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Impact of Urban sprawl would reduce potential carbon storage in Pakistan

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Abstract

In recent years, carbon emission from land use change have become major global issues. How land use and land cover change affect carbon sequestration is important for carbon neutrality and climate change mitigation. This study evaluated the effect of urbanization on land use and the carbon cycle in Pakistan in the years 2050 and 2100. The outcome was achieved through the mapping of land use and land cover for the years through geosimulation. Using Geographic information system (GIS) to analyzed the territorial dynamics in Pakistan Land use change data and soil organic carbon density data (SOCD) to assets the country's carbon stocks. The study noted an increase in farmland and urban area and a reduction in forestland, shrub land, and barren land areas during the study period. In 2050, the estimated areas for urban land under the four scenarios are (A1B 25,800 ~ A2 26,090 ~ B1 19,664 ~ B2 10,782 Km2). It is expected to rise to (A1B 26,269 ~ A2 36,449 ~ B1 19,718 ~ B2 14,339 Km2) in 2100. Carbon loss will also increase throughout the country. carbon loss is projected to rise from (A1B 24,034,560~ A2 24,405,760~ B1 16,180,480~ B2 4,811,520 t) in 2050 to (A1B 24,634,880~ A2 37,665,280~ B1 16,249,600~ B2 9,364,480 t) in 2100.This is attributed to economic development in the country, which increases industrialization in urban areas, we found that the carbon in major areas of Pakistan will be reduced in Punjab province of Pakistan, the predicted annual carbon loss will be increased (9.31 t to 13.28 t).This study provides important information that can be used by the government in conjunction with land managers to establish effective strategies that will enable sustainable management and protection of natural resources in the country.

Keywords: Pakistan, urban sprawl, carbon storage, land use change

INTRODUCTION

Urban sprawl is the unplanned and unrestricted growth in many urban areas of housing, roads, and commercial development. It often leads to low-density residential housing, high water and air pollution levels, and increased reliance on private automobiles for transportation (Habibi & Asadi, 2011). Over the years, the human population has grown significantly, and the economy has become more industrialized, which has attracted more people into cities. It is estimated that more than half of the world's population resides in urban areas (Bohnet & Pert, 2010). Urban areas account for less than 2% of the earth's surface, yet they are the major contributors to climate change. Cities produce more than 60% of greenhouse gas emissions and consume 78% of the world's energy (Delphin et al.,2016). Climate change effects are worse in low-income countries because of poor living conditions, inadequate resources, and reduced access to emergency services. The effects are more pronounced in developing countries such as India and China (Grimm et al.,2008).

Carbon dioxide is the second most abundant greenhouse gas after water vapor in the earth's atmosphere (Abd-Elmabod et al.,2019). Together with other greenhouse gases, it keeps the atmosphere warm. If these gases are emitted in high concentrations, the atmosphere overheats, leading to global warming (Eggleston et al.,2006).

Carbon cycling is an essential phenomenon to processes that provide food, fuel, and fiber in the environment (Baccini et al.,2017). In the presence of light, photosynthetic organisms such as algae and plants take up carbon dioxide to produce carbon-based compounds. These compounds exist in different forms, and they are the main components of biological molecules and minerals suitable for human survival (Baccini et al.,2017). Soil is the primary carbon reservoir, and it possesses maximum carbon sequestration potential (Jaiarree et al.,2011). It has thrice the amount of carbon stored in vegetation and twice the amount of carbon present in the atmosphere. Soil organic carbon (SOC) enhances food production by increasing soil quality and productivity. Factors that affect SOC levels in the environment are climate change, land use, and its management (Jaiarree et al.,2011). The leading cause of carbon loss in the environment is vegetation loss through activities such as deforestation. Approximately 20-50% of soil carbon is lost when forest land is converted to cultivated land (Kassa et al., 2017). Between 2015-2017, approximately 4.8 billion tons of carbon dioxide were released annually into the atmosphere due to the global loss of tropical forests (Gibbs et al.,2018).

In recent decades, urban sprawl has increased the demand for urban land. This has resulted in land use land cover change (LULC), whereby the natural land cover is replaced with built-up urban settlements leading to loss of vegetation (Bohnet & Pert, 2010). When LULC occurs due to urban expansion, natural or seminatural terrestrial covers are converted to impervious land surfaces (D'Amour et al., 2017). This interrupts the biogeochemical processes and cycle patterns leading to the loss of ecosystem services such as soil quality, water regulation, carbon sequestration, and climate regulation (Habibi & Asadi, 2011). Urbanization is one of the common causes of LULC, especially in developing countries such as Pakistan (Hassan et al., 2016). In these countries, urban development is usually done without proper planning, which affects cities' ecology, resulting in climate change, pollution, and the elimination of native habitats. Pakistan is the world's fifth most populated country, and it is located in an arid and semi-arid zone (Ali et al.,2013). Its capital city (Islamabad) is made up of the largest immigrant and expatriate population.

The population is constantly increasing, resulting in urban sprawl to the valuable fertile rural land of the capital (Hassan et al., 2016). Increased urban developments and industries have attracted many people into the city leading to urban expansion. This has led to the loss of vegetation, leading to increased carbon emissions into the atmosphere. High levels of carbon emissions into the atmosphere result in global warming, which is associated with negative climatic changes such as more intensive rainfall, severe floods, frequent drought and shorter rainy seasons (Hassan et al.,2016). Over the years, scientists have discovered new techniques for monitoring and evaluating urban sprawl and its impacts on the landscape. They include urban sprawl indicators and geospatial techniques such as GIS, remote sensing, and statistical techniques (Smith et al.,2008). The application of these methods has been efficient in detecting LULC caused by urban sprawl in many countries. This report will calculate the expected amount of carbon loss caused by urban sprawl and LULC in Pakistan in the years 2050 and 2100.

MATERIALS AND METHODS

Study Area

Pakistan is the world's fifth most populated country located in South Asia, with a population of more than 225.2 million (Ali et al.,2013). The country is part of the greater Indian subcontinent belonging to the crossing points of Asia and the Middle East (Spate & Learmonth, 2017). Being an Islamic state, it has the second-largest Muslim population globally. It is one of the largest countries with an estimated area of 796,100 square kilometers with global coordinates of 30.3753^0 N and 69.3451^0 E (Naqvi et al.,2018). The country has four provinces: Punjab, Baluchistan, Sindh, and Khyber Pakhtunkhwa, and one federal territory- Islamabad. Five distinct geographical areas roughly correspond with the provinces of the country. They include the Baluchistan plateau located in the western province of Baluchistan. It is an arid tableland lying between 1000 and 3000 feet above sea level, and it covers nearly half of the entire country with mountains and covers surrounding it (Spate & Learmonth, 2017). The next region is the Thar desert and lower Indus valley located in Sindh province, and it consists of arid valleys and rocky hills (Yaseen et al.,2015). The other region is the Indus basin which is the largest contiguous irrigation system globally, and a larger part of it is located in Punjab.

Lastly, the northwest frontier region consists of barren mountains sheltering rich irrigated valleys. The far north region provides a spectacular scene with deep narrow valleys, glaciers, and snow-capped mountains (Spate & Learmonth, 2017). The country is located in an arid to semiarid climate with seasonal temperatures varying in the five geographic regions. Except for the

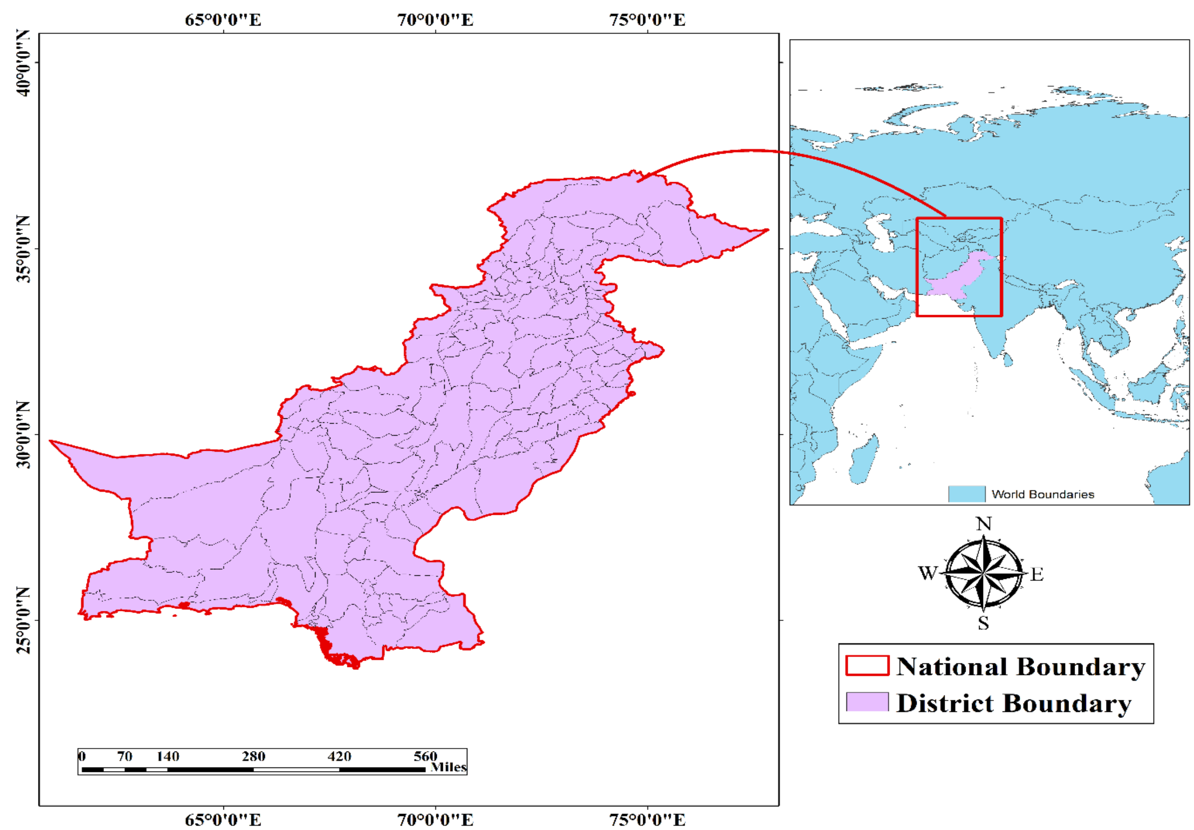


Figure 1. The four provinces of Pakistan- Punjab, Baluchistan, Sindh, and Khyber Pakhtunkhwa

far north region, summers are hot throughout the country, with temperatures ranging 90° F to 120°F. In the far north area, the climate is controlled by altitude, with perpetual snows in the higher mountains and pleasant summers in the lower regions. Rainfall varies greatly from year to year, with frequent flooding due to the monsoon season (Salma et al., 2012). Landscape diversity and climate in the country allow a variety of trees and plants to flourish. The flora ranges from coniferous alpine and subalpine trees to deciduous trees. The world bank collection of development indicators estimated that 4.9406 % of the landscape in 2018 was forested (Qureshi et al.,2014). The forests provide the primary sources of food, medicine, and fuelwood, and they are also crucial in ecotourism and wildlife conservation. The country has about 1027 known species of amphibians, reptiles, mammals, and birds, of which 3.5% are endemic, and 5.5% are threatened (Malkani, 2015)

The main economic, social and political challenge in the country is the rapidly growing population (Bhutta et al.,2013). The high population in the country has led to increased deforestation, which has affected the number of plant and animal species. The lack of vegetative cover has reduced carbon storage leading to severe climate changes that have negatively affected wildlife in the country. Between 1990 and 2010, carbon stock in living forests biomass has declined by 35% (Hassan et al.,2016). Pakistan is an impoverished, low-income country with decades of internal political disputes and low foreign investments. With limited public services and unplanned population growth, the country has suffered from food insecurity, poor healthcare, and severe resource shortages (Bandara & Cai, 2014). Less than 1% of the GDP (gross domestic income) is spent on healthcare, and with the fast-growing population, economic growth and per capita income is expected to decrease (Ezeh et al.,2012). This is attributed to increased expenditures on education, infrastructure, and healthcare. As a result, the rapidly growing population negatively affects the country's economy, predictive yearly population, and carbon storage. ***(Fig. 1),*** below display various provinces in the study area respectively.

Data Sources and Acquisition

To evaluate the effect of LULC on carbon storage, data sources such as land use patterns, biomass images, strength intake data, and socio-economic data were obtained in this study. LULC of Pakistan was analyzed using GIS raster layers of 1Km resolution obtained from geo-simulation (Institute of Geographical Simulation and Optimization System) for two epochs; 2050 and 2100. The country has a total area of 796,100 square kilometers, and a large percentage of it deviates from open access resources that are sensitive to air and water erosion. Most of the land is covered by shrubs and grassland (60%), while 35% is used in agriculture, forests cover 2.4%, while 1.8% is wooded land (Aziz, 2021). The raster layers have four scenarios (A1b, A2, B1, and B2) classified into six land use classes: farmland, water, grassland, forest, barren and urban settlements. Spatial resolution and projections of 10*10 were used in classification, and a different spatial resolution scheme was used in generalization. GIS data was used to calculate land use changes of the classes (grassland, forest, barren area, and farmland) under the four scenarios in 2050 and 2100. The raster layers also provided soil profiles such as organic carbon stock, gravel content, bulk density, and coarse fragments of the soil layer.

In addition to using raster images, CDIAC (Carbon dioxide Information Analysis Center) provided global biomass carbon map data, 1Km grid, for a predictive period of 2050-2100. This information was compared with SOC data from the country. The covariates used in the study were obtained from earth observation derived products, environmental layers, land cover, climate and terrain morphology. Evaluation of carbon stock was done using AGB (Above Ground Biomass) data provided by ISRIC (International Soil Reference and Information Centre). SOC is necessary for plants' growth, which in turn replenishes the soil after they die and decay. Total SOC is the measure of carbon contained in soil organic matter. SOC density (SOCD) was calculated using the following equation;

$$\text{SOCD (t/ha)} = \sum_{i=1}^{n} (1 - \theta_i\%) \times \rho_i \times C_i \times T_i / 100 \qquad (1)$$

In this equation, θ_i represents the gravel content in g/kg at 200 cm depth in the soil layer, pi represents soil organic carbon content in dg/kg of the soil layer, Ci is the bulk density in cg/m^{3}, and TI stands for the coarse fragment in cm^3/dm^3. Carbon loss was calculated through the following equation.

$$\text{Carbon loss (t)} = \text{SOCD} \times IU_{area}\ \text{(ha)} \qquad (2)$$

The units for carbon loss are (t), and IU_{area} represents increased urban area units, units are (ha). AGB loss was also calculated using a similar equation as shown below.

$$AGB_{loss} = AGB_{density} \times IU_{area} \qquad (3)$$

AGB loss represents above-ground biomass loss, units are (t/ha), AGB density represents the density over an urban area on the spatial data, units are (t/ha). Tables 1 below show the GIS data used in the study, respectively. ***(Fig. 2),*** shows the data processing schema flow chart used for analysis.

RESULTS

Land use change

The percentage of land in Pakistan is classified based

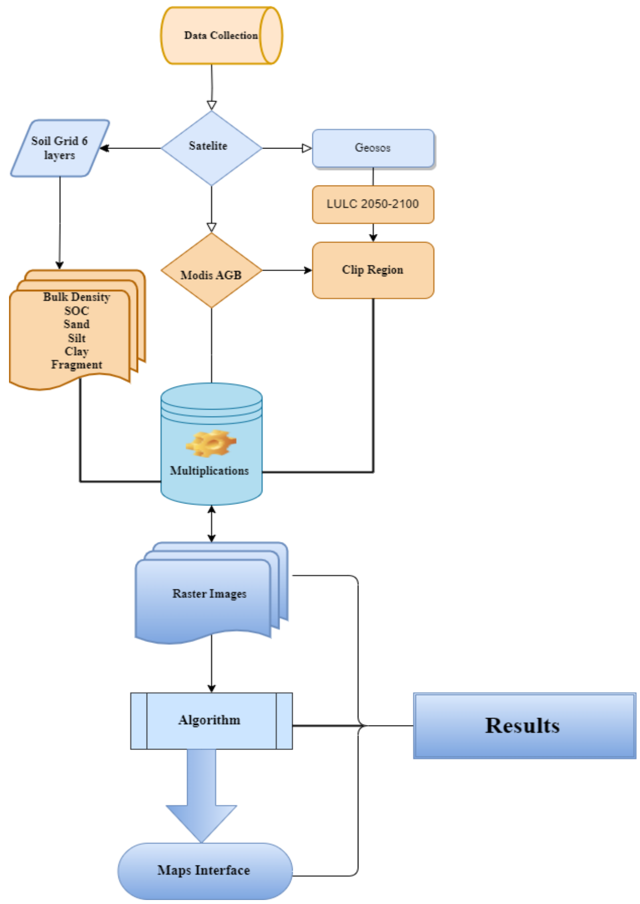
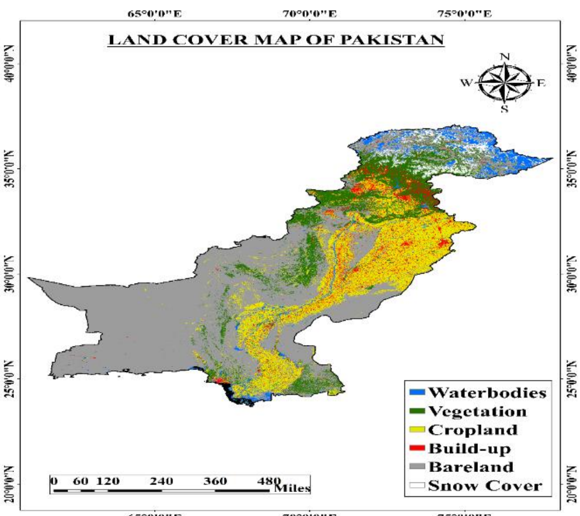


Figure 2. The flow chart of data methodology

on its use. The country covers an area of 796,100 square kilometers. Shrubs and grassland cover 60% of the land, 35% is agricultural land, 2.4% is wooded land, while 1.8% is forest land. This is displayed in ***(Fig. 3)***. LULC results show changes in the sizes of different areas examined under the four scenarios in 2050 and 2100. In 2050, the total area of farmland is almost (A1B 268,575 ~ A2 259,061 ~ B1 231,781 ~ B2 350,808 km^2), grassland area is almost (A1B 511,54 ~ A2 477,72 ~ B1 53,637 ~ B2 284,39 km^2), barren area is almost (A1B 524,000 ~ A2 536,886 ~ B1 561,763 ~ B2 481,616 km^2) and forest area is about (A1B 2,299 ~ A2 2,023 ~ B1 4,990 ~ B2 193 km^2). In 2100, the estimated total areas of the four scenarios are; farmland ((A1B 199,757 ~ A2 285,604 ~ B1 146,402 ~ B2 287,880 km2), barren ((A1B 579,209 ~ A2 502,364 ~ B1 633,227 ~ B2 528,415 km2),

Table 1. GIS data and sources		
Name	Spatial Resolution	Data Source
Geo-simulation	1km	(http://geosimulation.cn/download/globalsimulation/)
Biomass	1km	(https://cdiac.essdive.lbl.gov/epubs/ndp/global_carbon/carbon)
Soil grid	1km	(https://files.isric.org/soilgrids/data/aggregated/1km/)
Sentinal-2 LULC	1km	(https://dynamicworld.app/explore)

grassland ((A1B 60,994 ~ A2 45,886 ~ B1 62,543 ~ B2 40,962 km2) and forest land (A1B 5,598 ~ A2 1,528 ~ B1 9,948 ~ B2 240 km2). Between 2050 and 2100, there was an increase in farmland area and a decrease in the barren area, grassland and forest land. This is reflected in the A2 scenario. Under the A2 scenario, farmland area increased by 26, 543 km^2, grassland reduced by 1886 km^2, forestland declined by 495 $km^{2,}$ and barren area decreased by 34,522 km^2. Results for the A2 scenario were more consistent and accurate. Carbon loss caused by urban sprawl occurred in almost all soil profile types. Land use changes in 2050 and 2100 under the four scenarios are displayed in ***(Fig. 4 and 5),*** respectively.



Above ground biomass loss due to urban sprawl in Pakistan

To estimate AGB loss due to urban sprawl, the IPCC method for estimating vegetation carbon stocks were used. The raster tool and grid data were used to calculate AGB loss, and they demonstrated urban expansion and AGB changes caused by urban sprawl. Between 2050 and 2100, AGB loss is expected to increase, and this is consistent under four scenarios. In 2050, the biomass loss values are almost (A1B 20,654,700~ A2 20,973,700~ B1 13,905,100~ B2 4,134,900 t/ha), which is projected to increase in 2100 to (A1B 21,170,600~ A2 32,368,600~ B1 13,964,500~ B2 8,047,600 t/ha). The increase in AGB loss is consistent in all the scenarios. ***Table 2*** shows the increased urban area and AGB loss caused by urban sprawl in 2050 and 2100. ***(Fig. 6 and 7),*** represent AGB loss caused by urban sprawl in 2050 and 2100 under the four scenarios.

Table 2. AGB loss in 2050 and 2100 due to urban sprawl in Pakistan				
Scenario	Increased urban area in 2050 (ha)	AGB Loss in 2050 (t/ha)	Increased urban area in 2100 (ha)	AGB Loss in 2100 (t/ha)
AIB	1877,700	20,654,700	19,24,600	21,170,600
A2	19,06,700	20,973,700	29,42,600	32,368,600
B1	126,4100	13,905,100	12,69,500	13,964,500
B2	37,59,00	41,34,900	731,600	80,47,600

Soil carbon loss caused by Urban sprawl from 2050 to 2100 Pakistan

Soil carbon loss due to urban sprawl has rapidly increased for the past thirty years. Urbanization of the four scenarios from 2050 (A1B, A2, B1, B2) to 2100 (A1B, A2, B1, B2) has given rise to new urbanized areas, which correspond to carbon loss in the country The estimated results for urban sprawl under the four scenarios are: in 2050, (A1B 25,800 ~ A2 26,090 ~ B1 19,664 ~ B2 10,782 Km^2) which will rise to approximately (A1B 26,269 ~ A2 36,449 ~ B1 19,718 ~ B2 14,339 Km^2) in 2100. Under all the scenarios, urban area is expected to increase between 2050 and 2100, and this will increase carbon loss in the country. ***(Fig. 8 and 9),*** display the results of urban sprawl in 2050 and 2100, respectively ***Table 3*** displays the total urban area in 2050 and 2100 under the four scenarios.

According to some regional and global studies, urbanization is only associated with negative effects when assuming zero-carbon stocks in urban areas (Schulp et al., 2019). In these studies, soil carbon loss due to urban sprawl occurred in most soil profile types (Boughlala et al.,2013). Pakistan has the highest SOCD stocks, with soils ranging from 0-200cm depth.

In contrast to other studies that only predict carbon loss, this report estimated and analyzed carbon loss in Pakistan. It also revealed the significant differences in the direction and extent of soil carbon loss between the

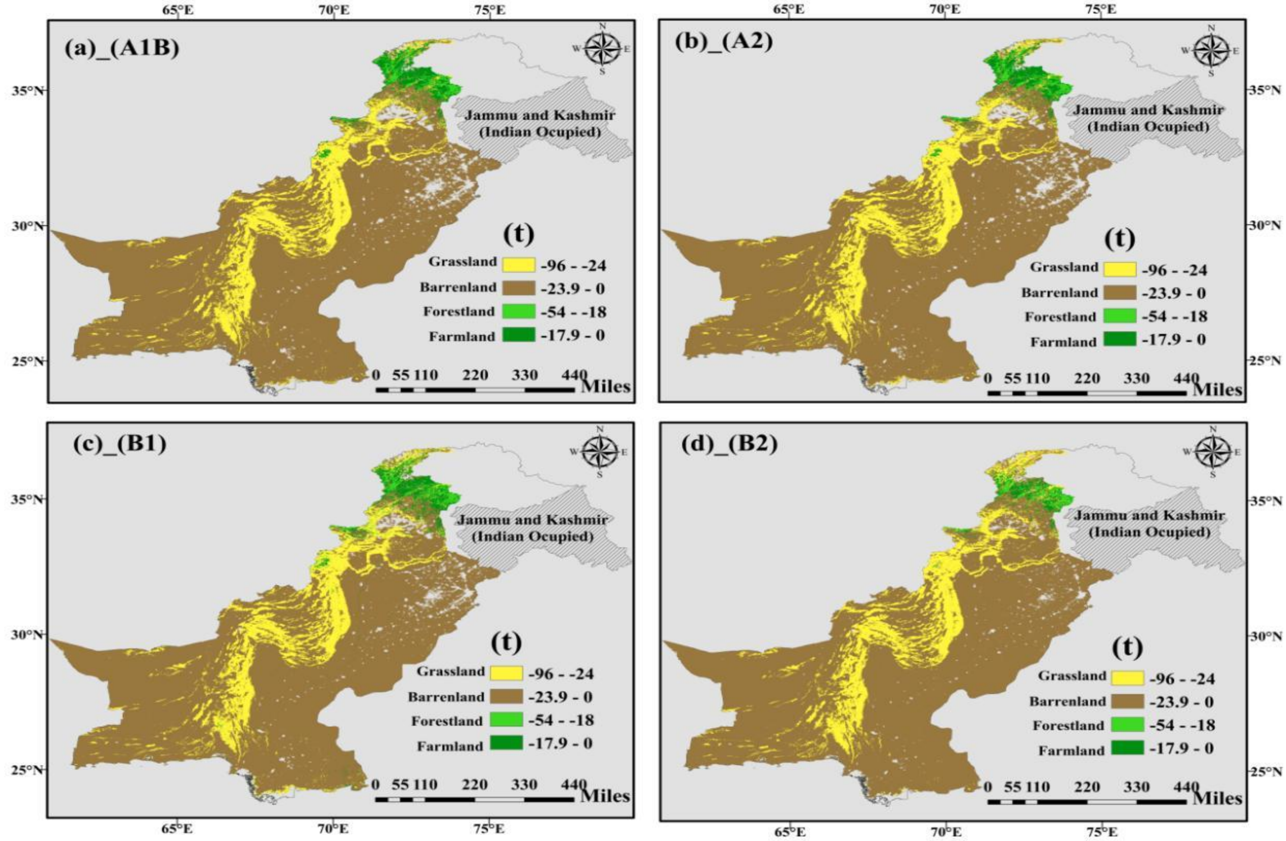


Figure 4. Land use changes in Pakistan in the year 2050

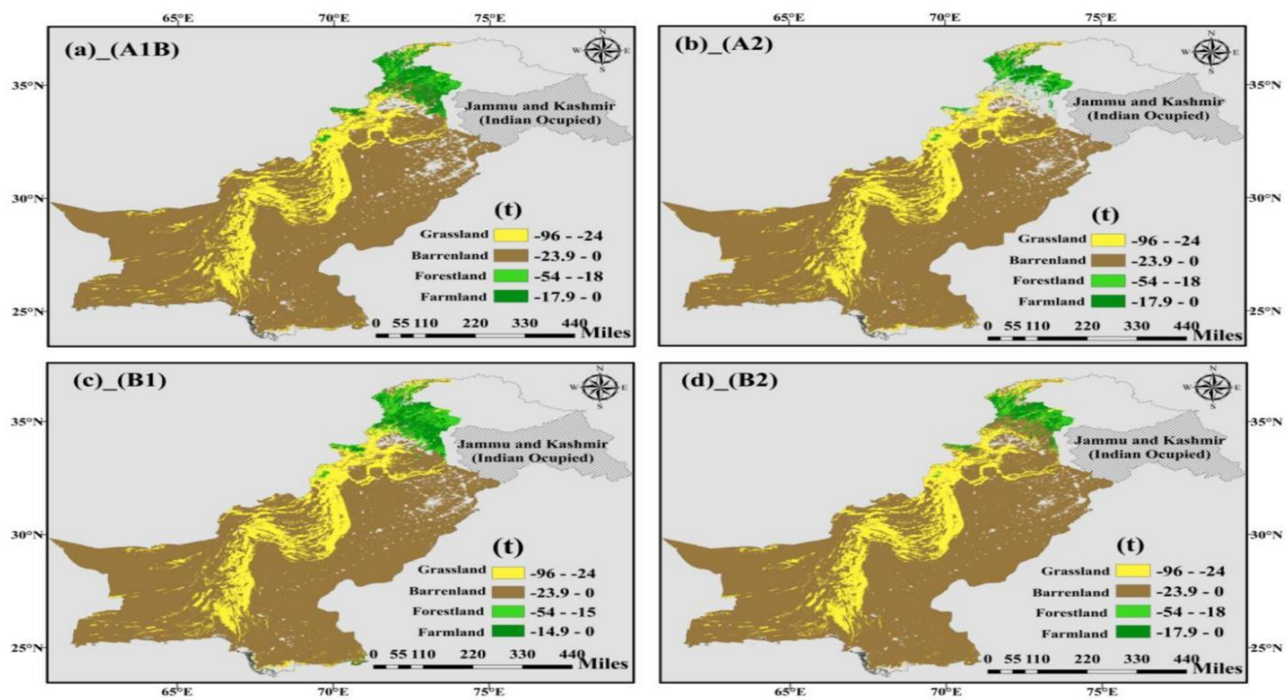


Figure 5. Land use changes in Pakistan in the year 2100.

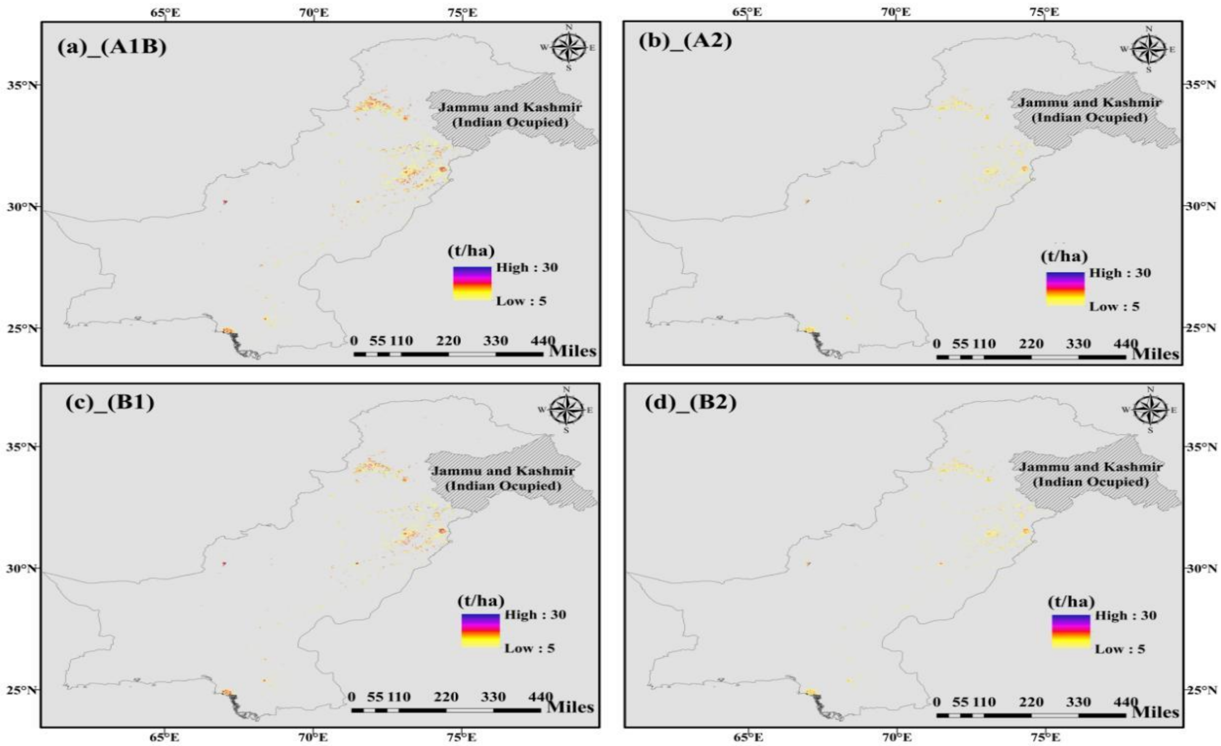


Figure 6. Biomass loss in the year 2050 due to urban sprawl in Pakistan

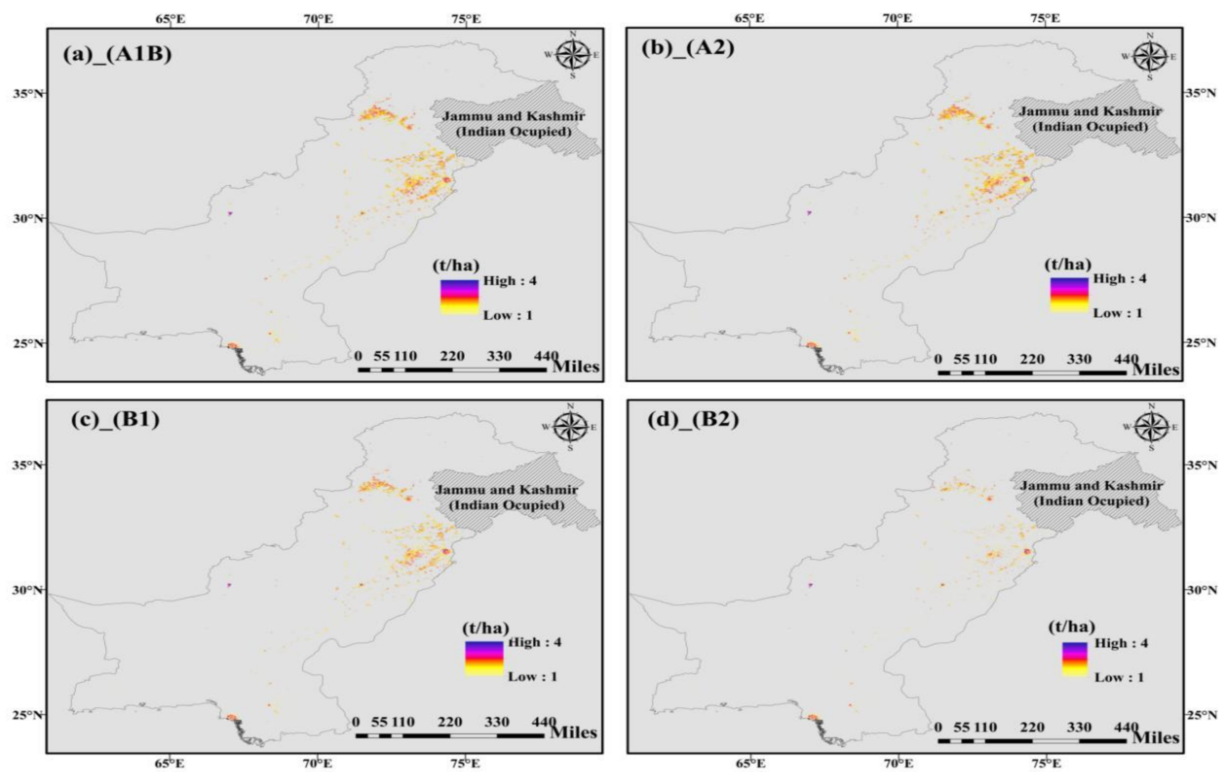


Figure 7. Biomass loss in the year 2100 due to urban sprawl in Pakistan.

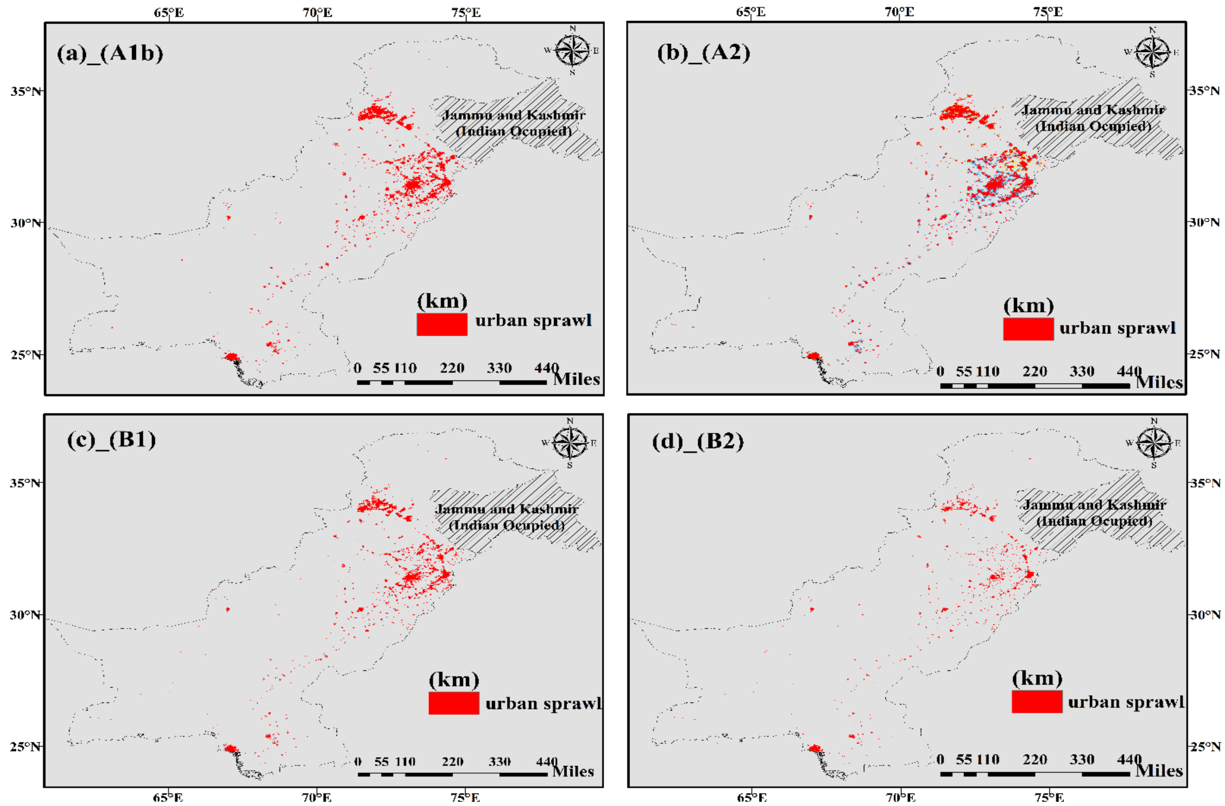


Figure 8. Urban sprawl in Pakistan in the year 2050 under the four scenarios

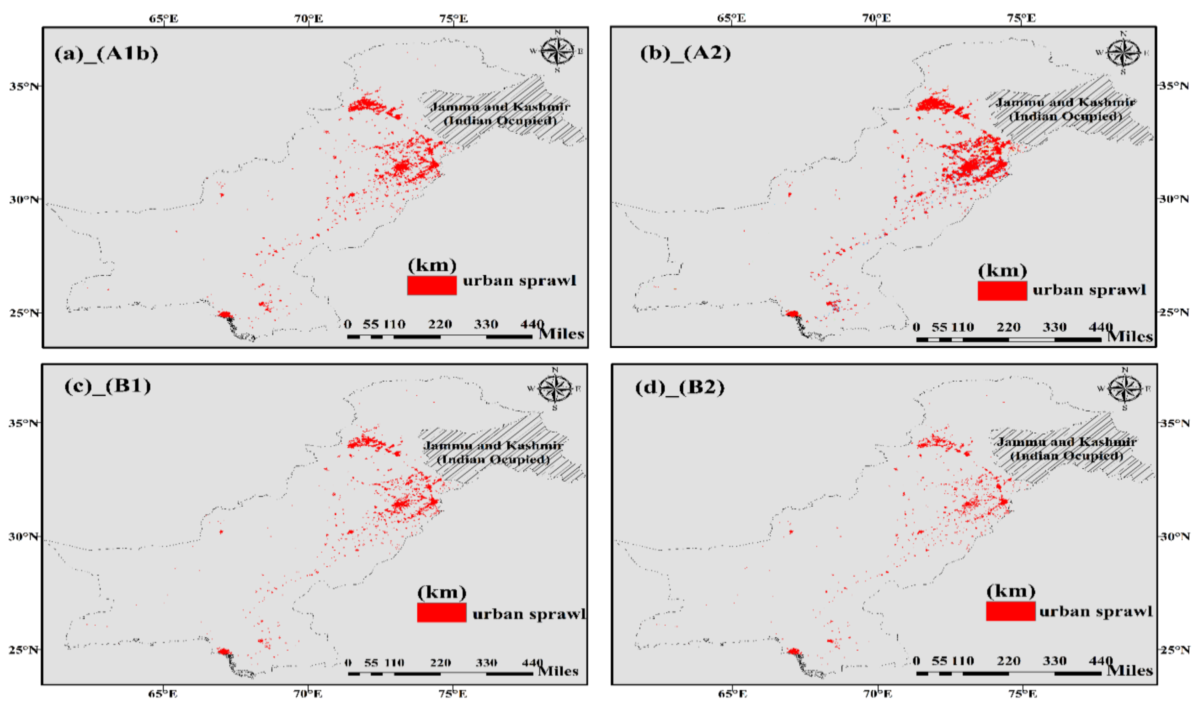


Figure 9. Urban sprawl in Pakistan in the year 2100 under the four scenarios

Table 3. Total urban area in 2050 and 2100 under the four scenarios

Scenarios	Urban area in 2050 (km^2)	Urban area in 2100 (km^2)
AIB	25,800	26,269
A2	26,090	36,449
B1	19,664	19,718
B2	10,782	14,339

main areas of Pakistan. Pakistan has the highest SOCD stocks, with soils ranging from 0-200cm depth. In contrast to other studies that only predict carbon loss, this report estimated and analyzed carbon loss in

Table 4. Increased urban area in 2050 and 2100 and the corresponding carbon loss

Scenarios	Urban area in 2050 (km^2)	Increased urban area in 2050 (ha)	Carbon loss in 2050 (t)	Urban area in 2100 (km^2)	Increased urban area in 2100 (ha)	Carbon loss in 2100 (t)
AIB	25,800	18,77,700	24,034,560	26,269	19,24,600	24,634,880
A2	26,090	19,06,700	24,405,760	36,449	29,42,600	37,665,280
B1	19,664	12,64,100	16,180,480	19,718	12,69,500	16,249,600
B2	10,782	375,900	48,11,520	14,339	731,600	93,64,480

Pakistan. It also revealed the significant differences in the direction and extent of soil carbon loss between the main areas of Pakistan. The four scenarios estimate the future carbon loss in Punjab province. In 2050, the

Table 5. Carbon loss from different types of land cover in 2050

Classes	**A1B (area ha)**	**A1B (C-loss t)**	**A2 (area ha)**	**A2 (C-loss t)**
Forest	1,100	12,320	1000	11,200
Grass	17,033	132,860	15,900	124,020
Farm	89,500	501,200	86,333	483,466
Barren	13,100	30,130	134,200	308,660
Classes	**B1 (area ha)**	**B1 (C-loss t)**	**B2 (area ha)**	**B2 (C-loss t)**
Forest	24,50	27,440	650	7,280
Grass	17,866	139,360	9,466	73,840
Farm	77,233	432,506	116,933	654,826
Barren	140,425	322,977	120,400	276,920

carbon loss values are approximately (A1B 24,034,560~ A2 24,405,760~ B1 16,180,480~ B2 48,11,520 t), which is expected to increase to almost (A1B 24,634,880~ A2 37,665,280~ B1 16,249,600~ B2 93,64,480 t) in 2100. ***Fig. 10 and 11*** represent carbon loss in Punjab province under the four scenarios. ***Table 4*** displays increased urban area and corresponding carbon loss in 2050 and 2100.

Carbon loss due to land use change in Pakistan

Land use change is a common phenomenon in Pakistan because of the rapidly growing population that leads to land expansion in urban areas. This scenario is different in other industrialized countries which have completed the urbanization process, such as Europe, the USA and Australia (Kuang et al.,2014). This study calculated carbon loss in Pakistan for each land class under the four scenarios ((A1B, A2, B1, B2). The results are based on a combination of data from vegetation carbon densities, land use, and SOC with statistical models. In 2050, carbon loss values in the forest area are about (A1B 12,320~ A2 11,200~ B1 27,440~ B2 7,280 t), grassland area values are (A1B 132,860~ A2 124,020~ B1 139,360~B2 73,840 t), farmland area values are about (A1B 132,860~ A2 124,020~ B1 139,360~B2 73,840 t), and barren area values are approximately (A1B 30,130~A2 308,660~B1 322,977~ B2 276,920 t). In 2100, estimated results of carbon loss for the four classes are as follows; forest area (A1B 30,800~ A2 8,400~ B1 55,440~ B2 6160 t), grassland area (A1B 158340~ A2 119080~ B1 162500~ B2 106,340 t), farmland area (A1B 372,773~A2 533,120~B1

273,280~B2 537,226 t) and barren land area values reached (A1B 333,040~A2 288,822~B1 364,090~B2 303,657 t). ***Fig. 12 and 13*** display carbon loss due to land use change in Pakistan for the years 2050 and 2100.***Tables 5 and 6*** show SOC loss from different land cover types in 2050 and 2100.

DISCUSSION

Climate change and LULC are significant in Pakistan. Unplanned urban growth exposes the country to a range of climate risks and water-related disasters. These effects include rapid snow and ice melt in the mountains and heavy rainfall in the foothills during the monsoon season (Jiang et al.,2013). More than 50% of emitted greenhouse gases in the country result from LULC, agriculture, industries, and forests (Chuai et al., (2015). The country depends on agriculture and tourism for income and livelihood. Climate changes, therefore, threaten the economic development of the country. Shrubs and grassland cover 60% of the land, 35% is agricultural land, 2.4% is wooded land, while 1.8% is forest land. The results showed that farmland increased while forestland, barren land, and grassland areas reduced. These values signify the dramatic land cover change caused by urban expansion on non-built surfaces. Economic activities such as manufacturing and processing industries have led to urban expansion in the area. These activities usually contribute to GDP growth, which requires transforming forests, shrubs, and grassland into urban settlements (Abd-Elmabod et al., 2019). Soil carbon loss increased between 2050 and 2100. High rates of carbon loss were caused by urban expansion under the four scenarios. With the rapidly growing population in the country, most of the vegetation has been cleared to accommodate building and construction activities as well as cropland farming (Apan et al.,2017). Most of the land in Pakistan is covered with vegetation such as shrubs, trees, and other plants. These plants are major carbon reservoirs, and they absorb carbon dioxide from the environment, which is then stored as carbon. During urban expansion, vegetation is cleared or burnt, resulting in carbon emissions into the atmosphere (He et al., 2016). The study also noted a high reduction of AGB for both years. AGB is the aboveground dry mass of live or dead matter from woody or herbaceous life forms above the soil, such as shrubs or trees (Castillo et al.,2017). It is crucial in quantifying terrestrial carbon storage and potential emissions into the atmosphere resulting from LULC caused by deforestation and land degradation. In urban areas, trees account for 97% of AGB (Assefa et al.,2017).

Table 6. Carbon loss from different types of land cover in 2100

Classes	A1B (area ha)	A1B (C-loss t)	A2 (area ha)	A2 (C-loss t)
Forest	2,750	30,800	750	8,400
Grass	20,300	158,340	15,266	119,080
Farm	66,566	372,773	95,200	533,120
Barren	144,800	333,040	125,575	288,822
Classes	**B1 (area ha)**	**B1 (C-loss t)**	**B2 (area ha)**	**B2 (C-loss t)**
Forest	4,950	55,440	550	6,160
Grass	20,833	162,500	13,633	106,340
Farm	48,800	273,280	95,933	537,226
Barren	158,300	364,090	132,025	303,657

Urban vegetation provides essential ecosystem services such as sequestration of carbon from the atmosphere. This is achieved during photosynthesis, whereby carbon dioxide is absorbed into plant tissues and converted into carbon stored in the woody tissues as biomass. Large trees have a higher carbon absorption capacity than their counterparts (Shah et al.,2015). The raster tool used in this report showed how urban sprawl reduced AGB and agricultural development in the study area. The results show significant changes in land cover throughout the country resulting from rapid deforestation and deterioration of critical points surrounding demographic centers. Deforestation involves clearing, burning, or destroying trees through natural, deliberate, or accidental means. In urban areas, it occurs through deliberate human activities done to provide space for building and construction activities. The rapidly growing population in Pakistan has increased human activities such as deforestation, mining, and burning fossil fuels. This has destroyed carbon sinks leading to a reduction of AGB and

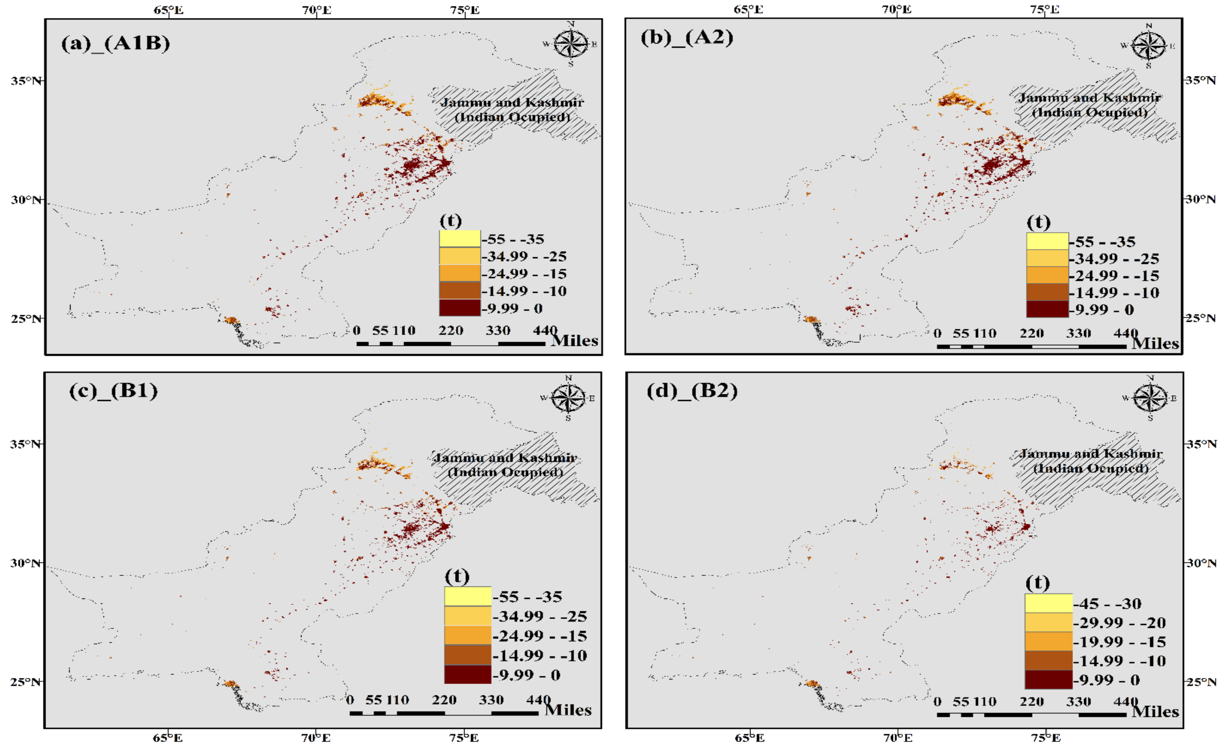


Figure 10. Carbon loss caused by urban sprawl in the year 2050 under the four scenarios

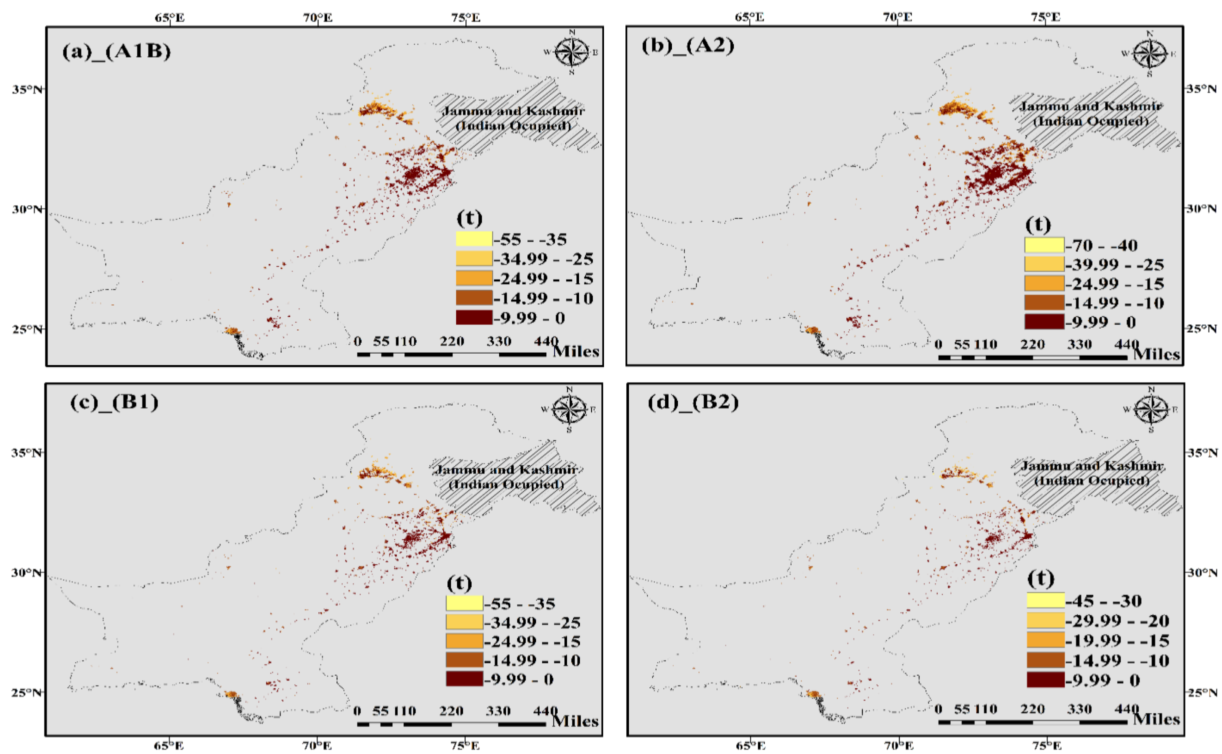


Figure 11. Carbon loss caused by urban sprawl in the year 2100 under the four scenarios

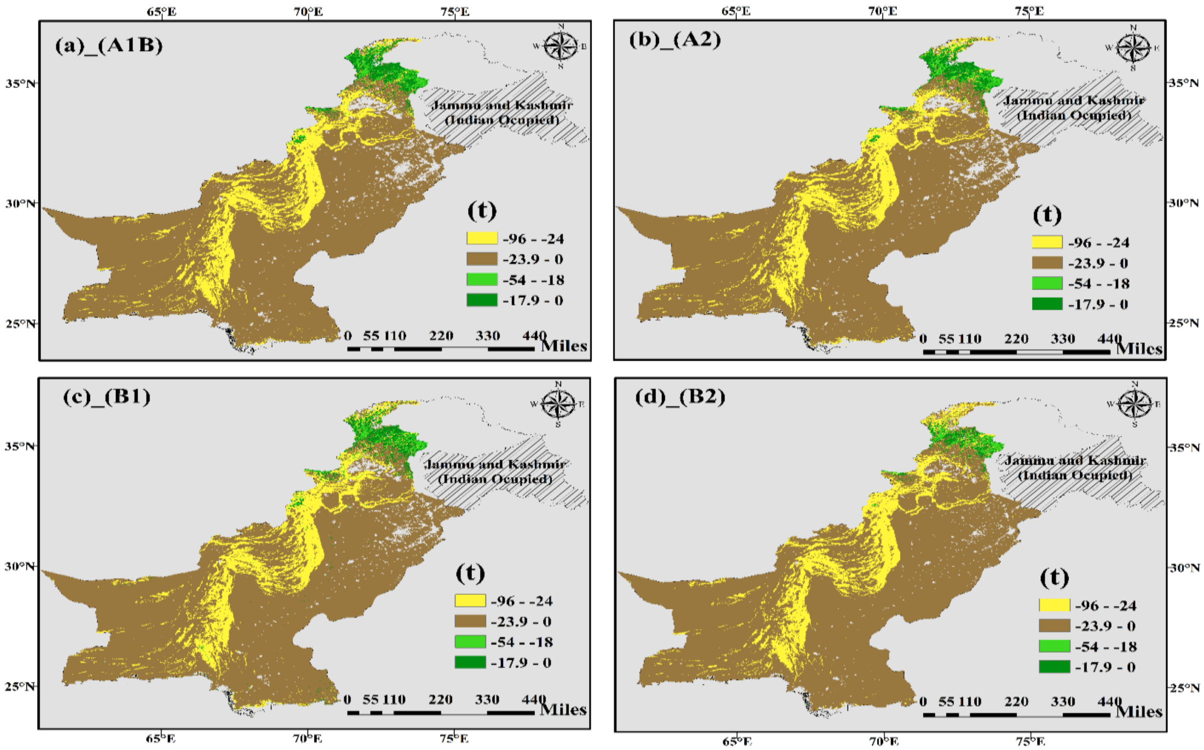


Figure 12. Soil carbon loss due to land use change in Pakistan in the year 2050

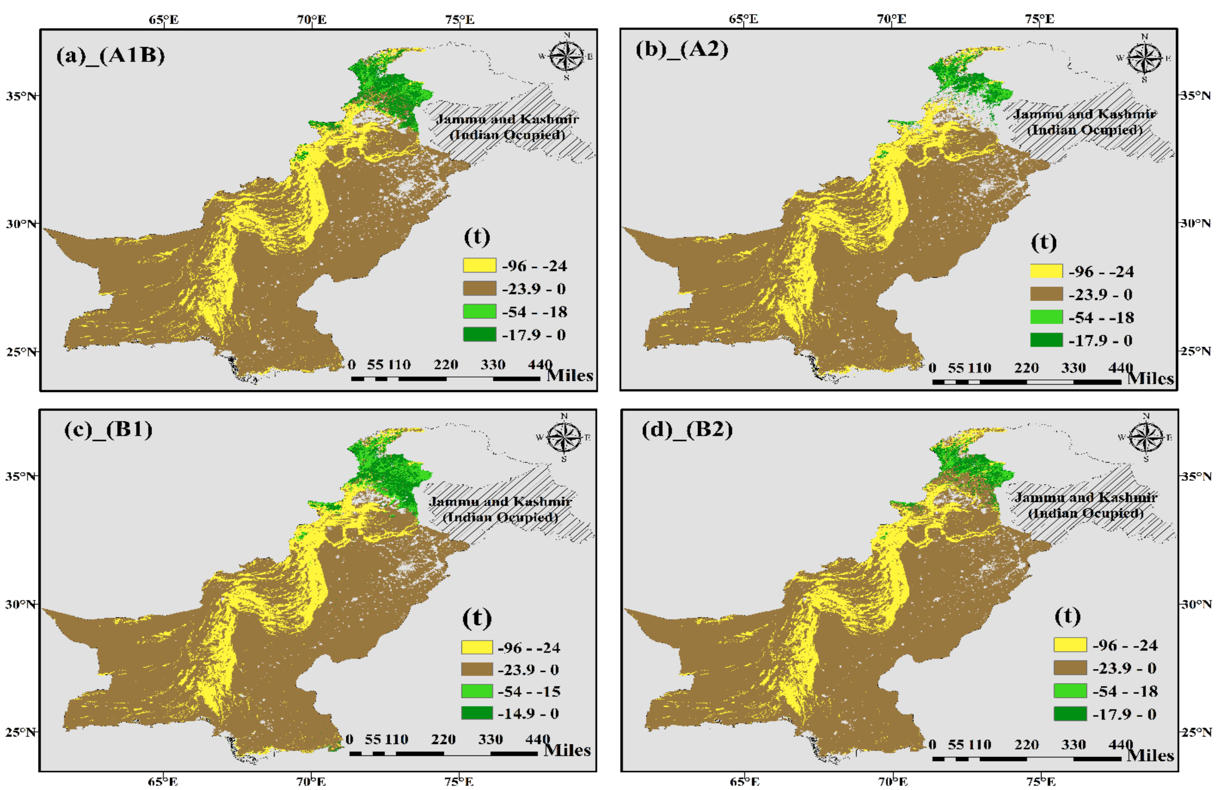


Figure 13. Soil carbon loss due to land use change in Pakistan in the year 2100

increased carbon emission into the atmosphere (Assefa et al.,2017).

Loss of vegetation cover is associated with soil erosion, increased carbon emissions into the atmosphere, desertification, and flooding (Seto et al.,2012). High atmospheric carbon levels trap more heat in the lower atmosphere leading to global warming (Tubiello et al.,2013). This results in high temperatures and precipitation which cause adverse climatic changes such as intense flooding and drought (Kiran,2017). Consequently, soil erosion occurs, leading to soil loss and its organic carbon, thus reducing soil fertility and increasing landslides. Overall, urban sprawl is expected to reduce carbon storage in Pakistan between 2050 and 2100. This will lead to adverse climate changes, which will negatively affect agricultural production and economic development.

CONCLUSION

Urban sprawl is a predominant process that affects land use and potential carbon storage in the environment. Analyzing land use changes caused by urbanization provides vital information for global environmental change and sustainable development studies (Salvati et al.,2018). Using a combination of remotely sensed technology, forest resources inventory and GIS data, this study examined the impact of urban sprawl on land use patterns, forest dynamics, carbon storage in Pakistan between 2050 and 2100. The results show that forest area and shrubland will decline while farmland and urban settlements will increase leading to LULC. The effects of urban sprawl on forestland area led to high carbon emissions into the environment. There is a significant correlation between LULC and climate change. The massive expansion of urban land will reduce potential carbon storage leading to adverse climatic changes such as severe floods and frequent droughts. Factors that accelerate LULC and carbon loss are rapid population growth, industrialization and economic development. The findings of this report are in line with the results of other authors who used land cover to evaluate carbon loss in the study area. The rapid LULC and carbon loss caused by urban sprawl reflect how national policies have failed to enforce proper land management practices (Khan et al.,2013). If the issue is not solved, the country will experience intense implications such as loss of biodiversity, alteration of hydrological cycles, and increased soil erosion. This will negatively affect the country's economic activities such as agriculture and tourism, thus reducing GDP. There is a need for the government to develop policies that will encourage national resource management practices and lower population growth in the country. This study has demonstrated the importance of using a combined research strategy. The research procedure can be applied to study land use changes in other countries experiencing environmental problems.

RECOMMENDATIONS

Pakistan is one of the most populated countries, with most of the people residing in urban areas. Industrialization had attracted many individuals in the city with the hope of getting jobs and bettering their lives (Bhalli et al.,2012). However, this urban sprawl has increased demand for resources leading to environmental degradation, water, air pollution, high energy consumption, waste disposal problems, and inadequate water supply (Habibi & Asadi, 2011). It has also posed a threat to the tourism sector since the animal population has been reduced by the loss of habitat, emission of toxic substances into the atmosphere, and lack of food sources. Protecting natural ecosystems and sustainably managing and reestablishing forests are crucial steps in reducing LULC and carbon emissions into the atmosphere in densely populated cities (Ouyang & Lin, 2017). From the results, the main drivers of LULC are rapid population growth, industrialization, high GDP, and poor land management policies. Several practices can increase carbon storage and reduce adverse climate changes caused by LULC in urban areas. They include agroecology practices such as agroforestry that increase carbon in the soil (Garrity, 2012). A slight increase in SOC will have a high impact on the carbon cycle and atmospheric carbon dioxide concentrations (Imam & Banerjee, 2016).

Increasing just 1% of carbon in the soil will have a higher effect on the carbon cycle than the corresponding amount of anthropogenic carbon emitted annually by human activities such as fossil fuel burning (Ali et al.,2019). Reversing LULC and increasing carbon storage in the soil is a vital step in climate change mitigation, increasing agricultural production, and conserving biodiversity. There is a need for planners from different sectors to come together and adopt effective strategies that will promote job creation and economic development throughout the country. This will help reduce the number of people migrating from rural to urban areas to seek employment opportunities (Mzuza et al.,2019). Air pollution caused by greenhouse gas emissions from fossil fuels should also be reduced by upgrading energy use and seeking alternative transport systems (Wang et al., 2016). The government should also modify weak policies that drive non-compliance to forest management regulations. For instance, all policies that encourage or result in deforestation should be amended. The local authorities should be given the power to participate in environmental conservation activities such as planting trees. Resources needed for the operation such as seedlings should be provided by the government. This activity should be conducted in a competitive manner that allows the public to participate, and incentives can be issued to increase motivation.

Clearing of forests to increase farmland can be prevented by encouraging the use of fertilizers that will boost yields and reduce the need to clear forests for farming purposes (Sileshi et al.,2014). Rapid population growth is the leading cause of urban sprawl and LULC (O'neill et al., 2010). There are several ways in which population growth can be controlled, and they include encouraging and increasing the use of family planning methods (Coale & Hoover, 2015). Measures should be put in place to ensure every child attends school to avoid early marriages linked to poverty and high population growth. At the national level, early marriages contribute to population growth by increasing fertility. Studies indicate that school-aged girls who get married at 13 have a higher likelihood of bearing more children than those who get married at 18 or more years (Parsons et al.,2015). By reducing population growth in Pakistan, we decrease the demand for land resources, which will prevent LULC caused by human activities such as deforestation. Lastly, there is a need for the government to establish deliberate programs that will mitigate climate change effects such as intense floods and drought caused by LULC and urban sprawl. These programs include farming practices that conserve soil and its organic carbon, banning charcoal use as well as establishing and encouraging afforestation activities. Implementation of these strategies will enable the conservation of carbon sinks in the environment.

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AUTHORS CONTRIBUTIONS

Mehjabeen Khan; Conceptualization; Collection data; Contributed data or analysis tool; Prepared Figures and Tables; Methodology; Visualization; Writing and Editing; Original Draft.

Ruishan Chen; Supervision; Review; Project Administration

Sujo Meghwar; Methodology; Visualization; Conceptualization

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