

REVIEW



Assessment of urban sprawl and its environmental impact

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ABSTRACT

In recent decades, urban sprawl has emerged as a critical issue, with significant social, economic, and environmental repercussions. This phenomenon, often characterized by low-density, unplanned development at the urban periphery, results in excessive resource consumption and negative urban expansion. Urban sprawl is commonly seen as counterproductive to sustainable development, which emphasizes integrated, high-density city planning. To mitigate the adverse effects of urban sprawl, effective urban growth management strategies are essential. These strategies must consider the socio-economic and environmental drivers of urbanization. This review article delves into the specific characteristics and consequences of urban sprawl, drawing on case studies and empirical data to illustrate its impact. Furthermore, it discusses various urban growth management approaches and their effectiveness in promoting sustainable urban development. By analyzing these aspects, the article aims to provide a comprehensive understanding of urban sprawl and propose viable solutions for its management.

KEYWORDS

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Environmental impact;
Geoinformatics;
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Introduction

Rapid and unplanned urban growth has led to urban sprawl and induced irreversible land cover conversions. Uncontrolled urban growth has become a concern even before the concept of sustainable development was introduced. As a result, urban growth management strategies and policies have been implemented to mitigate the impact and manage the growth [1]. However, urban expansion has made sprawl worse due to a lack of knowledge about the characteristics of urban growth patterns and the variety of socio-environmental and economic transformations. This study examines the features and implications of urban sprawl as they are currently being researched and applied. Urban sprawl has been defined, measured, quantified, and examined from a variety of angles by research, which has produced creative ways of dealing with the issue [2].

Urban sprawl, characterized by the uncontrolled expansion of urban areas into peripheral rural lands, poses substantial environmental, social, and economic challenges. As cities expand, the demand for land, infrastructure, and services increases, often detrimentally affecting the natural environment. Geoinformatics, which includes remote sensing and Geographic Information Systems (GIS), provides powerful tools for assessing, monitoring, and managing urban sprawl. This review explores how these geospatial techniques can be utilized to understand the patterns and impacts of urban sprawl, providing valuable insights for sustainable urban planning and management [3].

The necessity of presenting proof of urban sprawl stems from the significance of measuring its influence on sustainable development.

Developing an Urban Sprawl Concept

Urban expansion is essentially a clustering procedure that includes the gradual evolution of physical and functional

components. Agglomeration economies drive this growth, boosting productivity and encouraging urban expansion. The way cities expand is influenced by various factors such as social, economic, environmental, spatial, technological, and institutional factors [4,5]. Every one of these factors adds to the quick speed of urban development. Nevertheless, unchecked growth frequently results in adverse effects like urban sprawl [1,6]. Urban agglomeration is considered to be a complex spatial arrangement consisting of interconnected cities, as stated by Fang and Yu (2017), whereas urban sprawl happens at lower densities and involves the expansion of urban peripheries, characterized by scattered and leapfrogging development, as highlighted by Ahyuni & Nur (2020) [7,8]. Urban sprawl is interpreted variably depending on context, indicating differing viewpoints on its origins and consequences despite being widespread worldwide [9].

In Eastern Europe, urban sprawl is seen as a result of the shift from autocratic rule to more liberalized economic and social systems following the socialist transition [10,11]. After World War II, sprawl started happening in the United States because people believed that suburban areas were safer, more appealing, and cheaper than cities [12-14]. Urban sprawl is quickly increasing in Asia, specifically in China and India, because of major economic changes and urbanization pressures, as noted by Lv et al. (2016), Du (2017), and Zhang & Xie (2019) [15-17]. Urban sprawl is seen as a complex occurrence influenced by different factors, resulting in similar impacts on sustainable social, economic, political, and environmental progress.

Features of Metropolitan Sprawl

Based on the definition and theory of urban sprawl, several general characteristics are identified as follows:

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Challenges related to reliance on automobiles and limited accessibility

Scattered and sparse development results in reliance on cars and limits access to public transportation systems [18]. This form of urban growth also has a significant impact on the expenses of offering public transportation, leading to a decrease in its effectiveness and competitiveness [19]. With a decrease in density, the amount of developed space per land parcel is reduced. As a result, scattered and sparse development causes a decrease in the number of activities, leading to lower transportation demand. Consequently, a growing number of individuals choose to drive instead of utilizing public transportation, which makes it more challenging to promote the use of public transit. Poor accessibility has resulted from the combination of expensive transportation infrastructure and limited public transportation usage. In the end, these factors have resulted in the pressing requirement for people to commute to work by car.

Scattered and sparsely populated development

Urban sprawl is distinguished by its widespread and sparse development. In contrast to compact development in the urban center, this sprawl pattern expands on the outskirts of the city and diminishes in density as one moves away from the central area. The expansion of cities into surrounding rural areas, characterized by uneven development, is a key aspect of urban sprawl. This progress comes with potential dangers, such as the invasion of rural farming areas and environmentally delicate regions [18,20]. In suburbs with low population density, residential areas and urban infrastructure like health facilities, public schools, and community halls are intermingled with agricultural and arable lands. The central parts of these sparse suburbs function as centripetal forces, drawing in businesses and services. On the other hand, the nearby farmable and cultivatable areas demonstrate outward pulling forces because of their scattered layout and the existence of scattered natural resources. As a result, the cost of providing infrastructure and utilities in these areas is significantly high.

Development with a focus on multiple centres

Polycentric development refers to the existence of multiple centres of development control within a region. The impact of polycentric development on urban sprawl remains a contentious issue among scholars. Liu and Liu (2018) examined the effects of planned versus unplanned polycentric development in China's mega-cities [21]. In China, rapid urbanization has led to the emergence of polycentric development patterns. The overpopulation and congestion in Chinese mega-cities are primarily attributed to their monocentric spatial configurations. In response, planning policies have adopted polycentric development strategies to alleviate the pressures on central urban areas. Strategic development in multiple centers within a city opens up new possibilities for businesses and industries located on the outskirts, stimulating the need for more workers and additional residential areas. On the other hand, unplanned polycentric growth does not have organized workforce expansion and faces uneven population growth and urbanization. As a result, the research discovered that spontaneous polycentric growth frequently results in unregulated expansion and subsequent sprawl. Zambon et al. (2017) delve into polycentric development as a strategic method for spatial planning and

economic advancement [22]. The research suggests that polycentric development seeks to promote more even and environmentally friendly urban expansion through the establishment of numerous centers in a metropolitan region. Historically, European cities have been characterized by compact and dense urban forms [23].

Implications in society

Urban sprawl has greatly increased the length of commutes and made traffic patterns more complicated, resulting in serious traffic congestion [24]. Urban sprawl leads to a spread-out land use which results in essential services like schools and healthcare facilities being located further away from residential areas, therefore increasing travel distances and times. This physical distance also limits the availability of important public transportation for disadvantaged communities [25]. Extended daily commuting, especially during busy times, could slowly harm your general health. In Atlanta, Ambinakudige et al. (2017) found that the segregation of land use due to urban sprawl intensifies socio-spatial divisions, impacting social interactions negatively, creating urban disparities, and leading to racially segregated communities [26]. The research also indicated that these social and spatial divisions impede job prospects, particularly in outlying regions. Additionally, urban sprawl can worsen financial inequalities between communities, emphasizing multiple aspects of unfairness. Affluent suburban neighborhoods have higher tax revenues and fewer social services, leading to increased gaps in public services like education and resources in urban areas [27].

Financial implications

Significant attention has been directed towards the economic repercussions of urban sprawl, particularly focusing on urban decline and diminished economic agglomeration within city centers. Previous studies have consistently demonstrated a correlation between urban sprawl and decreased economic concentration and productivity in core urban areas. Wolff et al. (2018) suggest that economic activities in central urban areas are significantly impacted by urban sprawl as businesses and industries have been forced to move to outer areas due to the decrease in activity [28]. This change is frequently prompted by the necessity of reducing operational expenses or serving upscale businesses that cater to wealthy city dwellers. Because of geographical factors, economic activities in central urban areas are limited to high-level businesses and premium services. Urban economic clusters that are formed as a result create a need for multinational corporations and big businesses, allowing them to take advantage of lower transportation costs, a talented workforce, extensive local markets, and the sharing of knowledge. Additionally, affluent families have increasingly moved away from congested city centers to suburban areas, exacerbating economic disparities and leading to volatile land, service, and goods costs in the outskirts.

Implications in the political state

A growing body of literature parallels the rise of urban sprawl with the expansion of developmental volumes. Urban sprawl is often analyzed through the lens of the political dynamics within metropolitan regions [29]. The phenomena of low-density, dispersed, and leapfrogged development significantly impact the spatial and locational aspects of local government expenditures. This impact stems from the increased costs associated with

providing public services across larger areas with lower population densities. Consequently, to uphold service quality in newly urbanizing areas, new local governments and special districts are frequently established. This process is crucial for sustaining urbanization in peripheral areas, as new local governments or entities can support ongoing development [30]. These structural changes in urbanized areas affect not only public services but also the political framework and potentially the electoral boundaries.

Environmental Impacts

Environmental degradation is a major concern resulting from urban sprawl, and it is further intensified by the unique characteristics and patterns of this phenomenon. Urban sprawl results in a decrease in open spaces, forests, and agricultural land. The development patterns characterized by low density, scattered placement, and leapfrogging require a significant amount of infrastructure, such as road networks, that transform permeable surfaces into impermeable ones. The depletion of open space, forest, and agricultural land has a negative impact on the quality of water sources, as it leads to nonpoint source pollution and sedimentation. In addition, the proliferation of impermeable surfaces amplifies water runoff and heightens the potential for sudden floods [31]. The rise in impervious surfaces, especially in urban areas, plays a role in the urban heat island effect, temperature fluctuations, and alterations in microclimate. As an example, a study conducted by Siles et al. (2018) in Quebec, Canada, revealed the negative consequences of urban sprawl on wetland areas [32]. This has resulted in the fragmentation and loss of these areas, which in turn has had a detrimental impact on biodiversity and ecosystems. Specifically, certain wildlife and bird species have been adversely affected. In a study conducted by Manjunatha et al. (2019), it was emphasized that the extensive commercial development in Chicago has had detrimental effects on the environment of the Illinois Basin and Mississippi River [33]. This has led to the loss of habitats along these major rivers and has put the sustainability of wildlife populations at risk.

The loss of arable and farming land poses a major obstacle to agricultural output and food safety. Li et al. (2018) reported that in the Changchun-Jilin Economic Zone (CJEZ), productive land known for growing premium crops like golden maize is quickly being transformed into residential and urban zones [34]. This intrusion resulted in considerable harm to the environment and endangered food security. Likewise, the Nile Delta, located by the Nile River, has been affected by unplanned urban development and expansion, posing a risk to soil fertility and food security for 90 million Egyptians, as reported by El-Ramady et al. (2019) [35]. Climate change, flash floods, soil pollution, topsoil erosion, reduced soil fertility, and salinization have been associated with unregulated growth and urban spread. On the other hand, urbanization in the Moscow Region has led to the substitution of soil organic carbon stores, as examined by Demina et al. (2018) [36]. The process of soil sealing and topsoil excavation during construction has turned once unproductive land into carbon-rich soil, benefiting vegetation and ecosystem development.

Urban sprawl is connected to the division of natural paths and habitats, causing disruption in ecosystems, including imbalances in ecological food chains and an increase in species at risk. In Sri Lanka, Tella et al. (2020) investigated how overhead

powerlines in diverse urban areas pose dangerous risks to animal populations [37]. These powerlines, located within diverse forest environments, lead to animals being electrocuted and disturb natural pathways. The establishment of forests and infrastructure has significantly impaired ecological connectivity by harming fragile natural pathways and habitats. The expansion of cities into farming and woodland areas is causing a rise in carbon emissions, leading to the depletion of the ozone layer and adding to the issue of climate change.

Conclusions

Geospatial methodologies are pivotal in the evaluation and management of urban sprawl. Advanced remote sensing and Geographic Information Systems (GIS) deliver precise, actionable data that empower researchers and policymakers to grasp the intricate patterns of urban growth. By employing techniques such as spatial mapping, land use analysis, environmental impact assessments, and socio-economic evaluations, geoinformatics provides an in-depth understanding of the diverse consequences of urban sprawl. This critical insight is fundamental for formulating strategies to counteract the adverse effects of urban sprawl, thereby promoting sustainable and resilient urban planning and development.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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