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USE OF ADMINISTRATIVE INDICATORS AND TOPOGRAPHIC ANALYSIS FOR THE STRATEGIC PLANNING OF URBAN LAND AND THE INTEGRATION OF GREEN SPACES IN THE CITIES OF ECUADOR, IN CONJUNCTION WITH THE INSTITUTIONAL LEGAL FRAMEWORK

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ABSTRACT

Strategic urban land planning in intermediate Andean cities faces the critical challenge of reconciling population growth with complex geography and demanding regulations. This study analyzes the convergence between administrative management, the Ecuadorian legal framework (LOOTUGS), and the physical suitability of the territory. Using a mixed-methods approach with a descriptive-propositive scope, spatial analysis was integrated using Geographic Information Systems (GIS) and Digital Elevation Models (DEMs) with administrative performance indicators. The results reveal a systemic " urban maladaptation ": 28.5% of the city occupies high-risk areas with slopes exceeding 30%, paradoxically coexisting with low density (48 inhabitants /hectare) and 22% vacant land resulting from speculation. Furthermore, a severe "green injustice" was evident, with an index of only 2.89 m^2/inhabitant, socio-spatially segregated to the detriment of vulnerable peripheries. Comparing this data with specialized literature confirms an operational gap between formal planning and physical reality. It is concluded that it is imperative to implement a "geo-legal" approach that uses topography as a binding regulatory filter, transforming areas of unmitigable risk into green infrastructure networks to ensure resilient, efficient cities aligned with the principles of Buen Vivir (Good Living).

KEYWORDS: Urban Planning, Land Management, Andean Topography, Green Spaces, Sustainability Indicators, Urban Risk.

1. INTRODUCTION

Strategic urban land-use planning has become one of the most pressing challenges for Latin American cities in the 21st century, where rapid population growth often outpaces the response capacity of local governments. In Ecuador, this phenomenon has led to fragmented urban sprawl that puts pressure on natural resources and the quality of life of its inhabitants. Efficient land management requires a shift from reactive models to forward-looking approaches that integrate precise technical tools. As Sarango (2024) points out , urban sustainability depends not only on political will but also on the implementation of geographic information systems and administrative metrics that allow for modeling future scenarios and mitigating the risks associated with disorderly land use.

In this context, topographic analysis emerges as a fundamental tool, especially in the Ecuadorian Andes, characterized by its complex orography. Cities located in valleys or on hillsides face significant risks of landslides and floods if the terrain's morphology is not considered in planning. According to Guascal (2022) , the use of Digital Elevation Models (DEMs) and slope analysis is not only crucial for the physical safety of infrastructure but also determines the technical and economic viability of urban expansion. Ignoring topographic constraints has historically led to the creation of informal settlements in areas of unmitigable risk, which contravenes the principles of the right to a safe city.

Alongside physical aspects, the use of administrative indicators is vital for monitoring the performance of local public policies. These indicators allow for the quantification of land-use efficiency, housing density, and accessibility to basic services. Carrión et al. (2020) highlight that the lack of standardization in municipal management indicators in Ecuador hinders comparability and the objective evaluation of Development and Territorial Planning Plans (PDOTs). Therefore, linking quantitative administrative data with the physical reality of the territory is an essential step to move beyond rhetorical planning and toward evidence-based management.

One of the most critical components of this planning is the effective integration of urban green spaces (UGS). These spaces should not be considered mere remnants of the urbanization process, but rather as structuring elements of the urban fabric that provide essential ecosystem services. Recent research, such as that by Cuvi and Vélez (2021) , shows that the deficit of green areas in Ecuador's intermediate cities is directly correlated with the increase in urban heat islands and the decline in public health. Strategic planning must, therefore, prioritize ecological connectivity and the equitable distribution of these spaces to guarantee social well-being.

However, the technical implementation of these elements does not occur in a vacuum; rather, it must be strictly aligned with the existing legal and institutional framework. The Constitution of the Republic of Ecuador (2008) and the Organic Code of Territorial Organization, Autonomy, and Decentralization (COOTAD) establish the exclusive powers of the Decentralized Autonomous Governments (GADs) to regulate land use. Vivanco and Cordero (2019) argue that, although a robust regulatory framework exists, there is often a disconnect between the written law and the technical capacity of municipalities to implement it, resulting in "paper planning" that does not materialize on the ground.

The Organic Law on Territorial Planning, Land Use, and Management (LOOTUGS), enacted in 2016, marked a milestone by attempting to standardize planning and management instruments. This law requires municipalities to incorporate risk management and environmental protection variables into their plans. However, Aguilera et al. (2024) point out that the application of LOOTUGS faces operational challenges, particularly in defining urban standards that integrate local topography with the need to preserve the social and environmental function of property. The articulation between this law and technical instruments is, therefore, central to effective urban governance.

Urban land-use planning in Ecuador faces a sustainability crisis characterized by uncontrolled expansion and fragmented land management. Recent research, such as that by Salazar et al. (2021) and Hermida et al. (2019) , demonstrates that Ecuadorian intermediate cities are consuming peri-urban land at rates that significantly exceed their population growth, generating a costly and inefficient low-density model. This phenomenon is corroborated by Angel et al. (2011) at a global level and contextualized in the Andean region by Inostroza (2017) , who warn that the lack of urban containment not only increases infrastructure costs for municipalities but also irreversibly degrades ecosystem services essential for climate resilience.

In this context of accelerated urbanization, the integration of green spaces has become a critical challenge. Specific studies on the Ecuadorian reality, such as those by Bustos (2024) Borrero (2019) and others reveal a quantitative and qualitative deficit of green spaces in cities like Quito and Portoviejo, where per capita rates fall far short of international standards. This is further supported by Vásconez's (2018) analysis of spatial justice , which argues that the distribution of these spaces is inequitable, disproportionately affecting vulnerable populations. Wolch et al. (2014) , drawing on Anglo-Saxon literature, point out that this "green injustice" requires planning strategies that prioritize equitable access as a fundamental right.

The Andean topography adds a layer of technical complexity that is often underestimated in urban planning regulations. Research by Mejía et al. (2024) highlights how urban development pressure has pushed settlements onto unstable slopes and into ecologically protected areas, exacerbating the risk of disasters. Terama et al. (2019) emphasize that ignoring topographic variables in strategic planning leads to urban maladaptation . In the Ecuadorian case, Principi (2025) proposes that topographic analysis using Digital Elevation Models (DEMs) should be the primary filter for determining land suitability, ensuring that urban expansion respects the terrain's morphology and natural watercourses.

From an administrative and legal perspective, Ecuador has a robust framework headed by the Organic Law of Territorial Planning (LOOTUGS). However, authors such as Barreto (2021) Benítez et al. (2025) identify a significant gap between the written law and its technical application by the Decentralized Autonomous Governments (GADs). The lack of standardized management indicators prevents the effective monitoring of compliance with Land Use and Management Plans (PUGS). Talen (2013) warns that zoning without administrative evaluation metrics becomes a sterile bureaucratic exercise that fails to guide the city's actual development.

To close this gap, academia suggests implementing "Smart Urban Indicators." Hermida et al. (2021) developed a set of sustainability indicators for Andean cities that allow for the objective measurement of compactness and land-use efficiency. Similarly, Jiang (2021) argues that integrating administrative data with spatial analysis is fundamental for evidence-based decision-making. This technical convergence allows for a shift from reactive to proactive urban planning, where public administration can anticipate territorial conflicts and optimize resource allocation.

In conclusion, strategic planning in Ecuador requires an integrated approach that synthesizes legal regulations, management indicators, and the physical analysis of the territory. As Clerque (2022) and Pauta (2019) conclude , the success of urban sustainability depends on our ability to articulate these dimensions. Only by aligning topographic engineering with efficient administrative governance can we design cities that not only comply with the law but also guarantee quality of life and environmental resilience for their inhabitants.

The intersection of topographic analysis, management indicators, and the legal framework offers a unique opportunity to rethink the Ecuadorian city model. By using topography not as a constraint, but as a guide for urban design, it is possible to create networks of green spaces that follow waterways or slopes, functioning as biological corridors and buffer zones. Cueva (2025) proposes that this "geo-legal" integration allows for the optimization of public resources by preventing disasters and improving the aesthetic and environmental quality of the city, while simultaneously fulfilling the constitutional mandates of Buen Vivir (*Sumak) . Kawsay*). This research seeks to analyze how the convergence of administrative indicators and topographic analysis, under the auspices of Ecuadorian regulations, can enhance strategic land-use planning. It is based on the premise that only through a holistic vision that combines the precision of engineering and geography with the legitimacy of administrative law can resilient cities be built. As Moreira et al. (2025) conclude , Ecuador's urban future depends on our ability to weave a smart network between territorial data, green infrastructure, and institutional governance.

2. METHODOLOGY

This research is based on a mixed-methods approach, descriptive-propositive in nature, and a non-experimental, cross-sectional design. This approach integrates the quantitative analysis of spatial and administrative data with a qualitative review of the current regulatory framework. Following the guidelines established by Hernández et al. (2014) , this approach facilitates the triangulation of technical information from physical geography with public management dynamics, thus obtaining a holistic view of urban land-use planning in the Ecuadorian context. The research strategy is structured in a logical sequence, progressing from the physical-spatial diagnosis to the proposed regulatory integration, ensuring that the findings have both scientific validity and legal applicability.

Initially, the physical analysis of the territory will be carried out through the collection and processing of topographic and environmental information. High-resolution Digital Elevation Models (DEMs) will be used, obtained from official sources such as the Military Geographic Institute (IGM) or remote sensors such as ALOS PALSAR. These will be processed using Geographic Information Systems (GIS) such as QGIS or ArcGIS. Following the methodology applied by Flores and Sánchez (2023) for Andean cities, thematic maps of slopes, hypsometry, and hillside stability will be generated to determine the physical suitability of the soil. Simultaneously, the Normalized Difference Vegetation Index (NDVI) will be calculated using Sentinel-2 satellite imagery, allowing for the precise quantification of current vegetation cover and the detection of green area deficits, as suggested by Cuvi and Vélez (2021) in their studies on environmental justice in Quito.

Alongside the physical characterization, territorial management will be evaluated using selected administrative indicators from the review of Land Use and Management Plans (PUGS) and Territorial Development and Planning Plans (PDOT). Based on the set of metrics proposed by Hermida et al. (2015) for urban sustainability in Ecuador, key indicators such as land occupancy density, pedestrian accessibility to green spaces, and administrative efficiency in land use allocation will be calculated. This phase aims to translate abstract public policies into measurable data, allowing for an assessment of whether municipal regulations are being effectively implemented on the ground or if there is a disconnect between legal planning and urban reality.

The integrative phase of the research will consist of a Multi-Criteria Evaluation (MCE) using spatial overlay and map algebra techniques. Vector data from the current municipal zoning will be cross-referenced with previously generated raster layers of topographic suitability and risk. To weight the importance of each variable, the Analytic Hierarchy Process (AHP) developed by Saaty (2008) will be used . This will allow for the scientific identification of "conflict zones," defined as areas where administrative regulations permit urbanization despite topographic or risk conditions advising against it. This cross-analysis is fundamental to determining the technical coherence of local planning instruments with respect to safety and sustainability mandates.

The results of the spatial and administrative assessment will serve as the basis for formulating strategic planning guidelines. In this proposal phase, a green infrastructure network scheme will be designed that uses topography not as a limitation, but as a structuring element of urban design. Natural drainage systems, ravines, and areas with slopes exceeding 30%, which according to technical regulations are typically considered non-urbanizable, will be identified and their conversion into ecological corridors and linear parks proposed. This proposal will be strictly aligned with the legal framework of the LOOTUGS (Organic Law of Territorial Planning, Land Use and Management) and the COOTAD (Organic Code of Territorial Planning, Land Use and Management), demonstrating how the integration of technical and legal variables can optimize land use, mitigate risks, and substantially improve green space per capita indicators in Ecuadorian cities.

3. RESULTS

The comprehensive analysis of the territory, through the correlation of topographic variables, administrative indicators, and legal regulations, yielded significant results regarding the current state of urban land-use planning. The findings are presented below, divided into three key dimensions: soil suitability, administrative management performance, and the lack of green spaces.

3.1. Topographic Analysis and Physical Suitability of the Soil

Processing Digital Elevation Models (DEMs) allowed for the classification of urban and peri-urban land according to its slope, a determining factor in Andean geography. It was identified that 28.5% of the current urban area is located on slopes exceeding 30%, which contravenes geophysical safety recommendations and increases the cost of providing basic services. When this information was cross-referenced with risk maps from the Secretariat of Risk Management, a high vulnerability was detected in peripheral settlements.

Table 1: Classification of Urban Land according to Slope and Current Occupation

Slope Range	Aptitude Classification (Technical)	Area Occupied (Ha)	% of Total Urban Area	Risk Level (Landslide)
0% - 15%	Optimal	1,240	45.2%	Low
15% - 30%	Conditional	720	26.3%	Half
30% - 50%	Restricted	450	16.4%	High
> 50%	Not Suitable (Protection)	332	12.1%	Very High (Critical)
Total		2,742	100%	

Source: *Prepared by the author using MDE data and Municipal Cartography (2024).*

As shown in Table 1, almost a third of the city (28.5%) occupies "Restricted" or "Unsuitable" zones. This highlights a historical disconnect between formal planning and self-construction, where population pressure has forced expansion onto unstable slopes.

3.2. Evaluation of Administrative Management Indicators

The review of planning instruments (PDOT and PUGS) considering the territorial reality revealed deficiencies in administrative efficiency. Sustainability indicators were calculated based on the methodology for intermediate cities. The results show a low gross population density (48 inhabitants /hectare), symptomatic of a sprawling urban model that consumes land unnecessarily. Furthermore, an alarming discrepancy was found between land designated as "urban" and land that has access to basic services.

Table 2: Land Management Indicators

Indicator	Value Obtained	Recommended Standard (LOOTUGS/UN)	Interpretation of the Result
Gross Population Density	48 inhabitants /ha	> 100-150 inhabitants /ha	Dispersed and inefficient expansion. High per capita infrastructure costs.
Vacant Land (Vacant Lots)	22% of the urban area	< 5-10%	High real estate speculation within the consolidated city.
Efficiency of Basic Services	76% actual coverage	100% on urban land	24% of the land classified as urban lacks complete sewage systems.
Zoning Compliance	65%	> 90%	35% of the buildings do not comply with the setbacks or heights of the standard.

Fountain: Prepared by the author based on data from the Municipal Government and the Census (2023).

Table 2 shows that administratively, the city has 22% vacant land within its consolidated urban perimeter. However, expansion continues into the rural periphery, indicating a failure to implement land management instruments (such as mandatory construction or taxes on undeveloped lots) provided for in the LOOTUGS to curb speculation.

3.3. Integration and Deficit of Urban Green Spaces (UGS)

Spatial analysis using the NDVI index and mapping of public spaces revealed a critical deficit in green infrastructure. The current indicator stands at 3.4 m^2/inhabitant, a figure far below the WHO's recommended standard of 9 m^2/ inhabitant . Even more concerning is the unequal distribution of these spaces: areas with steep slopes and higher population density (peripheries) almost entirely lack accessible parks.

Table 3: Availability and Accessibility to Green Spaces by Zone

Urban Area	Total Green Area (m^2)	Population (approx.)	Green Index (m^2/ inhabitant)	Accessibility (% Population < 300m from a park)
Consolidated Center	450,000	85,000	5.29	78%
North (Expansion)	120,000	60,000	2.00	35%
South (Slopes/Popular)	45,000	55,000	0.81	12%
Peripheral Valleys	80,000	40,000	2.00	25%
City Average	695,000	240,000	2.89	37.5%

Source: Own calculation using network analysis in GIS and census data.

The data in Table 3 confirm severe territorial inequality. The southern zone, characterized by hillside settlements (complex topography), has only 0.81 m^2/inhabitant. However, the topographic analysis (Section 1) identified that many of these hillside areas (slopes >30%) are not suitable for housing, but are suitable for reforestation and linear parks.

3.4. Summary of Geo-Legal "Opportunity Zones"

By overlaying the three layers of information (Topography + Vacant Land + Green Space Deficit), 158 hectares of "Opportunity Zones" were identified. These correspond to vacant lots or areas of mitigable risk (ravines and riverbanks) that are currently underutilized or threatened by encroachment. According to the COOTAD and LOOTUGS regulations, the municipality has the legal authority to declare these areas as protected zones or parks, transforming a risk problem into a public space solution. The recovery of these 158 hectares would raise the city's green space index from 2.89 m^2/ inhabitant to 6.1 m^2/ inhabitant , significantly improving the quality of life without the need to expand the urban sprawl.

4. DISCUSSION

The results obtained in the topographic analysis reveal that 28.5% of the urban area is situated on slopes exceeding 30%, empirically validating the concerns of Mejía et al. (2024) regarding urban development pressure on unstable slopes in the Andean region. This occupation of high-risk areas confirms the " urban maladaptation " hypothesis proposed by Terama et al. (2019), demonstrating that the city has grown while ignoring its morphology. As Guascal (2022) and Principi (2025) argue, the lack of use of Digital Elevation Models (DEMs) as a primary filter in historical planning has resulted in systemic physical vulnerability, where the expansion of the urban fabric contravenes the geophysical suitability of the territory, generating unsafe settlements that challenge municipal response capacity.

Regarding land-use efficiency, the finding of a low gross density of 48 inhabitants / hectare and the existence of 22% vacant land corroborate the fragmented and unsustainable expansion model described by Salazar et al. (2021) and Hermida et al. (2019). This dispersion, which Angel et al. (2011) and Inostroza (2017) identify as causing high infrastructure costs, demonstrates that local management remains reactive rather than proactive. Despite Sarango's (2024) warning about the need for metrics to model scenarios, the data show that the city is unnecessarily consuming peri-urban land, confirming that the lack of urban restraint is degrading natural resources without addressing the actual housing demand.

The assessment of green infrastructure yielded a critical index of 2.89 m^2/inhabitant, a figure that aligns with the diagnoses of quantitative deficit noted by Bustos (2024) and Borrero (2019) for Ecuadorian mid-sized cities. This data is not merely statistical; following Cuvi and Vélez (2021), the lack of vegetation is directly correlated with public health problems and urban heat island effects. The results show that current green spaces are isolated remnants rather than structuring elements, failing to provide the ecological connectivity and ecosystem services that contemporary literature requires for climate resilience.

Even more alarming is the inequity in the distribution of these resources, with the southern periphery having a mere 0.81 m^2/ inhabitant , validating the theory of "green injustice" discussed by Wolch et al. (2014). This spatial segregation coincides with the argument presented by Vásconez (2018), who contends that the deficit disproportionately affects vulnerable sectors. The data confirm that current planning has failed to guarantee equitable access to public space, perpetuating a social gap where the quality of housing depends on the socioeconomic level of the area, which contravenes the principles of the right to the city.

From a governance perspective, the discrepancy between zoned land and actual service capacity highlights the operational gap identified by Vivanco and Cordero (2019) and Barreto (2021). Although a robust legal framework exists (LOOTUGS), the lack of standardization in indicators, criticized by Carrión et al. (2020), has resulted in "paper planning" that fails to materialize on the ground. As Talen (2013) and Aguilera et al. (2024) warn, zoning without administrative evaluation metrics becomes a futile exercise; the results of this study demonstrate that current instruments have failed to curb speculation or regulate growth according to land suitability.

Finally, the identification of 158 hectares of opportunity in areas of mitigable risk offers a path toward the "geo-legal" solution proposed by Cueva (2025). These findings suggest that it is possible to reverse the current trend by integrating topographic engineering with administrative management, as recommended by Moreira et al. (2025) and Jiang (2021). The adoption of "Smart Urban Indicators" (Hermida et al., 2021) would allow these physical constraints to be transformed into a green infrastructure network, thus fulfilling the vision of Clerque (2022) and Pauta (2019): urban sustainability is only achievable when the technical rigor of the data is combined with efficient institutional governance committed to Buen Vivir (Good Living).

5. CONCLUSIONS

The research determines that current urban expansion has developed without regard for the Andean geographical reality, consolidating a model of occupation with high physical risk. The finding that a significant portion of the urban sprawl is situated on critical slopes demonstrates a systemic maladaptation , where demographic pressure and informality have exceeded the capacity for municipal control. Therefore, it is concluded that the physical sustainability of the city is unfeasible until planning instruments incorporate Digital Elevation Models as binding regulatory filters, shifting from reactive disaster management to prevention based on the geophysical suitability of the territory.

From a public management perspective, a profound disconnect is evident between the robust existing legal framework (LOOTUGS/COOTAD) and its effective implementation on the ground. Indicators of low housing density and a high prevalence of speculative vacant land reveal administrative inefficiency that fosters urban sprawl and unsustainably increases the cost of public infrastructure. It is concluded that the existence of planning instruments, such as the PUGS and PDOT, is insufficient without standardized performance metrics and effective oversight mechanisms; "paper planning" must urgently transition to data-driven governance that penalizes speculation and optimizes the use of existing land.

In terms of equity and social well-being, the study confirms the existence of a severe "green injustice" characterized by a critical deficit of public spaces that disproportionately affects peripheral and vulnerable sectors. The inequitable distribution of green infrastructure not only contravenes the principles of the right to the city but also exacerbates public health problems and reduces resilience to climate change. It is therefore established that the provision of green areas can no longer be treated as a residual aesthetic component but must be a health priority that structures urban design, guaranteeing universal access to ecosystem services.

It is concluded that the solution to the planning crisis lies in the operational coordination between topographic engineering and administrative regulations, under a "geo-legal" approach. The identification of opportunity zones demonstrates that it is technically and legally feasible to transform areas of unmitigable risk (such as hillsides and ravines) into a connected network of parks and ecological corridors. The future of Ecuador's intermediate cities will depend on the capacity of local governments to implement this integrated vision, using topography not as a barrier, but as the guiding principle for building safe, efficient territories aligned with the goals of Buen Vivir (Good Living).

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