VULNERABILITY ANALYSIS ON HYDERABAD CITY, INDIA

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Abstract

City vulnerability is an assessment of priorities for implementation in a city. Thus, it is imperative to determine vulnerable regions in the city to identify priority areas that may require immediate intervention. Several methods used for national, international and local level vulnerability assessment are based on remote sensing and GIS technology. This paper aims to determine the vulnerability of Hyderabad city using a geospatial based vulnerability index for sustainable development of the city. We use an urbanization and vulnerability concept for the development of city policy measures. We assessed the city vulnerability using a conceptual diagram composed of exposure, sensitivity and adaptive capacity. For Exposure, we considered the elevation (contour), watershed, waterway, roads, railways and airport thematic layers. For Sensitivity, the built-up area, industry, manages (?) system such as farmland and land use/cover map from GIS data were used. To examine the adaptive capacity, we addressed the natural vegetation layer, economic points and infrastructure. Results show that the center and northern part of the city are highly and extremely vulnerable due to industry and high socio-economic activities when compared with the southern part of the city. We divided the whole city into 5 types of vulnerability: Resilient 2.24%, at risk 13.20%, vulnerable 46.15%, highly vulnerable 7.26% and extremely vulnerable 31.15% , in terms of the city area percentage. The vegetation area (50.51%) has the maximum vulnerable area and the vulnerable class covers the maximum area (46.15%) of the city. All this information is very indispensable and can be used to address management issues, such as resource prioritization and optimization.

Key words: City vulnerability, Landsat data, Remote Sensing, GIS.

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Introduction

Urban areas are more vulnerable to disasters and need a plan to take up reduction measures than village, where people are capable of coping with such contingencies. Simultaneously, megacities are also highly fragmented places [1-3]. Most often, this fragmentation relates to processes of socio-spatial differentiation, the spatial structure of the urban area as well as governance issues. The underlying fragmentation approach of this article goes beyond these traditional considerations as ongoing urban expansion and vulnerability to hazards in the context of climate change and opens up new perspectives with regards to socio-environmental conditions [4]. This article poses the question of whether the socio-environmental fragmentation of urban areas is a precondition for an unequal distribution of the impacts with regards to vulnerability.

Management of city vulnerability is prerequisite to global sustainable development. For this reason, many international agencies have conducted assessments that compare city vulnerabilities on a global scale and used the results of these assessments as standards for setting their institutional priorities. For example, the South Pacific Applied Geoscience Commission (SOPAC) and the United Nations Environment Programme (UNEP) have developed the Environmental Vulnerability Index (EVI), which compiles 50 different indicators regarding weather and climate, geology, geography, ecosystem resources and human populations and composites them into a single index [5]. This kind of composite index is a relatively simple way to combine various aspects of vulnerabilities for consideration. The concept of city vulnerability typically incorporates both biophysical and socioeconomic factors [5-6]. Data on biophysical aspects mainly relate to risk of hazards, climate, geology and geography, whereas socioeconomic aspects include the system's inherent resistance to damage and acquired adaptive capacity [5-6].

The vulnerability is a function of the character, magnitude and rate of eco-environment change and variation to which a system is exposed, its sensitivity and its adaptive capacity. Landscape condition is determined the susceptibility of a community to the impact of hazards the degree to which a system is susceptible to, or unable to cope with, adverse effects on eco-environment, including variability and extremes. So we can say vulnerability is a function of exposure, sensitivity and adaptive capacity. Where potential impacts are a function of exposure and sensitivity therefore, vulnerability is a function of potential impacts and adaptive capacity [7-8]. As vulnerability include the three dimensions: exposure, sensitivity and adaptive capacity. Where exposure components characterize the stressors and the entities under stress; sensitivity components characterize the first-order effects of the stresses; and adaptive capacity components characterize responses to the effects of the stresses (fig. 1).

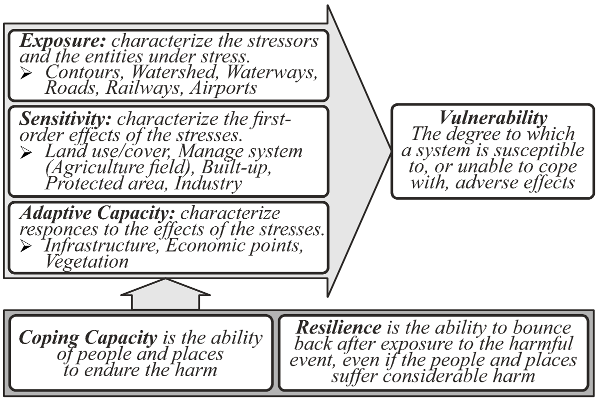


Fig. 1. Conceptual framework of city vulnerability.

These measures can be quantitative (e.g., precipitation variability, distance to market) or qualitative (e.g., political party affiliation, environmental preservation ethic). Another slightly different view favored by the hazards and disasters research community is that adaptive capacity consists of two subcomponents: coping capacity and resilience. Coping capacity is the ability of people and places to endure the harm and resilience is the ability to bounce back after exposure to the harmful event, even if the people and places suffer considerable harm. In both cases, individuals and communities can take measures to increase their abilities to cope and bounce back; again depending on the physical, social, economic, spiritual and other resources they have or have access to [9].

As we use three terms (exposure, sensitivity and adaptive capacity) inside the city vulnerability. While there is considerable heterogeneity in both the potential impacts of environmental changes and the adaptive capacity to cope with these impacts, this assessment shows that study area in particular will be vulnerable to ecosystem and land use change. Projected economic growth increases adaptive capacity, but is also associated with the most negative potential impacts [10-11]. The potential impacts of more environmentally oriented developments are smaller, indicating an important role for both policy and society in determining eventual residual impacts in the Hyderabad, India.

The ultimate objective of this work is to find a new methodology to assess local vulnerabilities that includes consideration of site-specific characteristics. Another goal is to develop a new tool assessment to aid local policy makers in assessing local conditions and developing appropriate environmental measures based on the results.

1. Material and methodology

1.1 Study area

Hyderabad is the sixth largest city in India and capital of Telangana state in central South India. Hyderabad occupies 650 square kilometers (250 sq mi), along the banks of the Musi River a tributary of Krishna River, it has population of about 6.8 million and metropolitan population of about 7.75 million, making it the sixth most populous city and sixth most populous urban agglomeration in India. It grew from about one million inhabitants in 1951 to about seven million in 2001. It is characterized by population growth rates of more than 50% during 1981-91 and of 27% during 1991-2001 (GHMC 2010). A Survey by Telangana State Government, 'Samagra kutumba survey' on August 19, 2014, reveals that Hyderabad's population has crossed 12 million. At an average altitude of 542 meters (1,778 ft), much of Hyderabad is situated on hilly terrain around artificial lakes, including Hussain Sagar predating the city's founding north of the city center (fig. 2).

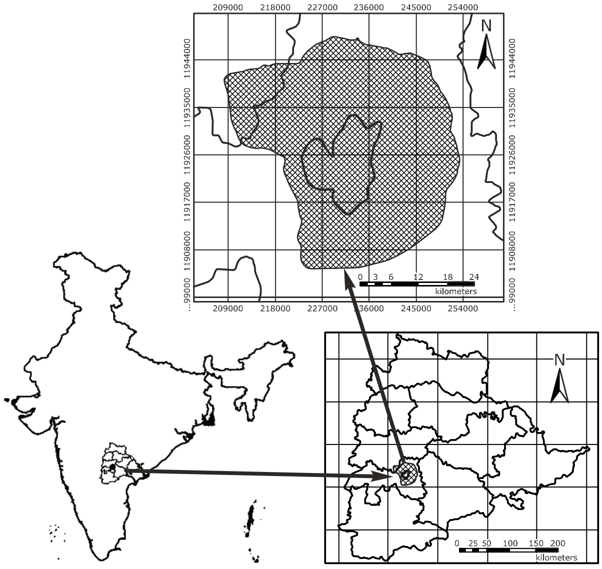


Fig. 2. Location of study area.

1.2 Maps processing

The images obtained as standard products were geometrically and radiometrically corrected by data providers but, because of the different standards and references used by the various image-supplying agencies all images were georeferenced again at the pre-processing stage. Images from different sensors have different spatial resolutions. In this study we preferred to retain the spatial detail, original pixel size and value of each image. Therefore the images were kept without changing their pixel sizes despite the possible varying accuracy level of classification with the different spatial, spectral and radiometric resolutions. Next at the classification stage a uniform supervised classification was applied on the images. All of the images were classified by creating accurate polygons as training areas for introducing ideal classes for each image separately and by using the maximum likelihood classification method. To create a closer correspondence between the maps produced the classification was done by only considering four main classes: urban built-up area, soil, vegetation and water [12-13].

Post-classification refinement was used to improve the accuracy of the classification. In addition, because the urban surface is heterogeneous with a complex combination of features (buildings, roads, grass, trees, soil, and water), mixed pixels and the salt and-pepper effect were common problems when using medium spatial resolution data, such as Landsat 8 [14-16]. In this step a 3 * 3 majority filter was applied to all the classified land covers [17].

1.3 Procedures to calculate the sensitivity, exposure, and adaptive capacity sub-indexes

Another basic issue for the evaluation a model is to assign weights to each factor according to its relative effects or importance in an indicator/factor considered in the city vulnerability in a thematic layer. The analytic hierarchy process, a theory dealing with complex technological, economical and socio-political problems ([18], is an appropriate method for deriving the weight assigned to each factor. The dimension index rescales all variables into a range from 1 to 7.

The proxy variables used to quantify the aspects of city vulnerability exposure, sensitivity, and adaptive capacity had various units and needed to be standardized prior to their synthesis. We used a dimension index method adopted from [5] to standardize the proxy variables. The dimension index is a widely used rescaling method to standardize data; it is based on the range of data, independent of standard deviation [17, 5, 18, 19, 20]. We propose that the data should be transformed to their natural logarithms LN(X). This renders the transformed data normally distributed and provides a better spread among whole study region [5]. The LN(X) transformed data were plotted as a frequency distribution within 7 categories. We designated the vulnerability index score from 1 to 7 [5-6]. The application of subjective weights on the one hand gives us some indication of how the relative importance of different factors might vary with context and can also tell us how sensitive city vulnerability ratings are to perceptions of vulnerability in the expert community in Hyderabad, India [4].

For Exposure we consider elevation (contour), watershed, waterway, roads, railways and airport thematic layers. For sensitivity built-up areas, industry, manage system such as farmland and land use/cover map were used. To examine adaptive capacity, we addressed natural vegetation layer, economic points and infrastructure. After standardized the factors, subsequently the component value (Exposure, sensitivity and adaptive capacity) was obtained according to following formula:

$$Component\,value = \frac{Factor_1 + Factor_2 + \ldots + Factor_n}{n}$$

Where n is the number of factors for a particular component (Exposure, sensitivity and adaptive capacity).

After weight of each factor and calculation of Exposure, sensitivity and adaptive capacity, the city vulnerability index was calculated using the following equation.

$$City\ vulnerability =$$
$$= Expoure_{value} + Sensitivity_{value} - Adaptive\,capacity_{value}\,.$$

Note: that a negative sign is used for adaptive capacity because adaptive capacity reduces the overall city vulnerability.

Results

First, we use supervised classification method in ArcGIS software and generate land use/cover maps. After classification we used city vulnerability formula in ArcGIS software and derive vulnerability for Hyderabad city. Vulnerability results show that, center and north part of the city is most vulnerable and need immediate attention. South parts of city are less vulnerable and have less human interference. All scales given to 14 indicators were mapped and overlaid to produce the vulnerability map of Hyderabad city (fig. 3).

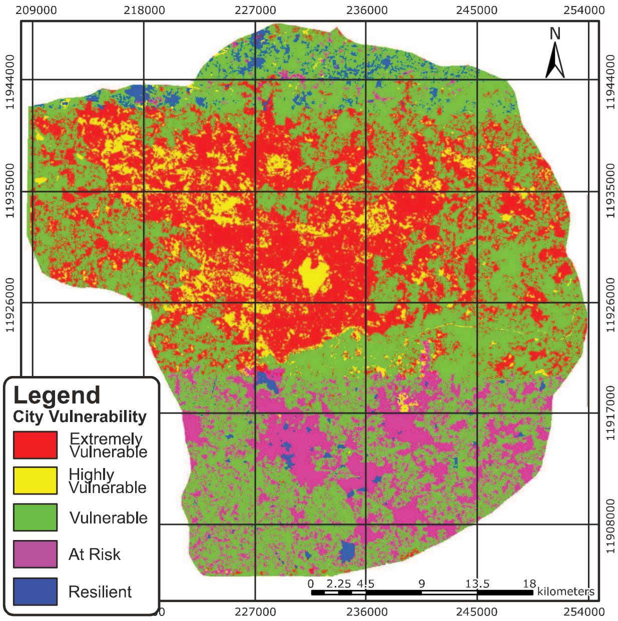
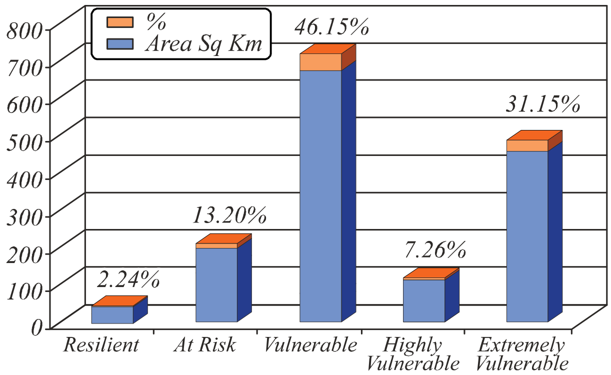


Fig. 3. Vulnerability map of Hyderabad city.

This map generated varying scales ranging from -1.77 to 5.73. The distribution of scales in the vulnerability map excluded the Hyderabad; hence a total area of about 1441.15 km^2 was derived. It was found that around 46.15% or 665.05 km^2 of the area has a scale of vulnerable (fig. 4).



Class	Area Sq. Km.	%
Resilient	32.28	2.24
At Risk	190.22	13.20
Vulnerability	665.05	46.15
Highly Vulnerable	104.62	7.26
Extremely Vulnerable	448.99	31.15
Total	1441.16	100.00

Fig. 4. Vulnerability graph of Hyderabad city

These areas are mainly located other than central part of the city, mostly outside of the city (fig. 3). On the other hand, there are 31.15% or 448.99 km^2 area is in extreme vulnerable due to high socio-economic activities, highly dense population, lack of infra-structure and high industry. Resilient and at risk area is 2.24% and 13.20% of the total area respectively. This area is in very upper and southern part of the city. Resilient and at risk class have maximum open field and less socio-economic activities. High vulnerability area is 7.26% or 104.62 km^2 of the city. It is in-between extreme vulnerability class (fig. 3). This implies that interventions, such as landscape rehabilitation and vegetation protection, must be considered by the management to abate adverse impacts of future hazards.

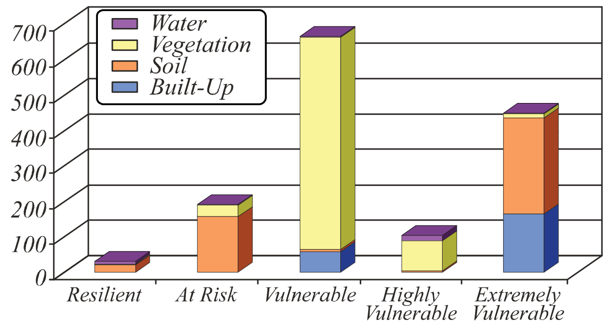
Vulnerability map showing the low to high priority levels (fig. 3). Based on the results, high priority areas have 38.41% accounting to about 553.61 km^2 (fig 3). Medium lave vulnerable area is 665.05 km^2 or 46.15%, which is the highest area of the total study area. Low to very low priority areas, on the city, have only a total of 15.44% or 222.50 km^2. Most of these low to very low levels are situated outside of the city. Areas with very low levels indicate that these areas are the least priority in terms of restoration efforts because of its intact vegetation cover and high resilience. Moreover, this level signifies that the area has higher capacity to sustain itself against future environmental hazards and there is minimal risk that such hazards are likely to occur in the area. However, areas with very high levels are considered to have unacceptable levels of risk to some extent which may also lead to the degradation of ecological services if not properly addressed with appropriate actions. Landscape restoration endeavors (e.g. reforestation, implementation of mitigation measures, etc.) are likely to be applied in these areas.

Based on the overall assessment, Hyderabad city is vulnerable as at risk level. The most resilient indicators identified are land use change, human development and erosion potential. Meanwhile, the most vulnerable indicators observed are maximum industry, elevation, threatened species and road density. The assessment on the various components of vulnerability revealed that exposure component has the highest scale (5.16), while the lowest scale observed is the adaptive component (4.33). This means that one of the major problems in city lies in its external factors such as climate variability as well as its topography. This is followed by its demographic-related problems that capture the impacts of high population density and high annual growth rate in the area. In terms of the sensitivity aspects the highest vulnerability scale is 4.40.

In vulnerability, vegetation class is the highest vulnerable class (50.51%). It's come in vulnerable (597.85 km^2) and highly vulnerable (86.17 km^2) category. Open soil area is second most vulnerable area (32.18%). It is present in extreme vulnerable 273.22 km^2 (60.85%) and 160.84 km^2 (84.56%) in at risk category (table. 1). Built-up has third most vulnerable class and it's have extreme and vulnerable category with 220.94 km^2 (15.33%) area. Water class is the lowest vulnerable and present in all categories (fig. 5).

Class	Resilient		At Risk		Vulnerable		High Vulnerable		Extreme Vulnerable	
	Area	%	Area	%	Area	%	Area	%	Area	%
Built-up	0.56	1.74	0.40	0.21	57.43	8.64	0.27	0.26	162.26	36.14
Soil	20.61	63.87	160.84	84.56	6.92	1.04	2.15	2.06	273.22	60.85
Vegetation	2.09	6.48	28.75	15.11	597.85	89.90	86.17	82.37	12.98	2.89
Water	9.01	27.92	0.22	0.12	2.82	0.42	16.02	15.31	0.52	0.12
Total	32.27	100.00	190.21	100.00	665.02	100.00	104.61	100.00	448.98	100.00

Table 1 Vulnerability categories in land cover classes



Class	Area	%
Built-up	220.94	15.33
Soil	463.75	32.18
Vegetation	727.86	50.51
Water	28.60	1.98
Total	1441.15	100.00

Fig. 5. Land cover classes vulnerability in Hyderabad

Remote sensing and GIS is a useful tool for such study. This study is helpful for governmental policies for sustainable development in Hyderabad. Centre and north part of city has higher damage situation due to industry, high population density, lack of general amenities or facilities and degradation of water quality. Slum population is also high with low income groups and all these things indicate high level of Exposure and sensitivity. To reduce the vulnerability, city has low adaptive capacity for these potential impacts. So government need to give subsides and financial support to build infrastructure. As adaptive capacity is very low in this city so police maker should focus on natural resource management. Natural resources such as swamps, grassland and mangroves are environmentally important ecosystems because they serve as a buffer against natural disasters, including self-purification [21]. If policies regarding nature protection and restoration are implemented, sensitivity to exposure can be reduced. As south part is less vulnerable and have more adaptive capacity to reduce vulnerability. This part is mainly Exposure due to artificial resource management such as various pollution controls. So implementation of pollution control, develop the infrastructure such as water treatment plants is a good approach. Shifting the high population density could be a good approach in the whole city to reduce the vulnerability.

Discussion

City vulnerability and socio-economic aspects offers a new perspective on vulnerabilities at city level. It is also innovative as it uses a different set of variables, combining social, economic, morphological and environmental dimensions in order to determine the urban structure according to socio-environmental conditions, rather than working with the traditional socio-economic variables alone. This approach allows for more wide-ranging considerations, more closely related to climate change related vulnerabilities, going beyond poverty, age and gender as the most commonly used measurements of vulnerability. Furthermore, it is sought to delve into how local adaptation options can be defined, agreed upon and implemented. So far, no practical application has been implemented but it is argued that in-depth information on exposed hotspot areas based on fragmentation patterns and existing susceptibility and coping capacities can be utilized to reduce vulnerability to climate change related hazards through the development of context-specific adaptive responses. Based on the results achieved, it is possible to determine whether adaptation should occur in either an anticipatory manner (prior to a perceived risk) or in a reactive fashion (after a specific change or event has occurred). This aspect also supports the research decision that was made to consider coping capacity and adaptive capacity separately from each other in order to determine both short and long-term perspectives regarding local climate change adaptation and planning. Therefore, this research offers one possible approach in order to provide a feasible database in support of local coping and adaptive capacities regarding hazards.

The most frequent disturbance vectors identified for the Hyderabad city are anthropogenic, such as urban development, disposal of solid waste, sewage pollution and extensive alterations of the local hydrological regime. Although quantitative information on changes in forest structure, productivity and resource availability is still scant, the survey provided strong evidence that frequent and intense man-made impacts are the main causes of overall vulnerability. Contrary to what happens in tropical areas [22-23], natural physical disturbances, such as strong tempests and hurricanes, are rare and may play a minor role on structuring local stands or affecting their vulnerability. Vulnerability indexes are commonly applied in the social sciences, but the usage of empirical indexes to assess the current conditions and trends of socioecological systems is still a novel approach. Practical and operational indicators of vulnerability are strongly needed [24].

Conclusions

The remote sensing and GIS approach is initiated to provide an avenue to assess the vulnerability. This research has shown interesting results that can be used for other cities sustainable development. City vulnerability integrated exposure and sensitivity with adaptive capacity, which included considerations of both biophysical and socioeconomic aspects. Contextualization, which is defined as the ability "to adjust indicator and index to the specific socioeconomic context, they are applied to and to the function", is an important issue when assessing local environmental vulnerability [25]. This research work considers local condition of Hyderabad city such as land use/cover information from GIS to assign different weight factors for each component for vulnerability. So vulnerability application of future management plans focused on the varying sensitivity, exposure and adaptive capacity of the local city stands becomes necessary. This empirical index of vulnerability can also be used as a multiple management tool through the exploration of its sub-indexes or components. Such management strategies could enhance ecosystem resilience to both anthropogenic and natural stressors expected in future in Hyderabad, India.

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