to quantify the nature and magnitude of riparian landscape structural changes within a catchment. The study employed digital image processing techniques to produce land cover maps from the 1973 and 1997 Landsat imagery. Fixed and variable width buffering of streams were implemented using a geographic information system (GIS) to estimate the riparian zone and to subsequently calculate the landscape patterns using the Patch Analyst (Grid) program (a FRAGSTATS interface). The nature of vegetation clearing was characterised based on land tenure, slope and stream order. Using the Pearson $\chi 2$-test and Cramer's V-statistic, the relationships between the vegetation clearing and land tenure were further assessed. The results show the significant decrease in woody vegetation areas mainly due to conversion to pasture. Riparian vegetation corridors have become more fragmented, isolated and of much smaller patches. Land tenure was found to be significantly associated with the vegetation clearing, although the strength of association was weak. The large proportion of deforested riparian zones within steep slopes or first-order streams raises serious questions about the catchment health and the longer-term potential for land degradation by upland clearing. This study highlights the use of satellite imagery and GISs in mapping and analysis of landscape structural change, as well as the identification of key issues related to sensor spatial resolution, stream buffering widths, and the quantification of land transformation processes.

Baker et al. [21] Geographical information systems (GIS) are well suited to the spatial analysis of landscape data, but generally lack programs for calculating traditional measures of landscape structure (e.g., fractal dimension). Standalone programs for calculating landscape structure measures do exist, but these programs do not enable the user to take advantage of GIS facilities for manipulating and analyzing landscape data. Moreover, these programs lack capabilities for analysis with sampling areas of different size (multiscale analysis) and also lack some needed measures of landscape structure (e.g., texture). Developed the r.le programs for analyzing landscape structure using the GRASS GIS. The programs can be used to calculate over sixty measures of landscape structure (e.g., distance, size, shape, fractal dimension, perimeters, diversity, texture, juxtaposition, edges) within sampling areas of several sizes simultaneously. Also possible are moving window analyses, which enable the production of new maps of the landscape structure within windows of a particular size. These new maps can then be used in other analyses with the GIS.

Congalton et al. [22] reviewed the necessary considerations and available techniques for assessing the accuracy of remotely sensed data. Included in this review are the classification system, the sampling scheme, the sample size, spatial autocorrelation, and the assessment techniques. All analysis is based on the use of an error matrix or contingency table. Example matrices and results of the analysis are presented. Future trends including the need for assessment of other spatial data are also discussed.

Dewan et al. [23] objective to assess flood hazard in Greater Dhaka for the historical flood event of 1998 using Synthetic Aperture Radar (SAR) data with GIS data. Floods are a common feature in rapidly urbanizing Dhaka and its adjoining areas. Though Greater Dhaka experiences flood almost in every year, flood management policies are mostly based on structural options including flood walls, dykes, embankments etc. Many shortcomings of the existing flood management systems are reported in numerous literatures. Flood-affected frequency and flood depth calculated from the multi-date SAR imageries were used as hydrologic parameters. Elevation heights, land cover classification, geomorphic division and drainage network data generated from optical remote sensing and analogue maps were used through GIS approach. Using a ranking matrix in three-dimensional multiplication mode, flood hazard was assessed. All possible combination of flood hazard maps was prepared using land-cover, geomorphology and elevation heights for flood-affected frequency and floodwater depth. Using two hazard maps which produced the highest congruence for flood frequency and flood depth, a new flood hazard map was developed by considering the interactive effect of flood-affected frequency and floodwater depth, simultaneously. This new hazard map can provide more safety for flood countermeasures because pixels belonging to higher hazard degrees were increased due to the consideration of higher degrees of ranks. The estimation of flood hazard areas revealed that a major portion of Greater Dhaka comprised moderate to very high hazard zone. Only a little portion (8.04%) was found to be the least vulnerable to potential flood hazard. Conversely, 28.70% of Greater Dhaka was found within very high hazard zone. Based on this study, comprehensive flood hazard management strategies for land use planning decision were proposed for the efficient management of future flood disasters.

Dorner et al. [24] presented a a set of techniques designed to incorporate the topographic mosaic into analyses of landscape pattern and dynamics. Ecological research provides ample evidence that topography can exert a significant influence on the processes shaping broad-scale landscape vegetation patterns. Studies that ignore this influence run the

risk of misinterpreting observations and making inappropriate recommendations to the management community. Unfortunately, the standard of the methodologies for landscape pattern analysis are not designed to include topography as a pattern-shaping factor. This toolbox includes adjustments to ‘classic’ landscape indices that account for non-uniform landscape topography, indices that capture associations and directionality in vegetation pattern due to topographic structure, and the application of statistical models to describe relationships between topographic characteristics and vegetation pattern. To illustrate these methods, draw on examples from our own analysis of landscape pattern dynamics in logged and unlogged forest landscapes in southwestern British Columbia. These examples also serve to illustrate the importance of considering topography in both researches to be done and management applications.

Chapter 3: Research Methodology

All Many efforts have been made earlier to understand the hydrological effects of urbanization on river basins using RS and GIS technology. Most of the studies constitute study of impacts of urbanization on either or combination of these components viz. LULC, vegetation, river network, rainfall-runoff, stream flow, stream water quality, ground water etc. But the cumulative effect of all these components together on the river basin ecosystem is yet to be studied. A functionally viable model is now required to establish the interrelationship between these components and to understand the trend of spatio-temporal changes with increasing urbanization. For better planning and management of river basin ecosystem, a comprehensive study is to be done on regional as well as on local scale. During river basin management planning and catchment modelling in India, the main focus is given to increasing anthropogenic water demands. But determining the environmental demands/ecosystem demands (e.g. environmental flows) of river basins is equally important for sustainable development. At present it is assumed to be zero therefore this area of study has wide scope. The ecosystem requirements of the river basins and the effect of urbanization on ecosystem components. Based on the background work, the main objective of the study is to develop an integrated model to study the effects of urbanization on river basin ecosystem. The specific objectives of the study include:

(1) Study of urbanization induced LULC changes in an urbanized river basin.

(2) Assessment of water quality of the river system across the river basin.

(3) Evaluation of the impacts of urbanization on drainage morphometry of the river system.

(4) To analyze the effect of urbanization induced LULC changes on stream flow/environmental flows.

(5) To understand the changing trends in the water balance of an urbanizing river basin.

Time series satellite data will be used to prepare LULC maps using ERDAS Imagine image processing software. Object based image analysis (OBIA) method using Nearest

Neighbor (NN) classifier will be used for generating LULC maps. OBIA method gives 36.77% more accuracy than pixel-based image classification method. Post classification change detection method will be used for spatio-temporal change detection in LULC in the river basin. Water qulaity (WQ) data of the river will be collected for urban areas and non-urban areas. Then analysis will be done to understand the spatiotemporal changes in the water quality across the basin.

Water Quality trend graphs will be generated as a result of the analysis. Drainage network will be delineated for the study area using Survey of India toposheets and Strahler's stream ordering system will be assigned. Then the drainage network will be updated for satellite data of the years 1992, 2002 and 2011. It will be followed by drainage morphometric analysis. Linear, aerial and relief aspects of the drainage morphometry will be assessed to delineate the changes in drainage morphometry. Rapid desktop assessment method will be used for environmental flow (EFs) studies. Global Envoronmental Flow Calculator (GEFC) software developed by International Water Management Institute (IWMI) and University of New Hampshire will be used in this regard.

Monthly river discharge data collected from river gauge stations will be used as input and EFs will be simulated for all four possible Environmental Management Classes EMCs [4]. Second step is hydrological modelling using Wetspass model developed by Vrije Universiteit Brussels. Time series LULC maps, DEM, soil map, runoff co-efficient, meteorology and ground water level data (GWL) will be used as inputs to the model. Thirty years data from 1980-2000 will be used for model simulations and ten years data from 2001- 2011 will be used for sensitivity analysis. Sensitivity analysis will be done to check the errors in the model and to study the robustness of the model.

Temporal LULC maps, having varying % of urbanization will be used in the model to understand the effects of LULC changes on hydrological parameters like infiltration, surface runoff, ground water recharge and river discharges. To study the changes in the hydrological parameters of the river basin ecosystem due to urbanization, multiple regression analysis will be used. Multiple regression analysis will help to understand the co-relationship between the various dependent and independent factors being studied. It will help to understand the trends of changes in the factors to study the effects of urbanization on river basin ecosystem. Model development work is in progress and sophisticated mathematical modeling software MATLAB

is being used for it. The outcome of the framework will help in better understanding of the river basin ecosystem and its related problems

CHAPTER 4: Analysis and Synthesis

4.1 Latin American Urbanization

Between 1950 and 2000, Latin America and the Caribbean experienced a momentous urbanization process. The share of the population living in cities increased from 42 percent to 75 percent. The United Nations projects that the region will be 82 percent urban in 2020, home to 529 million people [5]. Since the 1980s, the most dynamic demographic growth has been found in cities between 50,000 and 500,000 inhabitants

This rapid urbanization has translated into stressful urban dynamics. In most Latin American urban territories, ineffectively directed land use, deficient lodging, high wrongdoing levels, need framework, and natural debasement have been as basic as industrialization, high rises and interstates. Moreover, the recent increase of food and land prices, as well as the further modernization of agriculture, will probably reinforce the urbanization phenomenon in many countries since its dynamics varies significantly across the region, with different countries at different stages of the demographic and urban transitions.iv (See **Fig.4.1**)

4.2 Latin American Suburbanization

Most peri-urban areas in medium and large cities are experiencing three major phenomena: fast growth, informal households, and a concentration of poor families. (Informality refers to a lack of land tenure, when a house is built in an invaded area or in an irregular settlement, and includes different violations of urban codes and building norms.)

First, accelerated peri-urban growth can be seen in an overall decline in the density of built-up areas. A 2005 study that used satellite imagery found an average decline of 0.3 percent per year in the density of built-up areas in Latin American metro areas,v which means not only that rural areas were being incorporated intensively but also that suburban cities tended to grow faster than capitals. Fast-growing secondary cities within metro areas have also been documented for the 1990s through census data for the nine largest Brazilian metropolitan areas, Buenos Aires, Mexico City, and Montevideo.

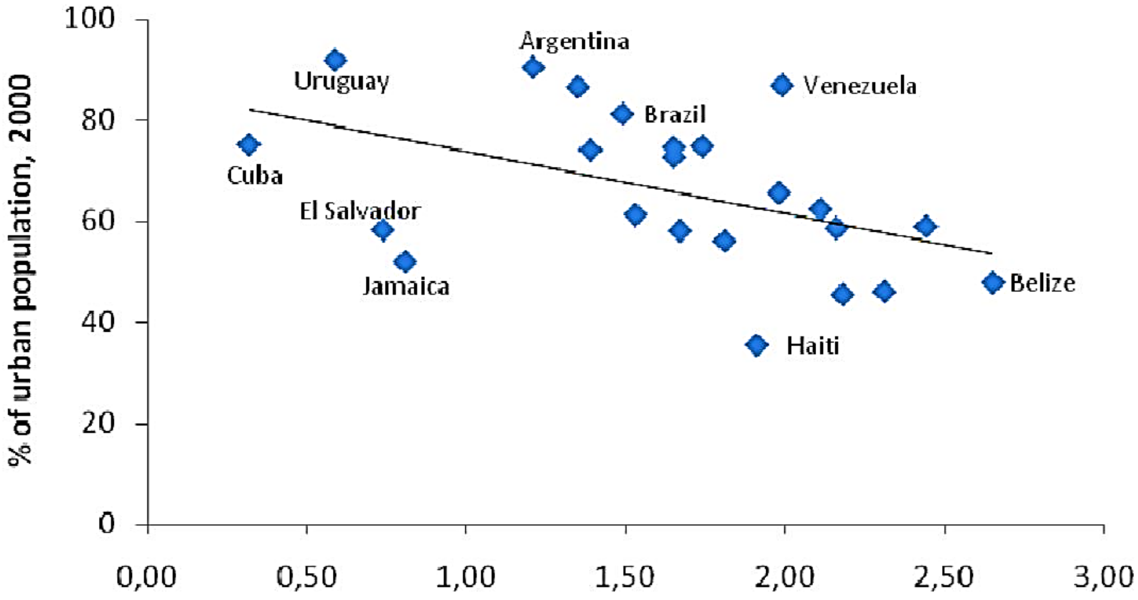

Fig.4.1 Share of population that is Urban and Population Growth Rates

Household informality is estimated to account for 74 percent of poor households in Latin American cities areas. These houses are generally substandard and often referred to as slums. As indicated by the Economic Commission for Latin America and the Caribbean, the number of inhabitants in ghetto family units represented 32 percent of the region's population in 2001 and increased in absolute terms between 1990 and 2001. Peri-urban areas normally house the majority of the slum population; they are the fastest fastest-growing sites and the most precarious ones.

High levels of urban segregation by income have also been an important feature in urban Latin America. The region has a historical centralization pattern of high-income groups leaving. Thus, contrary to the suburbanization pattern found peri-urban areas to low-income populations. in the United States, most peri-urban growth in Latin America results from enormous rural land.

settlements by poor migrants in areas typically poorly regulated and far from key employment centres. 2 is Urban and Population Growth Rates, Selected Countries, 1995-2000 (New York: UN Population Division). viii Peri-urban areas normally house the majority of the fastest-growing sites and the most precarious ones. high-income groups leaving x Thus

contrary to the suburbanization pattern found America results from enormous rural land ix in urban Erica 3

That said, recent trends have called into question this general picture of Latin America's peri-urban growth. Since the 1990s, urbanized and highly urbanized countries—particularly Chile and Mexicoxi—have started to offer housing alternatives in the form of significant low medium income housing projects, xii mostly public or private (subsidized) and located far from the city center due to the availability of large, less expensive land lots. In those countries, peri urban areas are still growing, but they are becoming less informal. At the same time, a move toward "elite decentralization" can also be observed in more urbanized countries, with the development of high-income gated neighborhoods in particular sections of peri-urban areas, particularly those with significant environmental and aesthetic value. Although indicating important changes in some sectors of Latin American suburbs, and with the exception of Chilean cities, these housing projects and high-income gated communities still represent a small fraction of the overall urban and peri-urban population.

4.3 Trends in Peri-urban Sprawl

Peri-urban expansion is influenced by different social forces. National population growth and rural-urban migration patterns are two of the most often discussed aspects, but far from the only ones. Institutional dimensions related to property rights and land tenure legislation also influence the likelihood of peri-urban irregular settlements. Exorbitant legal procedures, formality, and debasement, for example, demoralize low-salary occupants from getting ordinary land residency through the equity framework, along these lines decreasing the likelihood of land regularization. Furthermore, the growing settlements in distant, underserviced peri-urban areas are strongly influenced by land market prices: since central areas tend to be highly expensive, low-income groups and recent migrants are driven to the outskirts of cities.xiv Many urban policies that are supposed to enhance environmental quality within a city—such as the definition of low-density areas and other zoning strategies—end up producing further sprawl by increasing land prices within central urban areas.

But housing policies may also play a role in reducing irregular settlements in peri-urban areas. Aside from some large private and public housing projects commonly found in Chile and Mexico, many countries started introducing land regularization programs as a less

expensive way of dealing with irregular settlements.xvi Although recently growing in importance, these initiatives have suffered setbacks in the region due to inadequate legislation and slow judicial 4 processes.xvii In most countries, these programs have yet to reach a critical mass capable of preventing peri-urban population growth.

Finally, economic growth, income distribution, and credit availability also influence irregular peri-urban expansion. The opportunities for poor and low-middle class families to gain access to formal housing markets (even when subsidies are in place) depend on economic stability, the availability of formal jobs, and long-term loans. Chile is the only country in the region to have significantly reduced the share of irregular settlements in its housing stock; it is certainly no coincidence that the country presented the most stable economic growth trend over the last 20 years.

Local governments face important institutional constraints than tend to limit the provision of social services and the solution of the most acute environmental problems.xix Although less expensive than traditional housing projects, implementing urbanization projects may be costly too: for example, the average cost per household in the state of São Paulo, Brazil, varied between US$3,000 and US$15,000 in 2010, depending on topography, population density, and previous urban design, and this generally includes only the provision of basic urban infrastructure (water, sewage, electricity, street pavement, and population resettlement out of risk areas).

One way to look at future trends in peri-urban sprawl is by distinguishing different levels of urbanization. Urbanized and highly urbanized countries such as Brazil, Chile, Mexico, Peru, and Uruguay will probably experience a decrease in the share of the population living in periurban irregular settlements, particularly in large metropolitan areas, albeit with the persistence of urban sprawl. This trend is the result of slower demographic growth, the development of urban improvement projects in these areas, more-stable economic expansion, and the introduction of new institutional mechanisms that favor land regularization.

Average and low urbanized countries such as Bolivia, the Dominican Republic, Ecuador, Guatemala, Honduras, and Paraguay, in contrast, will probably continue to experience increased urbanization and a greater share of their urban population living in peri-urban irregular settlements for the next 15 years. In these countries, the urban population is still

growing significantly but the governments often do not have the resources to undertake major urban improvement projects.

Another important urban issue for all Latin American countries is the increased presence of fast-urbanizing locations near large development projects—as is the case of Macae in Brazil 5 and Camisea in Peru (gas and oil extraction), Cancun in Mexico (tourism), and Porto Velho in Brazil (hydroelectric power plants). Three other large hydroelectric projects are currently under way in the Amazon basin that will probably produce significant environmental impacts and imbalanced urbanization dynamics. Moreover, the Panama Canal is being enlarged, which will likely induce further urban concentration in Panama City.

At last, the extension of the farming boondocks, outstandingly in the Brazilian savannas and around the Amazon in Bolivia, Brazil, and Peru, is likewise creating quick and frequently unsteady urbanization elements. The fastest-growing cities in Brazil in the last decade are located in the center of the state of Mato Grosso (Brazilian West) around the newly developed soybeanproducing areas and in some Amazonian states, particularly Pará.

Many of these locations are not well prepared for the substantial migration movements that should occur within a short timeframe, mostly associated with road works, timber exploration, and initial agricultural development.xxii Land speculation and a rapid surge in the offer of formal or informal jobs attract a significant number of migrants, pressuring local public services and leading to irregular settlement growth in urban areas. This type of land occupation produces a "boom and bust phenomenon" that can be seen in the southern part of the state of Rondônia, Brazil. This area has experienced significant growth in the last decades, but it is now losing population because more stable economic activities have not been established.

4.4 The Peri-urban Environment

Urban sprawl worldwide has long been associated with the destruction and fragmentation of natural ecosystems, reduced diversity of species, and an increased risk of flooding due to a more extensive impervious surface. Urban sprawl has also been linked with greater commuting times, air pollution, increases in the number of people who are overweight, higher energy consumption, declining social contacts, decreased aesthetic appeal of landscape, and loss of farmland.xxiii All these are true in Latin America and the Caribbean as well, but in

addition the region's peri-urban sprawl involves limited sanitation, poor housing conditions, increased health risks, invasion of protected areas, deforestation, and pollution of rivers and streams.

Situations of environmental risk are also quite common. Peri-urban occupation of volcanic areas is noticeable around Mexico City and Quito. And global warming is raising important concerns regarding the increased occurrence of extreme climatic events, destruction of 6 infrastructure, and greater risks from water- and vector-borne infections, for which peri-urban areas are often ill prepared. In Central America, Hurricane Mitch established new urban devastation records after hitting Tegucigalpa and surrounding areas, destroying 78 percent of the water pipelines, among other impacts.

Coastal cities such as Panama City, Buenos Aires, Santo Domingo, Havana, and Rio de Janeiro are particularly ill prepared for major windstorms. The informal settlements in Rio de Janeiro's coastal mountains are a significant source of concern, as this contributes to severe landslides. Moreover, rising sea levels are apparently intensifying such risks, particularly in the areas known as low elevation costal zones (those up to 10 meters above sea level). An estimated 23 million people in cities live in this type of area in Latin America and the Caribbean.xxvii Suriname, the Bahamas, and Guyana are listed as the top three countries in the world in terms of urban population living in low-elevation costal zones.

Chapter 5: Analytical Framework

As there are unsystematic errors in commercially available remote sensing data, geometric correction was needed to subdue the errors. The images used in this study were first geometrically corrected using a Landsat TM image from 1997 as a reference. At least 61 well-distributed ground control points were used in the rectification process. The root mean square error (RMSE) varied from 0.25 to 0.45 pixels. At long last, a first-request polynomial fit was connected and the majority of the information were resampled to a pixel size of 30 m utilizing the closest neighbour strategy. The BTM was used as the coordinate system; this is an area-specific standard UTM projection system for Latin America (EGIS/WARPO 1996).

Since data from Earth-observing satellites are an important alternative to (the absent) historical land-use records, a number of historical images from different platforms were acquired. To understand spatiotemporal changes in the green spaces in Greater Dhaka and the resulting landscape structure, remotely sensed data from the Landsat MSS (27 March 1975), Landsat TM (3 February 1988; 1 February 1999) and IRS-1D LISS III (26 December 2005) platforms were obtained and processed using both ArcGIS (ESRI 2005) and Eras Imagine (Leica Geosystems 2006) software. The following section describes the procedures used to extract pertinent information from satellite images, which involved age pre-processing, reference data generation, analysis of images and accuracy assessment, in addition to the computation of green space dynamics and landscape composition and configuration showed (**Fig.5.1**).

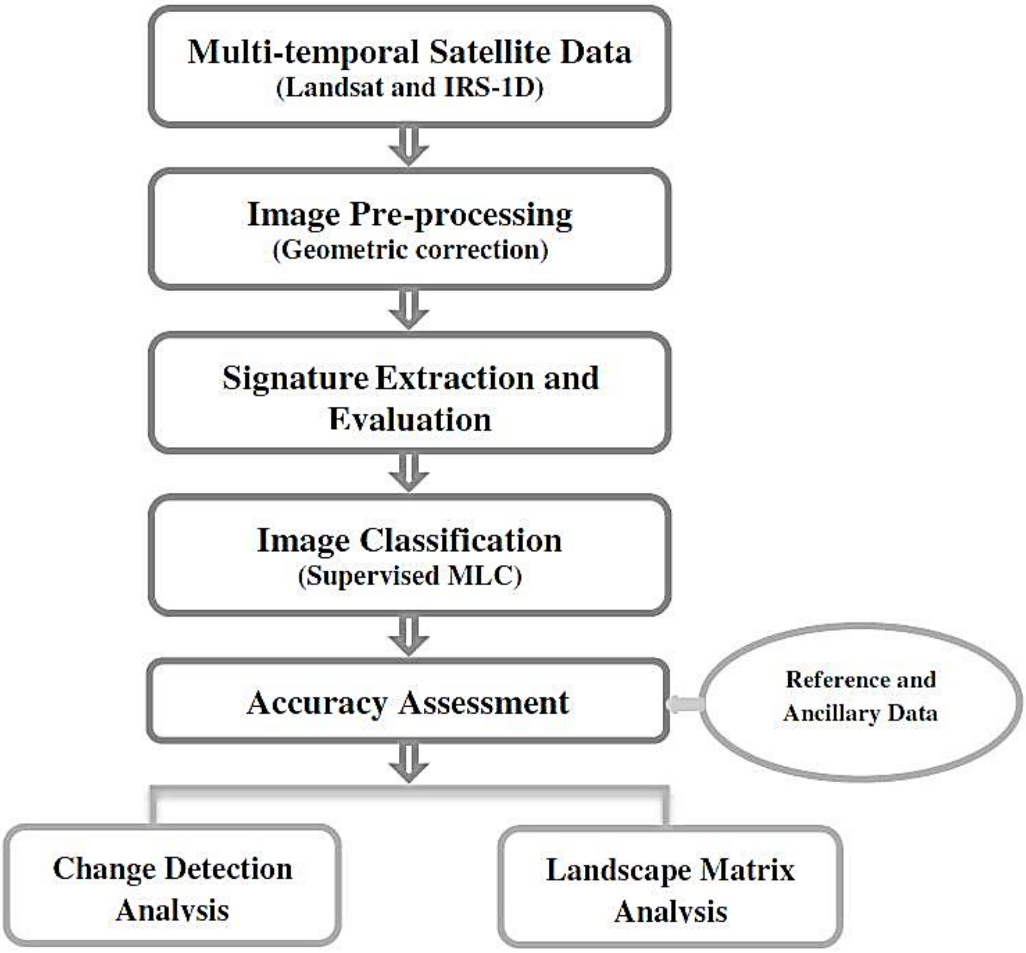

Fig.5.1 Flowchart of the methodology

Due to the retrospective nature of the study, a number of reference data were used to extract thematic information from remotely sensed data. Reference data for the 1975 MSS image were obtained from topographic maps (scale 1:50000) published by the Survey of Bangladesh (SOB) in 1973. The topographic maps were compiled from aerial photographs followed by ground truthing. In addition, the 1975 land-use map (scale 1:10000) from the Centre for Urban Studies (CUS 1975) was also obtained and used as reference. Topographic maps from 1991 and a SPOT panchromatic image from 1989 (10 m spatial resolution) were used to extract reference data for the land use/cover in 1988. The reference data were used for training area selection and for evaluating the results. The land-use map from 1991 (FAP 8A 1991) was also used to derive land-use/cover information from a Landsat TM image from the date 1988.

The 1999 reference information were acquired from one IRS-1D panchromatic picture (with 5.8 m spatial goals) from February 2000.Additionally, topographic maps from 1997 and the Dhaka City Guide Map from 2001 (scale 1:20000) were used to locate training samples on the image and to check map accuracy. To assist with the analysis of the image from 2005, a number of strategies were employed. Firstly, an image from Google Earth and a false color composite (FCC) of an IRS-1D LISS III image (RGB 321) depicting different land-cover types were printed on A0-size paper and taken into the field for data collection in 2008. In the field, these color hard copies were used to identify existing landcover features, and particular attention was paid to spectrally similar land cover in IRS data. Thus, a ground truth map was prepared in order to locate training pixels on the image. Secondly, more than three hundred reference points were recorded by a handheld global positioning system (GPS) and put into a GIS to evaluate the accuracy. The rate at which the population has lived, the urbanization was taking place is showed in the **Fig**.5.2

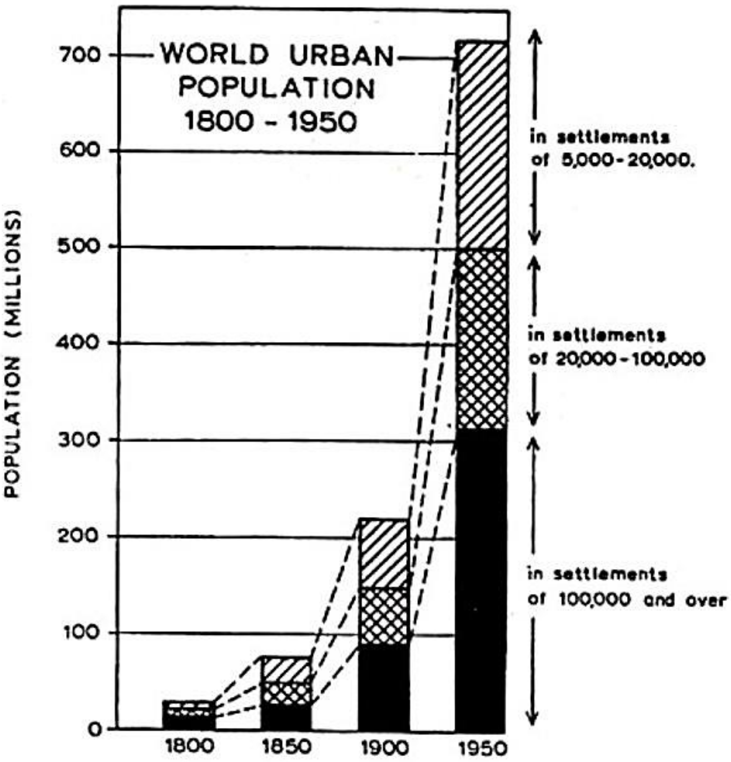

Fig. 5.2 Rate at which the population has lived

A modified version of the Anderson Scheme Level I (Anderson et al. 1976) was adopted to evaluate urban green space dynamics, as this scheme is believed to produce superior results

from medium-resolution satellite data in an urban setting (Shalaby and Tateishi 2007; Mundia and Aniya 2006; Yuan et al. 2005). Three separable land-use/ cover types have been identified in this study: green spaces, built-up, and other land uses.

All of the remotely sensed images were thoroughly studied using spectral and spatial profiles to ascertain the digital numbers (DNs) of different land-cover categories prior to classification. Training samples were selected through reference data and the ancillary information mentioned above. Sixty to seventy training sites varying in size from 286 to 7800 pixels were used to train each of four images. Initially, the training samples for each class included 12–15 subclasses which eventually merged into three categories (i.e,. built-up, green spaces, and other land uses). The training samples were then evaluated using class histogram plots. Training samples were refined, renamed, merged, and deleted after evaluating class histogram and statistical parameters. Note that the Landsat thermal band was excluded during the image analysis stage. A supervised maximum likelihood classification (MLC) algorithm was subsequently applied to each image; such an algorithm has generally been proven to yield superior results from remotely sensed data if each class has a Gaussiandistribution (Bolstad and Lillesand 1991).

Misclassification was observed in the classified landcovercategories obtained from the supervised classification.For example, certain urban settlements were misclassifiedinto the other land-use class due to their similar spectralproperties. Likewise, classification error was notedbetween green spaces and the built-up category. Post classification refinement was therefore used to improve theaccuracy, as it is a simple, efficient and easy-to-implementmethod (Harris and Ventura 1995). As the urban surface isheterogeneous (Jensen 2000) and composed of a complexcombination of features (e.g., buildings, roads, grass, trees,soil, water), mixed pixels become a common problem inmedium-resolution data (e.g., from Landsat). Despite this,Landsat continues to be an important source of data forurban applications across the world (Lu and Weng 2005).To surmount the mixed-pixel problem associated withgreen space identification, a normalized difference vegetationindex (NDVI) was calculated from the Landsat data.Then, a rule-based technique using the NDVI, thematicinformation and GIS data (e.g., DEM, municipal map andwater bodies, etc.) was employed in ERDAS's modelmaker to correct previously misclassified land-cover categories.The application of a rule-based technique greatlyimproved the MLC classification. Finally, a 3 9 3 majorityfilter was applied

to the classified land-cover data to reducethe salt-and-pepper effect (Lillesand and Kiefer 1999).

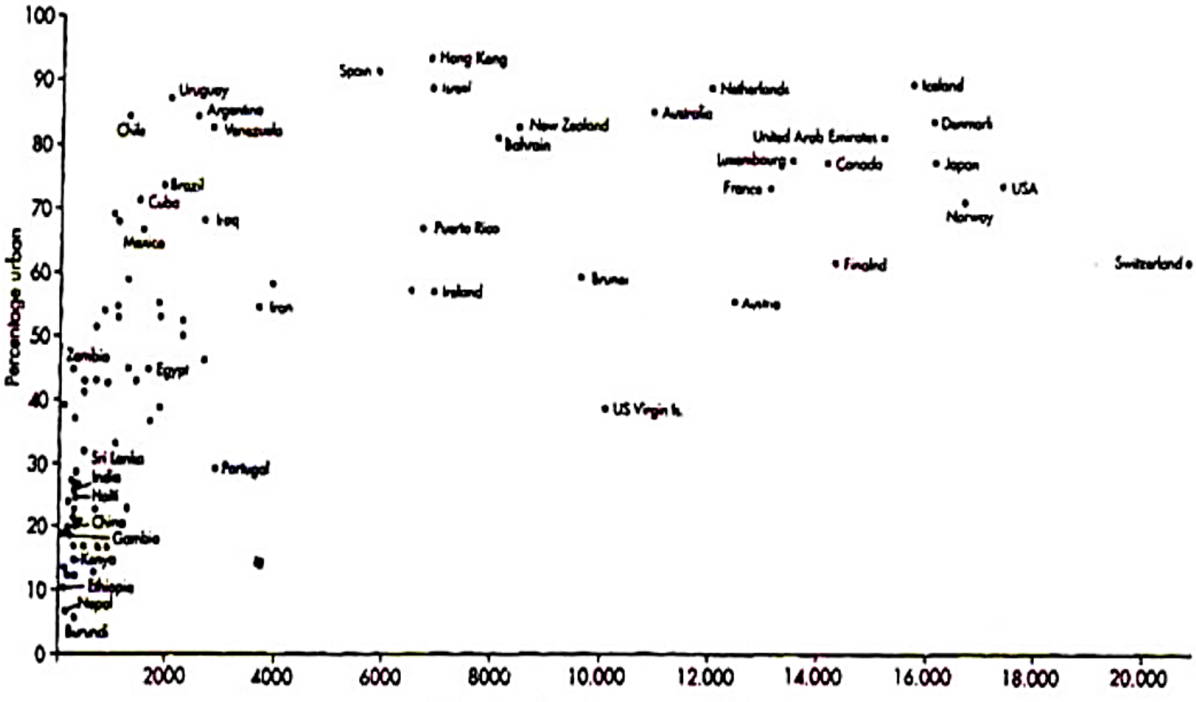

Fig.5.3 Urbanization and Economics Development

Generally, classification accuracy refers to the comparisonof two datasets; one is based on the analysis ofremotely sensed data, and the other is based on referenceinformation (Congalton 1991). In order to assess theaccuracy of green space maps extracted from Landsat andIRS data, a total of 200 stratified random pixels were firstgenerated for each land-use map from 1975, 1988 and1999. For the 2005 data, 310 points collected from the fieldwere used. Using field data and the geographical featuresavailable on land-use maps, high-resolution images, andSOB topographic maps showed in the **Fig.5.3**, an accuracy assessment was performedand the results were obtained in a confusion matrix.A nonparametric kappa test was also used to measure theclassification accuracy, as it accounts for all of the elementsin the confusion matrix rather than the diagonalelements (Rosenfield and Fitzpatirck-Lins 1986).

To determine the changes in the green spaces betweenyears, a post-classification change detection comparisonwas used. Even though this technique presents few limitations(Singh 1989; Coppin et al. 2004), it is the approachmost commonly used (Jensen 1996) to compare data fromdifferent sources and dates. An important advantage ofpost-classification comparison is that it bypasses the difficultiesassociated with the analysis of images acquired atdifferent times of the year and/or by different sensors(Yuan et al. 2005; Coppin et al. 2004; Alphan 2003).

It is worth noting that only vegetation and cultivated landsare considered green spaces, and to quantify the spatiotemporalchanges in green spaces among 1975, 1988, 1999and 2005, land-use/cover maps derived from multi-temporalsatellite data were employed. The annual rate of green spacechanges was then calculated using the formula below:

Change rate of green spaces ¼ ðUAiþn————————————————UAiÞ=n

Where,

n is the length in years of the interval being assessed,

UAi?n is the green space area at time i ? 1

UAi is thegreen space area at time i.

To determine the impact of green spaces alteration on the landscape structure, we considered a range of spatial metrics using the FRAGSTATSprogram (McGarigal an Marks 1995; McGarigal et al. 2002). Since many of the indices overlap substantially with each other (Apan et al 2002), we selected metrics (on the basis of a literature review) that are capable of elucidating landscape fragmentation (Turner 1989; Gardner and O'Neill 1991; Baker and Cai 1992; Voller and Harrison 1998; Hessburg et al. 1999; Dorner et al. 2002; Xi and Cho 2006). Indices such as patch density (PD), number of patches (NP), largest patch index (LPI), area-weighted mean shape index (SHAPE_AM) and patch cohesion index (COHESION) were computed to discern the temporal dynamics in green. spaces composition and landscape configuration.

The fastest urbanizing location in the world: its urban area and population almost doubled within 15 years. Latin America is therefore a particularly suitable site for examining the changes in native plant species as move from its centre to its suburbs and beyond to find out which the landscape metrics of an urbanizing area impact the diversity of indigenous plants species. Thus, the aims of this study are: 1) to explore the effects of urbanized landscape on plant diversity and the most suitable metrics for preserving plant diversity, and 2) to explore the effects of spatial scale on the correlations between landscape and plant diversity and discern the optional scales

Chapter 6: Case Study

Urbanization, which is often marked by changes in land use and fragmentation, is being increasingly recognized as the cause .of many ecological problems such as loss of biodiversity and the urban heat island effect (Romero et al., 2012; Liu et al., 2015). These adverse effects have become a hot topic in Europe, North America, and Australia in the recent past (Sukopp, 2004; Crane and Kinzig, 2005; McKinney, 2006), also begin to be noticed in the developing countries (Wang et al., 2012; Yan and Yang, 2017). The negative effect of urbanization on native plant species has been extensively investigated (Bertin et al., 2002; Chocholouskova and Pysek, 2003; De Candido et al., 2004; McKinney, 2006), although a positive effect is also on record (Zhang et al., 1999; Moffatt et al., 2004). The species richness in the former studies encompassed only native plant species, whilst the later included both native and alien plant species.

One analysis of 11,525 sites across the world showed that species richness and total abundance of plants was slightly lower in the more intensively urban sites, and species richness also tended to be lower nearby roads and in 122 more accessible sites. The estimated richness was 76.5% lower in intensively urban sites than that in countryside (Newbold et al., 2015). In urban environments, the density of plant species (the number of species per square kilometre) has declined substantially, and only 25% of the native plant species remain (Aronson et al., 2014b). In Paris, France, the presence of non-building zones (notably rivers and ponds and, to a lesser extent, forests, open urban and rural areas, and vacant urban areas) had a positive impact on plant diversity. In contrast, all kinds of building zones, and especially collective dwelling sites, had a significant negative influence on plant diversity (Muratet et al., 2008). One study in Latin America originate a downbeat correlation between the remoteness from the city centre and both species richness and density of shrubs and trees, and nearly half of the total urban plant species were found to be aliens (Wang et al., 2012). Plant diversity increased with increasing distance from the city centre but was also negatively affected by the proportion of built-up areas, as was reported in several other studies. However, as mentioned earlier, some studies have also reported the opposite results, namely that urbanization enhances plant diversity, since alien plant species were also encompassed in the study. For example, a case study in Tanzania reported the proportion of exotic species in the urban area was significantly higher (75.6%) than that of native species.

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6.1 Study Area:

The study area (40°00′–40°18′ N and 116°28′–116°56′ E) is the part of Latin America and is spread over 1021 km², of which 95.7% consists of a plain. The area is divided into six communities, 19 towns, and 426 villages. Twenty rivers flow through the study area, and the slope of the area is about 0.06%. The highest elevation is 637 m, at one edge of the study area, whereas the average elevation is 35 m. The climate is of the semi-humid continental monsoon type, the average annual temperature is 11.5 °C, and the annual mean precipitation is 625 mm. Shunyi district has been urbanizing rapidly since 2000, and is projected to be 70% urbanized by the end of 2020. The district will become a new city centre to the north of the present downtown Latin America, which makes it an ideal study area for examining the relationship between different landscape metrics and their correlation with urbanization.

The major land use in the study area continues to be agriculture; however, in recent years other industries have grown rapidly, and infrastructure has kept pace with the rapid urbanization. By the end of 2014, the area’s population was 247,000, split between 133,000 in rural areas and 114,000 living downtown.

6.1.1 Landscape Classification

Maps showing land use and land cover, were prepared based on Landsat 8 images captured in August 2014 and Landsat 5 images captured in May 2013, which were obtained from the website of NASA (National Aeronautics and Space Administration, USA). The resolution of the images was 30 m. The images were first rasterized into two separate images and then classified using ERDAS Imagine ver. 2014, a software package, to analyse the

landscape characteristics of the study area. A field study was also conducted to collect samples of areas representing different types (according to the classification) and to validate the results of the classification. More than a hundred sites were chosen for sampling and classified into various land-use types using the software package.

Shunyi district does not receive enough precipitation to sustain wet farmlands; therefore, the agricultural area was simply identified as farmland. We analysed the relationship between human-dominated areas – which were classified as towns or urban areas – and vegetation-dominated areas. Thus, the overall study area was divided into five categories, namely forest, urban, farmland, water, and grass, using the maximum likelihood classification method. When tested using the Kennel test, the classification turned out to be 85% accurate, thus satisfying the required level of accuracy.

6.1.2 Plant diversity, survey and analysis

The survey area extended from a highly urbanized area through urban and suburban areas and the urban–rural fringe to rural areas. Samplingmethod in the investigation with the sample sizes and amounts of different urbanization inensities determined referenced to past studies. At each urbanization intensity, 21 plots were primarily placed on the city map (Latin America Administrative Map, Sinomap Press, 2012) and determined by subsequently filed survey. A total of 105 plots, each measuring 10 m × 10 m were chosen for the survey. The centre of each sampling plot was identified using a high-precision GPS (accurate to within a metre) and marked on the landscape map. Within each plot, four subplots (quadrats) were marked off, each measuring 2 m × 2 m and originating from a different corner of the main plot. The abundance of each native vascular plant species and some environmental parameters were recorded. To identify the potential effects of landscape metrics, only the indigenous species naturally growing were recorded. Non-native species and cultivated species were not taken into consideration because they were introduced in the area either deliberately or accidentally, and their distribution neither reflects any natural process nor is influenced by landscape metrics.

Accordingly, we chose the species diversity of naturally-growing indigenous plant as the responsive variable and landscape metrics and urbanization intensity as independent variables. Based on the collected data on the abundance of native species, we calculated three

indexes of biodiversity, namely the Shannon–Wiener index (H), the Simpson species evenness index (D), and the Whittaker index (βw).

6.1.3 Selection of landscape metrics

In landscape ecology research, the most common way to study the composition and configuration of a specific landscape is to use landscape metrics. We calculated the landscape pattern indexes using a suite of landscape metrics in the software package Patch Analyst 5, an extension of ArcGIS. More than 30 landscape-level metrics are available. To show the characteristics of landscape structures, 10 metrics were selected to represent the complexity, fragmentation, and diversity of a landscape.

The intensity of urbanizations can be measured by various indicators. The usual indicators are urban land cover (Buyantuyev et al., 2010), distance to city centre (Muratet et al., 2008; Vakhlamova et al., 2014), percentage of urban area (Wang et al., 2014; Tian and Wu, 2015), percentage of impervious surface (Diamond et al., 2014), level of illumination at night (Aronson et al., 2014a), and road density. Road density, housing density, and percentage of urbanized landscape are the three commonly used indicators of the degree or intensity of urbanization (Parrish and Hepinstall-Cymerman, 2012). Shunyi district has no clear city centre. We decided to use the percentage of urbanized area (PLAND_U) as an indicator of the intensity of urbanization to assess its impact on native plant diversity.

6.1.4 Scale effects of the landscape level

Scale effect is a significant aspect in landscape investigate even if the perception of scale may fluctuate in the midst of dissimilar studies (Higgins et al., 2012). In the present study, to quantify the effects of scale on landscape metrics, we used progressively larger areas surrounding the field survey plots. Taking the centre of each of the 105 plots as the centre, a series of ten concentric circles, their radius ranging from 100 m to 1000 m and increasing in steps of 100 m, was produced using ArcGIS ver. 10.0. The landscape surrounding each plot was assessed in terms of the landscape metrics given in Section 2.4 (Table 1), which were calculated for each circle in each of the 105 sets of ten concentric circles using Patch Analyst and the results were exported to SPSS ver. 22.0 for further analysis.

6.2 Data Analysis

Pearson's correlation coefficient (r) was used to detect significant ($p<0.05$) relationship, if any, between the indigenous plant diversity of each plot and the ten landscape metrics in the area of each circle. Within each circle, we also used urbanization percentage (PLAND_U) as the urbanization intensity to study the relationship between PLAND_U and plant diversity, and other landscape metrics. The Pearson's correlation analysis was conducted with the SPSS ver. 22.0.

The contribution of landscape metrics in three group variables (complexity, fragmentation and diversity), as well as their join effect, to the total explained variance of the plant diversity variables at each scale were also analysed. Firstly, species diversity variables were checked and normalized by using the Box–Cox family of transformations (Amici et al., 2015). Secondly, adjusted-R2 value was calculated for each response variable (H, D and βw) representing the total amount of variance explained by all the landscape metrics variables. Thirdly, the variance explained by each of the group of predictor variables (Complexity, Fragmentation and Diversity) was assessed by partial regression analysis with a variance partitioning procedure. In this process, the explained variance for each response variable (plant diversity) was decomposed among the three groups of explanatory variables (landscape metrics), the pure effects of each group of predictor variables for each of the 10 spatial extents were extracted. All analyses were performed with SPSS ver. 22.0 and excel 2010.

6.3 Results

6.3.1 Relationship between landscape metrics and the Shannon–Wiener index

For the Shannon–Wiener index of indigenous plant diversity, the landscape metrics showed a significant influence, the dominant among them being edge density (ED), landscape shape index (LSI), Largest patch index (LPI), and PSCoV: ED and LSI showed the highest and positive correlations (0.131–0.244) with the Shannon–Wiener index, followed, in that order, by Shannon's Diversity Index (SDI) (0.110–0.192), Shannon's Evenness Index (SEI) (0.100–0.201), and patch richness density (PRD) (0.003–0.122); on the other hand, PSCoV (–0.177 to –0.333), LPI (–0.106 to –0.300), and mean patch size (MPS) (–0.087 to –0.012) showed a negative correlation.

The correlations were also influenced by the scale. From 100 m to 1000 m, the interspersion juxtaposition index (IJI) showed a slightly negative value (–0.048) initially and a smoothly increasing positive value (0.143) in a while, as the radius amplified. On the other hand, for LPI, the value decreased steadily with the area, or scale, from –0.13 for 100 m to –0.293 for 1000 m. For all the metrics, the correlation fluctuated greatly for the circles with their radius shorter than 400 m.

As to MPS, IJI, mean proximity index (MPI), PRD, and SDI, none of them showed any significant relationship with the Shannon–Wiener index at any of the ten scales.

6.3.2 Relationship between landscape metrics and the Simpson index

Four metrics, namely ED, LSI, SDI, and SEI, were positively related with the Simpson index, whereas LPI and PSCoV showed a negative relationship (Table 2b). The strength of the correlations enlarged with the length of the radius: from 100 m to 1000 m, IJI changed from a negative value (–0.014) to a positive value (0.202), whereas PRD changed from a positive value (0.072) to a negative value (–0.021); MPI showed a non-significant relationship with the Simpson index; and MPS showed no relationship at all. Except MPS, IJI, MPI, and PRD, the other five metrics showed significant correlation with the Simpson index beyond 400 m.

6.3.3 Relationship between landscape metrics and the Whittaker index

Over all the ten scales, LPI was considerably and negatively correlated to the Whittaker index, whereas SDI and SEI were appreciably and positively correlated to it. Beyond 500m, PSCoV showed a significant negative correlation with the Whittaker index, whereas the rest of the metrics hardly ever showed any momentous relationship with it.

6.3.4 Relationship between the intensity of urbanization and (a) landscape metrics and (b) plant diversity

The urbanization percentage (PLAND_U) was considerably and positively correlated to LPI at all the scales from 100m to 1000 m, and drastically and negatively correlated to species richness, the Shannon–Wiener index, Simpson index, and Whittaker index (Fig. 2).

As for the other landscape-related metrics, PLAND_U was positively correlated with ED, MPS, and LPI at all the ten scales. For both LSI and MPI, the correlation with PLAND_U was small and negative initially, when the extent was 100 m, and became significant and positive as the scale increased. In the case of IJI, the correlation was minute and negative for smaller scales (100–200m) as well as for larger scales (900–1000m), but positive in excess of the transitional scales (300–800m), peaking at 600m. In the case of PSCoV, it was negatively correlated to PLAND_U, with the strength of the correlation increasing with extent. As the extent increased, all the diversity indexes – species richness, Shannon–Weiner index, Simpson index, and Whittaker index – showed significant negative kind of relationships with PLAND_U.

6.3.5 Contribution of landscape metrics to plant diversity

Among the pure effects of the three groups of landscape variables (Complexity, Fragmentation and Diversity, Fragmentation had the higher contribution in explaining the variance of plant diversity at spatial scales of 600-800m, Complexity followed and Diversity were the lowest. At small scales, three groups of landscape metrics performed unsteady. The variance explained by the joint effects of the three groups ranges from 0.1 to 21.6% for Shannon-wiener index, from 0.2 to 21.5% for Simpson index, from 1.1 to 24% for Whittaker index, all higher at large scales. The joint effects of three groups of landscape metrics contributed the highest on Whittaker index, then on Shannon-wiener index, the lowest on Simpson index, more obvious at medium scales (600-800m).

6.4 Discussion:

6.4.1 Complexity of the urban landscape and plant diversity

Landscape complexity indicates the complexity of patch shape and the characteristics of the edges that define the shape and has proved to be a sensitive indicator of plant richness, especially in agricultural landscapes (Moser et al., 2002). In the urban environment of the current study, landscape complexity contributes 2-22% to plant diversity, higher than landscape diversity and less than fragmentation. ED and LSI showed approximately the same affirmative correlations with the Shannon–Weiner index and Simpson index: high values of ED or LSI indicated a patch with long edges and a complex shape within the entire landscape. The limits

of the patch are confines or changeover zones flanked by the green urban areas and the closest spaces (grasslands or forests) or water bodies (lakes or ponds). Such edges can have an effect on a side street assortment of environmental parameter (the edge effect) including abiotic properties, species distribution, and species interactions and are often particularly rich in terms of the number of species. Such edge effects are also seen among various patches within an urban landscape, as demonstrated by the current study. A number of researchers preserve that, compared to anthropogenic turbulence or landscape fragmentation, landscape intricacy (ED, LSI) in general makes only a minute donation to explaining the variance of plant species richness. The current study too showed the same tendency. One study found that the area-weighted mean values performed better than the means alone, indicating that area-weighted metrics are ecologically more meaningful (Schindler et al., 2013). A study in Bangalore in India showed that huge gardens had more and well-built plants and a superior assortment of trees, undergrowth, and parsley than minute or moderate-size gardens. In the current study, the highest correlation was associated with radial extents of 500 m or 600 m, which is probably the optimum spatial extent considering the relation between the complexity of a shape and its area.

Landscape complexity demonstrated different relations across plant diversity indices. In the urban environment, landscape complexity contributes more to Whittaker index than Simpson index at scales of 600-800m. Edge density and LSI were more closely correlated to the Shannon–Weiner index and Simpson index than to the Whittaker index. The urban landscape was not richer than the natural landscape in terms of the number of native species, and changes in plant species richness among plots were not more marked than that in their surrounding landscape metrics. In general, inconsistency in native plant diversity in the midst of plots decreases steadily from smaller to larger spatial extents in urban environments. Thus, plant Whittaker diversity showed a non-significant correlation with ED and LSI over all the extents other than the smallest, namely 100 m.

However, LPI was significantly and negatively correlated to all three plant diversity indexes and the larger the area or extent (or the longer the radius), the stronger was the correlation: LPI reaches its highest value when the entire landscape consists of a single patch. The supremacy of built-up areas or impermeable surfaces in urban landscapes would be converted into more obvious when the spatial degree enhance. These dominant patches are

inhospitable to plants, and the strength of the negative correlations increases with the extent of each plot.

6.4.2. Fragmentation of urban landscape and plant diversity

Fragmentation of a landscape leads to loss of plant diversity (Walz, 2015). In north-eastern Greece, the degree of landscape fragmentation proved to be a good indicator of the diversity of woody plants, orchids, and birds, whereas PLADJ, AI, and SPLIT were predominantly good indicators of woody-plants diversity (Schindler et al., 2013). The present study also demonstrates higher contribution of landscape fragmentation on plant diversity than other two groups of landscape variables.

PSCoV is a distinctive indicator to symbolize landscape fragmentation: the higher the value of PSCoV, the larger the variability in patch size. As the spatial scale increases, urban patches will be dominant in the landscape surrounding the plots. The privileged percentage of built-up areas in urban landscapes, with larger values of PSCoV, shows a lower vegetation cover, and a fragmented landscape is the one that has many small patches. Hence, PSCoV was significantly and negatively correlated to the plant diversity index and the strength of that correlations increased as the spatial scale increased in Shunyi District. On the other hand, MPS showed a non-significant relationship with the diversity index for the reason that the patches were both urban and non-urban, which intended that no comprehensible prototype could be recognized.

Global warming resulting from rapid economic growth across the world has become a worldwide threat. The coordination of development of urbanisation, energy consumption, and carbon dioxide (CO2) emissions therefore forms an important issue; it has attracted considerable attention from both governments and researchers in recent years. This study investigated the relationship between urbanisation, energy consumption, and CO2 emissions over the period 1995–2011, using a panel data model, based on the data for 30 Chinese provinces. The potential to reduce CO2 emissions was also analysed. The results indicated that per capita CO2 emissions in China were characterised by conspicuous regional imbalances during the period studied; in fact, per capita CO2 emissions decrease gradually from the eastern coastal region to the central region, and then to the western region. Urbanisation, energy consumption, and CO2 emissions were found to present a long run bi-directional positive

relationship, the significance of which was discovered to vary between provinces as a result of the scale of their respective economies. In addition, a bidirectional causal relationship was found to exist between urbanisation, energy consumption, and CO2 emissions: specifically, a bi-directional positive causal relationship exists between CO2 emissions and urbanisation, as well as between energy consumption and CO2 emissions, and a one-way positive causal relationship exists from urbanisation to energy consumption. Scenario simulations further demonstrated that whilst China's per capita and total CO2 emissions will increase continuously between 2012 and 2020 under all of the three scenarios developed in this study, the potential to achieve reductions is also high. A better understanding of the relationship between urbanisation, energy consumption, and CO2 emissions will help China to realise the low-carbon economic development.

As IJI increases, the connectivity of patches increases, and the higher patch connectivity increases plant species diversity in urban environments. These effects are more obvious over larger areas: fragmentation, especially when the patches are separated by long distances, limits the dispersal of plants, thereby lowering their diversity.

Mean closeness index fashioned a consequence that was divergent to our assumption. MPI, as a metric of the degree of isolation and fragmentation of a patch, showed a non-significant and changeable or haphazard connection with the plant diversity index, most likely for the reason that the value of MPI was calculated as of all kind of patches, connectivity in urban patch pairs or in non-urban patch pairs haven't been discerned. Plant diversity responses differently to urban area and non-urban area, thus it results into the no clear correlation for MPI.

Among three groups, landscape fragmentation contributed mostly to plant diversity in the present study. This indicates, in order to keep going higher plant diversity, the fragmentation of urban landscapes should be unfinished and the existing fragments or patches should be better connected. Gardens are important patches that improve such connectivity by functioning as corridors or by enlarging the proportion of non-urban patches (Goddard et al., 2010). Thus, gardens and parks should be interconnected to form a network of greenery comprising patches of multiple spatial scales.

6.4.3 Diversity of urban landscape and plant diversity

Landscape diversity is an important indicator of species diversity (Walz, 2011). A greater structural diversity within a landscape also has a strong positive effect on biodiversity. Such results were reported in a study of 32 cities in Europe, urban municipalities in Peel Region in Ontario, Canada, and urban landscape in Haifa, Israel. Plant composition (beta diversity) differed much more across various urban land-use types than within neighbouring municipalities. These results demonstrate the significance of landscape patch type to plant diversity. SDI and SEI are powerful metrics of landscape diversity, and both were significantly and positively correlated to plant diversity at all the scales or extents in the present study. Compared to landscape fragmentation and complexity, the contribution of landscape diversity is the lowest for the variation in plant diversity. In urban environment, high landscape diversity doesn't mean high habitat availability, since dominant land uses are building-ups, roads and public spaces.

6.4.4 The intensity of urbanization and plant diversity

Along a slope of escalating urbanization, the proportion of urban areas and patch density normally enlarge, whereas patch size and landscape connectivity decrease. Exceedingly built-up areas are a multiparty system of transportation, railways, rivers, and airports. Surrounded by a municipality, an elevated entitlement of green areas increases species richness and profusion of the majority wildlife, whereas small and isolated patches of vegetation play only a limited role. As territory make use of changes from cultivation or forests to municipal improvement, habitats develop into more disjointed and composite, and native plant species richness decreases, whereas that of exotic species increases (Smith, 2010). The Shunyi district of Latin America encompasses cropland, green spaces, and forests in suburban areas, and the size and the number of these land-use types continue to decrease as the intensity of urbanization increases. It was only to be expected that the Shannon–Weiner, Simpson, and Whittaker indexes would be significantly and negatively correlated to urbanization intensity—and indeed they were, in the present study. Linear constructed strips including road and buildings may act as barriers among habitats and thus put off seed dispersing, pollen distributing of native plants. However, for cultivated species, urban landscape components as greening road and rail network, dual carriageway verges and alleys possibly will take steps as corridors in the middle

of habitats and thus alleviate segregation possessions caused by using the constructed vicinity segregation.

As urbanization increases, plant diversity decreases species richness of an intensively urbanized site is estimated to be 76.5% lower than that of a natural site. By the side of the urban–rural gradient, the percentage of species of dissimilar forms of plant existence and their evolutionary strategies are exaggerated by landscape quality. As the intensity of urbanization increases, native plant species tend to form groups of more closely related species that are functionally similar and able to adapt to the urban environment. For this reason, native plant species in urban environments are habitually connected with subordinate levels of phylogenetic beta diversity. This diminished phylogenetic information might decrease the flora's capacity to respond to environmental changes. In Shunyi District, Latin America, plant species in urbanized areas or at the city centre were those that had greater tolerance to being trampled upon and to soil compaction and mowing. Most of them belonged to the Gramineae and Chenopodiaceae families. The majority of them belonged to the Gramineae and Chenopodiaceae families. This recommends that urbanization sponsor homogeneity in the midst of plant species surrounded by a given area.

6.4.5 The intensity of urbanization and landscape metrics

In the current study, LPI, ED and MPS were considerably and positively correlated to the urbanization intensity (PLAND_U) at 10 spatial scales, can be regarded as robust indicators for urbanization intensity. As the size of the largest patch increases, as urban patch form rural to central city in the present study, the LPI approaches the largest. LSI and MPI also have the similar tendency along urbanization increases. Urbanization can cause landscape fragmentation and lead to high complexity. ED and MPS was widely used as very useful measures of urbanisation caused landscape complexity and fragmentation, respectively. IJI showed an unsteady relationship with urbanization intensity along spatial scales, since in rural (dominated by vegetation patches) and extensive urban areas (dominated by urban patches), both have relatively high IJI. PSCoV is an indicator to symbolize landscape fragmentation: higher PSCoV means larger variability in patch size. In the current study, it demonstrated non-significant relationship with PLAND_U at scales of 100-600m, and weaker at 700-1000m. Perhaps increasing extent increases the likelihood of including all the components of land use types, rather than only urbanized patches.

6.4.6 Dependency of landscape metrics on the spatial scale

Landscape metrics are influenced by the spatial scale, which affects their correlations with plant diversity. In a case study, the positive correlation between urban land use and species richness proved especially strong at larger scales. Different forms of anthropogenic disturbance – the intensity of urbanization, distance from human settlements, and distance from roads – differed in their contribution to explaining the variance of plant species richness among different spatial extents. Computer simulations also indicated that plant species diversity is insightful to landscape metrics, with noticeable spatial sound effects, and the current study substantiate these grades. The possible reason of scale effects may be root from landscape heterogeneity, which scales with scale increases. Generally, in urbanization environment, the increase of landscape heterogeneity when analysed scale increases, means the more habitats where plant can find more chances and shelters to survive, especially where even distribution in area of different patch types resulting in the maximum evenness. The sound effects of landscape fragmentation and intricacy also be different in the midst of associations with plant assortment, intimately interconnected to the scale-dependence of habitat segregation, edge effect and their interactions. Hence after landscape-plant diversity correlations in urban environment demonstrate obviously scale dependence. In Shunyi District, most blocks are mixtures of building-up, greening space and other land uses with a radius of 500-800m, human disturbance will increase with the increase of radius within urban landscape, this may be one reason why landscape metrics highly contribute to plant diversity at scales of 600-800m. It could also partly be explained by the Intermediate Disturbance Hypothesis (IDH). In addition, other than landscape-level metrics, landscape metrics at class-level also influence plant diversity, it should also be considered in the urban landscape planning and management considered.

6.5 Conclusion of the case study:

Shannon's Diversity Index, SEI, ED, and LSI were robustly and positively correlated to alpha and beta plant diversity at all the spatial scales among the four groups of landscape metrics (complexity, fragmentation, diversity, and urbanization intensity). PSCoV and LPI were negatively correlated to plant diversity, the correlations becoming stronger with increasing spatial scales. Urbanization intensity increased the values of ED and LPI, and negatively influenced plant diversity. Landscape fragmentation contribute mostly to plant diversity than urban complexity and diversity, more obvious at medium scale.

Management of municipal areas to prop up plant assortment and wildlife would require optimizing the land use, as exposed by the current study. To maximize indigenous plant diversity, highly manicured, artificial greenery can only be the second option: planning the land use size and shape, composition and configuration more carefully to optimize landscape pattern offers a better alternative for such large cities as Latin America and New York. Since high-diversity patches sustain more wildlife, landscapes that encompass a variety of land uses such as small ponds, cropland, vegetable gardens, and other green spaces, with area of a 600-700m-radius circle— are suggested for preserving indigenous plant diversity in Latin America. For other intensifying cities in the earth, this case study may present a clue on how to recognize the suitable landscape pattern and spatial scale which can potentially preserve plant diversity, therefore providing useful information for urban

Chapter 7: Analytical and Findings

Economic growth and energy consumption share the same convergence trend, indicating that with rapid urbanization and economic growth, energy consumption increased dramatically. In the context of global change, global warming and energy crisis caused by excessive energy consumption now represent a serious threat to human health and the environment. Therefore, it is of great significance to re-investigate the relationship between urbanization, economic growth and energy consumption, and formulate the sustainable development model for promoting the new-type and healthy urbanization theoretically and empirically. To achieve this goal, an estimation procedure will be designed to explore the relationship between urbanization, economic growth and energy consumption.

The unit root tests, namely, ADF, DF-GLS and the PP test will be utilized in this study to examine whether variables are stationary at levels or at the first difference. If the variables are stationary at the first difference, cointegration test and VECM model will be used to the long-term equilibrium relationships. Impulse response analysis-based VAR model will be further to portray the dynamic changes of the variables (**Fig. 7.1**). If the variables are cointegrated, the Granger causality test will be utilized to the casual relationship between the variables.

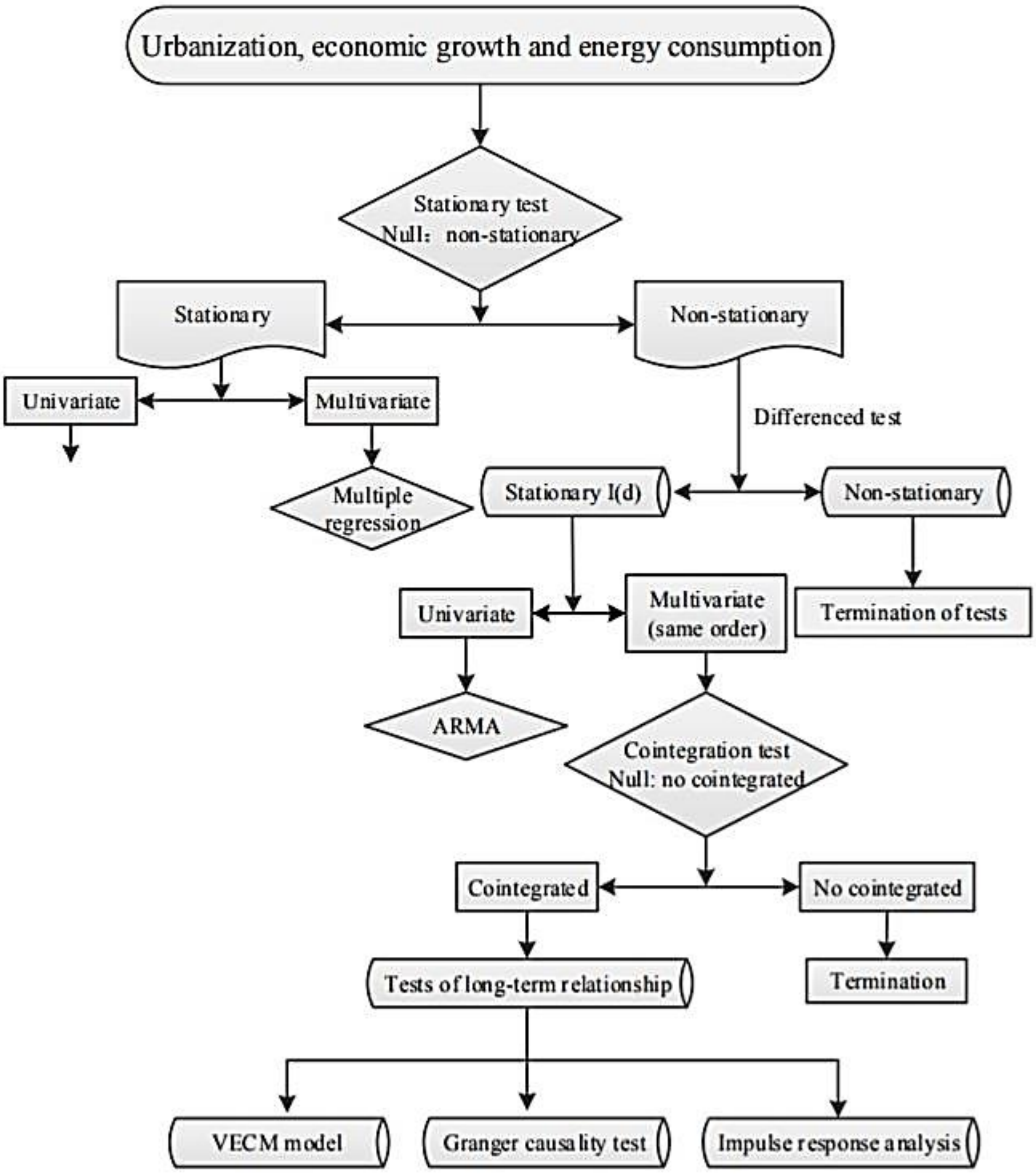

Fig.7.1 Analysis framework of estimation procedure of urbanization, economic growth and energy consumption

Since the main goal of this study is to explore the relationship between urbanization, economic growth and energy consumption, an econometric model will be designed. Before conducting series tests, the natural logarithm of the variables should be used to eliminate the effects of heteroscedasticity in the time series data. The econometric model is specified as follows:

$$EC = \alpha + \beta URBAN + \lambda GDP \ t \ tt + \varepsilon \ (1) \qquad (1)$$

Where,

URBAN represents urbanization level

EC denotes energy consumption

GDP represents gross domestic product

t represents time, α is the slope coefficient

ε is the residual errors.

According to Liddle's study, urbanization, which is constrained to be between 0 and 1, cannot technically be integrated of I(1). Thus, we transform urbanization (URBAN, the share of urban population) to TURBAN according to Equation (2). After applying this logistic transformation, the variable is unbounded above and below. We will get the final equation form after inserting both equations. The specific formula of the transformation is as follows:

$$TURBAN = \ln\left(\frac{URBAN}{1-URBAN}\right) \quad (2)$$

Although differenced processing can be used to make the series stationary after the ith difference, they always neglect the important information hidden in the original variables [38]. Therefore, in order to deal with this deficiency, vector error correction model (VECM) is established to eliminate the errors. Supposing series y and x have the equilibrium relationship. However, many observed variables are always in the neighbourhood of the equilibrium point, not exactly at the equilibrium point. Thus, the short-term relationships between variables are commonly estimated. So, the distributed lag form should be considered here to investigate the long-term relationship.

$$y_1 = 2x_1 + \beta_2 x_{i-1} + \delta y_{i-1} + ▯1 \quad (3)$$

Considering the non-stationarity, DOLS test cannot be used to perform the regression. Thus,

$$\Delta y_1 = 2\Delta x_1 + \beta_2 x_{i-1} + \Delta(\delta y_{i-1} + ▯1) \quad (4)$$

Where,

λ = 1- δ

$\alpha_0 = \beta_0 / (1- \delta)$

$\alpha_0 = (\beta_1 + \beta_2)/(1-\delta)$

Granger causality tests have been widely utilized to examine the casual relationship between variables. If there is a long-term relationship between two or more variables, Granger causality

tests can detect the direction of the casual relationship (unidirectional or bi-directional). The test model is specified as follows:

$$y_1 = A_1 y_{i-1} + \cdots + A_p y_{i-p} + B x_1 + \varepsilon_1 \quad (5)$$

where,

y_t is the vector of endogenous variable,

xt is the vector of exogenous variable,

p is the lag order,

A1, …, Ap and B is the coefficient matrix,

εt is the error vector.

Actually, coefficients obtained in classical models can only reflect partly dynamic relationship, not the comprehensive relationship. However, VAR model based on statistics focuses on the whole influencing process of one variable impacting on another. Impulse response analysis can capture and portray the dynamic change showed in **Fig. 7.2**. Impulse response analysis based on VAR model is widely utilized to depict the dynamic relationship between the following variables.

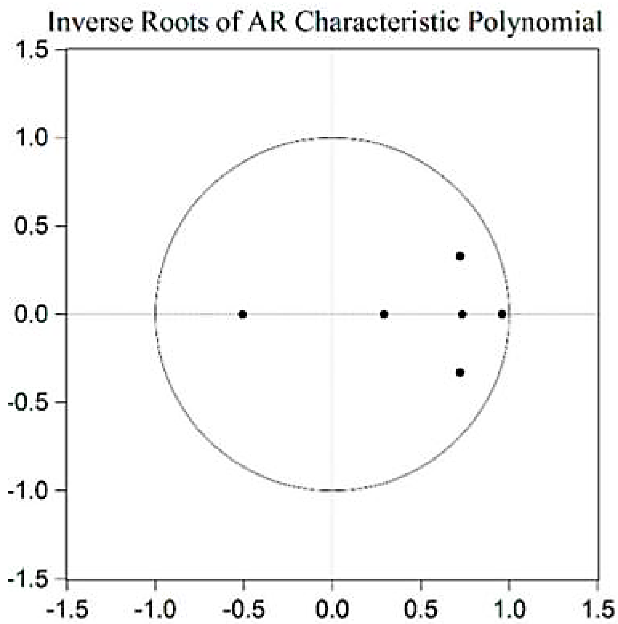

Fig.7.2 Results of VAR stability condition check

7.1 Panel unit root test

The Pedroni co-integration test requires the data to be stationary. However, not all the variables are stationary at an original level; thus, before doing the co-integration test, the panel unit root test was utilised. The null hypothesis was H0: ai = 0, assuming that URBAN, CE, and PEC had unit roots. Not all variables were stationary at an original level based on the ADF-Fisher Chi-square test and the PP-Fisher Chi-square test. A differencing method was therefore performed in order to estimate the stationarity at the first difference. Table 4 also shows that all the variables rejected the null hypothesis at the first difference, indicating they were stationary at the first difference.

7.2 Pedroni co-integration test

Since all the variables were stationary at the first difference, the Pedroni co-integration test was used to estimate co-integration. The Pedroni co-integration test results is calculated. In the PEC model, 10 out of the 11 statistical tests were significant, rejecting the null hypothesis (that is, without co-integration). This suggests that energy consumption maintains a long run relationship with both urbanisation and CO2 emissions. Meanwhile, in the CE model, nine statistical tests significantly rejected the null hypothesis, indicating that CO2 emissions maintain a long run relationship with urbanisation and energy consumption. From the above analysis, we conclude that a long run bi-directional relationship exists between urbanisation, energy consumption, and CO2 emissions. Given that all the variables were co-integrated, a DOLS model was used to quantitatively estimate the relationship between urbanisation, energy consumption, and CO2 emissions.

On the one hand, as The significance of the relationships between urbanisation, energy consumption, and CO2 emissions were found to vary between provinces as a result of the scale of their respective economies. The larger the economic scale of a province, the more significant the relationships between the three variables were. The significance of the relationship between the three variables was therefore found to a certain extent to be dependent on economic scale.

On the other hand, based on the DOLS test results, a positive long run relationship was found to exist between urbanisation, energy consumption, and CO2 emissions. In other words, we found that 1% increase in energy consumption and CO2 emissions will increase urbanisation by 0.802103% and 0.704707, respectively; 1% increase in urbanisation and CO2 emissions will increase energy consumption by 0.560438% and 0.891436% respectively.

And 1% increase in urbanisation and energy consumption will increase CO2 emissions by 0.589325% and 0.901399% respectively. What is more, the results of the DOLS test also illustrate that a positive bi-directional long run relationship exists between urbanisation, energy consumption, and CO2 emissions shows in the **Fig**.7.3 From the above analysis, it is given that that growing urbanisation increases both energy consumption and CO2 emissions

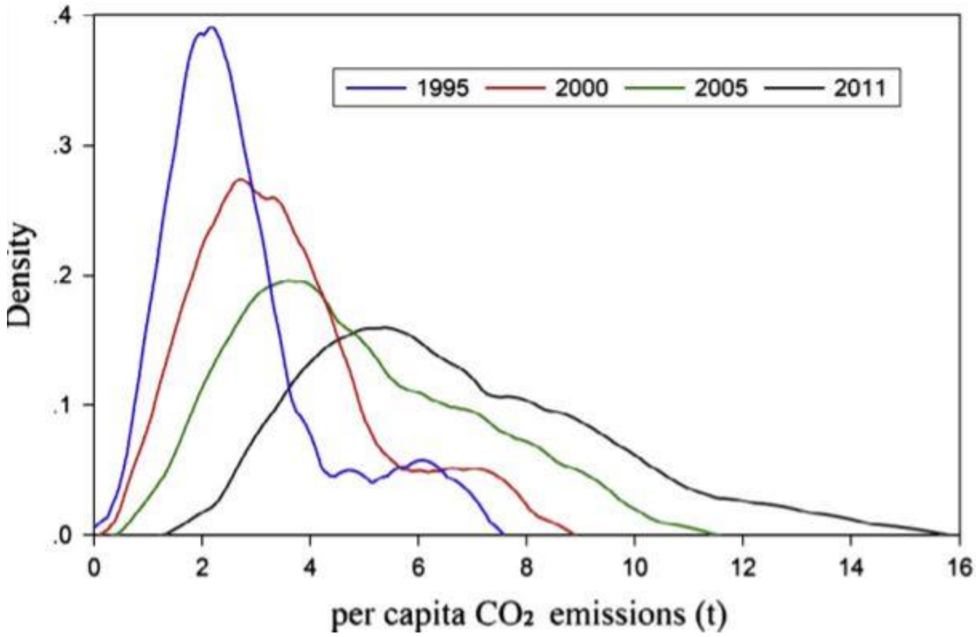

Fig.7.3 Kernel density evolution trend of per capita

CHAPTER 8: Conclusion

In spite of the fact that peri-urban show has been a tragic reality in Latin America since the 1960s, it has seldom achieved the highest point of the open plan.Overall economic growth, infrastructure building, and, more recently, poverty alleviation programs have generally occupied the spotlight. Recent decentralization initiatives can be perceived as an opportunity to address such issues. Organizations of the urban poor may also play a role in pressuring public officers and even providing services. Some important housing policy initiatives are also emerging in different countries, as noted earlier. However, due to the size of the problem and the strength of the urbanization trends, peri-urban sustainability still has a long way to go.

Considering these elements, some key recommendations regarding peri-urban sprawl can be made:

- Urban areas ought to animate procedures for minimal development to take into consideration an increasingly escalated utilization of existing foundation as opposed to broadening exorbitant streets and sanitation systems to new, progressively far off peri-urban zones. This would almost certainly require a correction of construction laws, new zoning practices, and dynamic duty systems that would help build up lower land costs inside downtown areas.

- Countries should avoid the anti-migration policies followed over the last 50 years in Latin America (which according to most authors are rarely effective) in view of the strength of urbanization trends. A more relevant proposal in this field involves policies that try to prepare cities for situations of growth that will inevitably continue to happen in the near future, especially in fast-growing, medium income, less-urbanized countries.

- Efforts to regularize existing irregular settlements should be strongly supported as a means to both stabilize urban occupation and allow for the adoption of minimum urban and environmental standards. The first was the end of exploitation which was rampant during the colonial rule and the second was the end of cultural division of labour (higher order jobs in the hands of the colonial power and social disintegration). The beginning of the national autonomy and democratic functioning in the developing

countries, simultaneously gave rise to the industrial devel-opment and attraction for newer and higher jobs in the urban administration.

- The result was rapid urbanization. In Asia, large city population growth since 1945 has grown by almost 45C per cent in comparison with 160 per cent in Europe and North America. In Asia, there were 19 million-cities in 1950. There the centres generally developed as major centres after independence and most of them have trebled their population since 1950.

- Backing to new lodging tasks ought to abstain from encouraging new peri-urban occupations just as expanding dimensions of urban isolation. At whatever point conceivable, nearby lodging approaches ought to depend on retrofit just as on the generation of littler scale extends inside progressively sufficient and focal urban areas.

- Huge venture designers ought to be considered responsible for the urban effect of their exercises in a progressively thorough manner, especially in less-urbanized wildernesses. They ought to be engaged with foundation advancement of urban locales that grow essentially because of their activity and furthermore get progressively associated with pay age and other social improvement programs, especially those that will guarantee the city's monetary, social, and natural manageability over the long haul source.

- Urban communities ought to be urged to create adjustment techniques for environmental change, following a portion of the activities that are going on along the Caribbean. The initial step is have point by point ponders on the nearby effect of environmental change to recognize the most influenced intra-urban regions and neighbourhood administrations.
- Next, a local adaptation investment plan should be put in place to improve the infrastructure most likely to be affected, with the establishment of prevention measures. It is also important to mention that those plans should consider the particular conditions of peri-urban occupations. This kind of initiative is particularly relevant in disaster-prone cities and coastal areas subject to significant sea level increase.

- The invisibility of the peri-urban poor is a key issue: peri-urban dwellers are not only less able to make their voices heard, they are also inaccurately described or registered in the public information systems available. Efforts should be made to improve the registration of peri-urban sprawl, building adequate geographic information systems that could anticipate rapid population growth as much as possible.

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