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Assessing the Impact of Urbanization on Land Use and Land Temperature in Lahore: An Empirical Analysis Using GIS Mapping

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ABSTRACT

The objective of this research is to examine the influences of changing land use and land cover on the land surface temperature (LST) of the Lahore metropolitan area. The study region is a rapidly urbanizing city in Pakistan, where land development has accelerated dramatically during the last 30 years. The satellite images acquired by LSAT-5 (TM) and LSAT-8 (OLI) are used to calculate land temperature and its various features. They are processed in the software named ERDAS imagine-14 and supervised classification is performed to calculate the area covered by major land features. The Persistence Matrix, a GIS analysis, is used to see if the Lahore urban area is developing at the expense of agricultural land over time. The results demonstrate that over the research period, urbanization accelerated in tandem with the loss of agricultural land. The ARDL model's findings suggest that Lahore's rapid urbanization has a significantly positive link with land surface temperature (LST), while cultivation area has an inverse relationship with land surface temperature (LST).

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1 Introduction

At an Eco-regional scale, the effects of urbanization on farmland are still inadequately studied. Increased urbanization is creating instability such as land scarcity for agricultural activities and atmospheric issues; particularly, the horizontal spread of large cities is causing such issues. In the present era, almost fifty percent of the world's population is part of cities, and there is a possibility that 60 percent of the world's population will be urbanized by 2030 (Avelar et al., 2009). Such facts perspicuously illustrate the swiftness in the conversion of small settlements into metropolitan city areas. China has been more affected by urban sprawl in the

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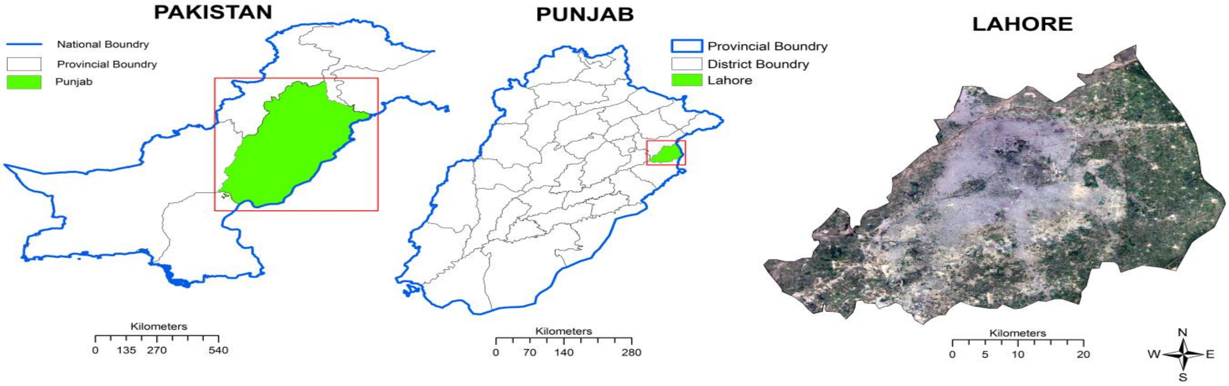
last four decades than any other developing country and this resulted in an expanded covered area by 224.7 percent between 1994 to 2003 (Su et al., 2011) leading to serious damage to the cultivable areas. Pakistan is also facing the problem of rapid urbanization and development of housing societies on yearly basis is an alarming signal in this regard. All this is happening at the cost of using agricultural land for this purpose due to which the land temperatre of such cities is being observed increased comparing to the other adjacent regions. This study aims to examine this impact in case of Lahore City which is highly concentrated due to having advanced infrastructure facilities, job opportunities and educational prospects. Urban sprawl has affected the life of the city immensely causing congestion on roads, poor quality of life due to polluted environment.

The covered area of the metropolitan city of Lahore increased by 97 percent from 1990 to 2021, which is turning into another classic example of urban sprawl. During the study period, Lahore's cultivable land shrank from 1047 square kilometers to barely 664 square kilometers, implying that 63.41 percent of the city's lush green space was switched to covered space. This has happened due to the absence of central policy-making regarding the construction of housing societies around the main city of Lahore; several housing societies were constructed from 1990 to 2021 on green land. The major share of the agricultural area and fruit gardens of Lahore city is plowed in the horizontal spread of the city. Such an enormous defective policy can disturb the whole environmental and economic conditions of a society; like the land surface temperature which will affect not only the atmospheric and meteorology but also the harvesting season of the crops by creating pre-monsoon or post-monsoon issues. Due to atmospheric factors such as an increase in the land surface temperature, the harvesting of wheat has been affected by intense storms with enormous rainfall over the last year. The increment of covered area can also create scarcity of green land for farming, which can disturb the food supply for the metropolitan city of Lahore. A lot of landless farmers have abandoned agriculture because of rising land rents as a result of the construction of housing societies in the vicinity of farmlands.

So far very few studies are available highlighting the impact of land use on land temperature and in case of Pakistan to our knowledge no empirical work is available for analysing properly the consequences of these new born housing societies on the economic and social lives of the city facing the issue of urban sprawl. The question arises why this city is chosen for the empirical analysis. The green land of the study area is very productive in agricultural output, as well as significantly diversified with all types of vegetables and having a wide range of fruits it provides food supply to the residents of Lahore. In agricultural output, the cultivation of staple food, fruits, and vegetables, are playing a significant role in the GDP of the city of Lahore, which is around 84 billion US dollars. The flower market of Lahore in Nain-Sukh is very important for the supply of fresh roses to the main city of Lahore; the source of fresh roses is the rose gardens of Nain-Sukh's locality, however, due to the construction of housing societies has damaged these rose fields during the last 20 years. The enormous urban sprawl on agricultural land has disrupted not just the rose gardens, but also the yield of litchi, guava, and jambolan.

Figure 1: Map of Study Area



Furthermore the weather conditions of the study area are enriched with all four seasons winter, spring, summer, and autumn; winter monsoon and summer monsoon play a vital role in meteorology and atmospheric conditions. The temperature also plays a valuable role in the atmospheric conditions; in winter (November to January) average temperature of the study area remains 5.9°c to 11.6°c (42.6°f to 52.9°f) and in summer (May to July) average temperature remains 36.1°c to 40.4°c (97.0°f to 104.7°f). On 30th May 1944 and 9th June 2007, the highest maximum temperature of 48.3°c (118.94°f) was recorded and it was the lowest one on 17th January 1935 recorded at -2.2°c (28.0°f) in the study area. Hence these notable changing conditions of environment also highlights the importance of the study area for agricultural outputs. Considering all these factors in view, the study designs its objectives in the section given below.

1.2 **Objectives**: The following are the main objectives of this study.

- To indicate how much-covered area increased during the last 30 years.
- To analyze how much agricultural land has been reduced by the horizontal spread of the metropolitan city of Lahore.
- To estimate the increment in the land surface temperature of central city Lahore due to changes in the land cover land use.
- To describe the consequential impact of land surface temperature on agricultural output.
- To suggest policy suggestions for eliminating the consequential effects of urban sprawl or the construction of housing societies on green land regarding long-term food supply to the Lahore market at reasonable prices.

2 Literature Review

This section covers the past literature which explains the relationship betweeb land use and land surface temperature due to urbanization process. The section is divided into various sub sections just to reach at the conclusion that how this nexus develops in the long run to impact negatively to the overall social lives of residents of such regions.

Urbanization is becoming a very well-liked research topic in the current era for research scholars due to its composite effects on human life. Whereas urban areas provide a variety of amenities and conveniences for human life, rapid urbanization complicates human life in terms of atmospheric oscillations due to a paucity of green land. With time, the green area from the surrounding cities is decreasing; due to urbanization, by which the land surface temperature is increasing day by day, and the thermal environment collapses during swift urbanization (Yang et al., 2017). Due to the diminishing of green land around the cities, the cities are becoming heat-land. Farmers are being pushed into less conducive situations as urbanization grows; the farmers are oppressed into unauthorized public spaces to continue farming (Kuusaana & Eledi, 2015). The urban sprawl is creating a scarcity of land for agricultural activities; the farmers are leaving the agriculture sector and preferring the housing societies. The scarcity of land is increasing the rent of land for the remaining farmers, which incrementing the output prices of the agricultural sector.

Recently Hussain & Karuppannan (2023) examined the relationship between land use and land temperature of Khanewal in Pakistan by using remote sensing technique and the finding of the study supported that there was a huge change in the land use from agricultural use to rapid increase in population density and infrastructure development. Furthermore the LST values have also sown rising trend by 0.50 degree due to more built up area.

2.1 Urbanization and Environment

Rapid urbanization, which is linked to a country's modernization, social advancement, and economic expansion, elevates the status of small settlements into city regions. Urban sprawl is causing a revolutionary transition of complex social roots on a massive level, with rural civilization being rapidly supplanted by urban culture. A large number of villagers are migrating to the areas of major cities in search of prosperity and social advancement. Rapid urbanization is also a result of such migration. However, the picture of urbanization is not as rosy as it may appear (Jaysawal & Saha, 2014). Inadequate sewerage systems and a huge collection of urban solid waste including building materials, plastic containers, medical wastes, and kitchen trash are producing environmental difficulties as cities grow. Due to the swift urban sprawl, human life is being harmed by environmental challenges, which are producing health and nutritional problems. The frequency of vascular and metabolic disorders has increased with greater rates in metropolitan areas (Zhu et al., 2011). Other disorders, such as hepatocellular carcinoma or lung disease, show little variation between rural and urban populations or may happen at a higher percentage in rural areas (e.g., esophageal cancer). As per the United Nations Population Fund's (UNFPA) study "State of the World Population 2007", mankind is on the verge of surpassing the point where city dwellers outnumber rural dwellers for the first time. Since this rate of urbanization is expanding, the cost of transport and communication is decreasing, and the population of urban regions is becoming more diversified. As a result, cultural issues have become increasingly important in our knowledge of urban psychological health. This form of urbanization has carried with it its particular set of cognitive health and well-being issues (Trivedi et al., 2008). Only diversification of cities is not a single factor of mental health problems in the city dwellers; Lack of basic affordable homes, clogging markets with customers, smog, ineffective drinking water, poor sanitation, and third-class solid waste disposal system, vector-borne diseases, toxic pollution, increasing engine vehicle traffic and stress due to poverty all these factors are also behind it.

Ullah et al. (2023) recently assessed the impact of land use change on environment by calculating normalized difference vegetation index (NDVI) for the lower Himalayan region of Pakistan. Correlaion analysiswas used to relat LST with NDVI and the results indicated that slopes in a region also matter while calaculating the impact on temperature of an area. The results showed that LST was decreased from North to South and from South to East, while increasing from North to East and South toWest directions. Similarly according to Larsen et al. (2019), in underdeveloped countries, unplanned urbanization is producing land use and land cover difficulties, as well as air and groundwater pollution, at an alarming rate. Khan et al. (2011) created a groundwater quality indicator (GQI) within such a geographic information system (GIS) to assess the consequences of fast urbanization. Land-use changes were intensively studied using multi-spectral satellite photos from 2003 to 2008, and the results showed that the covered area rose significantly. The groundwater quality index (GQI) declined from 84.16 to 83.26 over the research period, indicating that urbanization has caused environmental problems. Groundwater pollution at this level is causing Dyspeptic issues in city dwellers at an astonishing rate.

2.2 Urbanization and Fertile Land

Shawky et al. (2023) recently investigated the spatiotemporal changes in LST for SouthAsia using the data from 2020-21. The authors highlighted that the better understanding of land surface temperature will help in designing proper sustainable development policies for the region. By estimating monthly and yarly trends, the findings reported that most of the regions in central and west South Asia experienced highest daytime cooling in December while central and northwest regions observed highest warm night time in July and September showing environment change drastically in this region. The agricultural coastal area of Turkey has been the most affected area by the rapid urbanization during the last 40 years in the Mediterranean region as compared to other countries since its starting year of development, with the urban sprawl rate climbing from 18.5 percent in 1950 to almost 62 percent after 2000 (Burak et al., 2004). After the institutional motivations with financial help to stimulate tourism investment, smaller coastal villages have become rapidly urbanized. The horizontal spread of urban areas for commercial activities near the coastal area was the primary cause of agricultural land loss. The green agricultural area of the Mediterranean coast was converted into tourism areas; only just for extra revenue in the short run (Burak et al., 2004). This so-called development of fertile land is not only an alarming act for the agricultural sector but also contaminating the atmosphere. Farmers began to utilize more severe agricultural methods to fulfill output challenges, which resulted in increased soil and water contamination due to fertilizer usage (Burak et al., 2004). These types of urbanization issues can also be found in Punjab's capital city, Lahore. Whereas the covered area of Lahore's metropolitan city has doubled in the last forty years, the agricultural region has experienced a more than eighty percent contraction during the same period. In such circumstances, farmers must choose one of the following options: first, work in harsh conditions, as in the case of Turkey's coastline region, or second, abandon their valuable lush green lands in favor of sprawling urban regions, as in the case of Lahore's metropolitan city.

Riaz (2013) wrote about Lahore in comparison to urban areas in developed countries that the historic walled city of Lahore was a very tiny urban center when Pakistan gained independence in 1947. From 1951 until 1981, Lahore's growth was rather stable, but since the 1980s, it has exploded without bounds. The administration was forced to proclaim the entire Lahore district as Lahore city district in 2002 due to the rapid horizontal spread of the metropolis (Punjab Development Statistics 2018)[3]. Such horizontal urban development is extremely damaging to those who work in the agriculture sector, and it may result in long-term food supply difficulties. The uncontrolled urbanization on agricultural land in Ghana, as well as a lack of effective planning to make use of the lush green terrain, has exacerbated the potential for food production in urban areas. Better infrastructure design mechanisms for green and agricultural zones are necessary for the effectiveness of urban food systems (Kuusaana & Eledi, 2015). So, there is a need for effective policy-making regarding the urbanization of small villages and agricultural land in the metropolitan city's surrounding districts. However, due to demand from landowners to include in urban areas, the existing conventional land rights system makes it incredibly difficult for urban planning organizations to retain green spaces. A metropolitan agricultural policy and mapping of productive agricultural areas are required to protect urban and peri-urban agricultural lands (Kuusaana & Eledi, 2015). The lush green countryside can be saved from horizontal urban sprawl in this way.

2.3 Urban Heat Island (UHI)

The losses of fertile green space as a result of the covered area’s expansion; are posing an atmospheric hazard for human life. Due to the horizontal development of metropolitan centers, environmental conditions are deteriorating in terms of land surface temperature. In the Chinese city Dalian, 88.1 square km of lush green area was transformed into a covered area, implying a 29.4 percent reduction in urban green space from 1999 to 2013 was recorded (Yang et al., 2017). As in the instance of Dalian city of China, the fertile Greenland loss was the cost of uncontrolled urbanization; the atmospheric difficulties arose in the core city region, and from 1999 to 2013 the land surface temperature in this area climbed by +8.455 K. The spike in land surface temperature was indicating an increase in greenhouse gases and carbon emissions in the city's air, which was exacerbated by growing urbanization in the city's green areas. Due to the conversion of urban green land into masonry construction during fast urbanization, many actual features were swapped; low land surface temperature land was switched into high land surface temperature land (Yang et al., 2017). We can see apparent detrimental effects on the surrounding thermal climate when lush green land is converted into a substantial concrete structure. Some of the main reasons for global warming are the expansion of metropolitan areas instead of green land, industrialization in urban areas, and the construction of a significant number of concrete structures. Rafiq et al. (2016) found that as a result of horizontal urbanization, the intensity of energy use is significantly increasing, while the unavailability of renewable energy is also a significant reason for the intensity of energy in rising economies. These elements also contribute to rising land surface temperatures. Even in the presence of heavy energy consumption, the land surface temperature can be reduced by planting trees and securing them (Jiang & Tian, 2010). Furthermore, the findings demonstrated the cooling advantages of green areas. Natural land surfaces are transformed into modern land uses such as covered areas, roadways, and other impermeable surfaces as a result of urbanization. As a result of these changes, metropolitan landscapes have become more complicated in terms of

[3] https://bos.punjab.gov.pk/developmentstat

human living situations, and atmospheric issues such as high land surface temperatures have arisen. Increasing land surface temperature is probably a significant side effect of rapid urbanization on green land, but the impact of both rapid urbanization and high land surface temperature might have serious consequences for agricultural production and food supply. Rapid urbanization on green land may result in a scarcity of cultivable land, and rising land surface temperatures are certainly causing critical changes in atmospheric conditions; as a result, in Punjab, pre- and post-monsoon effects in wheat and vegetable harvesting have been observed in the last three years.

2.4 Scarcity of Agricultural Land

Rapid economic expansion has fostered urbanization; nevertheless, in the contemporary day, the majority of labor is shifted to industrial and service firms, leaving the agricultural sector behind, which is another reason for urbanization, but it also creates the problem of food shortage and farming. Food and farming are being disrupted by rapid urbanization and agricultural land loss, which is resulting in a diminishing ratio of food producers (Satterthwaite et al., 2010). Similarly, increases in urban populations lead to considerable surges in agricultural product demand as a result of urbanization. Agricultural land constraints have intensified in the previous two decades as a result of urbanization with rapid economic growth. A significant concern about land is articulated in terms of soil availability for crop production and loss of soil quality (Chen, 2007). The dynamics of China's cultivated land have been dramatically disrupted by urbanization, according to satellite photography, and it has been found that cultivable green land is declining at an alarming rate. With a per capita farmed land much below the global average, maintaining its 1.3 billion citizens is becoming increasingly difficult (Chen, 2007). As a result, the worst consequences of urbanization in cultivation and food supply can be seen, because it has the strength to wreak havoc on food security shortly. Cities should be aware of existing circumstances; anticipated urban expansions and population growth may exacerbate people's concerns about agricultural production shortages. To avert such situations, policymakers should adopt more stringent regulations to avoid urban food security difficulties; their policies should be sufficient to prevent future food security hotspots from becoming a severe scenario (Matuschke, 2009).

Keeping in view all these scenarios, policymakers are supposed to focus on this rapid strategy of development called ‘Urbanization’ and develop concrete urban policy-making that could benefit citizens in real terms. Presently the situation is alarming from both points of view; environmental and fertility of land for the agriculture sector. It is diagnosed that the current horizontal development in covered areas and reduction in green space will disrupt both the atmospheric conditions and the food supply of metropolitan regions further in the future for our generations.

3 Data and Methodological Framework

3.1 Source of Data and Applications

In a short period, it was not feasible to acquire detailed information about the covered and cultivable land of the metropolitan city of Lahore through a research survey. It was especially difficult to acquire data on a time series basis from 1990 to 2021, especially for the selected region. Therefore the authors chose to conduct this research using remotely sensed data. Remote sensing is the most effective method for collecting reliable data in a short period. Satellite images captured by LSAT-5 (TM) and LSAT-8 (OLI) were used to calculate the temperature of the land surface and spatial features of the land surface as well.

3.1.1 Classification of Land Cover Land Use

The images of LSAT-5 (TM), and LSAT-8 (OLI) were processed in ERDAS imagine-14, and supervised classification was performed to calculate areas covered by major land features like areas covering crops, vegetative, covered/constructed, barren, and water. As a result of these classes, the sum of crop and vegetative areas, as well as the covered area, are included as independent variables.

3.1.2 Land Surface Temperature

To collect land surface temperature on a temporal basis, two sources have been used; first satellite images and second from Terra-Climate Lab. Thermal bands of LANDSAT images were processed in ArcMap to estimate the pixel-base land surface temperature. All of the data has a monthly time resolution and a geographical resolution of about 4 kilometers.

Table: 1

Description of the variables

Variables	Descriptions	Source of Information
Covered Area	Constructed area during1990 to 2021 in sq. km kilometers	Satellite images Source: LSAT-5(TM) LSAT-8 (OLI)
Water Area	Surface Water of Lahore city from 1990 to 2021 in sq. km	
Crop Residual Burned Area	Crop Residual Burned Area of Lahore from 1990 to 2021 in sq. km	
Agri. Area	The area used for cultivation in Lahore from 1990 to 2021 in sq. km	
LST	Land temperature of Lahore from 1990 to 2021 in Celsius	Satellite images Source: LSAT-5(TM) LSAT-8 (OLI) & Terra-Climate Lab

3.2 Persistence Matrix

The Persistence Matrix is a Geographic Information System (GIS) analysis that can be used to monitor regional changes over time. The "Persistence Matrix" was constructed in ArcMap, by utilizing the results of supervised classifications to track regional changes in Lahore during the period from 1990 to 2021. The matrix's result shows us how the agricultural and vegetative areas are transitioning into covered areas.

3.3 Econometric Methodology

Only theoretical work is insufficient to evaluate the effects of the metropolitan metropolis of Lahore's horizontal development on cultivable land. As a result, a multivariate framework is designed considering Land surface temperature as the dependent variable with various independent variables. Time series data from the above-mentioned source is used to estimate the empirical model for this investigation. The data is further converted into log form for empirical estimation. As the variables of the model have different levels of stationarity, therefore ARDL model was the best choice for examining the relationship between the proposed variables. To check the short-run association between dependent and independent variables, the Error Correction Model (ECM) is also estimated.

3.3.1 The Empirical Model

The long-run empirical model is demonstrated below:

$$\log(\text{LST})_t = \alpha + \beta_1 \log(\text{Agricultural Area})_t + \beta_2 \log(\text{Covered Area})_t + \beta_3 \log(\text{Water Area})_t + \beta_4 \log(\text{Crop Residue Burn Area})_t + \varepsilon_t$$

- α is the constant term
- β_1, β_2, β_3, and β_4 are coefficients of the model which will show the slop of Agricultural, Covered areas, Water Areas, and Crop Residual Burned Areas respectively
- ε is the residual term of the model
- Index “t” represents the studied year

In the framework, all variables are taken into consideration in logarithmic form at time “t.”

4 Empirical Results and Analysis

4.1 Persistence Matrix

The land use and land cover (LULC) analysis of the metropolitan city of Lahore shows the transition of land utilization; from agricultural area and vegetation area to covered area. The LCLU matrix is developed for the 1990 to 2021 transitions. Through the matrix; the gain area, lost area, and persisted area is calculated in the following Table.

Table 2
Persistence Matrix. (period 1990-2021)

	Agricultural	Covered	Soil	Vegetation	Water	Total	Lose
Agricultural	473.94	281.11	159.57	7.88	1.48	923.99	450.05
Covered	84.19	279.46	53.29	3.30	2.18	422.42	142.96
Soil	61.97	166.81	91.80	1.52	0.93	323.03	231.23
Vegetation	23.04	9.46	6.01	26.30	0.06	64.87	38.57
Water	6.18	10.72	3.63	0.35	16.40	37.27	20.87
Total	649.32	747.57	314.30	39.35	21.05	1771.59	
Gain	175.37	468.10	222.50	13.05	4.65		

The horizontal spread of the metropolitan city of Lahore is clearly shown in the above table. The crop and vegetative areas had losses in other classifications of land between 1990 and 2021, with 450.05 square kilometers and 38.57 kilometers respectively. Whereas their gain is just 175.37 square kilometers, and 13.05 square kilometers respectively. This means crop area and vegetation area have a net loss of 175.37 - 450.03= -274.68 and 13.05 - 38.57 = -25.52 in square kilometers respectively (Gain - Loss = Net Loss). On the other hand, the greatest increase was in the urban covered region, which gained 468.10 square kilometers from other classifications of land, while losing just 142.96 square kilometers throughout the research period. This means 468.10 - 142.96 = 325.14 is a net gain of the covered area (Gain - Loss = Net Gain). The soil area, on the other hand, remained almost steady from 1990 to 2021, with just 8.73 square kilometers net loss (222.50 - 231.23 = -8.73). During the study period, the water area also decreased. The Gain of water is just 4.65 square kilometers and the loss is 20.87 square kilometers, which means 4.65 - 20.87 = -16.22 is a net loss of water area. it was reduced to 20.87 square kilometers. Such a rapid rate of urbanization is concerning not just for the land surface temperature but also for the metropolitan city of Lahore's food supply.

To better understand, the persistence matrix, the following two Tables 3 & 4 are designed. In these Tables losses, gains, and stable areas in square kilometers are shown in different shades. Table 3 shows the loss of one class in other classes like crop area has a loss of 281.11 square kilometers in the covered area, 159.57 square kilometers in soil area, 7.88 square kilometers in vegetation area, and 1.48 square kilometers in water area. The total loss of crop area is 450.05 square kilometers, and these values are highlighted in purple shade. In the same way, the losses of covered area, soil area, vegetation area, and water in other classes are highlighted in the green, orange, yellow, and pink shades respectively. The stable areas of all classes are highlighted in the blue shade.

Table 4 shows the gain of one class from other classes, like crop area has gained 84.19 square kilometers from covered area, 61.97 square kilometers from soil area, 23.04 square kilometers from vegetation area, and 6.18 square kilometers from the water area. The total gain of crop area is 175.37 square kilometers and these values are highlighted in orange shade.

Table 3
***Persistence Matrix*. (Losses)**

	Losses of One Class in Other Classes					
	Crop	Covered	Soil	Veg.	Water	Loss
Crop	473.94	281.11	159.57	7.88	1.48	450.05
Covered	84.19	279.46	53.29	3.3	2.18	142.96
Soil	61.97	166.81	91.8	1.52	0.93	231.23
Veg.	23.04	9.46	6.01	26.3	0.06	38.57
Water	6.18	10.72	3.63	0.35	16.4	20.87

Source: Author's own

In the same way, the gains of covered area, soil area, vegetation area, and water from other classes are highlighted in the pink, yellow, purple, and green shades respectively. The stable areas of all classes are highlighted in the blue shade.

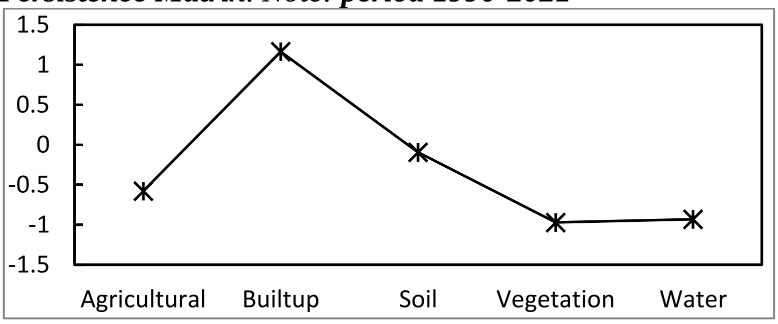
Table 4
***Persistence Matrix*. (Gains)**

	Gains of One Class from Other Classes				
	Crop	Covered	Soil	Veg.	Water
Crop	473.94	281.11	159.57	7.88 3.3	1.48 2.18
Covered	84.19	279.46	53.29	1.52	0.93
Soil	61.97	166.81	91.8		0.06
Veg.	23.04	9.46	6.01	26.3	
Water	6.18	10.72	3.63	0.35	16.4
Gain	175.37	468.1	222.5	13.05	4.65

Source: Author's Own

Figure 2 given below depicts the ratio of net change (gain-loss) to the diagonals of variables from the preceding table, with the diagonal values indicating the variable's sustained area.

Figure 2
Presentation of Persistence Matrix*. *Note:* *period 1990-2021



Source: Author's estimation

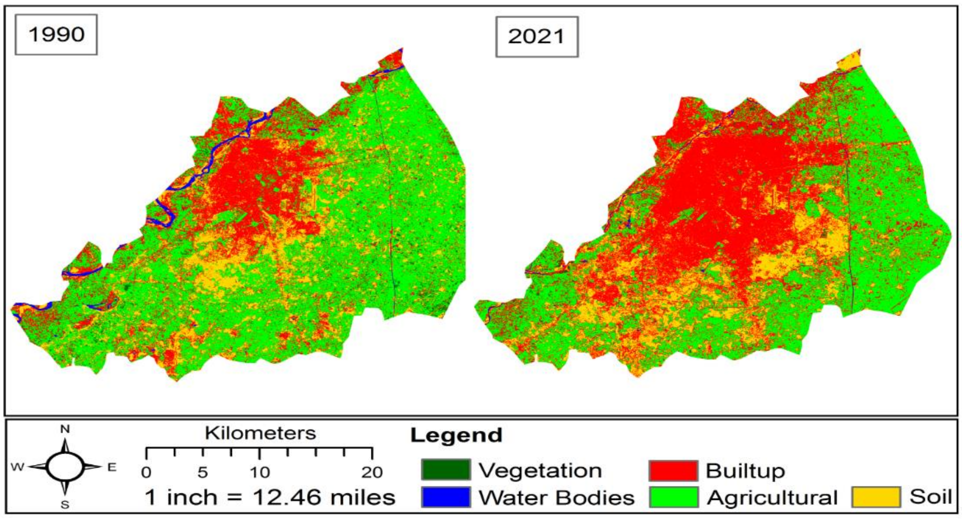
During the study period, the covered (covered) area had the highest net change to persistence ratio. As indicated in the graph, the covered area of the metropolitan metropolis of Lahore is the lowest persisting area on the gain side from 1990 to 2021. On the other hand, as illustrated in the graph by negative values, the cultivable areas including Agricultural & Vegetation and water on the other side are likewise the lowest persevering areas but on the loss side throughout the stipulated period. The persistence matrix shows that in the previous three decades, the urban sprawl of Lahore has approached the cultivable land. Unplanned urbanization and bad policy-making over the research period have also damaged the watershed.

4.1.1 Land Use Land Cover

Figure 3 indicates spatial variation in land use land cover and patterns of urban sprawl that were estimated by analyzing satellite images of temporal resolution during 1990-2021. During the study period covered area has increased by 96.7%. In 1990 covered area was 22.5% of the total area which will increase up to 44.18% in 2021. This spread was completely on fertile land. During these changes, the fraction of the area covered by bare soil remained almost unchanged but with the shift in spatial location as the transition zone between agricultural land and covered area. The area classified as bare soil in 2021 is an area of newly designed housing societies that will be changed into a covered area in the next few years. The findings predict based on the trend that was observed in the last 30 years; that the area under bare soil will not be reduced by the construction of housing societies but will be shifted by targeting agricultural land.

Figure 3

Maps of LCLU for Lahore from the period 1990 to 2021.



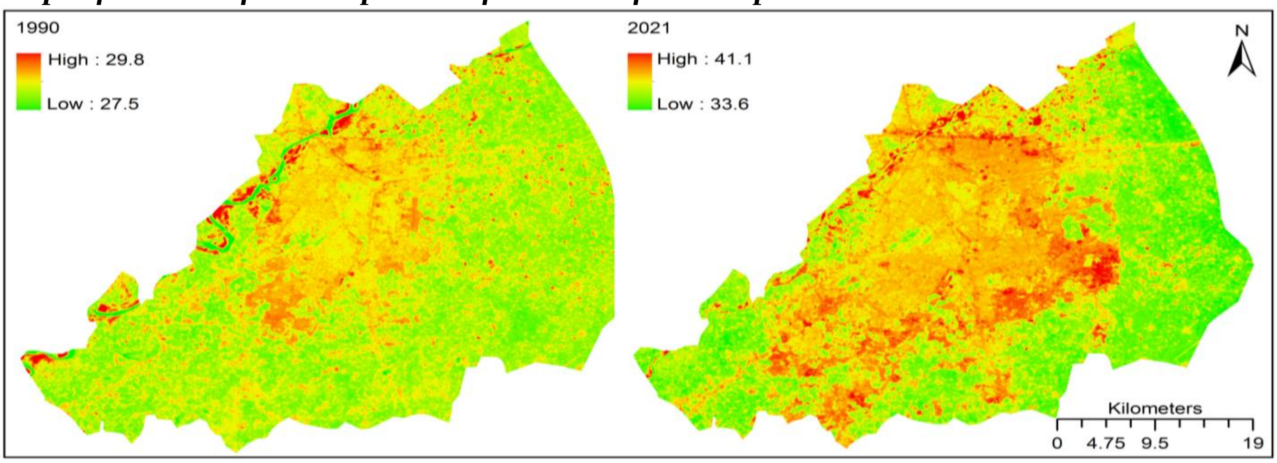
Source: Author's estimation

4.1.2 Land Surface Temperature

This is calculated by using satellite imagery in Figure 4 given below shows the relationship between land temperature and urbanization. The spatial trend of land temperature is similar to the trend that was observed in urban sprawl. Both maximum and minimum temperature limits increased from 29.8°C-27.5°C to 41.2°C-33.6°C respectively.

Figure 4

Maps of Land Surface Temperature for Lahore from the period 1990 to 2021



Source: Author's own

4.2 Econometric Results and Analysis

The persistence matrix clearly expresses the urban sprawl in cultivable areas during the study period, however for a better understanding between urbanization and temperature increase, there is a need to measure the long-run association between the regressors and regressands. For this purpose, the following econometric estimations are performed.

4.2.1 Descriptive Statistics

The following Table 6 given below depicts the picture of mean and standard deviation statistics of each variable of the model. The independent variables covered area and agricultural areas have mean values of 925.0317 square kilometers and 579.5238 square kilometers, respectively. The current agricultural area of Lahore is lower than the mean agricultural area, whereas the mean covered area of Lahore city is significantly higher than the covered area in 1990; this statistical analysis demonstrates the city's rapid urbanization. The mean value of dependent variable LST is 34.6165, which is lower than the current LST. The results are based on 63 observations from 1990 to 2021 with a monthly frequency. The findings are based on 63 observations of land surface temperature (LST), covered area, and the agricultural area of Lahore metropolitan city from 1990 to 2021.

Table 6

Descriptive Statistics Estimations. Note: period 1990-2021 (63 observations)

	Land Surface Temperature	Agricultural Area	Covered Area	Water Area	Crop Residue Burn Area
Mean	34.61	925.11	578.34	23.87	434
Median	34.14	983	556	24	433
Maximum	41.97	1047	796	38	521
Minimum	29.77	643	398	5	362
Std. Dev.	3.433	128.05	123.62	9.82	40.92
Skewness	0.55	-1.09	0.34	-0.13	0.14
Kurtosis	2.18	2.81	1.84	1.90	2.07
Sum	2180.8	58282	36436	1504	27342
Sum Sq. Dev.	729.47	1016618	947582.3	5986.98	103836
Observations	63	63	63	63	63

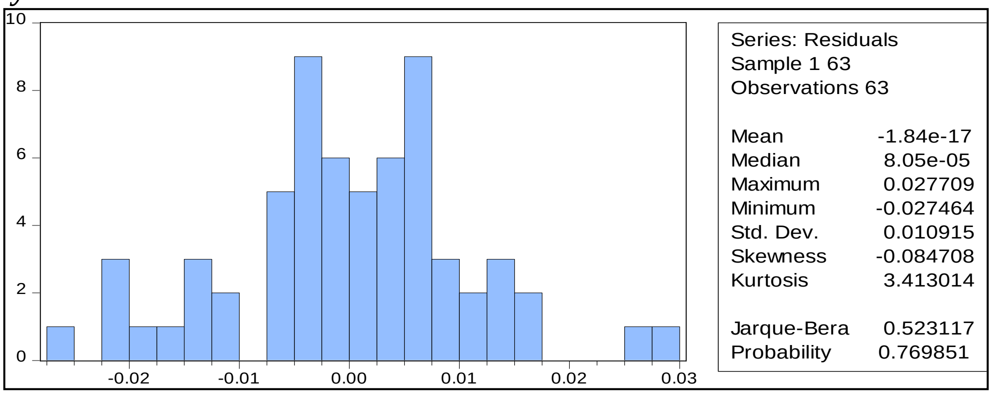
Source: Author's own

4.2.2 Histogram Normality Test

The residuals are normally distributed, as indicated by the histogram and the probability value of the Jarque-Bera test, which is greater than 0.05. As a result, we are unable to reject the null hypothesis.

Figure 6

Normality Test



4.2.3 Coefficient of Correlation

The results of the correlation among the variables of the Model are shown in Table 7 given below. Land surface temperature (LST) has a positive relationship with covered areas and an inverse relationship with agricultural areas. A time increase in the crop residue burning and the covered area will increase the land to 0.965 and 0.963-time land surface temperature of Lahore respectively. On the other hand, the reduction in the green area and water area will increase the land surface temperature by 0.929 and 0.959 times respectively. The covered area and agricultural area of Lahore also have inverse associations; the rise in the covered area is causing a 0.90 times fall in the agricultural land of the metropolitan city of Lahore.

Table 7

Correlation Coefficient

	Land Surface Temperature	Crop Residue Burn Area	Covered Area	Agricultural Area	Water Area
Land Surface Temperature	1	0.9655	0.963	-0.929	-0.959
Crop Residual Burn Area	0.965	1	0.988	-0.876	-0.952
Covered Area	0.962	0.987	1	-0.897	-0.947
Agricultural Area	-0.928	-0.876	-0.90	1	0.951
Water Area	-0.959	-0.952	-0.95	0.951	1

4.2.4 Unit Root Test

Table 8 given below shows the stationarity results of all variables using the most acknowledged unit root tests. A variable is said to be stationary if the probability value is less than 0.05 and following this rule of thumb, all the variables under consideration for this study are stationary at different levels revealing that regressors are stationary at the second difference while the regrassand is stationary at the integration level 1.

Table 8

Unit Root Test for all variables

Variables	Statistics	Significance	Order of Integration
Agricultural Area	Augmented Dickey-Fuller Phillips and Person	0.0000 0.0001	I(2) I(2)
Covered Area	Augmented Dickey-Fuller Phillips and Person	0.0000 0.0000	I(2) I(1)
Water Area	Augmented Dickey-Fuller Phillips and Person	0.0000 0.0000	I(1) I(1)
Crop Residue Burn Area	Augmented Dickey-Fuller Phillips and Person	0.0000 0.0000	I(1) I(1)
Land Surface Temperature	Augmented Dickey-Fuller Phillips and Person	0.0000 0.0000	I(1) I(1)

When the variables of the model remain stationary at different levels, the ARDL model is considered the best possible choice to estimate the Long-run coefficients and ECM to examine the short-run relationship between the dependent variable and the group of regressors on the right-hand side. However, the VAR Test is used to determine the optimum lag length for the ARDL model.

4.2.5 VAR Test for Lag Length

To use the ARDL model, we must first determine the model's optimal lag. To accomplish this, we use VAR-based lag order selection criteria, the results of which are displayed in Table 9 given below. Different criteria, such as the Schwarz information criterion, and the Hannan-Quinn criterion, can be used to find the maximum lag duration. Each of the above-mentioned criteria suggests the one optimum lag for the ARDL model.

Table 9
Leg Length Measurement

Lag	LogL	LR	FPE	AIC	SC	HQ
0	735.2519	NA	2.75E-17	-23.94268	-23.76966	-23.87487
1	1088.848	637.6324	5.78E-22	-34.71633	-33.67819*	-34.30947*
2	1118.488	48.58943*	5.05e-22*	-34.86845*	-32.9652	-34.12254

* depicts the selection of lag order

4.2.6 ARDL Model

Now in this section, the results of the ARDL model are shown and presented in Table 10. All the variables have a p-value of less than 0.005, indicating that these are significant at the 1% level of significance, including the constant term of the model as well. The coefficient of determination is 0.971, indicating that the independent variables covered area, water area, crop residue burn area, and agricultural area are responsible for 97.1 percent of the variation in the dependent variable. The overall fitness of the model's p-value is less than 0.05, indicating that the model is well-fit.

Table 10
Estimation of the ARDL model

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LST(-1)	0.451282	0.105535	4.276155	0.0001
Water Area	-0.162712	0.057376	2.835892	0.0064
Crop Residue Burn Area	0.650124	0.201695	3.223303	0.0022
Covered Area	0.628418	0.217104	2.894544	0.0055
Agricultural Area	-0.185202	0.061597	-3.006674	0.004
C	0.088237	0.30958	0.285022	0.7767

$$\textbf{LST} = \textbf{0.088} - \textbf{0.185 (Agricultural Area)}_t + \textbf{0.628 (Covered Area)}_t - \textbf{0.162 (Water Area)}_t + \textbf{0.65 (Crop Residue Burn Area)}_t$$

The above regression equation shows the results of the ARDL model; the independent variables agricultural area and water area have opposite relations with the dependent variable land surface temperature (LST) and the other regressors i.e., covered area and crop residue, and burn area have a direct relationship with the dependent variable. According to the estimates of the regression coefficients for the agricultural, water, crop residue burning, and covered areas; a 1% fall in the agricultural and water areas raises the dependent variable LST by 18.5 and 16.2 percent respectively. A 1% increase in the covered and crop residue burn areas raises the LST by 62.8 and 65 percent respectively. The findings strongly support the study's theoretical concepts and GIS estimations, namely that the land surface temperature of Lahore increased with the increase in the urban area and crop residue burning, and increased with the decrease in the agricultural area and water area.

4.2.7 Error Correction Model (ECM)

The ECM is used to examine the short-run relationship between the grassland and the proposed regressors. Below is provided the designed ECM Model:

$$\Delta log(\text{LST})_t = \alpha + \beta_1 \Delta log(\text{Agricultural Area})_t + \beta_2 \Delta log(\text{Covered Area})_t + \beta_3 \Delta log(\text{Water Area})_t + \beta_4 \Delta log(\text{Crop Residue Burn Area})_t + \gamma \text{ ECT}_{(t-1)} + \varepsilon_t$$

Table 11
ECM Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Residual ECT(-1)	-0.479474	0.161064	-2.976919	0.004

The ECT with lag (-1) was added to the model as an independent variable to test the short-run association. Because the p-value is less than 0.05, the residual ECT (-1) was significant at a 5% threshold of significance. As a result, the model confirms that the dependent variable and a group of independent factors have a short-run association. The ECT coefficient is 0.4794, indicating that the rate of adjustment to equilibrium is 47.94 percent per unit time.

4.2.8 Diagnostics

Below are different diagnostics for checking whether the model is a good fit or not. Two tests Heteroskedasticity are used i.e. Breusch-Pagan-Godfrey and ARCH. In our study, the statistics support the absence of a heteroskedasticity problem. Similarly, the Breusch-Goldfrey Serial Correlation LM test also diagnosed that a serial correlation problem is absent. Furthermore, the Ramsey RESET test to check the specification level of the model. According to the results the p-value is greater than 0.05 we cannot reject H0, the model fully specifies there is no misspecification in the model, and we do not reject the null hypothesis.

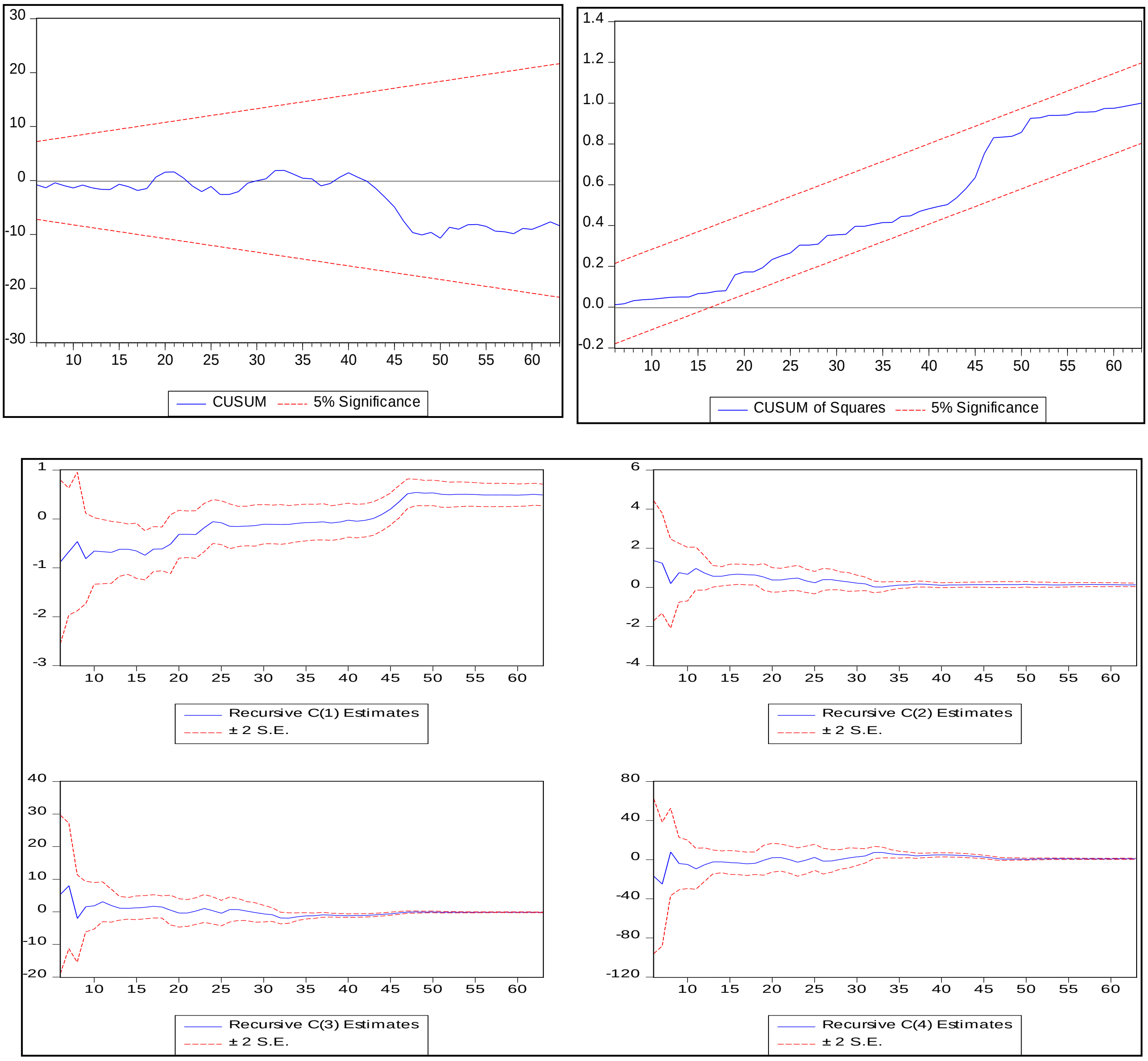
Table 12
Diagnostics of the Model

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	1.208587	Prob. F(7,54)	0.3141
Obs*R-squared	8.397788	Prob. Chi-Square(7)	0.2988
Scaled explained SS	6.226312	Prob. Chi-Square(7)	0.5136
Breusch-Godfrey Serial Correlation LM Test			
F-statistic	3.757871	Prob. F(1,57)	0.0575
Obs*R squared	3.834697	Prob. χ^2 Chi-Square(1)	0.0502
Heteroskedasticity Test: ARCH			
F-statistic	0.420194	Prob. F(1,59)	0.5194
Obs*R-squared	0.431366	Prob. Chi-Square(1)	0.5113

4.2.9 Sustainability of Coefficients: CUSUM CUSUMQ Tests

The sustainability of the design variables has been verified in this section of the study by using the Cumulative Sum (CUSUM) and Cumulative Sum Square of residuals (CUSUMSQ). The CUSUM test is used to look for variability in the projected coefficient values, whereas the CUSUMQ is used to account for unanticipated or seismic in the calculated coefficient's stability. The parameters' consistency is validated when the derived statistics fall between both the blue lines. The computed coefficients are steady, as evidenced by the outcomes of the CUSUM and CUSMQ tests, and both are valid at the 5% significance level.

Figure 7: CUSUM and CUSMQ analysis



The following results belong to the recursive coefficient test, the recursive coefficient test results show that the model is stable and statistically significant at a 5% significance level.

5 Conclusion

The association between covered area, cultivable area, and land surface temperature in Lahore is explored in this research. The goal of this research was to examine whether urbanization has affected the cultivable area or not. Additionally, its goal was to investigate further the effects of urbanization on (LST) and the consequences of less green land on (LST). The rise in the (LST) as a result of increased covered area in the lush green area can have a substantial impact on the environment as well as the food supply for the residents of the study area. The persistence matrix reveals that the urban area is being developed at the cost of cultivable land in Lahore. According to the ARDL Model, ECM, and correlation analysis estimates, rapid urbanization has a significantly positive relationship with the (LST), and cultivation area has an inverse association with the (LST). The findings are based on time series data spanning the years 1990 to 2021.

These findings can be used to make effective policies for urban planning regarding the urban sprawl of metropolitan cities. In 1990, the cultivable area was 1047 square kilometers and the covered area was only 398 square kilometers; whereas in 2021, the cultivable area is reduced to only 664 square kilometers and the covered area increased to 783 square kilometers, owing to poor urban planning and approval of multiple housing schemes. As a result of this form of urbanization, the environmental conditions in Lahore's major metropolis have deteriorated, and the land surface temperature has also climbed from its mean value of 34.6165 over the study period. Lahore's current Air Quality Index (AQI) is 108, with a 2.5MP pollution level. Due to uncontrolled urbanization over the previous 30 years, groundwater is also damaged. To avoid such hazardous environmental conditions and climate variations, officials should build a new metropolis on uncultivable soil rather than expanding an existing metropolitan city into green areas.

During the research period, the conversion of cultivable land to covered land (urbanized) posed a serious threat to the food supply in Lahore's central city. This study can be used as one of the sources of guide to policymakers that uncontrolled urbanization is reducing the amount of cultivable land in Lahore. Therefore, agricultural land contraction is likely to contribute to food scarcity shortly, or at the very least be one of the primary sources of food inflation. On the other hand, an increase in land surface temperature is one of the fundamental causes of climate change. As a result of climate change, pre-monsoon and post-monsoon events are becoming increasingly common. During the last two years, these pre- and post-monsoon occurrences have hampered the harvesting season in our region. So, this research can assist policymakers in developing stronger policies to protect agricultural productivity from agricultural land losses due to urban sprawl which is ultimately causing climate change rapidly.

References

Avelar, S., Zah, R., & Tavares-Corrêa, C. (2009). Linking socioeconomic classes and land cover data in Lima, Peru: Assessment through the application of remote sensing and GIS. *International Journal of Applied Earth Observation and Geoinformation*, *11*(1), 27-37.

Burak, S., Dogan, E., & Gazioglu, C. (2004). Impact of urbanization and tourism on coastal environment. *Ocean & Coastal Management*, *47*(9-10), 515-527.

Chen, J. (2007). Rapid urbanization in China: A real challenge to soil protection and food security. *Catena*, *69*(1), 1-15.

Hussain, S., & Karuppannan, S. (2023). Land use/land cover changes and their impact on land surface temperature using remote sensing technique in district Khanewal, Punjab Pakistan. Geology, Ecology, and Landscapes, 7(1), 46-58.

Jaysawal, D. N., & Saha, S. (2014). Urbanization in India: An impact assessment. *International Journal of Applied Sociology*, *4*(2), 60-65.

Jiang, J., & Tian, G. (2010). Analysis of the impact of land use/land cover change on land surface temperature with remote sensing. *Procedia environmental sciences*, *2*, 571-575.

Khan, H. H., Khan, A., Ahmed, S., & Perrin, J. (2011). GIS-based impact assessment of land-use changes on groundwater quality: study from a rapidly urbanizing region of South India. *Environmental Earth Sciences*, *63*, 1289-1302.

Kuusaana, E. D., & Eledi, J. A. (2015). As the city grows, where do the farmers go? Understanding Peri-urbanization and food systems in Ghana-Evidence from the Tamale Metropolis. Urban Forum,

Larsen, L., Yeshitela, K., Mulatu, T., Seifu, S., & Desta, H. (2019). The impact of rapid urbanization and public housing development on urban form and density in Addis Ababa, Ethiopia. *Land*, *8*(4), 66.

Matuschke, I. (2009). Rapid urbanization and food security: Using food density maps to identify future food security hotspots.

Rafiq, S., Salim, R., & Nielsen, I. (2016). Urbanization, openness, emissions, and energy intensity: a study of increasingly urbanized emerging economies. *Energy Economics*, *56*, 20-28.

Riaz, O. (2013). Urban change detection of Lahore (Pakistan) using a time series of satellite images since 1972. *Asian journal of natural and applied sciences*, *2*(4), 101-104.

Satterthwaite, D., McGranahan, G., & Tacoli, C. (2010). Urbanization and its implications for food and farming. *Philosophical transactions of the royal society B: biological sciences*, *365*(1554), 2809-2820.

Shawky, M., Ahmed, M. R., Ghaderpour, E., Gupta, A., Achari, G., Dewan, A., & Hassan, Q. K. (2023). Remote sensing-derived land surface temperature trends over South Asia. Ecological Informatics, 74, 101969.

Su, S., Jiang, Z., Zhang, Q., & Zhang, Y. (2011). Transformation of agricultural landscapes under rapid urbanization: A threat to sustainability in Hang-Jia-Hu region, China. *Applied Geography*, *31*(2), 439-449.

Trivedi, J. K., Sareen, H., & Dhyani, M. (2008). Rapid urbanization-Its impact on mental health: A South Asian perspective. *Indian journal of psychiatry*, *50*(3), 161-165.

Ullah, W., Ahmad, K., Ullah, S., Tahir, A. A., Javed, M. F., Nazir, A., ... & Mohamed, A. (2023). Analysis of the relationship among land surface temperature (LST), land use land cover (LULC), and normalized difference vegetation index (NDVI) with topographic elements in the lower Himalayan region. Heliyon, 9(2).

Yang, J., Sun, J., Ge, Q., & Li, X. (2017). Assessing the impacts of urbanization-associated green space on urban land surface temperature: A case study of Dalian, China. *Urban Forestry & Urban Greening*, *22*, 1-10.

Yang, P., Ren, G., & Yan, P. (2017). Evidence for a strong association of short-duration intense rainfall with urbanization in the Beijing urban area. *Journal of Climate*, *30*(15), 5851-5870.

Zhu, Y.-G., Ioannidis, J. P., Li, H., Jones, K. C., & Martin, F. L. (2011). *Understanding and harnessing the health effects of rapid urbanization in China* (0013-936X).