

THE DYNAMICS OF URBANIZATIONS AND CONCOMITANT LAND USE LAND COVER TRANSFORMATIONS IN PLANNED AND QUASI-PLANNED URBAN SETTLEMENTS OF PAKISTAN

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ABSTRACT. An attempt has been made to compare the salient characteristics of LULC transformations in planned (Faisalabad) and quasi-planned (Jhang) urban settlements of Pakistan. The Landsat-5 TM, Landsat 7 EMT+ and Landsat-8 images of 1989, 1999, 2009 and 2019, respectively, were retrieved and processed through google earth engine. The dynamics of LULC critically analyzed for the three periods 1989–1999, 1999–2009 and 2009–2019. The LULC analyzed in terms of quantity of change, gains, losses, and persistence of the study area examined carefully. The study mainly focuses on the LULC transformations of the previous 30 years (1989–2019). These 30 years witnessed massive physical expansions and LULC convergences. During this time interval, the built-up areas in these cities expanded, and productive agricultural land substantially squeezed. The spatial-temporal analysis of LULC changes calls for improvised strategies for the resilience of land and environmental resources. The direct beneficiaries of this research are resource managers and regional planners as well as others scientific community.

KEY WORDS: Landsat images, LULC mapping, LULC dynamics, Planned Settlement, Quasi-planned settlement, Pakistan

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INTRODUCTION

Land resources are indispensable for the existence of life in all forms (Pimentel and Pimentel, 2003). Human beings are a product of the land environment and it is this very environment that provides man the wherewithal for survival (Davis et al. 2009; Goudie 2018). The intrusions in the lithospheric environment by them are, primarily, conceived for acquiring food and sustaining socio-economic progressions. The perception, action, and exchanges between human and land resources have witnessed many transformations. The phenomenon of permanent settlements stimulated man's role in changing the face of the earth (Metzger et al. 2006; Roberts 2013). The ensuing demographic transitions, also, have their peculiar imprints on the interrelationship between human and land resources. The advent of agriculture, the expansions in the permanent settlements, and socio-technological changes further redefine the orientation and magnitude of these exchanges (Larondelle et al. 2016; Seto et al. 2011). The resultant urbanization and associated lifestyle changes are now challenging the carrying capacity of the environment (Saarela and Rinne 2016; Elmqvist et al. 2013; Appiah et al. 2017; Cobbinah et al. 2015b; Cobbinah et al. 2015a).

The consequential implications produce different types of strains for city-based urbanization and in-situ urbanization. The city-based urbanization is a product of planned LULC modifications in natural landscapes, while, the in-situ urbanization are the gradual transformations of rural settlements into urban areas. It was during such conversions that the semi-planned or quasi-planned urban settlements evolved (Zhu et al. 2007; Iftikhar et al. 2018; Zhu 2002). The concomitant initiatives for developments in such quasi-planned (semi-planned) contextual settings blur the distinction between the urban and rural settlements (Zhu 2004; SUN et al. 2010).

Therefore, the planned and unplanned modifications in the urban land resources necessitate careful assessments. The Land Use Land Cover (LULC) assessments are a realistic option to quantify such transformations as are required for the resilience of land resources. The LULC is a combination of two distinctive terminologies, often used interchangeably, while, Land Cover (LC) describes the physical characteristics of land surface, Land Use (LU) focuses on the particular use of a certain land area. Hence, the term LU evaluates the functional utility of land from the perspective of its practical utility (Rawat and Kumar 2015).

Presently, the LULC changes are intensifying (Tian et al. 2014) to an extent that they are now compromising the resilience of the hydrosphere, the lithosphere, and the atmosphere at all possible spatial scales (Adhikari and Hartemink 2016). The resultant alterations, thus, characteristically impact the terrestrial and aquatic ecosystems (Du and Huang 2017; De Groot et al. 2002; Lambin et al. 2000; Briassoulis 2000; Cai et al. 2016; Aguilar et al. 2003; Hamad et al. 2017; Rimal et al. 2018). Therefore, scholars such as Gill et al. (2008), Du and Huang (2017) and Rimal et al. (2018) emphasize scrupulous assessments of land resources as a mean to ameliorate the stresses. Consequently, LULC change-detection is gaining focus in research. These inclinations are obligatory to enhance the productivity of land resources (El-Kawy et al. 2011; Shalaby and Tateishi 2007).

Schneider et al. (2015), Appiah et al. (2017) and Rimal et al. (2018) delved on the causes responsible for the reported urbanization in the developing countries. They assiduously tried to decipher the ensuing impacts in the form of LULC changes on the urban landscape. The findings infer that these resource-stricken regions are rapidly transforming under the influence of globalization. The lack of awareness, capacity building, inconsistencies in the land-use policies, and paucity of resources are exacerbating the urban environmental degradation in these regions (Atif et al. 2018a; Bokhari et al. 2018; Amir et al. 2020). Resultantly, the urban environmental dilapidation is more pronounced in these countries as compared to the developed ones (Ahern et al. 2014; Cohen 2006). Environmental degradation has corollary impacts on social dilapidations in these regions. The emerging scenario is, thus, posing challenges for life and livelihood in developing countries like Pakistan (Amir et al. 2020).

The phenomena of permanent settlement started thousands of years ago in the Indus valley located in Pakistan (Kenoyer 1998; Kenoyer et al. 2013; Danino 2008).

The Indus valley civilization evolved in a depositional plain formed by the river Indus and its tributaries. The physiographic region is sub-divided into Upper and Lower Indus plains. The Upper Indus plain is the northern section formed by the Indus and its five eastern tributaries. The Lower Indus plain is the southern section and is solely developed by the Indus itself. The land area between the two adjoining streams in the Upper Indus plain is called a doab (river-interfluvies). The upper Indus plain is subdivided in Sind Saghar; Chaj; Rechna and Bari doabs (Grewal 2004). These land areas offer fertile tract for abode and agriculture. Overtimes, a varied set of factors such as the canalization of Indus plains (Khan 1990) the migration (Valentine et al. 2015); the green revolution of 1960s in Pakistan (Ali et al. 2017; Byerlee and Siddiq 1994) and associated industrial and infrastructural developments stimulated population growth and urbanization in this geographical region (Farah et al. 2016). However, the expansion was not supported by the desired management initiatives and, thus, added to the misery of fragile urban ecological resources in these areas (Mayo, 2012).

Therefore, the LULC based impact assessments are incumbent for postulating preventive and curative measures to ensure socio-ecological and environmental resilience (El-Kawy et al. 2011; Shalaby and Tateishi 2007). It entails for reliable estimations and assessments based upon empirical findings. The advancements in the Remote Sensing (RS) and Geographic Information System (GIS) enable the measurements of all spatial-temporal LULC changes (La Rosa and Wiesmann 2013; Thapa 2012; Khalil 2017). Therefore, the reliance on RS and GIS is gaining recognition to ensure accurate estimation of land resource management (Naqvi et al. 2014; Rawat and Kumar 2015; Hegazy and Kaloop 2015).

The present study tries to compare the salient characteristics of LULC transformations in planned and quasi-planned urban settlements of Pakistan. The specific objectives of this study are 1) to compare the impacts of

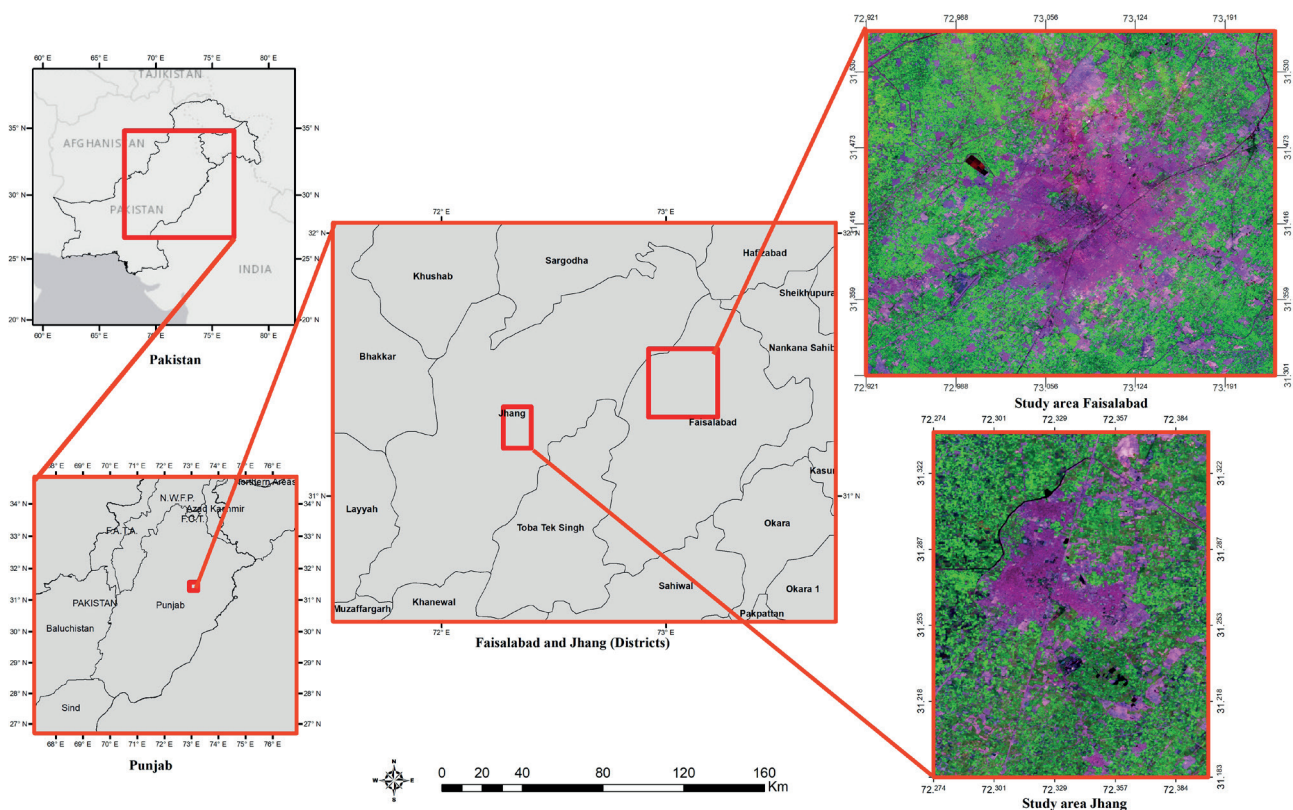


Fig. 1. Location map of study area

urbanization on the LULC changes in urban Faisalabad and Jhang from 1989 to 2019, and 2) to quantify the changes in the selected LULC categories of these urban centers for a similar time period (1989–2019).

MATERIALS AND METHODS

The study area

The current investigation evaluates the impacts of urbanization on LULC changes in the urban areas of Pakistan. The study was carried out in the contrasting contextual settings of the Faisalabad and Jhang cities (Fig. 1). Whereas, these urban settlements are located in a similar physical environment i.e. Rechna doab (river-interfluvium) of the Indus plain but evolved differently to cater for different socio-economic needs.

Faisalabad city is ranked third amongst the big cities of Pakistan, after Karachi and Lahore (<https://worldpopulationreview.com/world-cities/faisalabad-population>). Faisalabad was conceived as a planned urban settlement. It was designed to serve as a trading centre for promoting agricultural activities during the colonial period (Stock and Chusid 2019). The subsequent industrialization and the accompanying demographic changes have their peculiar imprints on the LULC of this sprawling urban settlement. The urban area of Faisalabad stretches across an area of approximately 1163.60 km². It lies between 72° 55'15.041 E to 73°13'38.803 eastern longitudes and from 31°33'44.988 N to 31°18'9.275 northern latitudes.

Jhang is among the oldest districts of Punjab province (Steedman, 1882). While the Jhang city is a quasi-planned and agro-based urban settlement. It covers an area of approximately 287.64 km². The urban center is located between 72°16'24.521 E to 72°23'55.075 E and from 31°20'27.309 N to 31°11'0.647 N. The Jhang city is also expanding (<https://worldpopulationreview.com/world-cities/jhang-population>) but the speed and scale of urban sprawl in this city is slower than Faisalabad. Thus, the contextual settings of these cities enable us to comprehend the dynamics of LULC changes in the urban landscape of Pakistan.

Data acquisition and assessment approach

The spatial-temporal changes in the LULC of these cities were assessed through remotely sensed data. The selected satellite images span the complete study areas, i.e., Faisalabad (Path 150/Row 38) and Jhang (Path 150/Row 39) cities. The images were retrieved through Landsat-5 TM, Landsat 7 EMT+ and Landsat-8 (Annexure. 1). The required images at 30-meter resolution for the selected time intervals (1989–2019) are available in the archives of USGS/EROS (U.S. Geological Survey/Earth Resources Observation and Science) (<https://www.usgs.gov>). The images were processed online in the Google Earth Engine (GEE) platform (<https://earthengine.google.com>).

Image normalization is carried out prior to change detection. The criterion at work here is the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS). Therefore, Top Of Atmosphere (TOA) reflectance

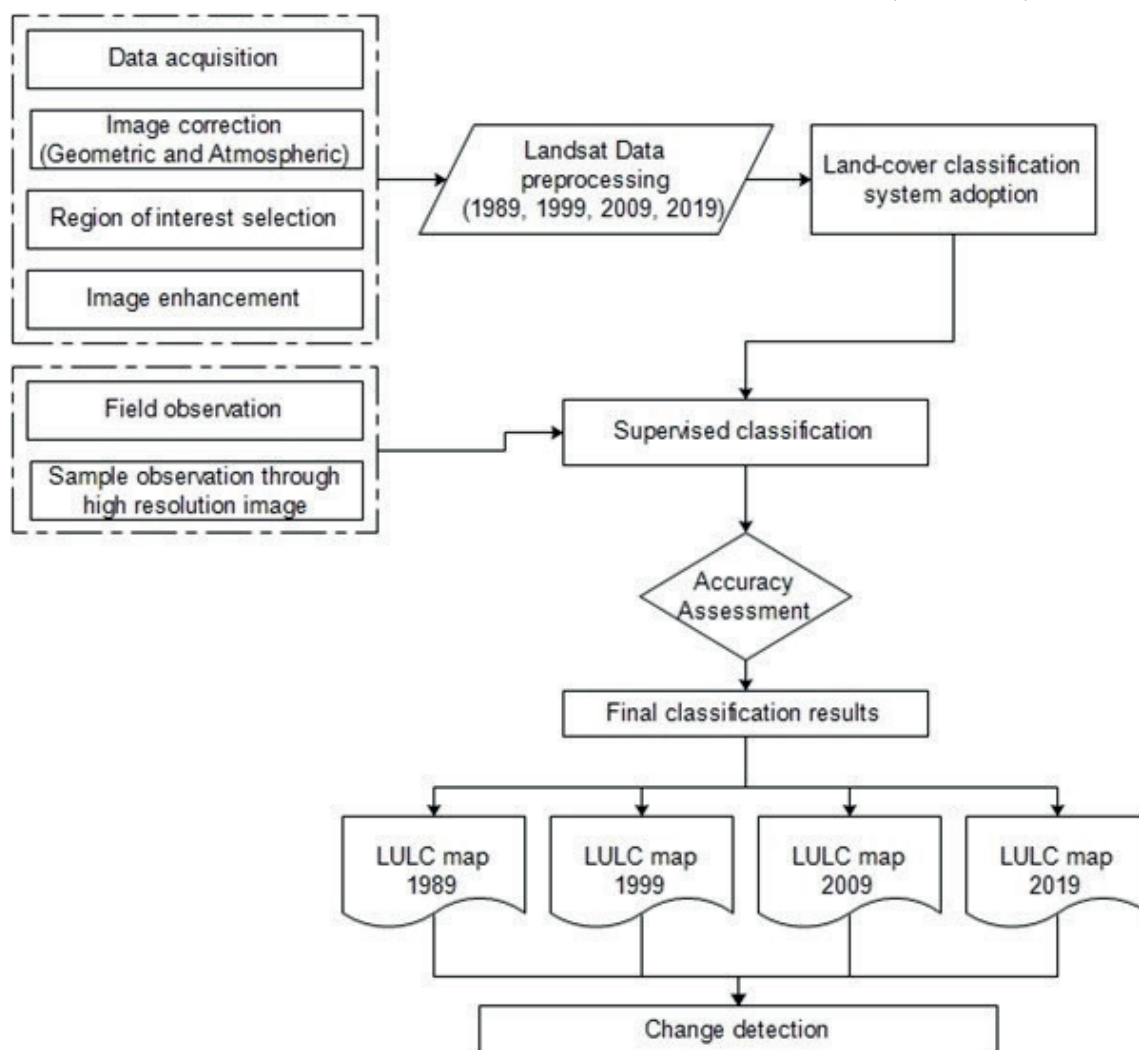


Fig. 2. The methodological framework for LULC change assessments

Table 1. LULC Classes considered for Classification

Class	Discription
Agriculture	Planned crop land, Agriculture fallow land, herbaceous vegetation and crop, lands that are regularly used for hay and grazing
Barren	Areas of sparse vegetation cover that is likely to change or be converted to other uses in near future
Built-up	Areas covered by residential, commercial services, industrial, transportation, communications, industrial and commercial, mixed urban or buildup land, airports, parking lots, highways, housing societies.
Grasses	Characterized by high percentage of grasses, other herbaceous vegetation, city parks
Trees	Areas covered by dense trees with relatively darker green colors, inner recreational areas, river line plantation
Water	All areas of open water, generally with greater than 95% cover of water, including lakes, streams, and reservoirs.

itemized by the bands 1 to 5 and 7 were adjudged relevant. The reference dataset and selected land cover classes were corroborated. The merger enables a quantification of the spatial-temporal changes in the designated LULC categories. Subsequently, the data was ported in the GIS environment to analyze, assess and illustrate oscillations in the observed land cover classes. Figure 2 succinctly illustrates the measures and mechanism deployed for the assessments.

Land-Use/Land-Cover classification

The research was confined to six classifiable LULC surfaces in the study area (Table 1). The field observations from 600 locations were carried out for quantitative assessments. These sites were marked with the help of the Global Positioning System (GPS). Besides, 2095 sample plots were manually observed from 1989 to 2019 through higher resolution images. For this purpose, the training and validation samples of each year were separately uploaded and integrated with the Google Fusion Tables (GFT) via GEE. For this purpose the Supervised and Un-supervised Classification techniques are considered standards (Shetty 2019; Prasad et al. 2006; Lewis 2000), and were, therefore, used (Table 1). For the land cover maps, the Classification and Regression Tree (CART) classifier was used because it is based upon the supervised classification mechanism.

Accuracy assessment

The accuracy assessment is a key feature and is useful to authenticate findings (Ahmadizadeh, 2014). The LULC based maps were cross-validated and scrutinized on the criteria of the Kappa test (Annexure 2).

RESULTS

Spatial-temporal transformations in LULC

The spatial-temporal assessments of LULC changes divulge the trajectories of urban expansions regarding these settlements. Therefore, the absolute and proportionate changes in the selected LULC classes during (1989–2019) in Faisalabad (Annexure 3) and Jhang cities (Annexure 4) were analysed. The illustrations (Fig. 3 and Fig. 4) succinctly portray the orientation and magnitude of such transformations in these settlements. The findings formulate that the agricultural land cover is shrinking, and built-up areas are expanding in both cities. The comparisons are portrayed with the help of a uniform intensity line. The line succinctly portrays the differences in the rate of LULC conversions between/among different contextual settings (Mondal et al. 2015). The line of

uniform intensity (Fig. 5) inferred that the speed and magnitude of such conversions is more pronounced in Faisalabad as compared to Jhang.

Besides this, the urban sprawl in these settlements was observed more inclined towards the lines of communications such as highways and motorways (Fig. 3 and Fig. 4). Resultantly, the arable land cover is transforming into a non-productive and a barren one (Fig. 8 and Fig. 9). However, the phenomena of urban densification is gaining momentum in recent times. Consequently, the resultant vertical growth is gaining impetus in these cities.

Quantitative assessments of LULC transformations

The oscillations in each specific land use category for Faisalabad (Fig. 6) and Jhang cities (Fig. 7) were computed. Subsequently, the relative changes and consistencies in the proportion of these land use categories were assessed. The assessments formulate a noticeable increase in the proportion of tree cover, grassy surfaces, barren lands, and water surfaces of these settlements during (1989–2019). However, the significant fluctuations in the shares of water surfaces and barren lands are also observed (Fig. 3 and Fig. 4).

Gross Gains, Losses and Persistence in LULC

The impacts of urbanization during (1989–2019) on the persistence, increases, or decreases in the share of a specific land category were quantified. The findings have been summarized (Fig. 8 and Fig. 9) to depict the orientation and magnitude of such transformations (Fig. 6) and (Fig. 7). The findings revealed that such transformations were more pronounced from 1999 to 2009 (Fig. 8 and Fig. 9). However, the speed and scale of such changes was stunted in the following decade (2009 to 2019).

The assessments formulate that the agricultural land considerably reduced (-17.38%) during (1989–2019) in Faisalabad (Fig. 8). Whereas, the percentage shares of all the other LULC categories remained stable or marginally enhanced during this time-frame. However, the most significant growth (16.05%) was observed in the built-up areas of Faisalabad.

The proportionate shares of agricultural land significantly reduced in (-8.93%) in Jhang city during (1989–2019). While, the proportions of tree covers (1.27%), water surfaces (0.09%), and grassy surfaces (0.03%) marginally enhanced. However, the chunks of barren land (3.10%) and built-up areas (4.44%) substantially inflated in this city during this time interval (Fig. 9).

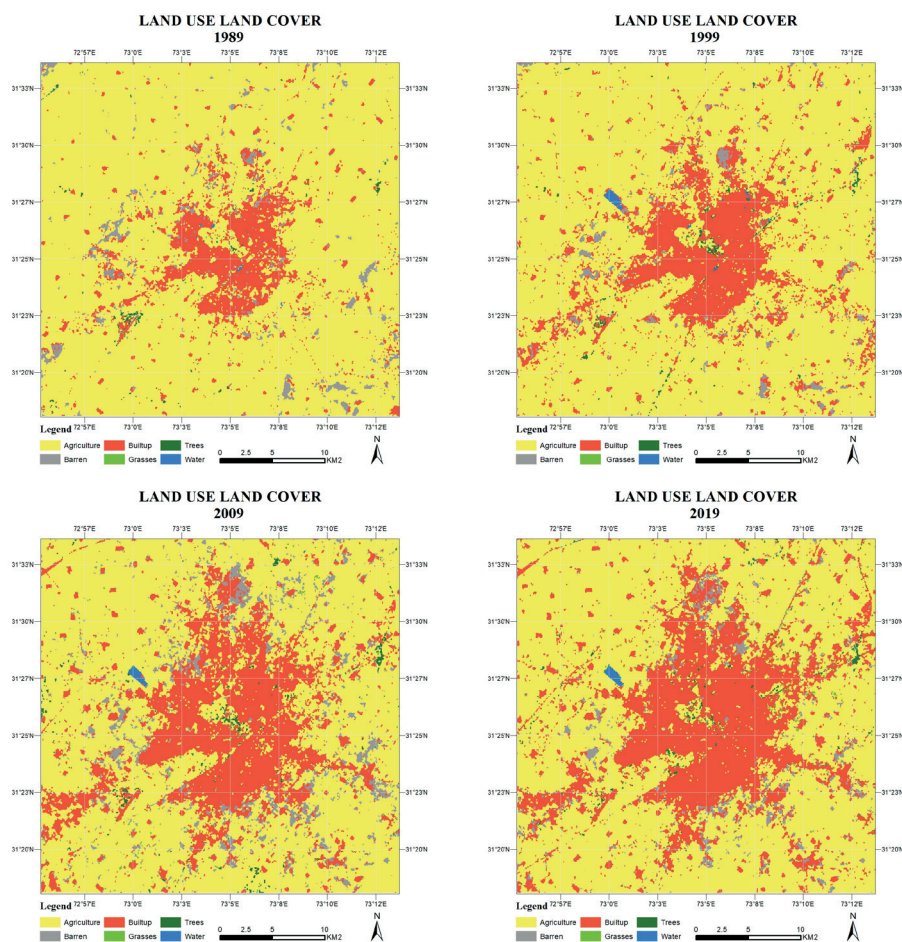


Fig. 3. Land use land cover classification maps of Faisalabad city

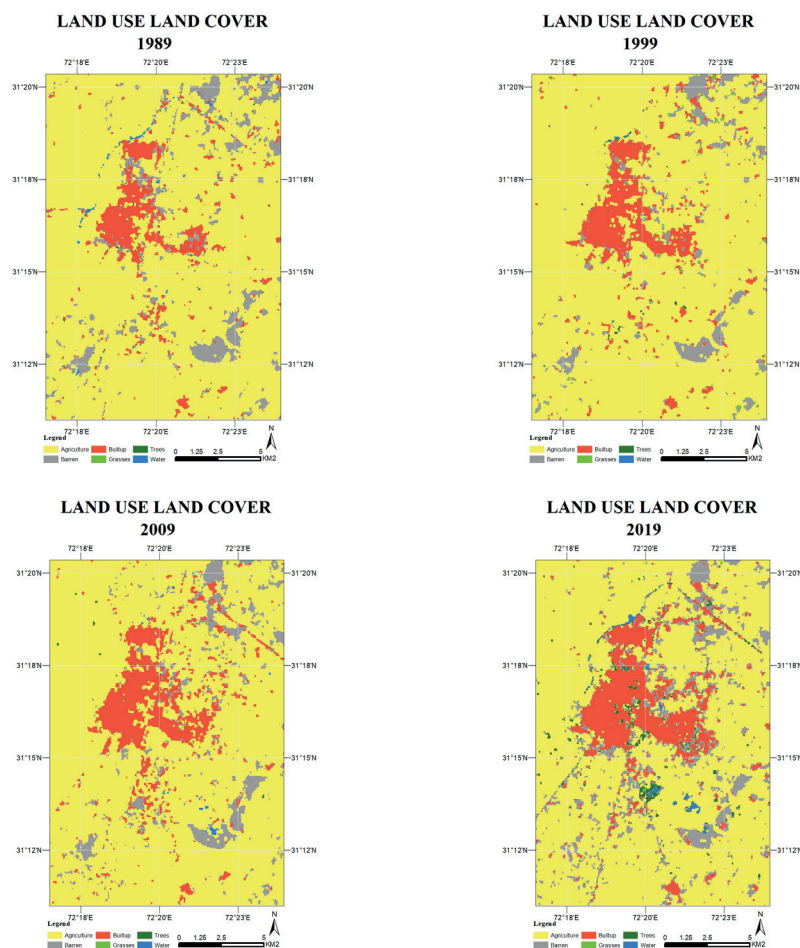


Fig. 4. Land use land cover classification maps of Jhang city
Uniform Intensity Line

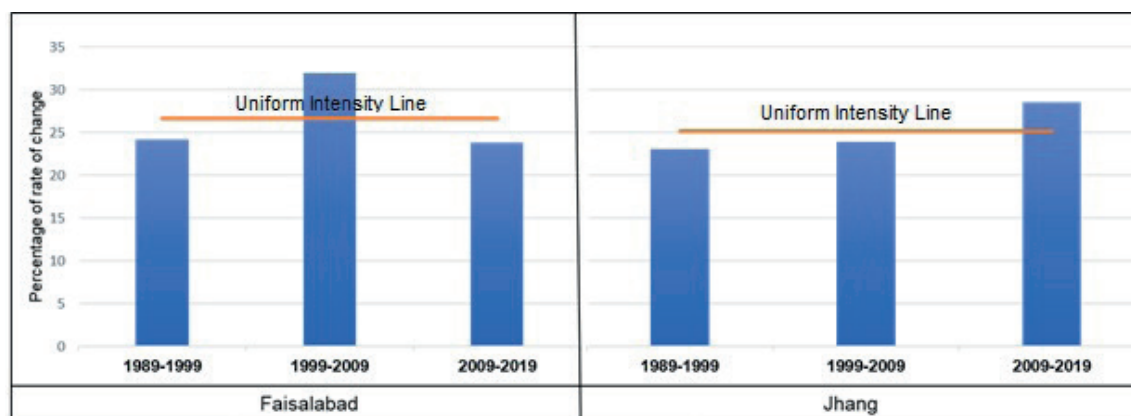


Fig. 5. The comparison of land conversion speed during the selected time intervals between Faisalabad and Jhang

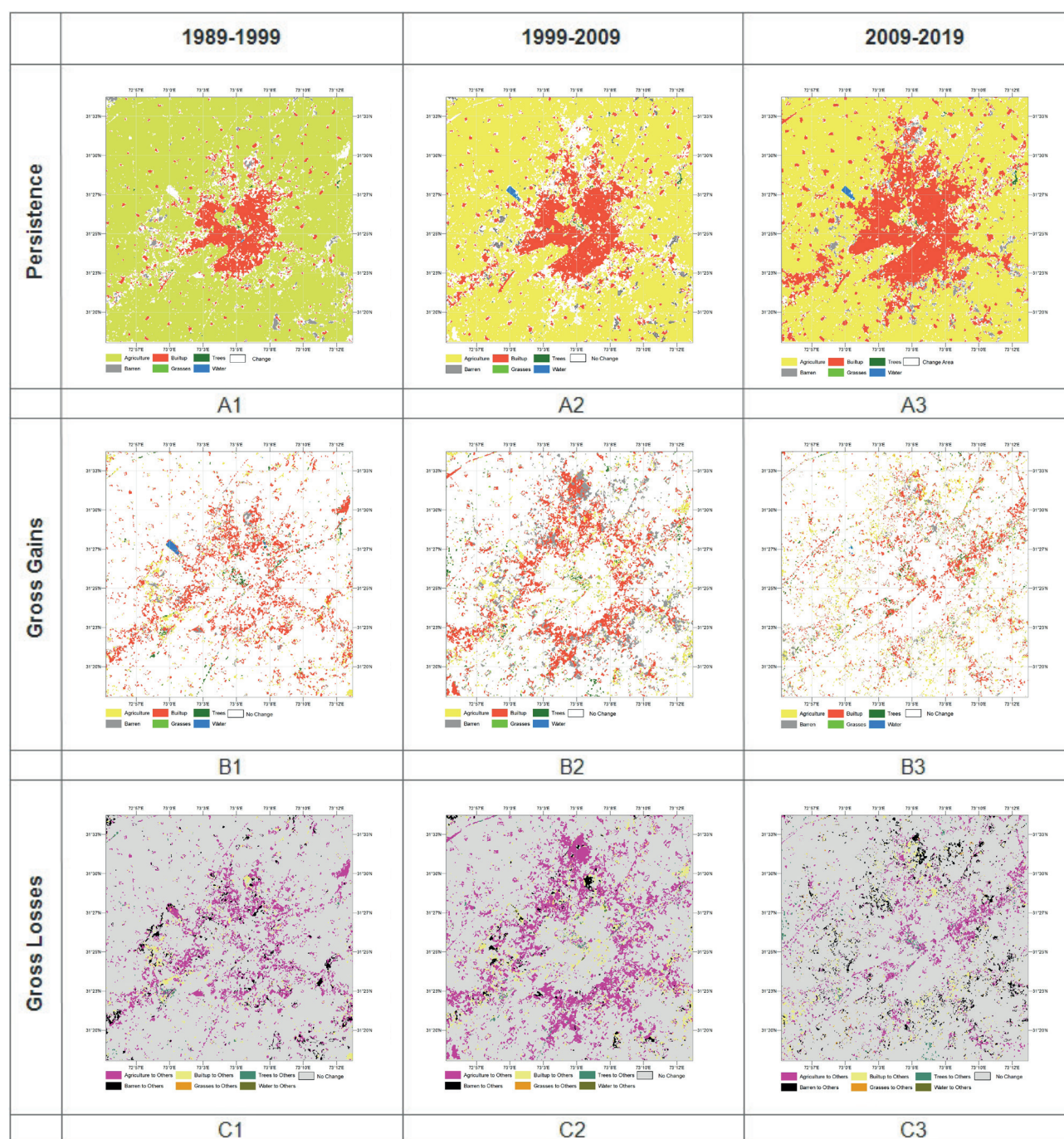


Fig. 6. Maps of persistence, gross gains and gross losses of urban center of Faisalabad

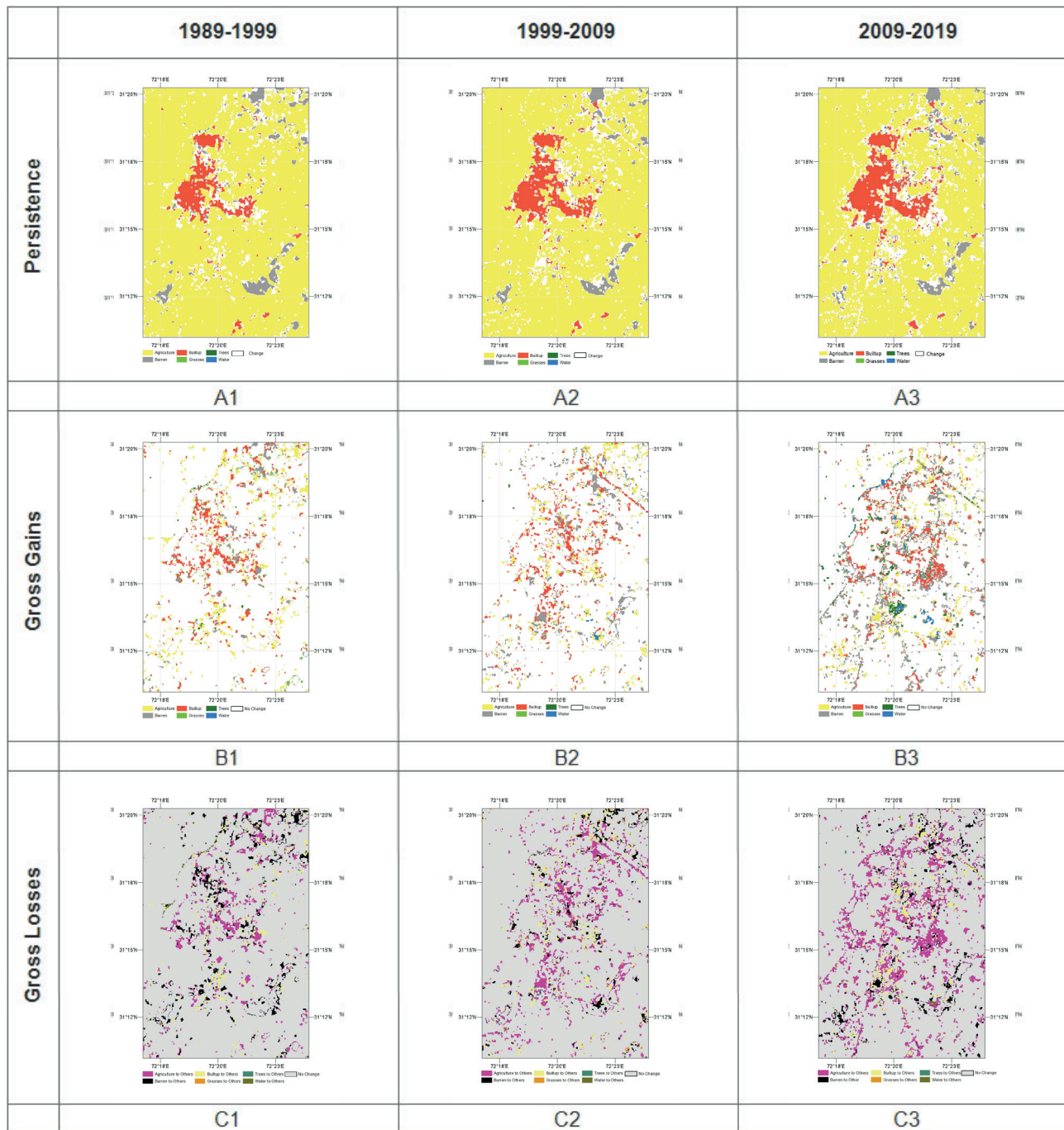


Fig. 7. Maps of persistence, gross gains and gross losses of urban center of Jhang

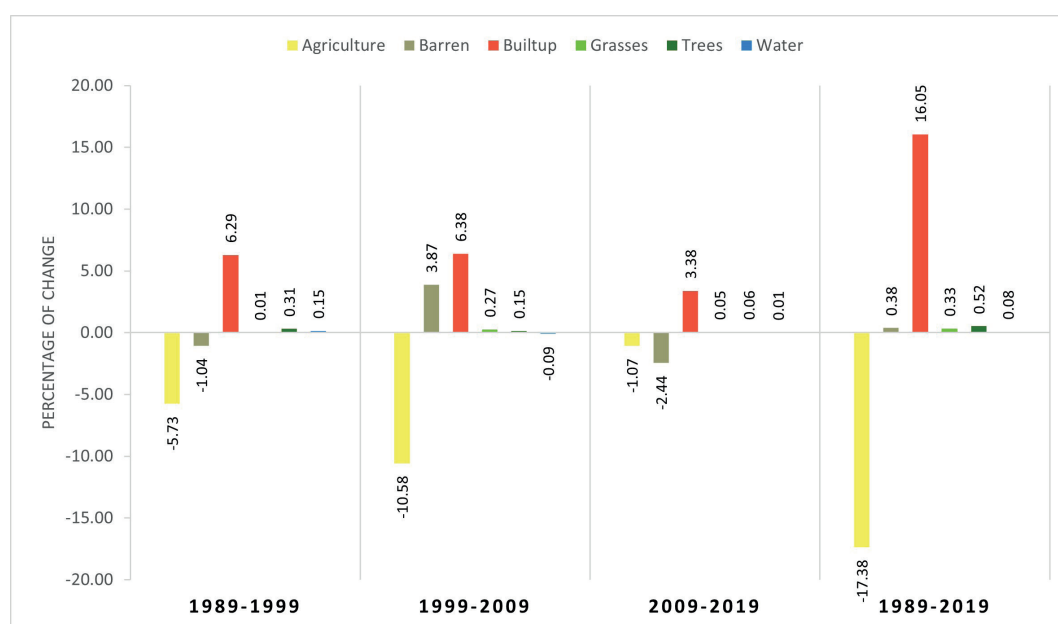


Fig. 8. Gains and losses in the LULC classes of Faisalabad (1989–2019)

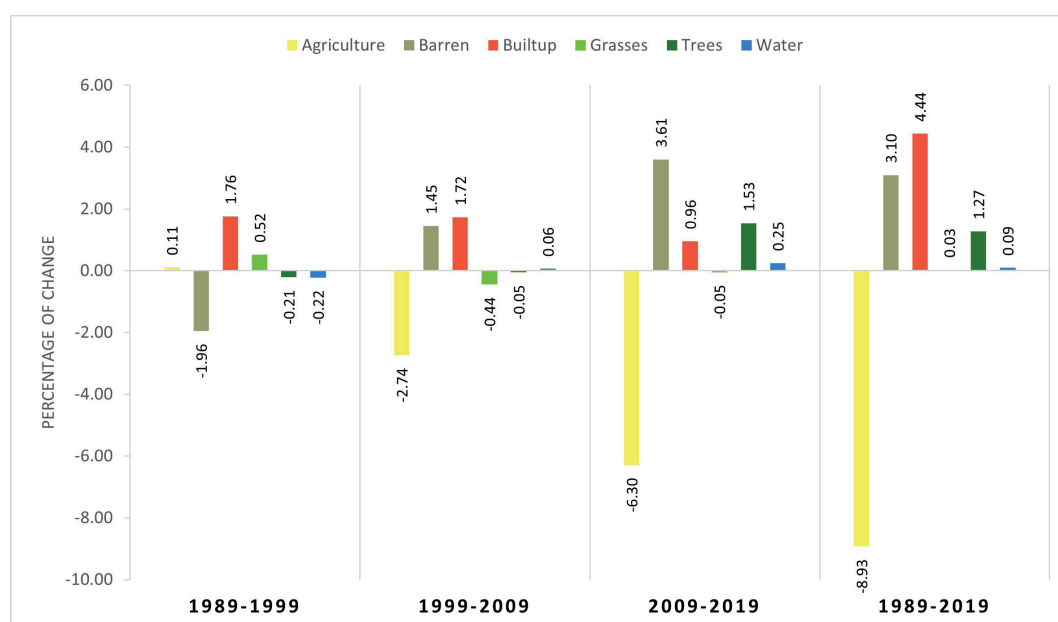


Fig. 9. Gains and losses in the lulc classes of Jhang (1989–2019)

DISCUSSION

Pakistan, like many other South Asian countries, has rapidly urbanized (Vasenev et al. 2019; Ouyang et al. 2016). The phenomenal increase in the rate and scale of urbanization in Pakistan (UNDP 2018; Shah et al. 2020) is attributed to the natural population growth (Kugelma, 2014) and rural-to-urban migration (Arif and Hami, 2009). This massive migration is attributable to the peculiar historic (Farooq et al. 2005; Farah et al. 2012; Safder and Babar 2019), social (Lopes and Farooq, 2020), economic (Chiesura and De Groot 2003; de Molina and Toledo 2014; Gilani et al. 2020), environmental (Shaheen et al. 2020) and geo-strategic (Shaheen et al. 2020) dynamics of this region.

The ensuing speed and impacts of urbanization in Pakistan (Nisar et al., 2013) are straining the urban land resources (Atif et al. 2018b; Atif et al. 2018a). It entails comprehending the dynamic and consequential impacts of the resultant changes in urban landscapes (Shao et al. 2005). The evolving scenario demands pragmatic

responses based on empirical findings. Therefore, the research should be oriented more towards LULC assessments for the sustainability of urban land resources (Naqvi et al. 2014; Rawat and Kumar 2015; Hegazy and Kaloop 2015). The spatial-temporal analysis of LULC changes calls for improvised strategies for the resilience of land and environmental resources (Atif et al. 2018b).

The current study evaluates the spatial-temporal dimensions of the LULC changes regarding Faisalabad and Jhang cities (Annexure 3 and Annexure 4). The study mainly focuses on the LULC transformations of the previous 30 years (1989–2019). These 30 years witnessed massive physical expansions and LULC convergences (Fig. 3 and Fig. 4). During this time interval, the built-up areas in these cities expanded, and productive agricultural land substantially squeezed (Fig. 8 and Fig. 9). These observations substantiate the reported assertions that the accompanying processes of urbanization characteristically modify the LULC patterns (Butt et al. 2015; Ali et al. 2011; Ali and Malik 2010; Hassan et al. 2016). The findings of the study substantiate the notions that

the reported population growth in these cities (Mazhar and Jamal 2011; Bukhari 1971; Farah et al. 2012; Ghalib et al. 2017) is stressing these urban centers

The chronological assessment of spatial expansions regarding Faisalabad formulates that the settlement was initially and intrinsically planned to serve as a market town. The area around Ghanta Ghar was designed to cater to the needs of the Central Business District (CBD). The initial extensions in the structure of Faisalabad city followed the pattern of the Concentric Zone Model (CZM). E. W. Burgess proposed it in 1923 (Brown and Holmes 1971). The model hypothesized that urban settlements expand outward from a central location like the water ripples in a pond. This urban settlement expanded outward from the CBD like the growth rings of a tree. The urban neighborhoods such as Jinnah Colony, Tata Bazaar, and Civil Lines developed during the early phases of urban expansion. The process of urban sprawl was expedited with the advent of canalization, and the subsequent industrial and manufacturing activities. However, the lateral growths in the city followed the orientation of road infrastructure. The demographic pressures, lacunas in the policies, and compromises over urban land management deter any possibility of a planned urban growth (Omwoma 2016). Besides this, the loose regulatory control encouraged unplanned and irregular LULC transformations in Faisalabad (Saeed et al. 2012; Shakeel et al. 2015). Resultantly, the unplanned and congested residential localities like Duglus Pura; Sant Nagar; Dhobi Ghaat; Islam Nagar emerged. These observations corroborate the notions that integrated management of urban environmental resources is a prerequisite for the socio-ecological resilience of urban life (Atif et al. 2018a).

While the historic city of Jhang is an autogenously developed human settlement it evolved without any formal planning. The embedded flaws of the earlier developments, still, haunt the process of urbanization in the Jhang city. The imprints of irregular growth are visible in such localities as Kot Akbar, Ludhan Shah, Loharan wali, Jalal Abad and Deewan wali. The provisioning of civic facilities is cumbersome in these unplanned, congested and irregular neighborhoods. The findings entail that a coordinated urban planning is obligatory for environmentally friendly urban growth. Therefore, the recent trends of urban expansion in Jhang city were adjudged more skewed towards organized and planned growth. These tendencies are quite visible in the form and structure of the recently developed Satellite town, Lal Zar Housing Schemes (Phase-1 and 2), Ali Garden and Al-Karam City etc. The planned orientations in these expansions are due to public pressures (Haaland and van Den Bosch 2015). These findings construe that consciousness about environmental issues is positively

contributing to urban planning in Pakistan. Contrarily, the demographic and economic stresses are culpable for unintended urban sprawl.

The impacts of road infrastructure on the process of urbanization were also evaluated. The recent urban expansions were observed more tilted towards inter-city highways and motorways during (1989–2019). These observations corroborate the postulations of sector theory. The model was envisaged by Homer Hoyt (Beauregard 2007; Ju et al. 2016). It formulates that urban expansions intensify along the lines of communications i.e., roads and railway networks.

The findings of this study substantiate that the RS and GIS-based understandings facilitate in deciphering the spatial-temporal connotations of urbanization (La Rosa and Wiesmann 2013). The findings corroborate the reported notions such as (La Rosa and Wiesmann 2013; Thapa 2012; Khalil 2017) regarding the robustness of RS and GIS techniques. These resources were also found appropriate for detecting previous changes in the LULC (El-Kawy et al. 2011). Therefore, the reliance on such cost-effective resources is a pragmatic option for developing economies such as Pakistan.

CONCLUSIONS

The holistic assessments of this study imply that the people in developing countries move towards urban areas for economic opportunities. The resultant uncontrolled urbanization and concomitant LULC transformations are adversely impacting the urban infrastructures. Therefore, integrated measures are obligatory to regulate the speed and scale of such LULC conversions. Besides this, the inflow of people is promoting horizontal and vertical growth in the city structure. The resultant impacts stress the ecological and environmental resources of the cities and their peripheral zones. The emerging scenario is proving burdensome specifically for the resource stricken regions. The massive urban growth, due to migration is exacerbating the urban social life of these countries. The scenario entails for synchronization in policies and an integration of efforts for a more resilient urban development. The decentralization of power is a pragmatic option for countries such as Pakistan. It will productively contribute towards curtailing the inflow of migrants from rural hinterlands towards the more central places like Faisalabad and Jhang. The creation of employment opportunities in the rural hinterlands is another viable preference to ameliorate stresses on urban infrastructures. However, the findings affirm that population control is the most reliable measure to address such daunting challenges in countries like Pakistan (Heinke 1997; Simon 2019). ■

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Appendix
Appendix 1. Satellite images characteristics

Path/Raw	Year	Satellite	Sensor	Data Acquired	Thermal Resolution	Radiometric Resolution	Bands Description		
							Name	Wavelength (μm)	Discription
149/38	1989	Landsat 5	TM	1989-06-19	16 Days	8bit	B1	0.45-0.52	Blue
							B2	0.52-0.60	Green
							B3	0.63-0.69	Red
150/38				1989-04-11			B4	0.77-0.90	Near infrared
							B5	1.55-1.75	Shortwave infrared 1
							B7	2.08-2.35	Shortwave infrared 2
149/38	1999	Landsat 5	TM	1999-05-14	16 Days	8bit	B1	0.45-0.52	Blue
							B2	0.52-0.60	Green
							B3	0.63-0.69	Red
150/38				1999-04-24			B4	0.77-0.90	Near infrared
							B5	1.55-1.75	Shortwave infrared 1
							B7	2.08-2.35	Shortwave infrared 2
149/38	2009	Landsat 7	ETM+	2009-06-16	16 Days	8bit	B1	0.45-0.52	Blue
							B2	0.52-0.60	Green
							B3	0.63-0.69	Red
150/38				2009-05-23			B4	0.77-0.90	Near infrared
							B5	1.55-1.75	Shortwave infrared 1
							B7	2.08-2.35	Shortwave infrared 2
149/38	2019	Landsat 8	TOA	2019-06-01	16 Days	16bit	B2	0.45-0.51	Blue
							B3	0.53-0.59	Green
							B4	0.64-0.67	Red
							B5	0.85-0.88	Near infrared
150/38				2019-04-17			B7	2.11-2.29	Shortwave infrared 2
							B10	10.60-11.19	Thermal infrared 1
							B11	11.50-12.51	Thermal infrared 2

Appendix 2. Accuracy assessment for each classified image

Image (Path/Raw)	Year	Classified Image	Overall Classification accuracy	Overall Kappa Statistics
Urban Center of Faisalabad (149/38)	1989	Landsat 5 TM	81.73%	0.6863
	1999	Landsat 5 TM	86.42%	0.7478
	2009	Landsat 7 EMT+	83.93%	0.7068
	2019	Landsat 8 TOA	91.11%	0.9285
Urban Center of Jhang (150/38)	1989	Landsat 5 TM	82.33%	0.6923
	1999	Landsat 5 TM	87.23%	0.7631
	2009	Landsat 7 EMT+	81.53%	0.7958
	2019	Landsat 8 TOA	89.41%	0.9101

Appendix 3. Land Use Land Cover (LULC) area of Urban Center of Faisalabad

		1989		1999		2009		2019	
Sr. No	Class	Area (km ²)	Area (%)	Area (km ²)	Area (%)	Area (km ²)	Area (%)	Area (km ²)	Area (%)
1	Agriculture	1003.57	86.25	936.87	80.51	813.78	69.94	801.38	68.87
2	Barren	33.33	2.86	21.23	1.82	66.22	5.69	37.80	3.25
3	Buildup	121.60	10.45	194.80	16.74	269.07	23.12	308.39	26.50
4	Grasses	0.06	0.01	0.23	0.02	3.33	0.29	3.96	0.34
5	Trees	4.16	0.36	7.80	0.67	9.54	0.82	10.25	0.88
6	Water	0.87	0.07	2.66	0.23	1.65	0.14	1.82	0.16
Total		1163.60	100.00	1163.60	100.00	1163.60	100.00	1163.60	100.00

Appendix 4. Land Use Land Cover (LULC) area of Urban Center of Jhang

		1989		1999		2009		2019	
Sr. No	Class	Area (km ²)	Area (%)	Area (km ²)	Area (%)	Area (km ²)	Area (%)	Area (km ²)	Area (%)
1	Agriculture	244.96	85.16	245.27	85.27	237.39	82.53	219.28	76.23
2	Barren	21.35	7.42	15.73	5.47	19.89	6.91	30.26	10.52
3	Buildup	19.44	6.76	24.49	8.52	29.45	10.24	32.20	11.20
4	Grasses	0.05	0.02	1.54	0.54	0.27	0.09	0.14	0.05
5	Trees	1.05	0.36	0.44	0.15	0.29	0.10	4.70	1.63
6	Water	0.79	0.27	0.16	0.06	0.35	0.12	1.06	0.37
Total		287.64	100.00	287.64	100.00	287.64	100.00	287.64	100.00