

# ASSESSING INFRASTRUCTURE DEVELOPMENT AND URBAN SUSTAINABILITY IN THE ITANAGAR CAPITAL REGION: AN INTEGRATED GEOSPATIAL AND SECONDARY-DATA FRAMEWORK

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## ABSTRACT

Rapid urbanization in India's Himalayan state capitals has intensified infrastructure investment, yet whether such investment translates into spatially balanced and environmentally sustainable development remains inadequately examined. This study develops and demonstrates an integrated geospatial and secondary-data framework to assess infrastructure development and urban sustainability at the ward level in the Itanagar Capital Region (ICR), Arunachal Pradesh. An Infrastructure Development Index (IDI) comprising 23 indicators across seven dimensions and an Urban Sustainability Index (USI) comprising 19 indicators across five dimensions were constructed using Min–Max normalization and equal-weight aggregation, with environmental indicators derived from Sentinel-2, ESA WorldCover and MODIS imagery processed in Google Earth Engine. The two indices were classified into five ordinal categories and their relationship examined through Pearson correlation and simple linear regression. Across the 20 wards analysed, infrastructure development was strongly and positively associated with urban sustainability ( $r = 0.889$ , 95% CI [0.735, 0.955],  $p < 0.001$ ;  $USI = 0.233 + 0.505 \cdot IDI$ ,  $R^2 = 0.790$ ), yet the two indices diverged in class for eleven of twenty wards, and ward-level green cover was inversely related to infrastructure ( $r = -0.893$ ). Infrastructure was concentrated in the urban core while a green-cover sustainability floor persisted in the periphery, indicating that infrastructure-led development is necessary but not sufficient for sustainable urban outcomes. The framework offers a transferable, low-cost tool for diagnosing intra-urban infrastructure inequality and infrastructure–sustainability linkages in data-scarce Himalayan cities.

**KEYWORDS:** infrastructure development index; urban sustainability index; geospatial analysis; Google Earth Engine; composite indicators; Himalayan urbanisation; Itanagar

## INTRODUCTION

Rapid and sustained urbanisation is transforming small and medium-sized capital cities throughout the Global South, and nowhere is this transformation more geographically constrained and less researched than in the mountain capitals of the Indian Himalayan Region (IHR). In the IHR, which covers an area of approximately 533,000 km<sup>2</sup> in 13 states and two hill districts, the urbanisation rate has been more than 40 per cent in the last 10 years, consistently outpacing the growth of water, sanitation, roads, drainage and solid-waste infrastructure provided by terrain-constrained local municipalities (Mitra, S., & Baruah, 2024). Ordinary challenges of providing infrastructure are exacerbated by fragile geology, steep slopes, seismic vulnerability and landsliding caused by the monsoon season; infrastructure deficits in Hindu-majority towns in the Himalayas are not just a matter of degree compared to plains towns but a planning challenge that requires a diagnosis at the ward level, based on terrain (Rimal & Rijal, 2025).

Infrastructure has always played a pivotal role in both urban and regional development theories. (Aschauer, 1989) has demonstrated that public infrastructure is a productive form of capital which raises the output of the private sector, and (Krugman, 1990), with the help of the New Economic Geography, has proved that public infrastructure can reduce transport costs and lead to spatial concentration of economic activity. These basic contributions focus on infrastructure as an engine of economic efficiency, rather than on the sustainability of the economic growth it delivers in terms of environmental, distributional, and shock resilience. Over the years, this "efficiency first" argument has been demonstrated again and again. Infrastructure that is durable, spatially dense, and hard to retrofit can easily reinforce and exacerbate inequities as much as it can solve them, using infrastructure indices derived from nighttime light data in India and South Africa, showed that infrastructure inequality is a stable urbanisation trait and not a transitional artefact, as inequalities are

greater at the regional scale compared to the intra-city scale, motivating the report at the ward-level rather than the city-level (Pandey, Brelsford, & Seto, 2022).

A parallel and growing line of enquiry asks what the ecological and climatic consequences of infrastructure development will be and whether it is compatible. This is particularly pertinent in the context of mountain environments. Comparative land-use studies of the cities in the Himalayas reveal that infrastructure-led unplanned growth is systematically linked to a loss of green and open space—built-up area at Srinagar has increased by almost double its share of the municipality area in last 20 years; whereas a longitudinal study based on satellite data of the Kathmandu and Pokhara metropolitan areas shows that urban growth has surpassed 400 percent and 250 percent respectively over the past four decades, with a significant contribution coming from encroachment of forest, agricultural and watershed land by infrastructure and real-estate development (Morshed et al., 2023). Similar effects have been described in Shimla, where road building for tourism is associated with deforestation and increased risk of landslides and water governance problems. Taken together, these findings indicate that infrastructure and sustainability in the Himalayan capitals are not a straightforward positive relationship; indeed, they could split up geographically, delivering services to the inner city and environmental costs to the outer.

There is, however, a growing body of literature, but there are three salient gaps for the current study. First, most of the infrastructure analysis and reporting is at the city or district level, and intra-urban-level heterogeneity (that shapes lived experience of access to services far more directly than city-averages) is comparatively under-measured, particularly outside large metropolitan India (Bhan, G., & Jana, 2015). Second, the often assumed causal or associative connections between infrastructure development and sustainability are not always analysed empirically in a reproducible and quantitative way, and if they are, they tend to lack satellite-derived information on the environment. Thirdly, although the institutional capacity of SMT cities is generally lower than that of the larger IHR cities, their topographic constraints are also as severe as those of the larger IHR cities; they are understudied (Sharma & Anand, 2025).

This study fills these gaps for the Itanagar Capital Region (ICR): (i) to develop an indicator-based Infrastructure Development Index (IDI) based on secondary statistics to assess the spatial pattern and level of infrastructure development for the ICR wards; and (ii) to investigate the empirical link between infrastructure development and urban sustainability using a parallel Urban Sustainability Index (USI) constructed from indicator-based environment derived from Sentinel-2, ESA WorldCover and MODIS satellite data processed in Google Earth Engine (Gorelick et al., 2017; Venter, Barton, Chakraborty, & Simensen, 2022). The study contributes to an integrated conceptual chain, in which infrastructure development is not a separate entity that is managed in isolation, but is instead interwoven with others such as spatial accessibility, urban sustainability and resilient urban development. It operationalises this chain with a transparent, low-cost, ward-level workflow that can be applied in other data-scarce Himalayan cities.

The rest of the paper is organised as follows: Section 2 reviews the theory and empirical evidence behind the relationship between infrastructure and sustainability, and contextualises the study within the realm of urban research in the Himalayas and India; Section 3 will detail the study area and discuss the data collection and the process for constructing the index; Section 4 will present the results of the analysis at the ward level; and Section 5 will discuss the implications for planning practice in the ICR and comparable urban capitals of the Himalayas.

## **2. RELATED WORK**

(Thacker et al., 2019) demonstrated that infrastructure choices today commit us to emissions and resource use and land-cover patterns for decades; they highlighted the need to consider infrastructure planning explicitly in relation to the Sustainable Development Goals and not just economic output. This logic is very transferrable to the capitals of the Himalayas, where infrastructure siting decisions are embedded in steep, eroding landscapes and constrained land areas, with the consequences for sustainability being particularly long-lasting and hard to undo. There has been significant empirical evidence over the last few years to support this equity issue.

(Cheshmehzangi et al., 2023) suggested that resilience thinking should not be added-on to the end of infrastructure planning processes, but be incorporated throughout the entire process. Landslides, flash floods and seismic activity regularly affect such hill settlements, including Itanagar, with severe impacts on infrastructure networks and a disproportionate burden on wards with the least baseline infrastructure provisioning in terms of reconstruction costs. Without inclusive governance, the technological and infrastructural investments could be expected to widen rather than close disparities, and to focus on the visible physical development at the expense of social inclusion, says (Datta, 2018). A recent evaluation of the India's Smart Cities Mission in 96 cities has found that scores on infrastructure capabilities are very unevenly distributed by urban size-class and region, and that this pattern is especially pronounced in the case of smaller and more peripheral cities, which are less likely to be targeted in national infrastructure development initiatives than larger-metropolitan centres, which are more likely to be targeted.

(Venkatesh & Velkennedy, 2026) identified and quantified intra-urban differences in urban infrastructure sustainability performance using machine learning clustering methods and stakeholder-weighted indicators across 55 wards of Tirunelveli City in India, showing significant intra-urban difference, even though the average score of the city was high, and were statistically identifiable between the northern and southern wards. The data, on a national scale, further reinforces

the fact that this is not a city-specific phenomenon, (Pandey et al., 2022) found that infrastructure inequality was a universal characteristic of Indian urbanisation and not a result of the failures of city governance.

Mitra and Baruah (2024) report that in IHR places, the planning models from plains cities often don't work in the mountains; and few IHR places have planning information from ward level, dis-aggregated by vulnerability.

There is a gap in research on the connection between infrastructure development and urban sustainability at ward level in the small Himalayan cities. Previous research typically has been based on city-level evaluations, potentially masking variation across regions on infrastructure provision and sustainability outcomes. This constraint is even more conspicuous in the data-poor areas of the Himalayan belt where urbanization is occurring at a quick pace, access is challenging, and development is uneven. The fact that Itanagar Capital Region is still under-researched and the lack of empirical evidence to integrate infrastructure and sustainability in a common spatial framework make this region a special concern. The present study thus aims to fill the gap by creating an IDI and an USI, and statistically analysing their relationship at the ward-level.

### 3. Study area

The Itanagar Capital Region (ICR) is the administrative and urban center of Arunachal Pradesh. It is located in the Papum Pare district in the Eastern Himalayas foothills of North-East India, roughly between 93.55° - 93.78° E and 27.03° - 27.18° N (Figure 1). The Itanagar Capital Region consists of twin urban centers of Itanagar and Naharlagun as well as adjacent settlements and has grown fast being the location of the state capital. The ICR territory is strongly dissected; it includes a narrow valley corridor with forested ridges and the region faces landslides, flash floods and earthquakes threats. All of these factors make the ICR an illustrative example where it is possible to study the relationship between infrastructure development and sustainability of the urban development process.

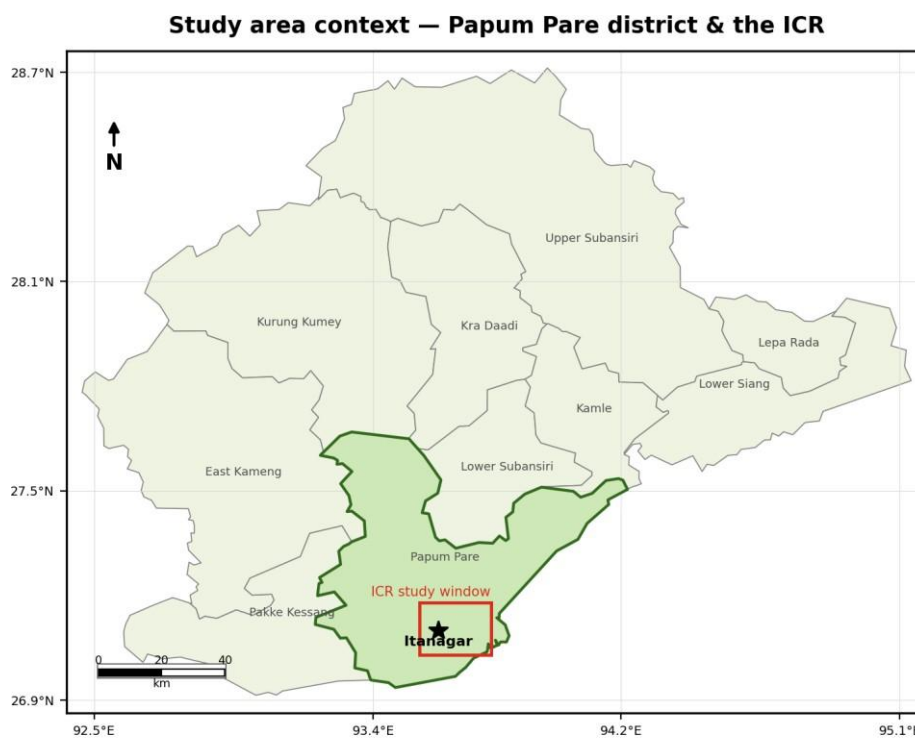


**Figure 1:** Study-area context. The Papum Pare district (green) containing the Itanagar Capital Region, shown among its neighbouring districts of Arunachal Pradesh, with the ICR study window (red) and Itanagar marked. District boundaries are from open Census-2011 district geometry.

## 4. MATERIALS AND METHODS

### 4.1 Analytical framework

The evaluation is based on two index values. First, the Infrastructure Development Index (IDI), which consists of 23 indicators classified into seven dimensions (transport, water and sanitation, energy, health, education, communication, and public services), and secondly, the Urban Sustainability Index (USI), which consists of 19 indicators classified into five dimensions (economic, social, environmental, institutional, and mobility) (see Table 1). The indicators and dimensions have been chosen so that they can be fully derived from secondary and remote sensing sources.

**Table 1: Indicator framework of the Infrastructure Development Index (IDI) and Urban Sustainability Index (USI).**

| Index | Dimension (indicators) | Representative indicators | Principal sources |
|-------|------------------------|---------------------------|-------------------|
|-------|------------------------|---------------------------|-------------------|

|     |                        |                                                                                    |                                    |
|-----|------------------------|------------------------------------------------------------------------------------|------------------------------------|
| IDI | Transport (5)          | Road density, connectivity, paved-road length, public transport, parking           | OSM, PWD, Master Plan              |
|     | Water & sanitation (4) | Water-supply, drainage & sewerage coverage, public water points                    | PHED, IMC, Census                  |
|     | Energy (2)             | Electricity coverage, street lighting                                              | Census, IMC                        |
|     | Health (3)             | Hospitals, PHCs, facility density                                                  | Health Department                  |
|     | Education (3)          | Primary/secondary schools, colleges                                                | Education Department               |
|     | Communication (2)      | Telecom towers, internet availability                                              | DoT, OSM, telecom reports          |
|     | Public services (4)    | Police, fire, parks/open space, solid-waste facilities                             | IMC, department records            |
|     | Economic (4)           | Household amenities, work participation, commercial establishments, service access | Census, IMC, GIS                   |
|     | Social (4)             | Literacy, school & health accessibility, population density                        | Census, departments                |
|     | Dimension (indicators) | Representative indicators                                                          | Principal sources                  |
|     | Environmental (5)      | Green cover, open space, drainage, waste collection, water bodies                  | Sentinel-2, WorldCover, MODIS, IMC |
|     | Institutional (3)      | Smart-City projects, municipal centres, e-governance                               | ISCDCL, IMC                        |

|  |              |                                                                         |          |
|--|--------------|-------------------------------------------------------------------------|----------|
|  | Mobility (3) | Road accessibility,<br>walkability,<br>public-transport<br>availability | OSM, GIS |
|--|--------------|-------------------------------------------------------------------------|----------|

#### 4.2 Data sources

Data sources include secondary data from Census of India (1991, 2001 & 2011), Itanagar Master Plan 2031, Itanagar Municipal Corporation (IMC), Itanagar Smart City Development Corporation (ISCDCL), Public Works Department (PWD), Public Health Engineering Department (PHED), and OpenStreetMap, supported by departmental data for health, education, police, and fire services. Environmental parameters were based on satellite data, which gave objective and continuous values of green coverage, open spaces, and water bodies, which could not be available at ward level.

#### 4.3 Satellite-derived environmental indicators

Environmental indicators were derived in Google Earth Engine. The green cover and NDVI indicator were calculated from cloud-filtered Sentinel-2 surface reflectance composite images; land cover fractions for forest, built-up areas, water bodies, bare and grasslands were acquired from ESA World Cover data; land surface temperature was derived from MODIS; and surface water fraction was acquired from JRC Global Surface Water product. Statistics per ward were derived through zonal reduction of each layer using ward geometry. In the area of ICR, these layers produced high green cover fractions (NDVI  $\approx 0.65 - 0.80$ ; forest  $\approx 80 - 99\%$ ), low built-up fractions ( $\approx 0.6 - 8\%$ ), and land surface temperature of  $22-25^\circ\text{C}$ , which is typical for a highly vegetated foothill landscape.

#### 4.4 Normalization and index construction

Since the selected indicators are expressed in terms of various units and scales, the selected indicators have been normalized into a scale of 0 to 1 through the application of Min-Max normalization technique. Normalization of the benefit indicators is done as follows:

For cost indicators, where lower values represent more favourable conditions, the transformation was reversed:

$$Z_{ij} = \frac{X_{ij} - X_j^{\min}}{X_j^{\max} - X_j^{\min}} \quad (1)$$

For cost indicators, where lower values represent more favourable conditions, the transformation was reversed:

$$Z_{ij} = \frac{X_j^{\max} - X_{ij}}{X_j^{\max} - X_j^{\min}} \quad (2)$$

where  $Z_{ij}$  is the normalized value of indicator  $j$  for ward  $i$ , and  $X_{j_{\min}}$  and  $X_{j_{\max}}$  are the minimum and maximum values of indicator  $j$ , respectively. In this way, high values of normalized indicators will always indicate better circumstances.

The normalized indicators were then classified into dimensions. The dimension score was obtained by computing the arithmetic mean of the indicators forming it:

$$D_{id} = \frac{1}{m_d} \sum_{j=1}^{m_d} Z_{ij} \quad (3)$$

where  $D_{id}$  is the score of dimension  $d$  forward  $i$ , and  $m_d$  is the number of indicators within that dimension.

The Infrastructure Development Index (IDI) and Urban Sustainability Index (USI) were then calculated as the equally weighted mean of their respective dimension scores:

$$I_i = \frac{1}{k} \sum_{d=1}^k D_{id} \quad (4)$$

where k is the number of dimensions making up each index. In this case, equal weighting was used in order to keep things clear and prevent any bias in assigning weights where there was no basis for doing so.

The indices are bounded between 0 and 1, and were categorized into five levels as follows: Very Low (0.00-0.20), Low (0.21-0.40), Moderate (0.41-0.60), High (0.61-0.80) and Very High (0.81-1.00).

#### 4.5 Statistical analysis

The association between infrastructure development and urban sustainability was investigated by employing the Pearson's product-moment correlation and simple ordinary least-squares (OLS) regression. The Pearson's correlation was applied to measure the magnitude and direction of linear association between IDI and USI:

$$r = \frac{\sum (IDI_i - \bar{IDI})(USI_i - \bar{USI})}{\sqrt{\sum (IDI_i - \bar{IDI})^2 \sum (USI_i - \bar{USI})^2}} \quad (5)$$

The relationship was further evaluated using the regression model:

$$USI_i = \beta_0 + \beta_1 IDI_i + \varepsilon_i \quad (6)$$

where  $\beta_0$  is the intercept,  $\beta_1$  is the regression coefficient, and  $\varepsilon_i$  is the residual error. The coefficient of determination ( $R^2$ ) was utilized to measure the percentage of variation in USI due to IDI. The statistical significance of the findings was established at 95% confidence level ( $p < 0.05$ ). Fisher's z-transformation was utilized to calculate the 95% confidence interval of the correlation coefficient.

#### 4.6 Data status and reproducibility

The following results represent a worked example of the analysis using the above framework on a twenty-ward illustrative dataset. The environmental variables are based on the Sentinel-2, ESA WorldCover and MODIS observations for the ICR, while the socio-economic and infrastructure

variables represent illustrative placeholders until the ward level secondary database is complete. The entire pipeline from satellite observation to correlation and regression analysis and mapping is contained in a documented and reproducible notebook which reproduces all the statistics and figures unaltered with the compilation of the ward database.

### 5 RESULTS

#### 5.1 Composite index construction

The IDI and USI were calculated for 20 wards. The values of the Infrastructure Development Index varied between 0.065 and 0.939 (average = 0.420, Standard Deviation = 0.261; Coefficient of Variation = 0.62), whereas the range of the Urban Sustainability Index lay between 0.200 and 0.729 (average = 0.446, Standard Deviation = 0.148; Coefficient of Variation = 0.33). The much higher Coefficient of Variation of the IDI meant that infrastructure development was far more uneven in distribution than sustainability

**Table 2: Ward-wise Infrastructure Development Index (IDI) and Urban Sustainability Index (USI) with five-class classifications.**

| Ward | IDI   | IDI class | USI   | USI class |
|------|-------|-----------|-------|-----------|
| W1   | 0.847 | Very High | 0.729 | High      |
| W2   | 0.939 | Very High | 0.668 | High      |
| W3   | 0.502 | Moderate  | 0.402 | Moderate  |

|      |       |           |       |           |
|------|-------|-----------|-------|-----------|
| W4   | 0.541 | Moderate  | 0.497 | Moderate  |
| W5   | 0.704 | High      | 0.624 | High      |
| W6   | 0.616 | High      | 0.550 | Moderate  |
| W7   | 0.760 | High      | 0.552 | Moderate  |
| W8   | 0.567 | Moderate  | 0.489 | Moderate  |
| W9   | 0.487 | Moderate  | 0.630 | High      |
| W10  | 0.308 | Low       | 0.414 | Moderate  |
| W11  | 0.309 | Low       | 0.424 | Moderate  |
| Ward | IDI   | IDI class | USI   | USI class |
| W12  | 0.430 | Moderate  | 0.475 | Moderate  |
| W13  | 0.211 | Low       | 0.408 | Moderate  |
| W14  | 0.275 | Low       | 0.349 | Low       |
| W15  | 0.245 | Low       | 0.229 | Low       |
| W16  | 0.154 | Very Low  | 0.309 | Low       |
| W17  | 0.100 | Very Low  | 0.388 | Low       |
| W18  | 0.094 | Very Low  | 0.200 | Very Low  |
| W19  | 0.247 | Low       | 0.299 | Low       |
| W20  | 0.065 | Very Low  | 0.276 | Low       |

## 5.2 Spatial pattern of infrastructure development

The ranked IDI distribution was highly bottom heavy: 4 wards were categorized as Very Low, and 6 as Low, accounting for half the area of study, while only 3 wards were categorized as High and 2 Very High. Geographically, the infrastructure distribution showed an obvious pattern of core-periphery differentiation (Figure 2a): the wards with high IDIs aggregated into a cluster in the well-established Itanagar-Naharlagun core, while their values dropped monotonously to the geographically restricted periphery. Of the seven components of infrastructure, water & sanitation (mean = 0.468) and transport (mean = 0.466) had the highest scores, while education (mean = 0.355) and public services (mean = 0.378) had the lowest scores, suggesting the lagging of social service infrastructure behind utility networks (Figure 2).

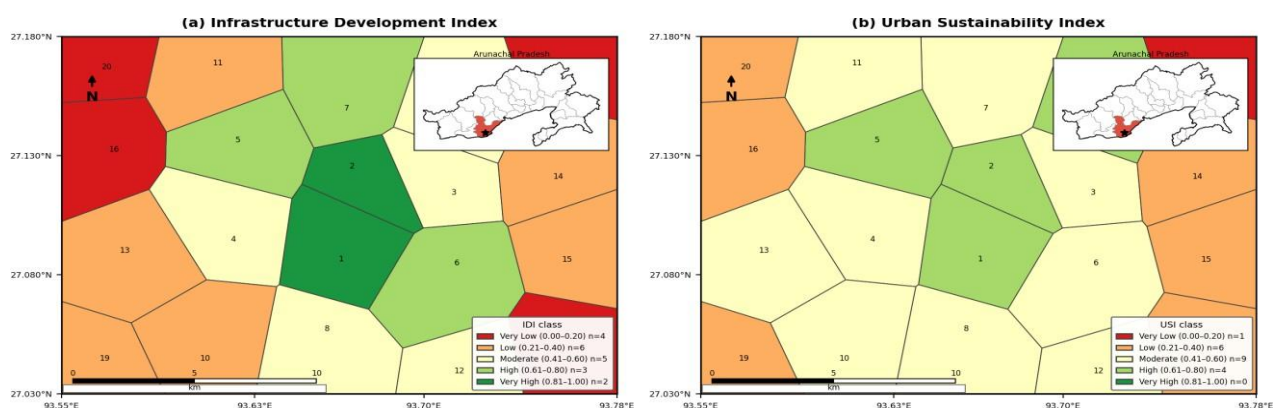


**Figure 2:** Ward-wise choropleth maps of (a) the Infrastructure Development Index and (b) the Urban Sustainability Index, classified into five ordinal categories; legends report class breaks and per-class ward counts; the inset locates the study area within Arunachal Pradesh (Papum Pare district highlighted).

### 5.3 Spatial pattern of urban sustainability

The USI was relatively focused on the intermediate classes, where there were 9 wards with Moderate classification, 4 with High and 6 Low; there was one ward with Very Low classification but no Very High category (Figure 2b). With respect to dimensions, the economic (mean = 0.476), social (mean = 0.472), and environmental (mean = 0.470) dimensions were strong, while the institutional dimension was weak (mean = 0.377) due to the limited spatial coverage of municipal, e-governance and Smart-City infrastructure. Importantly, the environmental dimension was contrary to the infrastructure, since ward-wise green cover was highly negatively correlated with IDI ( $r = -0.893$ ), which meant that the wards having maximum green cover on the periphery had high scores in this dimension (Table 3, Figure 3).

**Table 3: Mean normalized dimension scores of the IDI and USI across the wards.**

| Index | Dimension       | Mean normalized score |
|-------|-----------------|-----------------------|
| IDI   | Water           | 0.468                 |
|       | Transport       | 0.466                 |
|       | Energy          | 0.444                 |
|       | Dimension       | Mean normalized score |
|       | Communication   | 0.443                 |
|       | Health          | 0.388                 |
|       | Public Services | 0.378                 |
|       | Education       | 0.355                 |
|       | Economic        | 0.476                 |
|       | Social          | 0.472                 |
|       | Environmental   | 0.470                 |
|       | Mobility        | 0.432                 |
|       | Institutional   | 0.377                 |

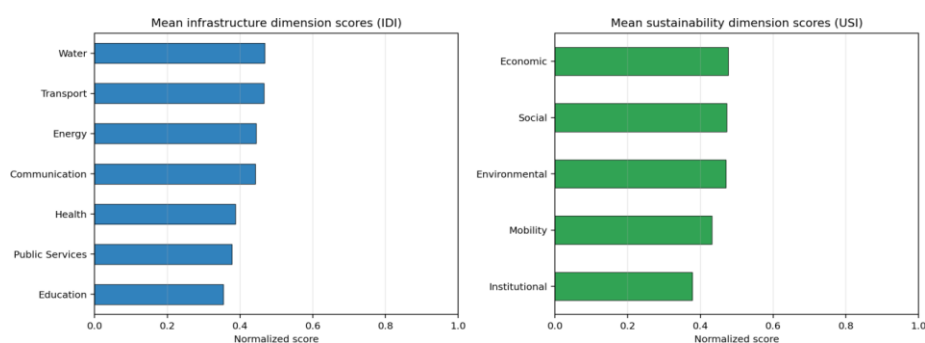


**Figure 3: Mean normalized dimension scores for the seven infrastructure dimensions (left) and five sustainability dimensions (right).**

### 5.4 Relationship between infrastructure development and urban sustainability

Infrastructure development and urban sustainability were strongly and positively correlated ( $r = 0.889$ , 95% CI [0.735, 0.955],  $p < 0.001$ ). The regression of the USI on the IDI was highly significant,  $F(1, 18) = 67.6$ ,  $p < 0.001$ , explaining most of the variance in sustainability ( $R^2 = 0.790$ , adjusted  $R^2 = 0.778$ ); the fitted model was  $USI = 0.233 + 0.505 \cdot IDI$ , with a slope significantly greater than zero ( $\beta_1 = 0.505$ ,  $SE = 0.061$ ,  $t = 8.22$ ,  $p < 0.001$ ; Table 4). A 0.10 increase in the IDI corresponded to a 0.051 increase in the USI. Because the slope (0.505) was well below unity and the fitted line crossed the 1:1 reference within the observed range, low-infrastructure wards lay above the 1:1 line—their sustainability exceeded what infrastructure alone predicted—while the highest-infrastructure wards fell below it (Figure 4).

**Table 4: Simple linear regression of the USI on the IDI (n = 20).**

| Parameter                | Estimate | Std. error | t    | p       |
|--------------------------|----------|------------|------|---------|
| Intercept ( $\beta_0$ )  | 0.233    | 0.043      | 5.42 | < 0.001 |
| Slope, IDI ( $\beta_1$ ) | 0.505    | 0.061      | 8.22 | < 0.001 |

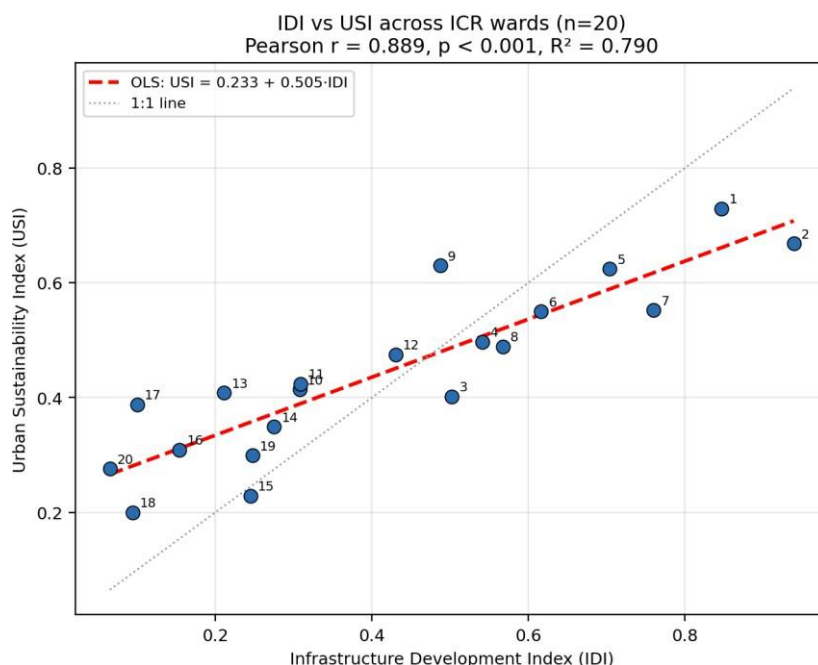


**Figure 4: Urban Sustainability Index against Infrastructure Development Index, with the ordinary-least-squares fit (dashed) and 1:1 reference (dotted). Pearson  $r = 0.889$ ,  $R^2 = 0.790$ .**

### 5.5 Spatial concordance and mismatch

In spite of their high level of correlation, the classes into which the two indexes have been classified did not match in all wards. Nine wards were found in the same class for both indexes, while four wards showed a higher class in the infrastructure index compared to the sustainability index, whereas the other seven wards had a higher sustainability class compared to infrastructure class (Figure 5). While the nine infrastructure-led wards were located in the urban core area the two wards with the highest IDI value were in the very high infrastructure but high sustainability classes, with one other core ward having the high infrastructure but moderate sustainability class the seven sustainability-led wards were located in the peripheral green areas, with the environmental factor being the driving force.

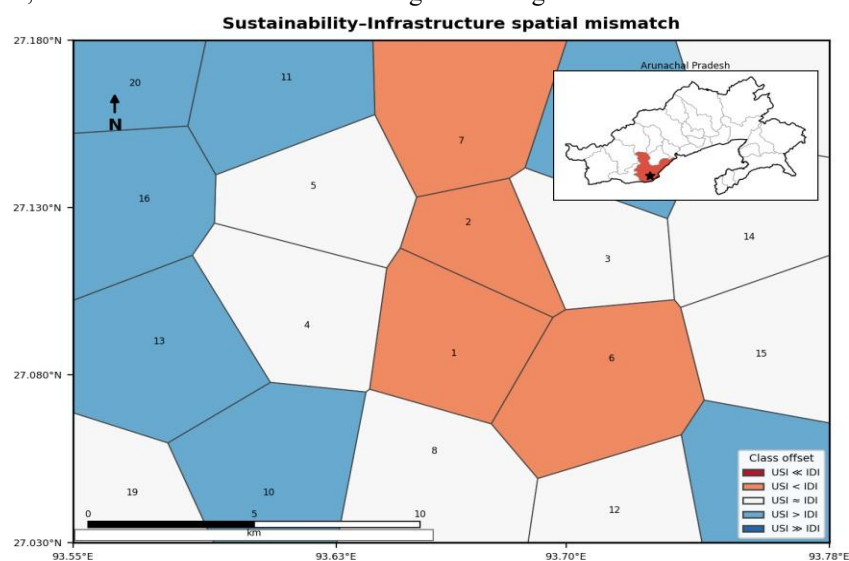


**Figure 5: Spatial mismatch between the USI and IDI classifications, expressed as the ordinal class offset (USI class minus IDI class). Blue denotes wards where sustainability exceeds infrastructure; red the reverse; near-white denotes concordance; inset locates the study area within Arunachal Pradesh.**

## 5.6 DISCUSSION

Given the strong positive relationship between infrastructure and urban sustainability, the classic theory, according to which infrastructure is the foundation of urban activity, has been confirmed (Aschauer, 1989; Krugman, 1990). At the same time, the regression coefficient of unity, deviation from the corresponding order classes in eleven out of twenty wards, and the negative correlation of green cover with infrastructure are in line with the "better infrastructure" approach (Newman & Kenworthy, 2013). The necessity of infrastructure for urban sustainability is evident; however, infrastructure alone does not guarantee sustainability since the green peripheral wards had a sustainable environment floor even with poor infrastructure whereas the core wards with developed infrastructure failed to score high sustainability due to destruction of green infrastructure.

The clear core-periphery imbalance with regard to the provision of infrastructure, coupled with the low performance of the education, public services and institutional aspects, is congruent with governance theories wherein the fragmented institutional capacity and unequal prioritization determine the outcome of the infrastructure (Pelling, 2012; Revi, 2008). The restricted territorial presence of facilities such as Smart-City and e-governance fits into critiques regarding the dominance of technological modernization devoid of inclusive governance and thereby favoring the visible physical infrastructure over the effective service provision (Gabrys, 2014). In terms of a city exposed to hazards, the core-periphery disparity in the distribution of infrastructure and the conservation of vegetation in the periphery have their relevance for resilience as well.

Implications of the results are straightforward and have real planning implications. Investing in the infrastructure-poor periphery, especially in terms of provision of services and institutions, would help to decrease inequality within the city. The maintenance of peripheral green cover will help preserve the environmental baseline that is now acting as a compensation for the lack of infrastructure. The spatial mismatch approach points to areas in which infrastructure and sustainability fail each other.

## 5.7 LIMITATIONS

There are three considerations here. First, as mentioned in Section 3.6, the values obtained herein have been based on an exemplary demonstration data set which is characterized by placeholder socioeconomic indicators based on the range observed through the satellite data, and the actual values will be obtained upon implementation of the ward-level secondary database in the same reproducible process pipeline. Second, equal weighting is clear and common but is also based on the assumption that all dimensions have equal weight. Sensitivity testing using principal component or entropy weighting is logical and straightforward. Finally, the official ward boundaries of the ICR were unavailable, thus approximating them for the purpose of this analysis within the time period covered in this study.

## 6. CONCLUSION

This paper presented and validated an approach for evaluating the relationship between infrastructure development and urban sustainability using geospatial and secondary data at the ward-level in the Itanagar Capital Region. Using a 23-indicator Infrastructure Development Index (IDI), a 19-indicator Urban Sustainability Index (USI) and a satellite-based environment index, the framework has shown a robust yet imperfect relationship between infrastructure and urban sustainability, a core-periphery inequality in infrastructure and a mismatch between infrastructure and urban sustainability, where the peripheral wards maintained high levels of environmental performance despite low infrastructure performance. It has been concluded that infrastructure-driven development is not enough to attain sustainable cities in fast-growing Himalayan capitals and requires environmentally sensitive development of infrastructure to be translated to sustainable cities. Outside the ICR, the transparent and replicable methodology can be used to assess infrastructure inequality and infrastructure-urban sustainability relationship in other mountainous regions.

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