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An Integrated Approach to Analysing the Urban Growth Patterns: The Case of Sialkot, Punjab, Pakistan

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Abstract: Urban growth is a worldwide phenomenon, and urbanisation is increasing rapidly, particularly in developing countries. The high pace of unmanaged urbanisation and consequent low-density urban sprawl poses severe challenges to most big cities globally. Such growth features are primarily contributing to haphazard changes in land uses, leading to agricultural loss. This research adopts an integrated approach to analysing the urban growth patterns in Sialkot, Pakistan. It utilises Landsat satellite data and examines the change of land use and land cover (LULC) over 28 years (1990 - 2018). It estimates the agricultural area converted into built-up area during this time frame. Moreover, a spatiotemporal saturation analysis is also performed to analyse the nature of urban growth further. This change analysis is then compared to urban growth strategies introduced under previous urban master plans. The results indicate that the built-up area of Sialkot city has increased from 2,786.49 ha (28.89%) to 7,191.63 ha (74.56%) during the years 1990 - 2018. In comparison, the agriculture area has reduced from 69.5% to 24.84%. Similarly, the saturation value has decreased from 0.85 to 0.75, depicting the city is moving towards urban sprawl. The policy review and interview results indicate a lack of focus toward implementation of urban master plans, which has contributed to ribbon development in Sialkot. The study provides recommendations for concerned urban planning authorities to control urban sprawl in Sialkot.

1. INTRODUCTION

Urbanisation plays a crucial role in transforming the land cover and land use patterns of a city(Oladele & Oladimeji, 2011). The high pace of un-managed urbanisation and consequent low-density urban sprawl poses severe global challenges to most big cities. Nevertheless, the widespread expansion of urban areas seems a continuous process (Kazemzadeh-Zow et al., 2017). With the consequent land use transformation, urban sprawl is currently one of

the significant and threatening urbanisation trends affecting land resources (Tombolini et al., 2018), as the expansion of urban areas may result in desertification, deforestation, soil erosion and loss of biodiversity and prime agricultural lands, with severe consequences for the global environment (Abahussain et al., 2002; Al-Rashid, Rao, & Ahmad, 2020a). This phenomenon is particularly valid for developing countries like India, Iran and some Middle Eastern countries, where the increases in urban population have promoted low-density development at the outskirts and along major roads of the cities (Kumar et al., 2011; Shalaby, Ali, & Gad, 2012; Rahman, 2016; Mosammam et al., 2017).

The urban sprawl phenomenon is characterised by the rapid expansion of the geographical extent of cities (Mazouz & Adad, 2018). The unregulated spatiotemporal demographic shift of urban areas has played a critical role in changing the landscape and contributing to unplanned growth. Moreover, the phenomenon of urban saturation – which can be estimated by examining population density (Lokoshchenko, 2014)– is deeply linked to several facets of urban sprawl. Numerous researchers have also used the concept of urban compactness and compact growth as an alternative to urban saturation (Tombolini et al., 2018; Bai et al., 2015). In line with this, Bai et al. (2015) supported the association between urban compactness and urban saturation, revealing that as urban compactness decreases, city saturation is also reduced, gradually complicating the city boundary. Moreover, (Tombolini et al., 2018) explained that compact growth is sustainable and involves the efficient use of urban land, and suggested the adoption of infill development to lead to higher urban saturation. On the contrary, the coexistence of the built environment and green areas may characterise a dispersed city that guarantees the partial existence of natural features.

The linkage between urban saturation and urban sprawl is two-fold. Firstly, urban areas can become saturated with population and industrial growth, thus aiding new development(Rose et al., 2016). This cycle of urban land transformation is also related to industrial activities, which have expanded to new areas in the last century due to lack of space and rising land prices (Fonseca, 2012). Secondly, due to inadequate urban growth management, urban areas develop in peri-urban zones resulting in dispersed growth or less saturated growth. Furthermore, the progressive encirclement of the built-up areas in cities has dramatically reduced the identification of agricultural buffer zones, which, upon losing their primary role, are considered empty spaces available for urban saturation (Shao & Liu, 2018).

This makes the concept of urban sprawl significantly essential to the assessment and prediction of urban growth scenarios. Therefore, understanding trends in urban growth is pivotal to sustainable development planning (Han & Jia, 2017). Various studies have been conducted to measure the spatiotemporal changes in land use in recent years, further offering direction for the sustainable management of cities (Rienow & Goetzke, 2015; Mitsova, Shuster, & Wang, 2011). Moreover, spatiotemporal land use changes have gained more attention in the field of urban sustainability in the last few years (Chen, 2015). Although managing urban growth is a complex phenomenon (Sakieh et al., 2017), remote sensing and geographic information system (Al-Rashid, Rao, & Ahmad) techniques have been widely used for urban growth analysis (Al-shalabi et al., 2013).

Several researchers have also studied integrated approaches to analysing urban growth. For instance, Sahana, Hong, and Sajjad (2018) quantified the urban spatial pattern and trend of urban growth in Kolkata, India, by adopting

an integrated approach with remote sensing, GIS, and an urban sprawl matrix, thus inferring that outskirt areas provide new opportunities for urban development and planning. Similarly, Mohammed (2013) conducted a study to measure the urban growth patterns in Duhok, Iraq, using Landsat satellite imagery, with an integrated approach of remote sensing and GIS techniques and statistical Shannon entropy (urban sprawl index). This study concluded that there is substantial conformity in the trends of urban sprawl across different periods (Mohammed, 2013). Furthermore, (Weng & Lo, 2001) applied an integrated approach using remote sensing and GIS for detecting urban growth and measuring its effects on vegetative greenness in Zhujiang Delta, China, showing a remarkably uneven urban growth pattern in the study area. Finally, Nadeem et al. (2021) analysed the potential of compact city development in Lahore, Pakistan, by using GIS and ERDAS IMAGINE to formulate the scaling matrix of sustainable development. The research concluded that Lahore is a semi-compact city, with the potential to be a true compact city in the future (Nadeem et al., 2021).

A review of the literature suggests that numerous researchers have contributed and adopted integrated approaches to analyse urban growth. However, these researchers have mainly employed geospatial and modelling techniques to examine land use and urban growth patterns (Kumar et al., 2011; Rahman, 2016). On the other hand, a critical review of urban policies and master plans can provide critical insights for managing urban growth. However, it is relatively unclear how the discrepancies in the existing master plans could promote urban sprawl, particularly in developing countries like Pakistan.

The present study is the first to adopt an integrated approach to address emerging urban growth issues in one of the intermediate cities of Pakistan. For this purpose, this study utilises Landsat data to examine land cover changes in Sialkot city between 1990 and 2018. The study assesses the extent of agricultural area converted into built-up land by evaluating the land cover changes in Sialkot, a less commonly discussed but economically significant city. Moreover, factors governing haphazard urban growth are identified in the study area. The study also portrays the spatiotemporal variation of urban saturation. Furthermore, it extends the existing knowledge and identifies the urban growth mechanism by comparing remote sensing analyses with the current urban master plans and highlighting the critical gaps responsible for haphazard growth in Sialkot.

This paper is organised as follows: the existing conditions of urbanisation, sprawl and the study context are summarised in Section 2; a brief overview of the urban growth strategies adopted in Sialkot is presented in Section 3; a detailed description of the research methodology is explained in Section 4; results are briefly discussed in Section 5; and later sections conclude the paper and provide practical implications and suggestions.

2. URBANISATION AND GROWTH IN SIALKOT

Major cities in Pakistan have experienced rapid urban growth over the past three decades (Kedir, Schmidt, & Wagas, 2016). Along the same lines, the urbanisation rate in Punjab is increasing rapidly and is slightly higher than that of the other provinces of Pakistan, except for Sindh. About 31% of Punjab's population lived in urban areas in 1998, a figure which rose to over 36% by

2017 (Statistics, 2017). Likewise, Sialkot is also experiencing rapid urban growth. The district of Sialkot lies within Punjab Province. It is comprised of four municipal corporations –Sialkot, Daska, Sambrial and Pasrur – and is situated at 256 meters above sea level, between 32°29′33″ north latitude and 74°31′52″ east longitude. The location of the Sialkot District in Punjab province and Pakistan is shown in *Figure 1*.

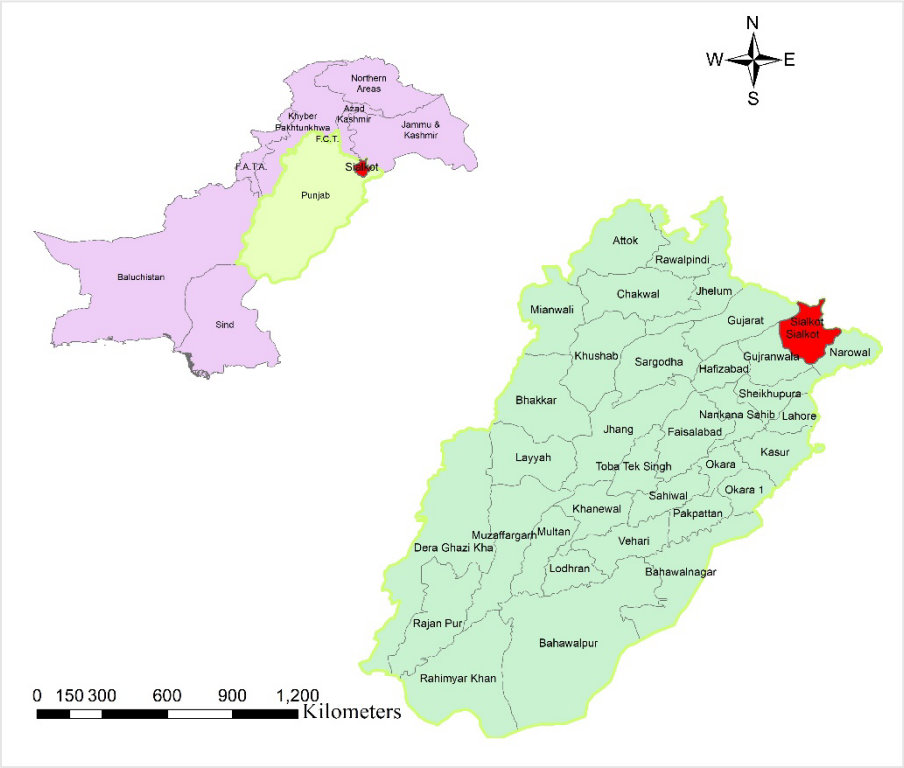

Figure 1. Location of Sialkot District in Punjab Province
Source. Map adapted from Al-Rashid, Rao, and Ahmad (2020a)

The urbanisation rate in Sialkot has risen from 32% in 1998 to 37.9% in 2017 (Statistics, 2017). Similarly, the population of Sialkot has been increasing rapidly over the past decades. A detailed description of the population trends is provided in *Table 1*.

Table 1. Population Trends in Sialkot

Measure	Year				
	1961	**1972**	**1981**	**1998**	**2017**
District Population	1,045,958	1,509,424	1,802,505	2,723,481	3,893,672
Municipal Corporation Population	167,294	203,650	314,845	439,876	679,977
Growth Rate (annual)	0.50%	2.01%	3.75%	2.18%	2.33%

Sialkot is a hub of industrial activities and contributes significantly to the economic development of Pakistan (Portal, 2017b). It has the third-largest export hub in Pakistan after Karachi and Lahore and contributes a significant

share of the total export profits of the country. According to Dobbs et al. (2012), the gross nominal GDP for the city of Sialkot was $13 billion, and per capita income was $2800, which was the fourth highest among the cities in Pakistan. Sialkot is also significant as a source of employment, attracting labour from neighbouring towns and villages (Ghani, 1996). According to an estimate by Punjab Portal (2017) (Portal, 2017a), around 400,000 people are engaged directly or indirectly by exporting different products, including sports goods, leather products and surgical instruments. Approximately 200,000 people work in the sports goods industry alone, exporting $450 million of sports products annually (Portal, 2017a). Moreover, Sialkot is also enriched with fertile agricultural basins, and a significant part of the city's economy comes from the agriculture sector (Rana & Routray, 2018). Rapid urban growth, especially in new housing schemes in the suburbs and haphazard industrial development, is a significant threat to agricultural production and should be studied critically (Manahal & Naveed, 2021). Therefore, the Sialkot municipal corporation is selected for this study to explore the urban growth patterns by analysing the extent of land cover changes in the past 28 years and their effect on agricultural land.

3. URBAN GROWTH STRATEGIES IN SIALKOT FROM IMPORTANT PLANS

It is essential to analyse sociodemographic attributes, past growth, and policies adopted in previous urban plans to examine the growth characteristics of Sialkot. Therefore, this section provides a comprehensive overview of the urban growth policies previously adopted in Sialkot city.

3.1 Outline Development Plan 1972

The Outline Development Plan 1972, primarily a zoning plan, covered the planning period of 1972–1987 (Punjab, 1972). The plan only emphasised physical planning, however, and strategic factors such as economics, geographical relations, and sociocultural factors were overlooked (Punjab, G. o., 2015). Even though the plan was well equipped in specific ways, it was too ambitious to effectively direct and track its progress. Some of the key features of the program and the related issues are: (1) the ring road was proposed to prevent and control haphazard growth, though only part of the planned ring road was built and urban growth moved beyond it; (2) the development of industrial zones and greenbelt areas were ignored and not implemented; (3) the zoning scheme did not expect the growth of commercial operations that continued to evolve on main corridors; and (4) the planned construction of low-density housing in many areas instead became high-density development, as market forces prevailed. Thus, the 1972 development plan shows the value of recognising market forces as well as the challenge of controlling growth, and recalls that unnecessary attempts to monitor planning may jeopardise its outcomes (Chaudhary, 2018).

3.2 Sialkot Master Plan 1996

The Sialkot Master Plan of 1996 was prepared under the 'Feasibility Studies and Urban Master Planning of Ten Cities of Punjab' project sponsored

by the World Bank (Punjab, G. o., 2015). The plan was designed to conserve its cultural and economic essence and expand it to the south and west. Compared to the potentially more expensive scattered growth strategy, the proposal suggested adding practical land uses to the natural development axis in the south and west to ensure robust growth. Thus, a series of concentric roads was recommended to maintain contiguity and promote economic and compact urban growth. In addition, a new central business district was proposed between Eminabad Road and Daska Road, and a sports complex and industrial estates were planned along Wazirabad Road and Daska Road (International, 2011; Punjab, G. o., 2015).

Several of the recommendations provided in the 1996 Master Plan are still valid, but the plan was never implemented (International, 2011). Sialkot continued to expand to the west and south, as envisaged in the 1996 plan; however, the fruit gardens that were supposed to be preserved along Eminabad Road are no longer there and the proposed sports complex and industrial properties along Daska Road and Wazirabad Road were never established, nor was the green belt along Defence Road.

The reasons for not implementing the 1996 Master Plan remain mostly unknown as it was never addressed publicly. Moreover, comprehensive research was not pursued to transition from a strategic plan to planning decisions. Analysing actual urban development versus the plan's expectations shows some of the main shortcomings of the pursued mechanism. For instance, various plan prescriptions were overly ambitious and far-reaching. In addition, the proposed plans and strategies demanded comprehensive public discussion and debate about their very character, which did not occur. Finally, even if such debates had occurred, the implementation of these projects may have surpassed the city's financial capability.

3.3 Sialkot Strategic Development Plan 2010

Under the Punjab Cities Improvement Investment Program (PICIIP), a Strategic Development Planning Framework and Action Plan for Sialkot was developed in 2010 (Punjab, G. o., 2015; International, 2011). The strategic development plan aimed to provide a more comprehensive set of goals, supportive and integrative organisational development, and legislative reforms. It constituted a development management system and comprehensive planning that could deliver optimal benefits to the present and future generations of the city of Sialkot. The urban strategic plan set its vision for 2030 with short-, medium- and long-term goals.

The short-term growth strategy (spanning from 2010–2015) aimed for continued development along the major corridors (*Figure 2*). Further, it planned to establish the pre-conditions for a radical pattern transition and circumferential development of the Inner Ring Road corridor. The medium-term plan (2015–2020) emphasised the actual implementation of circumferential growth by constructing the Inner Ring Road. In addition, it further designated the Mass Transit Economic Development Corridor (Sialkot to Sambrial) and the land use reclassification of the Outer Ring Road corridor. Finally, the long-term strategy (2020–2030) aims at controlling the radial development to support the short- and medium-term goals. Moreover, integrated public transport and specific structure plans for district clusters would shape the Sialkot regional metropolitan strategy. Thus, the project

explains the urban transformation from radial to circumscribed to decentralised concentrations (Manahal & Naveed, 2021).

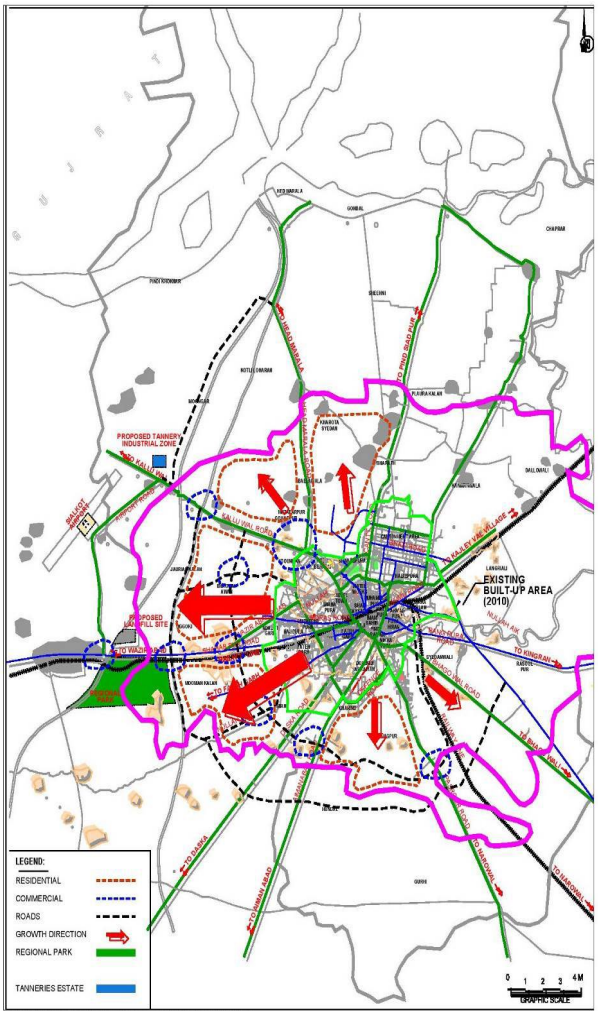

Figure 2. Proposed Outline under Sialkot Strategic Development Plan 2010
Source. GHK Assessment, Sialkot base map adopted from Urban Unit, Lahore

4. METHODOLOGY

This study has been divided into two main parts. The first part measures the effect of sprawl on agricultural land through spatiotemporal analysis using remote sensing and GIS. Moreover, it presents a saturation analysis to depict the level of urban sprawl. The second part discusses the urban growth patterns and provides a critical synthesis of development as an effect of the urban master plans.

4.1 Land Use and Land Cover Change Analysis

Freely available Landsat satellite imageries, with identical geo-referencing properties, were acquired for 1990, 2000, 2010 and 2018 from USGS Earth Explorer. The detailed descriptions of these imageries are given in *Table 2*.

Table 2. Details of Acquired Images for Classification

Year	Res. (m)	Landsat	Row/Path	Cloud Cover	Date of Acquisition	Source of Data
1990	30	LANDSAT_5	037/149	20	1990/03/16	USGS Earth Explorer
2000	15/30	LANDSAT_7	037/149	09	2000/03/19	USGS Earth Explorer
2010	30	LANDSAT_5	037/149	10	2010/11/21	USGS Earth Explorer
2018	15/30	LANDSAT_8	037/149	1.14	2018/03/29	USGS Earth Explorer

ERDAS Imagine, ENVI 5.1, Google Earth Pro and a GIS were used to analyse the land cover changes. For image processing, radiometric corrections were made to enhance the quality of the images and, thus, the ease of obtaining information from them. The extent of contiguous urban development was defined with ERDAS Imagine. The classification was developed based on prior information of the study area. Classification of satellite images is necessary to divide the imageries into several classes. After creating a signature file, the pixels of the images were sorted into classes based on the Signature using the classification decision rule. The maximum likelihood classification method was used to classify the pixels with the help of ENVI 5.1. For Sialkot, the Anderson classification scheme level I (*Table 3*) was used. Three (3) main classification fields were defined: (i) built-up area, including all types of covered development; (ii) agriculture, comprised of all crops and cultivated area; and (iii) water body.

Table 3. Anderson Classification Scheme Level I

Land Use & Land Cover (LULC) Types	Description
Agriculture	Trees, gardens, and cropped areas in and around urban areas
Built-up area	Impervious land and roads and low-, medium- and high-density built-up areas of the city, including residential, industrial, commercial, institutional and other administrative areas
Water bodies	Rivers, canals, and lakes

For the detailed analysis, the Geo-eye and Quick bird imageries, from the freely available Google Earth Pro version 7.1, were used as a reference for exploring the ground realities. The resulting raster image file consisted of the class values, colour table, class names, statistics and histogram (Bhalli et al., 2012).

After the maps were classified, the Raster Calculator option in ERDAS Imagine was used to calculate their areas. Post-classification rectification was applied using ArcGIS 10.1 to improve the classification results. Accuracy assessment was performed using 120 accuracy points to ensure the quality of the image classification. Error matrices were developed and analysed to show the accuracy assessment results. Error matrices are the typical method of site-specific error reporting (Campbell & Wynne, 2011), helping to determine the user's accuracy, producer's accuracy and kappa coefficient for each classified

dataset. *Table 4* shows that the overall accuracy of LULC classification was 82.00%, 86.57%, 90.11% and 93.52% with kappa coefficients of 0.72, 0.83, 0.92 and 0.94, respectively, for the years 1990, 2000, 2010 and 2018. The resulting accuracy level for the LULC classification was higher than the Anderson standard of 85% (Anderson, 1976).

Table 4. Error Matrices Using the Anderson Classification Method

Year	Producer's Accuracy (%)			User's Accuracy (%)			Overall Accuracy (%)	Kappa Coefficient
	Agriculture	Built-up	Water	Agriculture	Built-up	Water		
1990	87.50	84.90	81.00	79.50	89.72	83.33	82.00	0.72
2000	84.34	88.21	85.67	87.46	88.37	87.13	86.57	0.83
2010	87.45	88.67	89.13	89.38	90.44	91.31	90.11	0.92
2018	87.96	89.32	94.75	91.09	92.54	93.37	93.52	0.94

Thus, the unsupervised Anderson classified results were used for the LULC change detection analysis. The detailed process adopted for land cover change detection is shown in *Figure 3*.

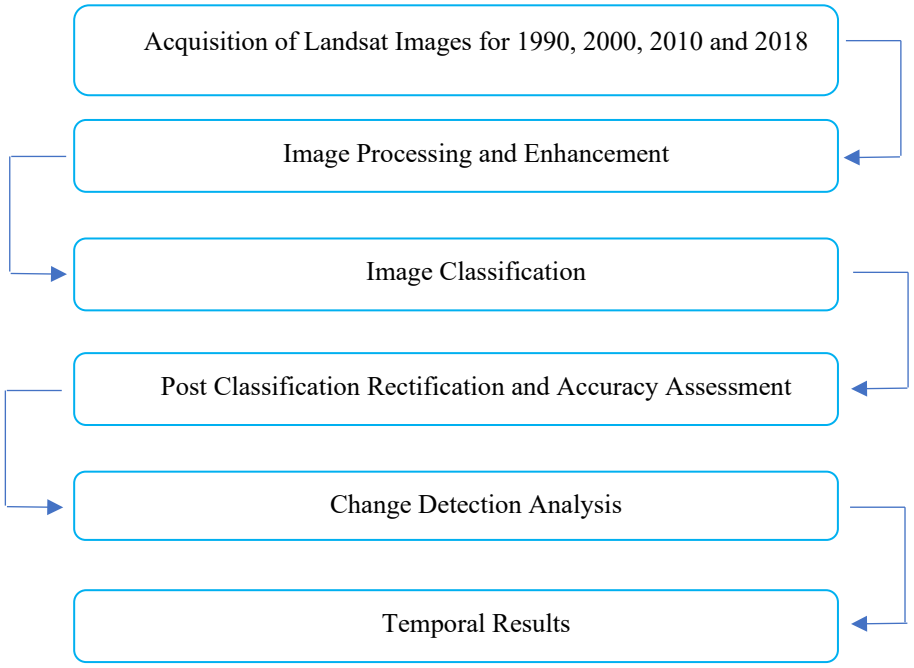

Figure 3. Steps involved in temporal analysis

4.2 Saturation Analysis

The saturation analysis was carried out for this research using Equation (1), which can assist in predicting the temporal changes in the saturation level of the city. For this research, saturation analysis was performed for the years 1990, 2000, 2010 and 2018. According to Ibrahim and Riaz (2018), the saturation level determines the extent to which the built-up area is accommodated in the boundary of the urban extent of the city. (Saeed &

Ahmad, 2018)calculated the saturation level of the city based on built-up area and urban extent, where the urban extent was considered a denominator. Thus, in the present research, the temporal changes in the urban saturation level were identified as:

$$\text{Saturation Level}_{(\text{year})} = \text{Sum of Built-up Area}_{(\text{year})} / \text{City Area}_{(\text{year})} \quad \ldots\ldots (1)$$

For a sustainable urban growth pattern, the saturation level of the city must be grown by developing vacant parcels within the urban extent of the city (Goldblatt et al., 2018). Furthermore, the saturation level signifies the level of compaction and where there is potential of infill development on a city. The built-up areas of Sialkot city for 1990, 2000, 2010 and 2018 were extracted using satellite images, ERDAS Imagine, and a GIS. Moreover, the city area boundaries were calculated by taking the urban extent of the city for each year and verified via secondary information obtained from the Sialkot Master Plan 1996 and PICIIP. Finally, the aggregated built-up area was divided by the city area for the same year to calculate the saturation level.

4.3 Effects of Existing Master Plans on Urban Growth Patterns

4.3.1 Review of Existing Master Plans

Urban master planning is the thorough understanding and execution of a specified functions, development scale and goals, land use and spatial layout within the city. In this regard, urban master plans are essential tools for sustainable urban land management (Wu et al., 2017). Hence, it is crucial to evaluate and understand how urban master plans affect urban growth patterns to improve current urban planning and management systems.

This study explores the effects of existing master plans on urban growth patterns in different plan periods in Sialkot. Three master plans have been executed in Sialkot and are considered ‘major directors’ of the city’s growth. Therefore, the three master plans briefly mentioned in Section 3 were critically reviewed to further assess the urban growth patterns in Sialkot. The main aim of this was to evaluate any coherence of the urban strategies proposed in the master plans with growth control or conservation. Moreover, the critical role of the master plans in promoting the haphazard growth and urban sprawl phenomena was also discussed. Finally, given the rapid urban growth in Sialkot, this can serve as a testbed to investigate the extent to which urban plans influence the resulting urban growth patterns.

4.3.2 Interviews with Policymakers

Interviews offer access to advanced information about the policy process that is not available through other methods. Interviewing policymakers often involves research with people who are in more powerful positions than the interviewer. Therefore, open-ended, unstructured interviews were conducted with four municipal corporation officials in Sialkot. The interviews were used to gain a thorough understanding of the dynamics of urban growth patterns and the urban strategies adopted in different periods, and to comprehend the perspectives of policymakers and the motivations behind present and future actions. They further helped to unravel hidden views and facilitated an

understanding of the reflections of local stakeholders on the strategies implemented in response to the haphazard growth patterns in Sialkot. Hence, the outcome of the interviews complemented the spatiotemporal land cover change and saturation analysis. Moreover, it further triangulates policy analysis concerning urban growth trends provided in the key planning documents.

5. RESULTS

5.1 Land Cover Change Analysis

In the form of classified images, the supervised classification results depict the land use changes from 1990 to 2018 (*Figures 4–7*). The spatial and temporal attributes of land use in the study area can be easily interpreted from these classified images. The light blue colour highlights the water bodies, the green colour represents agriculture and the light brown colour shows the built-up area. The analyses indicate that the dominant LULC types were agriculture and built-up area. The composition of LULC classes at various dates differed considerably, as shown in *Table 5*. The statistics inferred that the built-up area of Sialkot covered 2786.49 ha, agriculture covered 6703.2 ha and water bodies covered 155.79 ha of the total area in the year 1990. During the period 1990–2000, the urban built-up area significantly increased from 28.89% to 57.31% of the total area, while agriculture cover decreased dramatically from 69.5% to 41.56% during the same years. Moreover, the built-up area of Sialkot increased from 57.31% to 65.47% and agriculture cover declined from 41.56% to 33.64% from 2000 to 2010.

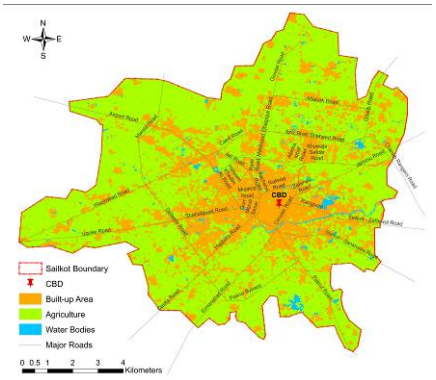

Figure 4. LULC for the year 1990

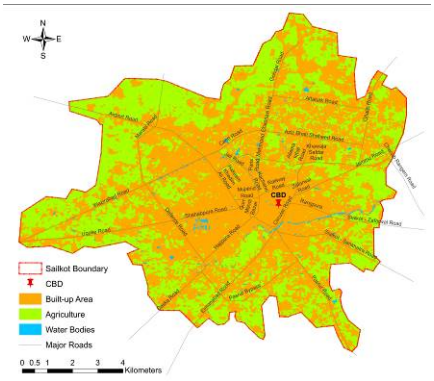

Figure 5. LULC for the year 2000

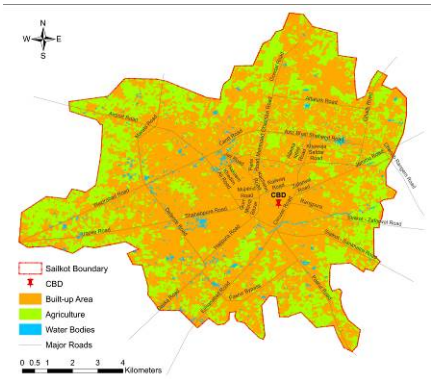

Figure 6. LULC for the year 2010

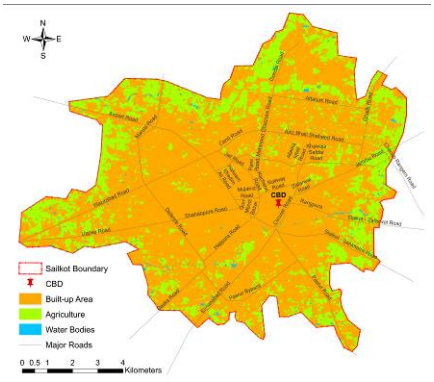

Figure 7. LULC for the year 2018

It was found that the built-up areas increased dramatically from 1990 to 2018, but agriculture showed a rapid decline. After 28 years, land cover in Sialkot changed considerably, with rapid urbanisation at the expense of agricultural land. The built-up area increased gradually, reaching 74.56% of the total area, which is more than 2.5 times its proportion in 1990. In contrast, agriculture cover was reduced significantly from 69.5% to 24.84% from 1990 to 2018, and the percentage of water bodies was reduced by more than half. Since 2010, built-up land has been the dominant LULC type.

The area measurements and percentages of LULC were derived from the classified maps of the city of Sialkot (*Figures 4–7*) and are shown in *Table 5*.

Table 5. Area Statement and Percentage of LULC

LULC Type	**1990**		**2000**		**2010**		**2018**	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Built-up area	2786.49	28.89	5528.16	57.31	6315.12	65.47	7191.63	74.56
Agriculture	6703.2	69.50	4009.08	41.56	3245.01	33.64	2396.2	24.84
Water Bodies	155.79	1.62	108.24	1.12	85.35	0.88	57.65	0.60
Total	9645.48	100	9645.48	100	9645.48	100	9645.48	100

Figures 4–7 also show the spatial distribution of the LULC transition, suggesting that clear trajectories of change occurred around the central business district and the Sialkot exurban built-up areas. The change trajectories of the built-up region, agriculture areas and water bodies were analysed because of the various LULC changes on the detection dates. A significant spatial difference is evident in agricultural land due to the downtown expansion. In 1990, the built-up areas of Sialkot were clustered mainly in the central business district, which includes the regions surrounding the corridors of Circular Road, Railway Road, Kutchery Road and Church Road. However, during 1990–2000, the conversion trend from agriculture to built-up areas is more apparent in the east, north and southeast parts of Sialkot, such as Haji Pura, Rangpura, Model Town and Shahab Pura.

The spatial distribution of different land uses during 2000–2018, as shown in *Figures 5* and *6*, depicts that haphazard expansion of the built-up areas is

carried out in almost all directions. However, the conversion rates during 2000–2010 and 2010–2018 are comparatively lower than that of 1990–2000. Between 2000 and 2018, the built-up area spread outwards primarily along the main roads of the city. With the maps as evidence, it can be argued that urban growth follows the ribbon development pattern while ignoring the crucial pockets in-between corridors. The east and southeast sides of Sialkot, including the areas between (1) Jammu Road and Zafarwal Road, (2) Sankhatra Road and Zafarwal Road and (3) Pasrur Road and Sankhatra Road are particular examples in this regard.

Similarly, on the southern side of the city, including the areas between (1) Pasrur Bypass and Eminabad Road, (2) Daska Road and Eminabad Road and (3) Hajipura Road and Eminabad Road, the precise patterns of ribbon development can be seen. Moreover, a similar development pattern is apparent on the western side, between Wazirabad and Ugoki Roads, and along Airport Road. Such a growth pattern can be ascribed as low-density development.

Table 6: Land use and land cover change from 1990 to 2018 (hectares/year).

Year	Agriculture Land	Built-up Areas	Water Bodies
	Area (ha)	Area (ha)	Area (ha)
1990–2000	−269.41	274.16	−4.75
2000–2010	−76.40	78.69	−2.29
2000–2018	−84.81	87.65	−2.77

The change per year for each LULC type in each period was analysed over the study period, as shown in *Table 6*. It is pertinent to note that the land cover change was more prominent during 1990–2000. It was found that the built-up area grew faster between 1990 and 2000, where the overall growth rate reached 274.16 ha/year, which is more than three times the rates in 2000–2010 and 2010–2018. This rapid expansion in Sialkot can be attributed to industrial reform and the urgent demand for rural and urban infrastructure due to industrial growth and residential construction in the outskirts.

5.2 Saturation Analysis

To further augment the findings provided in Section 5.1, saturation analysis was performed to measure the sprawl level in the city of Sialkot. The urban extent and built-up areas were extracted for the corresponding years selected for this research. *Figures 8–11* show the built-up areas and the urban extent of Sialkot for 1990, 2000, 2010 and 2018. The red line shows the urban boundary for each year, while the built-up area, extracted from satellite images, is reflected in a different colour in each figure. Moreover, the spatiotemporal map in *Figure 12* demonstrates the temporal growth of the contiguous urban development of Sialkot, representing the comparison of the built-up area for all years – i.e., from 1990 to 2018. An apparent change in the urban extent and urban growth pattern can be observed in this time frame (1990–2018).

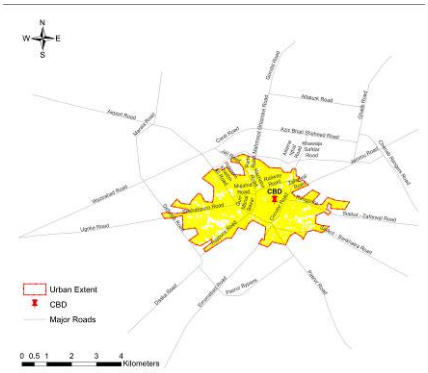

Figure 8. Built-up area & urban extent for the year 1990

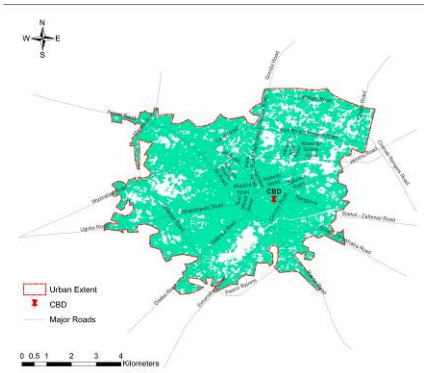

Figure 9. Built-up area & urban extent for the year 2000

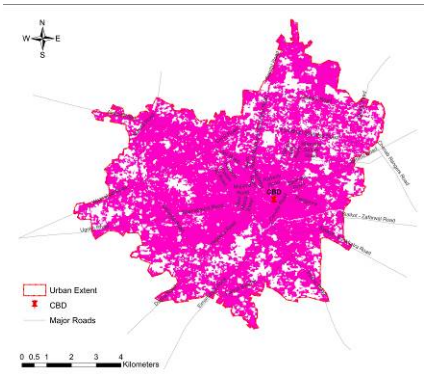

Figure 10. Built-up area & urban extent for the year 2010

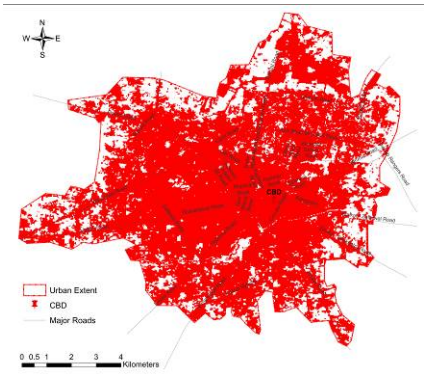

Figure 11. Built-up area & urban extent for the year 2018

It is clear from the above results that the city of Sialkot is expanding and an evident change in urban compactness can be observed from 1990 to 2018. In 1990, the built-up area was primarily accommodated in the boundary of the urban extent. However, there has been a continuous expansion of urban extent and a consistent decline in the level of compactness since 1990. A rapid change in the urban extent during 1990–2000 is depicted between *Figures 8* and *9*. Additionally, the sparse development and increase in the urban extent can be observed spatially among *Figures 8–11*.

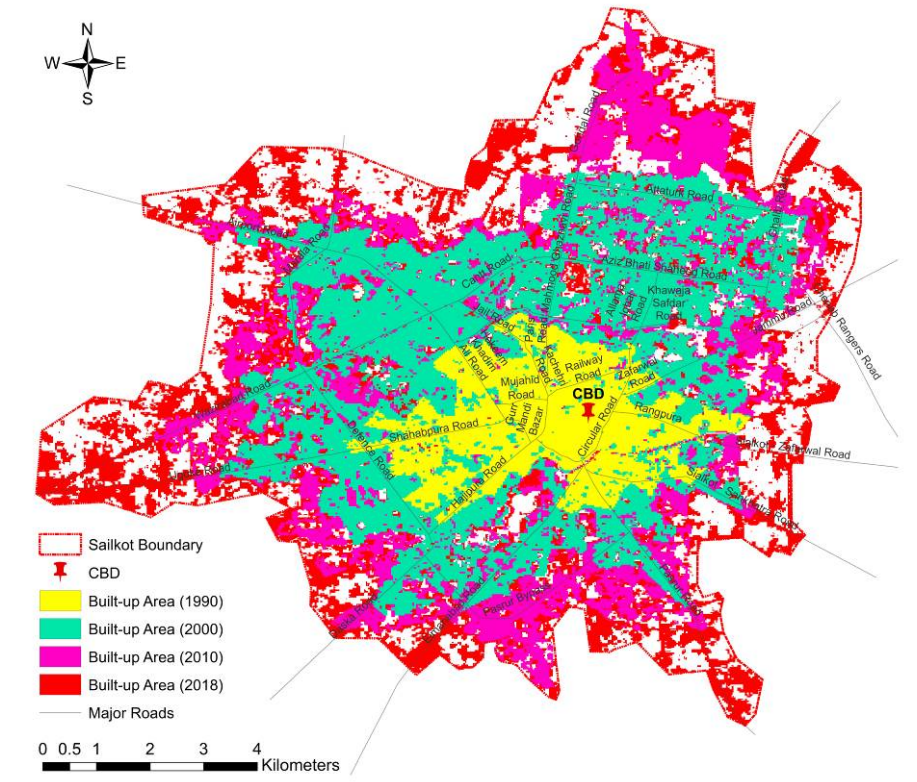

Figure 12. Comparison of built-up areas for the years 1990, 2000, 2010 and 2018

A quantifiable saturation level was also derived using Equation (1) to supplement the spatial and temporal analyses. Similar to the city compact ratio and fractal dimension in urban growth analyses, the theoretical saturation

values range from 0 to 1; the higher the value of saturation, the more compact the urban area is, and vice versa (Bai et al., 2015). The existing literature suggests that the saturation level should increase in a compact city (Ibrahim & Riaz, 2018), so the decreasing trend in saturation levels highlights the occurrence of urban sprawl.

Figure 13 shows the saturation level of Sialkot city calculated for selected years from 1990 to 2018, illustrating that the saturation level has gradually decreased over time. The results suggest that the saturation level decreased from 0.85 in 1990 to 0.80 in 2000 and 0.77 in 2010. Therefore, it is estimated that the saturation level was 0.75 in 2018.

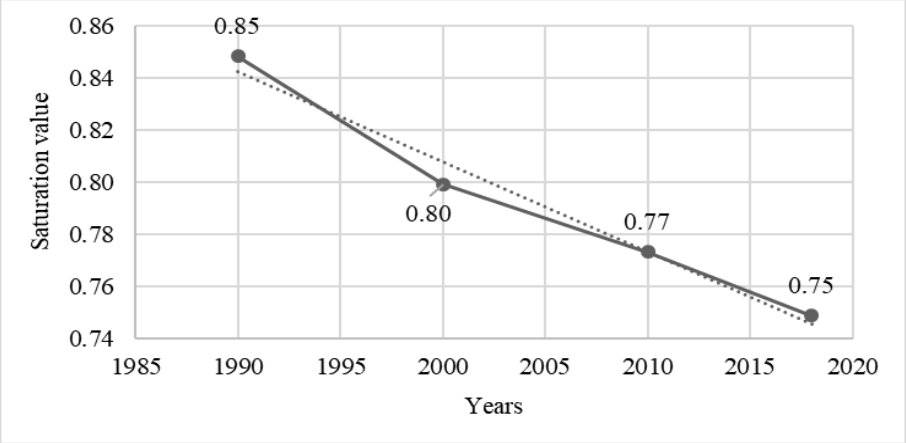

Figure 13. Saturation level of Sialkot city

The analysis further reveals that the built-up area increased significantly during 1990–2000, and the abrupt pattern of urban development in this phase is quite linear, as shown in *Figure 8*. However, this development pattern is still ongoing at a gradual pace. Furthermore, the decreasing trend in the level of saturation highlights urban sprawl instead of infill development in the existing vacant spaces available within the city domains. As a result, while uniform and compact urban development can be observed in the downtown area and its immediate surroundings, chaotically dispersed development is prominent in the city peripheries, particularly along the corridors, contributing to the urban sprawl pattern. Therefore, there is a need to develop a comprehensive strategy tominimise haphazard growth and control urban sprawl.

5.3 Urban Sprawl and the Previous Master Plans

The spatiotemporal analyses presented in the previous sections reveal that the urban growth phenomenon is evident in Sialkot's dynamics over the years. However, urban growth and urban sprawl must be distinguished. Urban sprawl refers to the low-density development and conversion of land use in a given period that changes the natural ecosystems into human-made environments. The land cover change and saturation analysis disclose that the urban sprawl phenomenon in Sialkot is mainly characterised as leapfrog or piecemeal development. Moreover, the policymakers have indicated the absence of a comprehensive master plan and negligible focus on sustainable urban growth in the past. Therefore, the role of master plans is critical to

guiding urban growth patterns. The following discussion summarises the interview results and policy analysis and indicates how the gaps in previous master plans have promoted urban sprawl in Sialkot.

At the time of preparation of the Outline Development Plan 1972, the population of Sialkot was only 203,650 and the growth rate was 2.01%. At that time, nodal development was in the initial stages. The industrial estates and green belt were proposed, as well as a ring road around the city to control the leapfrog development. However, the concept was oriented more towards physical planning, reflecting that the outline of the development plan overlooked critical economic and geographical factors. Due to the lack of an institutional framework, no systematic attempts were made to improve the economic basis of neighbouring and peripheral towns, nor were modern self-sustaining industrial estates able to be built. Thus, the influx of people towards Sialkot continued unabated. Moreover, the zoning plan promoted new development to the south and west of the city without considering the potential loss of prime agricultural land.

Later, at the time of the new master plan, i.e., Sialkot Master Plan 1996, the population of Sialkot city was about 405,000, almost double that of 1972. The program aimed to promote compact urban growth and proposed the new industrial zones and central business district. However, at the same time, it further exaggerated the western and southern expansion by suggesting operational uses along the major corridors. Consequently, the plan mainly relied on physical factors to guide city expansion. The choice to continue expanding the city to the southwest has remained the same as under the previous plan. There was a failure to implement a green belt strategy and maintain the existing fruit orchards along Eminabad Road. Thus, the project failed to realise the conservation policy for agricultural lands and allowed the haphazard expansion. The focus appeared to accommodate the future population without considering alternative options, such as controlling the in-migration phenomenon.

When the Sialkot Strategic Development Plan was completed in 2010, the urban Sialkot population exceeded 559,000. According to Punjab Development Statistics (2010), the urbanisation rate was around 34.66%, which is expected to increase in the future. By this time, Sialkot had experienced a significant impact of haphazard development in the form of pollution, caused by indiscriminate industrial growth along the city's major corridors and improper transport infrastructure and utilities. The Sialkot Strategic Development Plan was more comprehensive than the previous master plans, as it focused on phase-wise development and aimed to promote compact and decentralised growth. However, it did not discuss any conservation strategy or corresponding institutional structure to address prime agricultural land disruption by urban areas. Despite the anticipation of high urban growth, the issue of urban sprawl was not discussed. Moreover, there was no strategic environmental review in the plan. Another contradictory note is that the short-term strategy (2010–2015) targeted the agricultural corridors of the south, west and southwest for future urban growth and accommodating in-migration, implying the assumption that radial urban expansion was the only solution to accommodate future growth.

The above discussion reveals that the previous planning efforts in Sialkot have failed and that the issue of urban sprawl was not taken seriously, as the problems of urban development management and the protection of natural resources were not integrated into the city's urban master plans. Despite the growing recognition of urban sprawl, the development of new private housing

schemes and industrial activities were permitted on fertile agricultural lands, decreasing the annual agricultural production of the city.

6. DISCUSSION

Several studies have been conducted to examine the urban growth patterns in developing and developed countries. However, the existing studies have mainly followed spatiotemporal techniques to analyse the land use and land cover changes and urban growth. Moreover, none of these studies has revealed the relationships between urban planning and urban growth patterns. This research presented an integrated approach and provided novel insight into the urban sprawl mechanism in the less discussed context of Pakistan by adopting a GIS-based spatiotemporal technique, further supported by expert interviews and policy analysis, which helped identify essential gaps in the previous urban master plans.

The results suggest that Sialkot, as an intermediate city in Pakistan, is experiencing haphazard urban growth. The outward expansion of the town started with development around the central commercial district. Later, this urban expansion followed the pattern of ribbon development along all major roads of the city. As a result, expansion of the urban area was visible, particularly for the period 1990–2000, when urban growth was far more substantial than in the remaining period of 2000–2018. Based on these observations, several factors are deemed responsible for the current sprawl patterns:

- Industrial development is the backbone of economic growth in Sialkot. The city experienced an industrial boom during the late 1990s and 2000s that encouraged urban growth. However, unplanned industrial development is one contributing factor towards the urban sprawl in Sialkot. Most importantly, there was a lack of spatial planning and policy governing the city's emerging industrial development. The previous urban planning policies and plans (e.g., the Outline Development Plan 1972) have neglected the development of industrial zones. Similarly, the industrial growth policies proposed in the Sialkot Master Plan 1996 and the recent strategic development in 2010 were not implemented.

- Due to insufficient urban policy mechanisms, the availability of cheaper land in outlying areas and opportunities for better road accessibility, industrial growth primarily occurs in the outskirts of the city along transport corridors. For these reasons, industries have chosen to locate along the central south and southwest corridors of Sialkot. Farming communities close to factories and roads are thus increasingly becoming sporadically urbanised and trapping fertile agricultural land between them.

- As a hub of industrial enterprises, Sialkot has attracted the population from adjoining rural areas with better socioeconomic and employment opportunities. As a result, many people who work in the factories have settled on the outskirts of the city, ultimately increasing the demand for housing and other essential utilities. However, the poor management of this in-migration resulted in the haphazard growth of the city.

- Sialkot possesses a uniquely favourable position because of its geographical location in the Punjab province. It is well connected with other cities in Punjab and the rest of the Country via Grand Trunk Road. The accessibility through different transport nodes is one of the factors that led to the ribbon development of new residential neighbourhoods. The data obtained from Sialkot Municipal Corporation confirmed that there are 56 such private housing schemes currently under development. Many of these schemes are illegal and are situated west of the existing city along roads that run southwest, northwest and west of the area. This is one of the factors that cultivate relentless development in the city. Based on the past trends and this land cover change analysis, it is expected that future growth will happen in the quadrant between Sialkot-Daska Road and Sialkot-Pasrur Road. Furthermore, the construction of main roads – most notably the M11 motorway between Sialkot and Lahore – is expected to guide expansion in the southern part of the city.

- Sialkot is surrounded by peri-urban settlements, especially to the west, northwest and south. These settlements hold pockets of empty land with immense potential for infill development. Though these pockets currently possess rural character, they are expected to become semi-urban and then likely urban as the city grows. Using Google Earth and the maps created in this study, agricultural settlements were differentiated based on their distance from major roads and other infrastructure features. This delineation is provisional and should be validated as the city's planning progresses and deepens in substance. A close analysis of the peri-urban communities around Sialkot shows that they typically suffer from a shortage of well-defined roads. As a result, they have grown organically and, in response to this growth, the road network was extended.

These outcomes have uncovered that the extension of the city toward the north and eastern sides was insignificant because of the proximity of the Indian Occupied Kashmir periphery. Instead, the city mainly extended towards the south and southwest, heading along significant corridors to connect Sialkot with neighbouring towns. Based on current trends, future urban growth may be partially adjacent to, yet separate from, the existing city area by relying on the existing patterns of settlements and outlying road intersections, leading to a decrease in the level of saturation and an increase in urban sprawl. Therefore, it is essential to clearly understand the abovementioned factors to control the urbanisation process and haphazard growth patterns in Sialkot city.

6.1 Practical Implications

Given the findings, the research suggests an urgent need to introduce new policies, institutional reforms and a robust regulatory framework to save the prime agricultural lands. Therefore, some guidelines and policy implications for managing the urban growth in Sialkot are provided in the following discussion:

First and most importantly, revised masterplans are essential for directing, managing, and restricting disorderly sprawl to combat this problem. Such master plans should place spatiotemporal limits on residential development,

thus restricting it to specific periods and locations. The process of regeneration and infill development could also help to increase the population density. Urbanisation will continue to escalate unless politicians and city administrators pursue regeneration and renovation strategies in the inner-city areas to encourage vertical growth as opposed to horizontal, low-density development. Moreover, changes must be made to existing rules and regulations to curb the growing phenomenon of low-density housing development.

Second, the role of the Sialkot municipal administration should be clearly defined. The recent industrial and housing scheme developments along major corridors reflect that the land developers and mafias strongly influence the administration. Moreover, the authority has not considered the invasion of agricultural lands and the prioritisation of smart urban growth. Thus, the city administration should employ periodical land cover change analysis using remote sensing and GIS to monitor urban growth dynamics in the city and respond accordingly.

Third, the outskirt areas of Sialkot should be developed. Most importantly, these neglected areas must be provided with the necessary infrastructure to facilitate access to amenities that make living there more comfortable. However, reinvestment in the derived peri-urban neighbourhoods and providing more housing opportunities will pressure the urban core. It is also necessary to ensure and encourage citizens to live within a city domain; thus, the government should provide improved and efficient public transportation, housing, and essential utilities within the city. Moreover, the transformation from low-density development to compact cities would also reduce the stresses currently faced by the government in providing social and physical services in new growth areas far from other parts of town. According to the McKinsey Global Institute, the cost of supplying essential services to concentrated population areas decreases by 30%–50% compared to less concentrated areas.

Fourth, the spatiotemporal land cover analysis has indicated certain critical areas of concern, i.e., the dispersed, disintegrated and ribbon settlements along and within the important corridors in the south, west and southwestern parts of Sialkot. Based on the other suggestions provided in this research, the concerned policymakers and city administrators should focus on these critical areas and develop immediate policy and regulatory mechanisms to control the sprawl.

Finally, recognising the growth potential in Sialkot, more industrial development would require a larger labour force and more in-migration. Therefore, migration strategies should be developed and implemented on a larger scale. Moreover, these migration policies should be integrated with national or provincial development strategies to avoid conflicts. A decisive strategy aimed at enhancing vital social services in rural and small towns is most important, as it would eliminate a rural–urban divide and increase equity and living standards.

7. CONCLUSION

Urbanisation is a vital issue, and its implications are evident in Pakistan as urban areas proliferate and cause severe problems. This study presented an integrated approach to analysing urban growth patterns by applying a

supervised classification approach using ERDAS Imagine software and producing maps with ArcGIS to analyse LULC changes. The results show that the city of Sialkot has expanded rapidly and land cover practices have changed significantly during 1990–2018. The analyses further indicated that the built area of Sialkot expanded at a rapid pace at the expense of the region's agriculture cover. Such a growth pattern has led the city towards ribbon development, resulting in urban sprawl. The saturation level was also determined for this timeframe to analyse the growth pattern. The results suggest that the saturation level of Sialkot city has decreased gradually over time, i.e., from 0.85 in 1990 to 0.75 in 2018. The interview results and policy analysis also indicate a lack of focus on and implementation of conservation of agricultural lands. Thus, the future growth of Sialkot could accelerate this sprawling trend and exaggerate different environmental concerns. Based on the results, the research highlights some suggestions and practical recommendations to control the urban sprawl and haphazard growth in Sialkot.

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