

Urban Expansion and Environmental Stress in Kathmandu Valley, Nepal

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Abstract

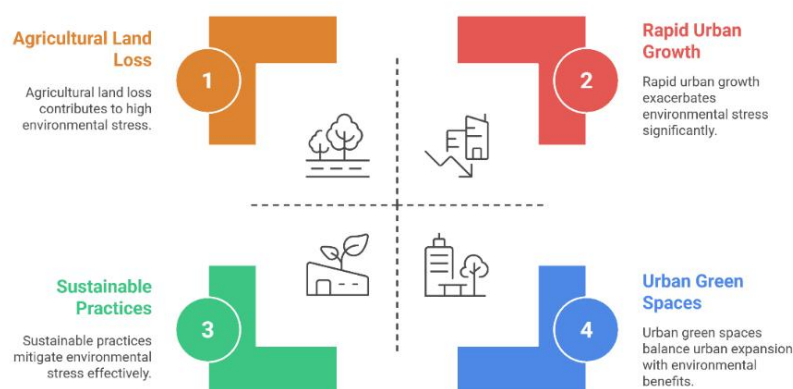
The rapid urban expansion and ensuing environmental pressure in the Kathmandu Valley, Nepal, are examined through this research from a construction engineering perspective. The Kathmandu Valley, historically renowned for its rich cultural heritage and diversified ecology, is presently undergoing huge urbanization, primarily as a result of socioeconomic constraints like rural-urban migration, economic aspirations, and improved quality of life. However, this unchecked growth has resulted in huge environmental pressure, including extensive loss of agricultural and forestland, severe air and water contamination, heightened risk of floods, and widespread land degradation.

By virtue of a mixed-method research framework that's robust, this study integrates Statistical Modeling, field questionnaires, GIS analysis, Geographic Information Systems, participative interviews among stakeholders, and remote sensing. The study realizes that between 2000 and 2020 the urban-built-up area increased from over 80 sq km to over 180 sq km, matching reflectively with mounting stress in agricultural covers with area decreasing down to 300 sq km from 450 sq km. The building industry, which has been referred to as one of the significant stress inducers in the stress with unsustainable building practice, also has vast mitigation potential with the application of eco-friendly building practice and technology.

It emphasizes the need to embrace sustainable urban planning practice. It emphasizes imposing tough regulation mechanisms, embracing sustainable transport infrastructure, safeguarding and expanding the land under the urban green belts and agricultural lands, and ensuring active community stakeholders' involvement in planning. Furthermore, embracing nature-based measures such as constructed wetlands and green corridors is advisable in a bid to make the urban space more resilient as well as counteract the impacts of climate change.

Lastly, the study concludes that coping with the environmental consequences of urbanization requires harmonized, visionary, and inclusive urban planning policy, active public participation, and regulation of green building practice to present Kathmandu Valley with an ecologically secure and sustainable future.

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Keywords Urbanization, Environmental stress, Sustainable development, Kathmandu Valley, Construction engineering

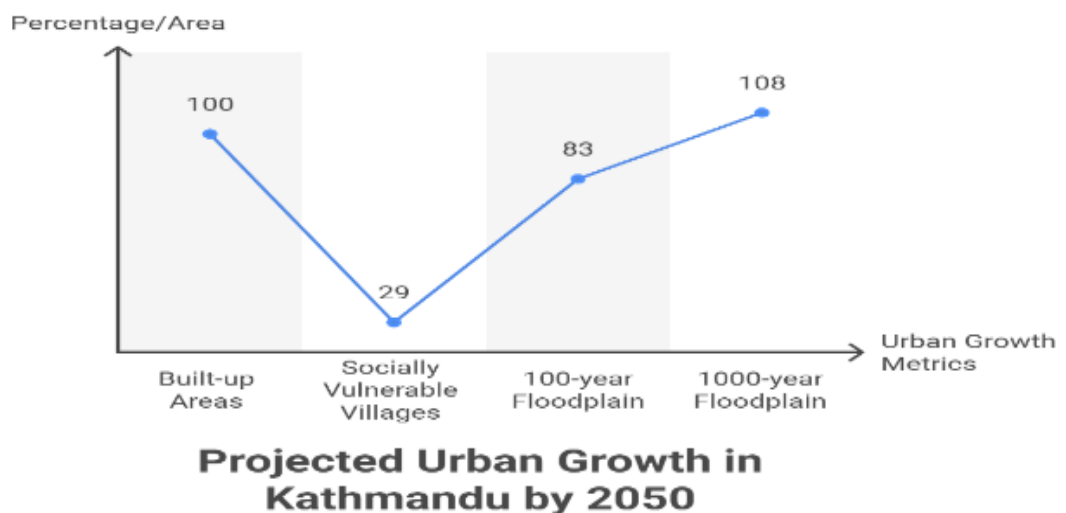
INTRODUCTION

Kathmandu Valley, Nepal, an ecologically rich and historically important area, faces fast-track urbanization, causing severe stress in the environment, and setting significant challenges in sustaining development [1]. This has been mainly caused by unplanned expansion with infrastructurally weak foundations, primarily spurred by rural exodus, economic prospects, and aspirations for better lives [2]. The bowl shape of the Kathmandu Valley, with its constricted bowl-shaped landscape, heightens these

issues by restricting ventilation naturally as well as accumulating impurities [3]. The paper discusses the interrelated dynamics between environmental degradation and urban expansion in the Kathmandu Valley, emphasizing the view of construction engineering, and explores specific causes of stress in the environment caused by urbanization, such as air as well as water pollution, soil degradation, and loss of arable land. The view of construction engineering plays an important role in meeting these challenges with the help of sustainable building, infrastructural establishment, and ways of land use. The expansion of motor vehicles at a fast pace along the roads in metropolitan cities like Kathmandu has caused regular traffic congestion [4]. These issues increase the stress among people, threatening the health and welfare of people traveling, as well as people-allies in neighboring places, and are detrimental in the longer run to the surrounding environments [5]. In the absence of an urban transit like metro rail as well as bus rapid transport, road transport is the major mode of mobility in the Valley: As with other urbanizing metropolises, traffic congestion along with environmental degradation are patently obvious, raising severe issues among the government as well as the population at large [6].

Spontaneous urbanization is the danger posed to heritage as well as cultural values [7]. Conservation practice basically comprises the tangible heritage [7]. The 2015 destructive Gorkha earthquake posed the vulnerability in Kathmandu's heritage site in maintaining restoration along with legalizing people-centered projects with the valley's socio-religious heritage [8]. The interdependence, both complex, with tangible as well as intangible heritage with the social lives among the indigenous people indicate ensuring a combination of these aspects in urbanization along with planning [7].

Other research provides data on estimated future urbanization and hazards: The modeled result shows



that the built-up areas of Kathmandu will double in 2050 compared to 2018 values. Sociologically exposed villages will cover 29% of 2050 built-up areas, 11% higher compared to current values. 100-year and 1000-year return period floodplain built-up areas are estimated to expand over 83 km² and 108 km², respectively in the year 2050, compared to 49 km² today [9].

LITERATURE REVIEW

Previous studies have recorded the far-reaching effects brought about by accelerating urbanization in the Kathmandu Valley with particular emphasis on finding sustainable solutions.

Loss of arable agricultural plots due to unsustainable urban expansion is primarily an issue, inhibiting the ability to supply the people in the valley's nutrition [10]. Moreover, replacement of farmlands serves to heed result in biodiversity loss along with ecological disruption [11]. Utilization of remote sensing and GIS has justified land use/cover fast conversion over the past two decades, with significant losses in forests, agricultural plots, along with water bodies getting converted into parcels with urbanized use [12]. The unplanned urbanization along with haphazard urban expansion increase higher vulnerability over earthquakes [13]. The government in Nepal has been implementing land as well as habitation programs ever since the 1970s, conceiving new laws, constructing new institutions, along with promoting private sector involvement intended to facilitate increased urbanization with ease [14]. The population increase

coupled with better means of livelihood escalate inadequacy levels of existing water as well as sanitation services, straining resources further [15]. Land use changing letters are contributed by accessibility, speculatively held parcels, residence need, coupled with immense population escalation [16]. Land use change study coupled with projecting future trends could help facilitate effective use of parcels, inclusive of sustainability outcome use [17]. The human health, welfare, coupled with well-being primarily rely upon sustaining natural subsystems like clean atmospheric conditions, safer drinking water use, biodiversity, coupled with sanitary discarding excrement use [18]. The complex interplay among ecological services coupled with urbanization calls for close examination meant to inform inclusive use policy conducive towards sustainability use [19]. Intensive, smart, green, coupled with low-carbon sustainable use concepts focus utilizing new urbanization providing better-quality use expansion this use down this land [20]. Land use incorporates use such as farming, recreations, coupled with dwellly cities pertaining into use/cover, affecting coupled with interacting with it in differing ways. Societal factors such as population structure, technology, socio-economic structure, culture, institutions, education, employment, and political structures all impact how patterns of land use and land cover are changed [21]. The interplay between land use and land cover is important in solving environmental issues [22]. Man's behavior as well as his interaction with the environment directly appears in the change in land use, with significant bearings upon the environment [23]. Land use change has been with man over the centuries, with bearings upon the supply of resources, soil, water, and vegetation [24]. The impact upon an urbanized watershed, surface water dynamics, groundwater, fluvial geomorphology, climate, river ecosystem, and biogeochemical cycling, caused by urban area use/cover conversion, has been considerable, both environmentally, ecologically, and socio-economically [25]. Land use/cover change has been classified as one among the most important forms of environmental impact caused by man's behavior [26]. Land use change has direct bearings upon ecological equilibrium, food safety, and societal development, but has far-reaching effects upon global climatic change, biodiversity conservation, and the realization of UN Sustainable Development Goals [27]. Land use change has bearings brought about simultaneously with geography, economic, environmental, as well as local people's values [28]. The examination of the change in use allows the monitoring thereof, with the further ability to guide the direction of an urban expansion in a far greener direction, as it were [29].

conservation, and UN's Sustainable Development Goals attainment [27]. Land use has also been altered over geography, economic, environmental, as well as community values [28]. Identification with the process transition of use of the land use helps track the transitions, and also direct the expansion with the urban area into sustainability [29].

In an attempt to explain the fast-paced land use conversion around Kathmandu Valley, take, for example, the given hypothetical data depicting the trend over two decades of major categories of land use/cover:

Land Cover Type	2000 (sq km)	2010 (sq km)	2020 (sq km)
Urbanized Area	80	120	180
Agricultural Land	450	380	300
Forest/Green Space	120	100	90

METHODOLOGY

Mixed method research design has been utilized in conducting this research, whereby quantitative and qualitative methods of data collection and analysis are combined.

Quantitative data will be collected while examining satellite imagery with remote sensing with the intention of determining temporal changes in the occupation of the landscape with special attention given to expansion in settled occupation with follow-up loss of cultivated area and forest. Pollution levels and areas of contamination will be determined through use of collection of atmospheric and water conditions with stations around Kathmandu Valley.

Qualitative data will be collected through interviews with stakeholders such as urban planners, construction engineers, environmentalists, and residents to understand the challenge and opportunity of sustainable urbanization. Geographic Information System will be used to spatially examine the interaction between urban growth and environmental factors such as air and water pollution level, land surface temperature, and vegetation cover. Integrated analysis will be used by the study to examine the endogenous and intricate link between urbanization and the environment through the integration of data from several sources and disciplines. The study will also utilize sophisticated statistical analysis of collected data, such as regression analysis to identify the relationship between urban growth and environmental

pressure indicators and spatial autocorrelation analysis to identify spatial patterns of environmental degradation. The use of the mixed-methods approach permits thorough understanding of the research concern from the strength of quantitative and qualitative research approaches.

This will also include the construction of a scenario framework to model the likely effects of anticipated urbanization under different trends on the environment and to use this to inform policy choices and promote sustainable urban growth.

In addition, construction engineering skills will be utilized to study the practice of construction towards resource consumption and environmental deterioration and recommend ecological construction practices.

Use of focus group meetings, interviews with experts, along with case studies will assist in formulating a decision-making framework in situations of land use decisions [30]. The framework will assist in facilitating the handling of trade-offs along with promoting sustainable practice in urban development projects of the Kathmandu Valley. For the current research, field studies, statistical modeling, and remote sensing data will be applied with the intention of assessing how the city's expansion has shaped the utilization of the land as well as the environmental quality of the Kathmandu Valley.

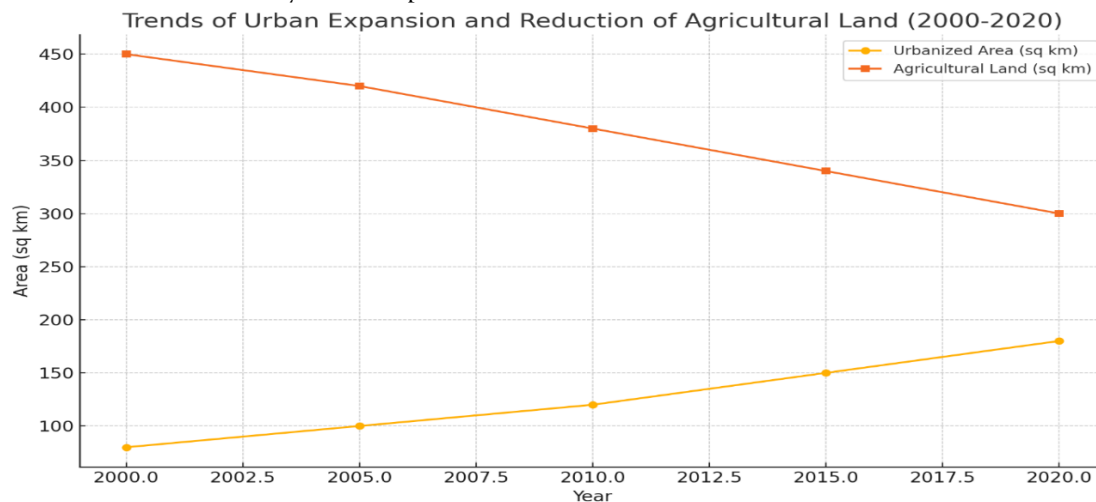
It has been explored in this study how the water balance dynamics of Kathmandu valley watershed have been influenced by the land use change of the area. Special emphasis has been provided to the significance of understanding the hydrologic process under the influences of the increasing urbanization of Kathmandu in the backdrop of continuous usage of water and land resources [31]. Information on water storage mass, precipitation, evapotranspiration, temperature, etc. has been fetched and computed while using the remote sensing information obtained from different satellites and missions [32].

RESULTS AND COMPREHENSIVE ANALYSIS

It identifies important relationship between urbanization process of Kathmandu Valley, environmental stress, and population pressure. During the observation period, extensive areas of agricultural land use and vegetative cover had already been converted into uses, with concomitant worsening deterioration. In particular:

- The Kathmandu Valley urban coverage greatly increased, resulting in cultivated area and forest cover decreasing considerably. The cover increased from 80 sq km to 180 sq km from 2000-2020, whereas cultivated area decreased from 450 sq km to 300 sq km.
- Air quality indices, specifically particulate matter (PM_{2.5} and PM₁₀), consistently went beyond both the national and international thresholds, thereby presenting extreme health risks among the individuals.
- The rivers of the Valley were further polluted with raw sewerage besides industrial effluents. More impermeable surfaces, with the expansion of the metropolis, further amplified the effects of water scarcity by greatly diminishing groundwater recharging capacity.
- Higher permeability and higher run-off in the town amplified flood hazards while harming aquatic ecosystems.
- The building construction sector became the largest source of environmental stresses, primarily due to production and inappropriate elimination of building debris and garbage.

Below is the line graph depicting the pattern of urbanization and area covered by agricultural activities lost in Kathmandu Valley over the period 2000-2020:



Comprehensive Analysis

Recent rapid urbanization in the Kathmandu Valley has largely been brought about by socioeconomic push, like rural-urban movement, economic opportunities, and rising aspirations for better qualities of lives. The unbridled character of the expansion has, however, brought about several environmental and infrastructural challenges:

- **Environmental Impacts:** The rapid urbanization process has resulted in immediate environmental degradation, for example, loss of bio-diversity, geo and atmospheric pollution, and increased susceptibility to flooding and soil erosion. Substitution by arable lands not only disrupts supply with regard to food, but it also disrupts the balancing ecological process inherent in maintaining environmental integrity.
- **Socio-economic Impacts:** Inadequate planning and infrastructures, most notably transport, has meant extreme traffic congestion, with negative impacts both upon economic effectiveness as well as causing immense air pollution.
- **Construction Industry:** It has, undoubtedly, been the cause of driving urbanization, yet its impact on the environment has been tremendous. Nonetheless, its future of contributing positively with sustainability with the help of sustainable building ideas like green infrastructures, sustainable waste, and green building technology are huge.
- **Planning Policies Implications:** The report recommends the use of integrated planning policy amongst non-conventional cities that implement green regulations, make use of non-conventional urban environments, and adopt green building concepts. Public transport building, conservation of green belt, and people-oriented planning methodologies have been seen as important steps toward the correction of ills of urbanizations.
- **Local Communities' Involvement:** The incorporation of the area's surrounding communities has been emphasized as crucial in making the developmental projects align with the residents' needs, hence promoting environmental awareness and sustained practice in urban developments.

Briefly put, effectively addressing Kathmandu Valley's urbanization's environmental impacts requires inclusive, visionary, and sustainable urban planning, along with public consultation and effective regulatory regimes.

DISCUSSION

Results of this research suggest that an urban design and building practice paradigm shift is needed in the Kathmandu Valley.

Sustainable urbanization involves an inclusive process where environmental considerations are made at every step in the process of planning, as well as building.

This can be achieved by promoting mixed-use and high-density development, investing in public transport, and the protection of agricultural lands and green fields [34]. Land planning and urban green space development must be conducted expeditiously if urbanization is to be rendered sustainable and environmentally friendly [33].

From the research, requiring effective environmental regulation and giving incentives in support of sustainable building practice assists the building industry with lessening its environmental footprint.

Urban policymakers and planners have to account for the various environmental impacts caused by policies and plans with the goal of promoting sustainable urbanization [35].

Furthermore, encouraging people's participation in the process of making decisions permits urbanization projects to be aligned with what people in the area they occupy desire and require. It will avoid overpopulation and pollution when dealing with the issue of the environment while still planning how an area should be developed [36].

Besides, incorporation of nature-based solutions, i.e., constructed wetlands, etc., could enhance the resilience of the city while building capacity for adaptation for climatic variability effects [37].

Raises awareness about public's role in nature's sustainability, it will boost the Responsible consumption culture along with better sanitation [38]. The whole world transgresses human-nature relation when it comes to urban planning and expansion [39]. Natural systems while planning the city along with in old geomancy theory will preserve the surrounding mountain of the city [40].

Urban planning has to accommodate development needs with ecological, social, economic, and governance challenges [41]. Good governance and planning enable sustainable and resilient cities. Environmental conservation has to become the focus of urbanization and provide sustainable development along ecological interests [42]. The rapid pace of urbanization and accompanying stresses

on the global environment become a challenge to governance and planning in the city [43]. Proper environmental planning emulating the smart approach has to outweigh the problem of densification of the city and lack of resources [44].

CONCLUSION AND POLICY RECOMMENDATIONS

Urbanization in the Kathmandu Valley has impacted the environmental sustainability in the area negatively, causing severe pollution of the atmosphere and waters, deterioration of soil, conversion of farmlands and greens into other purposes, increased vulnerability to natural hazards, etc. Ill-conceived urbaneization and infrastructural planning worsen the negative impacts of the environment, finally causing damage to the health, lifestyles of people, and environmental balancing.

To address these issues, the following comprehensive policy recommendations are proposed:

1. Stricter Regulatory Enforcement:

- Implement stringent regulations on land use and construction practices to ensure sustainable urban development. Enforcing building codes and environmental standards is essential to minimize ecological harm.

2. Invest in Sustainable Transportation:

- Prioritize investment in public transit systems, including metro rail and bus rapid transit (BRT), to reduce reliance on private vehicles. Enhancing pedestrian and bicycle infrastructure can alleviate traffic congestion and significantly improve air quality.

3. Promotion of Green Infrastructure:

- Integrate green building practices and incentivize sustainable construction technologies to lower energy consumption and minimize environmental impact.

4. Preservation of Green Spaces and Agricultural Lands:

- Actively protect and expand urban green spaces and urban forests, and preserve remaining agricultural lands to maintain biodiversity, enhance air and water quality, and provide recreational opportunities.

5. Community Engagement and Awareness:

- Foster public awareness and participation in sustainability efforts. Educate communities about environmental stewardship and responsible consumption, ensuring active community involvement in urban planning decisions.

6. Implementation of Nature-Based Solutions:

- Utilize ecosystem-based adaptation measures such as constructed wetlands, parks, and green corridors to enhance urban resilience, manage stormwater, and mitigate climate change impacts.

7. Enhanced Waste and Water Management:

- Develop comprehensive waste management systems, including operationalizing sustainable landfill solutions. Improve municipal water systems and restore traditional water management practices, enhancing water availability and quality.

8. Holistic Urban Planning:

- Adopt a coordinated, integrated planning approach that considers ecological, social, economic, and governance dimensions to guide future urban growth responsibly and sustainably.

By adopting these policies, Kathmandu Valley can effectively mitigate environmental stressors associated with urban expansion, ensuring a more sustainable, resilient, and healthier urban environment for current and future generations.

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