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The effects of urban decisions on the pattern of city expansion (Case study: Bushehr city)

Ranjbar Khadije[1]

1. PhD student of geography and urban planning, Islamic Azad University, Yazd, Iran, E-mail: kh.ranjbar@iau.ir

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ABSTRACT

Objective: Comprehensive and inclusive growth and development is an evolving and inevitable process that is ongoing in most countries of the world. Decentralization of population from city centers and suburbanization of population, as well as the transfer of activity centers (following the establishment of transportation systems along with the presence of large and cheaper plots of land around them) from city centers to the outskirts are ongoing. The aim of the study was to examine the pattern of urban growth and expansion in the period 1985-2024.

Methods: This study was conducted qualitatively in the city of Bushehr and its suburbs. In this context, the change in the area of urban and suburban areas in Bushehr city was studied using remote sensing techniques between 1985 and 2024. For this purpose, satellite images (1985-1999) TM, 9 and LANDSAT8 and TIRS/OLI were used. Then, the slope of the urban area files for the years 2024 and 1985 was prepared using digital tools in the ArcMap environment to be used for urban development comparisons.

Results: After determining the urban growth areas, the type of urban development structure was determined and examined. The structure of Bushehr city is multi-core and has 3 main cores: northern (primary), western, and eastern to southern.

Conclusion: Based on the research findings, 1- The expansion of Bushehr city in the northern part (primary core) is limited in terms of building density; 2- The greatest expansion has been in the eastern to southern part of the city; 3- The expansion in the western part is due to the morphological limitation of the city by the sea.

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Introduction

All-round and inclusive growth and development is an emerging and inevitable process occurring in most countries around the world. The decentralization of population from city centers and the suburbanization of residents-driven by the development of transportation systems and the availability of larger and cheaper plots of land-have led to the transfer of economic and activity centers to city outskirts. This trend, initially observed in industrialized nations, is now increasingly evident in developing countries as well (Faraji & Dehghan, 2024).

Iran is no exception to this trend. In recent decades, rapid urbanization caused by natural population growth, rural-to-urban migration, and the need to house new urban households has significantly impacted urban expansion. The annexation of surrounding villages into legal city boundaries and the transfer of land on the outskirts during the 1980s and 1990s disrupted the gradual and organic growth patterns of cities, accelerating horizontal expansion and unbalanced spatial growth (Taqvai & Saraei, 2013).

Uncontrolled and unplanned urban expansion led to a situation where the physical growth of cities outpaced their population growth. This phenomenon, described in urban planning literature with terms such as "uncontrolled sprawl," "rapid horizontal expansion," and "urban dispersion," has resulted in land resource waste, high service delivery costs, and environmental degradation. Construction activities have increasingly shifted to previously undeveloped or agricultural lands on the urban fringe instead of utilizing existing urban spaces (Nazarian, 2002).

Recent studies reveal that a key driver of horizontal urban growth in Iran is the speculative approach toward land and supportive government policies in urban development plans. In many newly developed or peri-urban areas, expansion has occurred not based on real population needs, but in pursuit of land profiteering and rapid land-use conversion. This pattern has contributed to physical-social fragmentation, unequal access to urban services, and the spread of informal settlements (Kargar et al., 2025).

Furthermore, in the absence of an integrated spatial management system, many Iranian cities face challenges such as insufficient infrastructure, disrupted transportation systems, and the destruction of agricultural land. Data obtained through remote sensing and GIS analyses indicate that, over the past decade, most Iranian cities have followed a disorganized and radial expansion pattern, which contradicts the principles of sustainable urban development (Faraji & Dehghan, 2024).

Given the current conditions, it is essential to prioritize planning approaches such as smart growth, transit-oriented development, and the protection of peripheral lands. Utilizing modern tools such as machine learning models to predict areas prone to sprawl and enhancing

coordination among various planning authorities can significantly help manage and control horizontal urban growth (Kargar et al., 2025).

Urbanization in the 21st Century: Patterns, Challenges, and Environmental Consequences

Human civilization is now entering the so-called urban century (Kourtit, Nijkamp, & Arribas, 2014). Urban areas are rapidly expanding, primarily due to population growth, increased incomes, and lower commuting costs (Brueckner & Largey, 2008). This trend is especially evident in developing countries, where cities have grown rapidly and the number of megacities has significantly increased. According to a United Nations report, the global urban population rose from 30% in 1950 to 54% in 2014, and is projected to reach 66% by 2050, posing major challenges for managing urban populations and spatial growth (United Nations, 2014). In Iran, census data show that 74% of the population lived in urban areas in 2015, with urban population growth increasing by 6.2% from 2010 (Statistical Center of Iran, 2016).

Unplanned physical expansion, excessive population growth, rapid economic transformation, and rural-to-urban migration have collectively led to extensive environmental and social challenges. These include declining quality of life in both urban and non-urban areas and increased health-related risks (Shafizadeh Moghadam, Karami, & Arzandeh, 2017). Consequently, monitoring and forecasting urban expansion trends have become critical tasks for planners and decision-makers (Lane, Guhathakurta, & Behr, 2014). Given the multifaceted nature of urban growth, including its ecological, social, and economic dimensions, sustainable development can only be achieved through carefully planned urban expansion that minimizes environmental and economic costs (Lettres, 2010).

Cities function as complex, dynamic, open systems with self-organizing features. To meet sustainable development goals, it is essential to understand these processes and integrate them into urban planning. One major manifestation of urban development is urban sprawl-the uncontrolled horizontal growth of urban areas. Although definitions vary, urban sprawl generally refers to dispersed suburban development that causes traffic congestion, misuses resources, and eliminates green spaces (Johnson, 2001). The extent of urban sprawl is measured by indicators such as population growth, commuting costs, employment shifts, changes in urban income, and the emergence of commercial units (Peiser, 2001).

Since the mid-1980s, global awareness of the environmental impacts of urban sprawl has increased. Major international conferences, including the World Commission on Environment and Development (WCED, 1987) and the United Nations Conference on Environment and Development (UNCED, 1992), brought sustainability to the forefront of urban discourse (Frumkin, 2002). Today, physical urban expansion is one of the leading contributors to declining environmental quality and resource depletion, extending beyond the boundaries of cities.

Despite these challenges, cities continue to drive economic growth. It is anticipated that a majority of the global population-particularly in developing nations-will reside in cities in the near future (Hosseinion, 2006). As a result, one of the most pressing issues in 21st-century urban studies is the spatial form of cities-how cities grow and expand over space. Urban sprawl, as defined by Anderson (1996), represents the spatial pattern of human activities at a specific point in time and must be understood and managed to achieve sustainable urban development.

The city of Bushehr, located on the northern coast of the Persian Gulf, has experienced rapid and unbalanced urban expansion over recent decades. Population growth without proportional infrastructural development has led to significant changes in the city's physical form and urban landscape. The city's transformation, driven by its coastal, port, and oil-based economy, has resulted in uncoordinated land uses and spatial fragmentation.

The external growth of Bushehr, accompanied by horizontal sprawl, has endangered historical neighborhoods and ecologically sensitive lands. Simultaneously, Bushehr's strategic geopolitical and economic position has attracted population and development, yet spatial constraints such as the sea, military installations, and the nuclear power plant have limited outward expansion. These limitations have created a paradox where demand for growth exists, but spatial capacity is restricted (Jalilian et al., 2024).

Internal challenges, such as the presence of military zones in both the northern and southern parts of the city, have hindered infill development and efficient land use. Moreover, the worn-out urban fabric in central areas has functioned as a population repeller, compounding issues related to inefficient spatial structure and unbalanced urban form (Mousavi & Rajabi, 2025).

Urban growth in developing countries is closely associated with land use/land cover (LULC) changes, often resulting in inefficient land use, traffic congestion, and environmental degradation (He et al., 2018). Bushehr is no exception. In fact, excessive horizontal development has led to fragmented spatial forms that disrupt ecological stability and infrastructure coherence.

The physical expansion of cities transforms agricultural, coastal, or unused lands into residential, commercial, and industrial spaces. Monitoring these transitions through spatial pattern analysis and GIS techniques is essential for managing land sustainability and urban growth (Karimi Firouzjaei et al., 2017; Zhang et al., 2025).

Horizontal urban expansion is not unique to developed nations. In many developing countries, cities expand in unregulated and informal ways due to the lack of effective governance, centralized urban planning, and formal housing supply (Menon, 2004). In Latin America and parts of Asia, the growth of peripheral informal settlements reflects spatial inequality and institutional incapacity.

Urban sprawl may lead to the displacement of populations and social fragmentation. Jane Jacobs (in Fukuyama, 1997) emphasized that tight-knit communities within older city centers represent a form of social capital critical for maintaining urban safety and hygiene. When horizontal development replaces these dense networks, social cohesion is undermined.

From a cost perspective, the implications of horizontal expansion must be examined across three dimensions: construction, urban planning, and policy. Construction-wise, sprawling cities require more land, infrastructure, and legal administration. Planning-wise, larger cities entail higher maintenance and service costs unless high population density offsets them. Policy-wise, turning productive land into urban space without considering food security is a critical risk (Kazemian, 2023).

Furthermore, horizontal growth accelerates land consumption and environmental degradation. Studies in 2024 show that increased built-up areas in Bushehr correspond with a decline in vegetative cover and biodiversity (Asgari et al., 2024). This impacts not only local ecosystems but also intensifies urban heat islands and coastal erosion.

The current pattern of development has been further documented by satellite image analysis. For instance, Ebrahimi and Maleki (2022) assessed 30 years of spatial change in Hendijan using ENVI and ArcGIS, finding a notable increase in residential land at the expense of natural areas. Such tools can provide critical insight into Bushehr's own expansion dynamics.

Varamesh et al. (2021) demonstrated the utility of Landsat imagery to track Ardabil’s uneven expansion, recommending updated comprehensive urban plans based on geospatial analysis. These approaches are directly applicable to Bushehr’s management, especially considering its geographical constraints and geopolitical sensitivity.

Rostami Saghez et al. (2020) employed Sentinel-1 imagery to assess shoreline change between Chalous and Tonekabon, finding average coastal erosion rates of 7 meters per year. This mirrors similar coastal vulnerabilities in Bushehr due to sea-level rise and sediment changes. Salehpour (2018) modeled optimal urban expansion in Yasuj using cellular automata in GIS, offering a replicable framework for controlled horizontal development. Similarly, Haj Alizadeh (2017) highlighted the relationship between land use change and urban economy in Ardabil, emphasizing the importance of economic planning alongside physical development.

International studies also reflect these trends. Filsa Biursita et al. (2016) in Surabaya, Indonesia, showed that VH-polarization in Sentinel-1 imagery effectively tracks coastal changes, offering methodologies applicable to Bushehr's erosion-prone coastline and urban boundaries.

Therefore, this study seeks to evaluate the effects of urban development decisions on the pattern of growth and expansion in Bushehr. It uses empirical findings and spatial models to highlight the need for sustainable urban management in light of environmental, social, and

geopolitical constraints. Such integrated analysis is essential to align future urban development with the principles of resilience, sustainability, and social equity.

Materials and Methods

2.1. Study Area

Bushehr is about 5,000 years old and was one of the important centers in different governments such as Elamite, Sassanid and Afsharian. Many actions were done for the first time in Bushehr, for example, the first stone printing press, electrical industry, ice making and the first telegraph line were set up in Bushehr.

The name of Bushehr has been recorded in books and historical documents under different names such as "Ram Ardeshir", "Abushehr", "Bokht Ardeshir", "Lian", and "Rishehr". Most of the people of Bushehr speak Persian with Bushehri dialect. Bushehr port has gained economic prosperity due to factors such as fishing, nuclear power plant, shipbuilding and exports, and this has made the importance of attention and development of social capital in this city doubled.

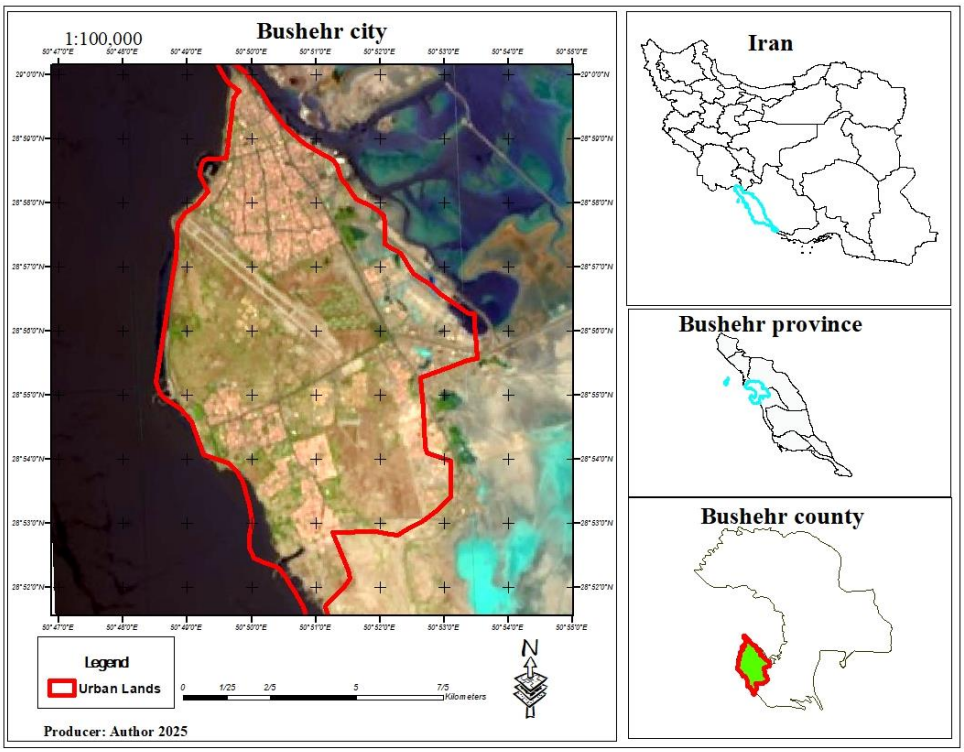

Figure 1- Location of Bushehr city

2.2. Method

This qualitative study was conducted in Bushehr city and its suburbs. In this context, the change of urban and suburban areas in Bushehr city was studied using remote sensing techniques between 1985 and 2024. For this purpose, TM, 9, LANDSAT8 and TIRS/OLI satellite images (1985-1999) were used. At this stage, by using the composite of the relevant bands in each of the satellite images, a suitable combination was prepared for visual analysis. Then, the slope files of urban areas for the years 1402 and 1363 were prepared using a digital tool in the ArcMap environment to be used for urban development comparisons. After determining the limits of urban growth, the type of urban development structure was determined and investigated.

Results

3.1. Check the expansion of the city

The horizontal expansion of Bushehr city has been clearly formed in several cores. The structure of the physical expansion of this city is based on the multi-core structure (based on the theory of Ullman and Harris). The main expansion cores of Bushehr city are located in the northern, western, eastern and southern parts of the city (Figures 1 and 2). The extent of expansion and change of urban and suburban land area in 1985 and 2024 is shown in Table 1.

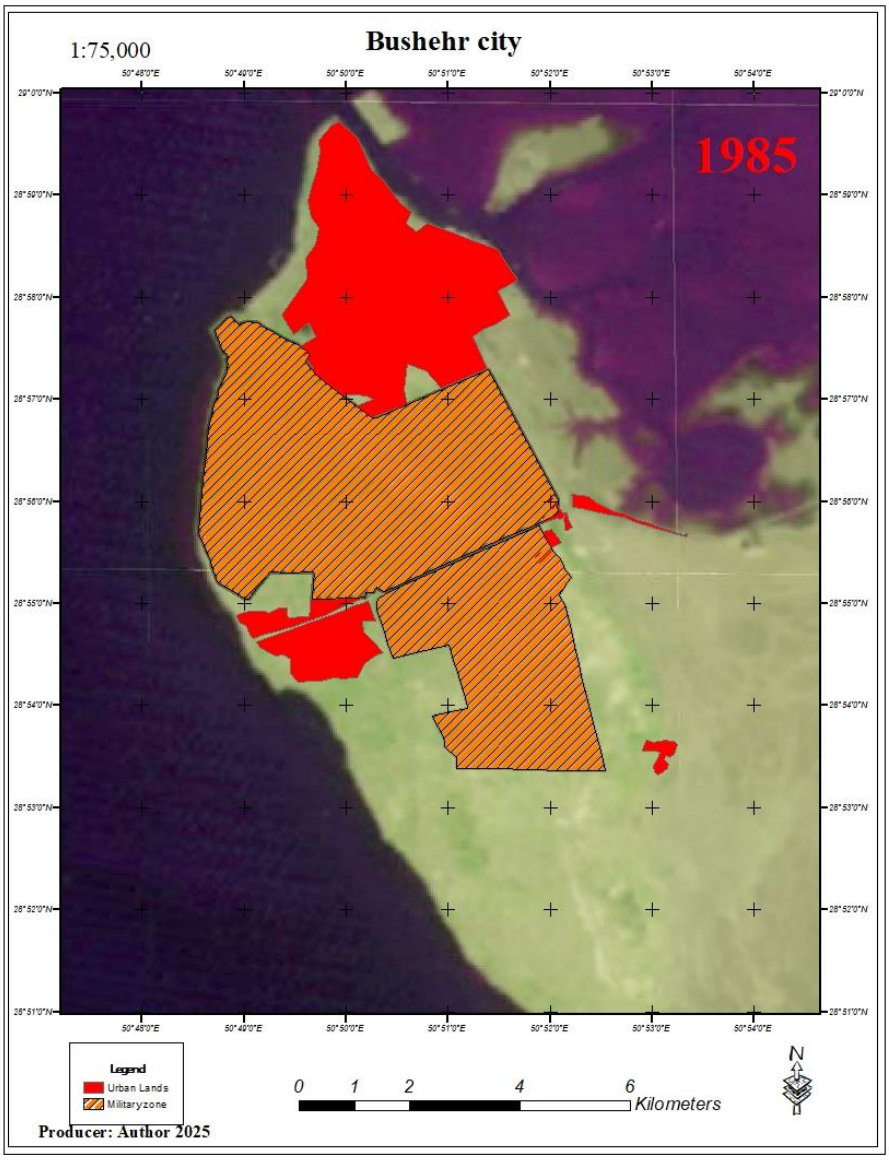

Figure 2- Urban land area of Bushehr city in 1985

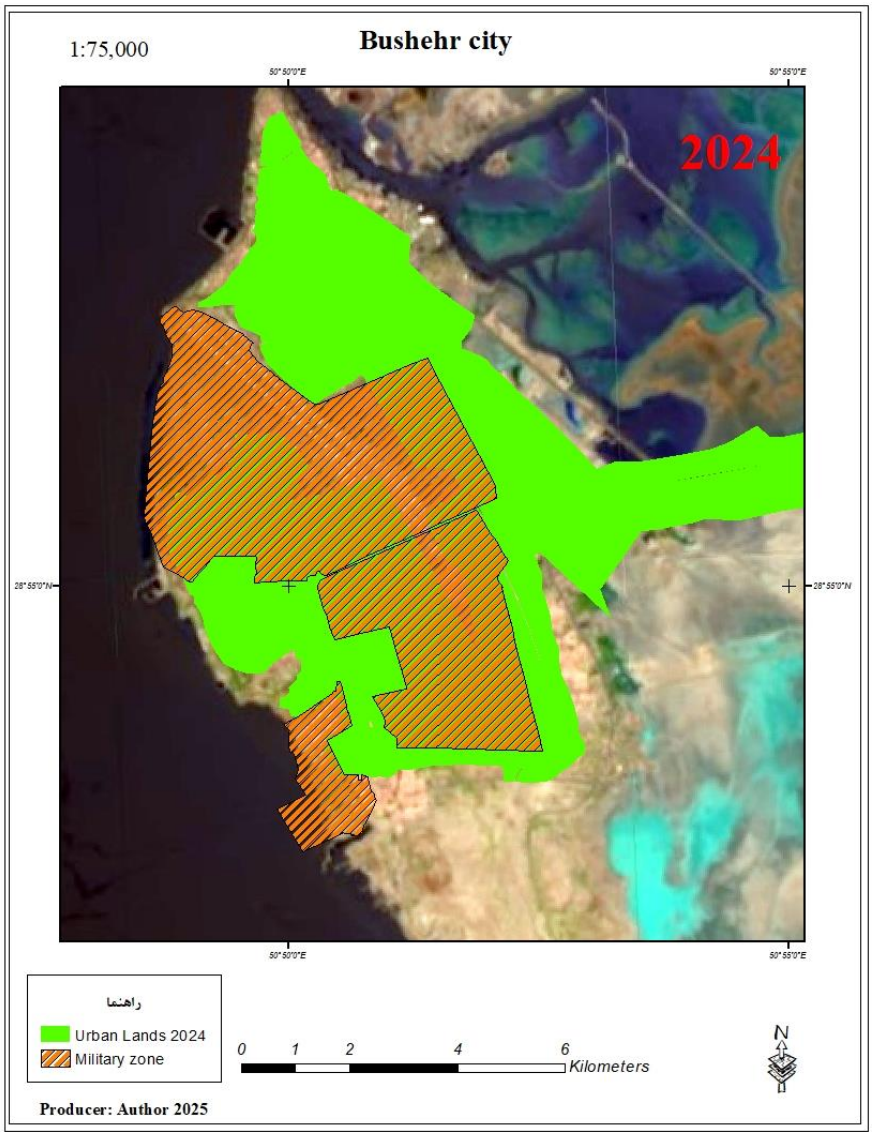

Figure 3- Urban lands of Bushehr city in 2024

3.2.Determining the extent of expansion

The extent of expansion and change of urban and suburban land area in 1985 and 2024 is shown in Table 2.

Table 2. Urban lands of Bushehr city in 2024

Urban core	1985	2024	percentage of horizontal development
Core 1 (northern part)	**10.71**	**12.5**	**16.71**
Core 2 (western part)	**6.4**	**9.5**	**48.43**
Core 3 (east to south)	**3.98**	**11.7**	**193.97**

Source: author's calculations

The highest amount of marginal physical expansion was found in core 3 (eastern to southern part) and the lowest amount of marginal physical expansion was found in the primary core (northern part) (Table 2).

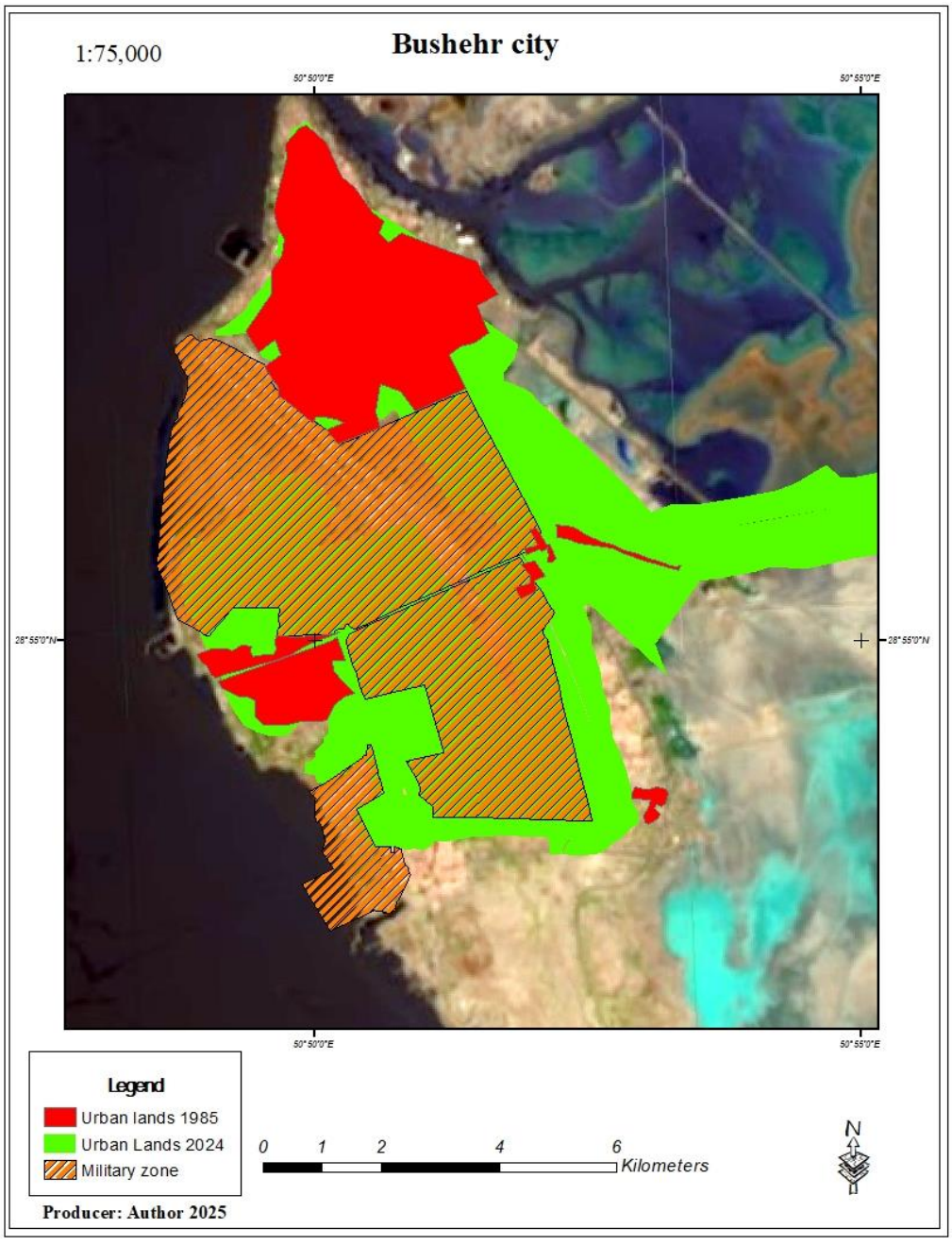

Figure 4- Adaptation of urban lands from 1985 to 2024 in Bushehr city

Discussion

The horizontal expansion of Bushehr, as evidenced by the findings, reflects a pattern common to many developing coastal cities—rapid urban sprawl in response to population growth, infrastructure limitations, and economic transformation. While Bushehr's strategic geopolitical and economic position has attracted significant industrial and port-related activity, its geographical and institutional constraints (such as proximity to the sea, military bases, and the nuclear power plant) have restricted the potential for compact urban growth and pushed development outward in an uncoordinated manner (Kazemian & Ranjbar, 2025).

The physical spread of Bushehr has brought with it several environmental consequences, most notably the encroachment on ecologically sensitive lands such as wetlands and agricultural zones. This is consistent with recent studies that demonstrate significant erosion and land use degradation along Iran's coastal areas due to unregulated development (Ebrahimi & Maleki, 2024; Zhang et al., 2025). In Bushehr, satellite image analysis indicates that urban expansion has occurred primarily in northern and southern sectors, often without accompanying infrastructure upgrades. This pattern is linked with an increase in inefficient land use, higher costs for public service provision, and growing inequality in access to urban amenities.

From a social standpoint, the displacement of long-established communities, combined with the lack of integrated public spaces and weak neighborhood connectivity, has contributed to a decline in social capital. As Jacobs (1997) and more recently Lane et al. (2014) suggest, traditional dense urban fabrics often foster social cohesion and informal governance mechanisms that are eroded by dispersed urban patterns. The worn-out core of Bushehr, which once functioned as the city's cultural and social hub, is now experiencing depopulation and disinvestment—an internal contradiction that both reflects and deepens the fragmentation caused by horizontal growth.

Moreover, the spatial expansion of Bushehr has outpaced the capacity of urban planning institutions. The current growth has not followed a coherent urban development policy aligned with sustainability or resilience principles. As noted by Karimi Firouzjaei et al. (2017), horizontal growth without effective land use planning leads to fragmented urban areas, inefficient transportation systems, and rising costs for service delivery. The absence of green belts, buffer zones, and transit-oriented development in Bushehr illustrates a reactive planning model, rather than a proactive, evidence-based approach.

Additionally, the findings align with broader urbanization trends in developing countries, where weak governance, rapid population increase, and limited regulatory enforcement result in informal settlements, underutilized infrastructure, and environmental degradation (Lungo, 2001; McGarrigal et al., 2018). In Bushehr, the lack of enforcement of urban boundary regulations and

environmental zoning has allowed development to proceed in areas prone to flooding, erosion, and sea-level rise, thus exacerbating vulnerability to natural hazards.

The analysis also highlights the fiscal implications of horizontal urban development. According to Kazemian (2023), horizontal growth increases per capita costs of service delivery and infrastructure maintenance. For Bushehr, which faces limited municipal revenue and growing urban demands, such a pattern risks long-term financial unsustainability. High land consumption with low population density creates inefficiencies that strain both operational budgets and future planning capacity.

Given these findings, urban planners and policymakers must reevaluate the city's spatial development strategy. Emphasizing vertical growth, infill development, and rehabilitation of the urban core would contribute to a more balanced and sustainable city structure. Lessons can also be drawn from international experiences where compact growth models have improved livability and environmental outcomes (Kourtit et al., 2014).

In conclusion, while Bushehr's urban expansion has responded to pressing economic and demographic demands, its current trajectory raises critical concerns for environmental integrity, social cohesion, and long-term resilience. Integrating spatial data analysis, participatory planning, and ecosystem-based management into future urban strategies is imperative to reverse the adverse consequences of unchecked horizontal growth. As Zhang et al. (2025) emphasize, coastal cities must adopt adaptive urban planning frameworks that account for ecological sensitivity, economic complexity, and social inclusiveness.

Conclusion

The horizontal expansion of Bushehr has unfolded amidst complex demographic pressures, geopolitical constraints, and infrastructural limitations. While the city has experienced significant spatial and economic growth over the past decades, this expansion has largely taken the form of unplanned horizontal sprawl. The findings of this study underscore the environmental, social, and urban governance challenges associated with such a development pattern.

Environmentally, the unchecked outward spread of the city has led to the degradation of coastal lands, wetlands, and agricultural zones, putting Bushehr at greater risk of erosion, flooding, and loss of ecological diversity. Socially, horizontal development has fragmented the urban fabric, weakened social capital, and increased inequality in access to services and public spaces. Economically and administratively, this pattern has strained municipal resources and revealed the inefficiencies of low-density expansion.

The limitations imposed by military bases, the nuclear power plant, and natural barriers like the sea and swamps further complicate the feasibility of continued horizontal development. The

city now finds itself at a critical juncture, where reliance on horizontal growth is not only unsustainable but potentially detrimental to its long-term resilience and livability.

To move forward, a paradigm shift in urban planning is essential—one that prioritizes compact development, the rehabilitation of the urban core, mixed land use, and vertical densification. Policymakers must integrate environmental sensitivity, spatial equity, and infrastructure efficiency into future urban development plans.

Ultimately, the experience of Bushehr offers valuable insights for other coastal and developing cities facing similar growth pressures. By adopting data-driven, inclusive, and sustainable planning strategies, cities can balance economic development with environmental protection and social well-being.

The structure of Bushehr city is multi-core and has 3 main cores: north (primary), west and east to south. Based on the research findings:

1. The expansion of Bushehr city in the northern part (primary core) is limited in terms of building density.

2. The greatest expansion has been in the eastern to southern parts of the city.

3. The expansion in the western part is due to the morphological limitation of the city due to the sea.

Author Contributions

The sole author was responsible for the conception and design of the study, data collection and analysis, interpretation of findings, and drafting and revising the manuscript. All aspects of the research were conducted independently by the author.

Data Availability Statement

The datasets used and/or analyzed during the current study are publicly available from official sources and satellite imagery repositories. Further details can be provided by the author upon request.

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Ethical considerations

This research was conducted in accordance with the ethical standards of academic research. All data used in the study were obtained from publicly available sources or institutional records with appropriate permissions. No human participants or animals were involved in this study, and therefore no ethical approval was required. The authors declare that there is no conflict of interest, and the research was carried out with integrity, transparency, and full respect for the principles of academic honesty.

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Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Appendix A: Classification of Land Use Types in Bushehr City

Land Use Type	Description	Area (hectares)	Percentage of Total Urban Area
Residential	Includes all residential zones	3,400	38%
Commercial	Includes shops, malls, markets	850	9.5%
Industrial	Includes factories, workshops, etc.	1,150	12.8%
Public Services	Schools, hospitals, administrative offices	1,200	13.4%
Green/Open Spaces	Parks, recreational spaces, vacant lands	980	10.9%
Transportation	Roads, highways, terminals	1,070	11.9%
Military/Restricted	Bases and restricted zones	650	7.5%
Total		**9,300**	**100%**

Appendix B: Method of Satellite Image Analysis

1. Data Acquisition:
Satellite images of Bushehr city for the year 2024 were obtained from [source, e.g., Sentinel-2, Landsat 8, or any specific provider]. The images had a spatial resolution of 10 meters (for Sentinel-2) or 30 meters (for Landsat 8), sufficient for urban land use classification.

2. Preprocessing:
The raw satellite images were preprocessed to enhance their quality and suitability for analysis, including:

- Radiometric correction to adjust sensor noise and atmospheric effects.
- Geometric correction to align images to real-world coordinates using ground control points (GCPs).
- Cloud masking to remove areas obscured by clouds.

3. Image Classification:
A supervised classification approach was adopted to categorize the land use types. The steps included:

- Selection of training samples representing known land use categories (residential, commercial, industrial, green spaces, etc.) based on field surveys and existing maps.
- Application of the Maximum Likelihood Classifier (MLC) algorithm within the GIS software to classify the entire image into land use classes.

4. Accuracy Assessment:
The classification accuracy was evaluated using a confusion matrix by comparing the classified map with ground truth data collected during field visits. Overall accuracy and Kappa coefficient were calculated to assess reliability. The classification achieved an overall accuracy of 89% and a Kappa coefficient of 0.85.

5. Post-Processing:
Minor misclassifications were corrected through manual editing in GIS based on expert knowledge and additional field verification.

6. Analysis and Mapping:
Final classified maps were produced illustrating the spatial distribution of different land use types in Bushehr city. Area statistics were extracted to quantify the extent of each category.

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