Methodology to Identify the Anthropogenic Activities Influencing the Vulnerability of Communities to Urban Floods - A Case of Nagpur, India

Abstract

of

Thesis to be

Submitted in partial fulfilment

for award of the Degree

of

Doctor of Philosophy

By

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2022

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Abstract

Globally, climate change and the issue of urbanization has been a matter of concern over the past few decades. Unplanned urban growth alters the natural drainage pattern and the water cycle, consequently, giving rise to floods. Floods are attributed to heavy precipitation but, human activities act as a catalyst in creating an imbalance in the environmental harmony. Predominantly, urban floods in the developing nations are known to affect quite a large population and infrastructure. Nagpur, in Maharashtra, India has been facing hydro-meteorological events in the last decade along with a persistent reduction of natural land and rapid urban growth. Nagpur, unlike the coastal cities never faced horrid floods. However in the past decade, it has become a hotspot for flash floods and droughts. The city requires Disaster Risk Reduction (DRR) strategies to tackle the disasters caused due to urban floods. As a result, the study aims at ascertaining the social and physical infrastructure vulnerability of the residents; Followed by developing a methodology for identifying the anthropogenic activities responsible for causing urban floods. Thereafter, the impact of landcover change on the surface runoff adding to the urban floods is testified by the application of a simplistic hydrological model. Further, the impact of identified anthropogenic activities on the vulnerability of settlements is tested through the application of statistical model.

Objective 1 focuses at conducting a micro-scale i.e. community vulnerability assessment by identifying the drivers of vulnerability. The existing physical infrastructure and social attributes make the population vulnerable to urban floods. A questionnaire based on the socio-economic and infrastructure characteristics was formulated and a primary survey was conducted. The study involves application of principal component analysis by means of python programming to develop socio-economic and physical infrastructure indices. The python code can act as a cheat sheet for researchers and policy makers in the domain of vulnerability assessment. The analysis enabled component wise and index wise visualization of low vulnerable to high vulnerable zones in Nagpur using Geographic Information System (GIS). Goodness-of-fit for socio-economic and physical infrastructure vulnerability index show R^2 value as 0.7219 and 0.7058 respectively, suggesting the models to be substantial. This robust vulnerability framework can gauge the real conditions of the population thereby assist in developing policies and strategies to reduce the impact of urban floods.

Objective 2 focuses at identifying the anthropogenic activities responsible for increased occurrences of urban flood events in Nagpur. A total of seven attributes and fourteen human

induced causative factors were identified to record the perception of residents and experts. Household surveys were conducted using a standardised Likert scale questionnaire. Such real-world occurrences contain the inherent imprecision and ambiguity of human judgements. As a result, the survey items were presumed to be fuzzy linguistic variables, and the raw dataset was converted into triangular fuzzy integers. For the hierarchical assessment of indicators and variables, fuzzy arithmetic and weighted averaging operators were used. In order to deal with subjective replies, a robust approach is experimented in the study. The process was conducted for every zone separately to understand the factors causing urban floods, the defuzzified scores for every attribute are presented through GIS. Towards the end, accuracy comparison of the Likert scale and fuzzy approach is carried out. The use of fuzzy approach in urban planning and related behavioural research helps cope with the inherent uncertainties in a humanistic system, in an effective and pragmatic manner.

Objective 3 attempts at establishing a relationship between temporal landcover change for years 1995, 2005, 2015 and increased surface runoff, eventually causing urban floods through application of the Soil Conservation Services Curve Number method. The above mentioned years marked remarkable urban development in Nagpur and hence were considered in the study. The outcome demonstrated a prominent urban sprawl of 12.84 percent and a severe loss of 16.32 percent in natural vegetation between 1995 and 2015. The objective examines the relationship between urban expansion and surface runoff at the catchment level by integrating landcover mapping with the application of hydrological model. It presents a successful application of remote sensing and GIS in hydrological studies.

Novelty of the study lies in (a) Developing a statistically and spatially explicit method for assessing the socio-economic and physical infrastructure vulnerability at micro scale; (b) A methodology to identify the urban flood (UF) causative factors. The study chalks down a list of factors that are deemed responsible for causing urban floods in the study area. These contributions can make a major difference in mainstreaming DRR into development plans for UF-prone regions. Specifically, for resource-constrained and water-stressed fast-growing cities with a comparable profile to that of the study area.

Keywords: Urban floods, Vulnerability Indices, Principal Component Analysis, Anthropogenic causative factors, Fuzzy Approach, Landcover change, SCS-CN