MANAGING MULTI-HAZARDS RISK OF URBAN DEPRIVATION IN THE CONTEXT OF URBAN PLANNING AND DESIGN

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IGARSS 2021 - 2021 IEEE International Geoscience and Remote Sensing Symposium | 978-1-6654-0369-6/21/$31.00 ©2021 IEEE | DOI: 10.1109/IGARSS47720.2021.9553673

ABSTRACT

Development of urban resilience is largely determined by the planning and design strategies proposed for managing the risk of vulnerable places exposed to different hazards. These places are commonly occupied by poor dwellers or known as deprived areas. However, efficient planning and design strategies are difficult to identify and evaluate even the exposure of urban deprivation is known. It is mainly because the knowledge about the exposure of vulnerable urban elements in deprived areas is not explicitly interpretable in the context of planning and design practice. This work is set upon the rationale that environmental and ecological patterns within urban areas can be interpreted by the morphology of cities, so that the exposure of different urban areas including those deprived can be interpreted by explicit measurements of urban forms, which can potentially inform planning and design practitioners. A workflow is proposed and exemplified for the entire city of Nairobi, Kenya, where several technical steps are involved including mapping and measuring the morphology of basic urban elements such as buildings, relating the measurements to potential hazards, and finally obtain an explicit characterization of multi-hazards exposure of urban deprivation.

Index Terms - Urban resilience, exposure, slums, urban morphology.

1. WHAT IS MISSING?

Although there is a set of clear action points prioritized within the Sendai framework for developing urban resilience [1], few action points have been approached by ongoing studies. Only a handful of studies can be considered as contributing to the *understanding* of risk if actions and resources to be invested are yet to be determined. These studies still remained at general levels, such as increasing vegetation and waterbodies for climate change adaptation, which can hardly inform planning and design actions [2]. Many other studies have successfully identified vulnerable places such as informal settlements or slums along with their exposure to different hazards [3], whereas the factors impacting the risk or exposure from the perspective of urban characteristics remained insufficient, leading to knowledge deficit in terms of planning and design actions for mitigations and adaptations (Fig. 1). Although some studies did focus on local scale mitigation and adaption strategies can hardly be generalized to deprived areas given the complicated characteristics within these areas [4][5].

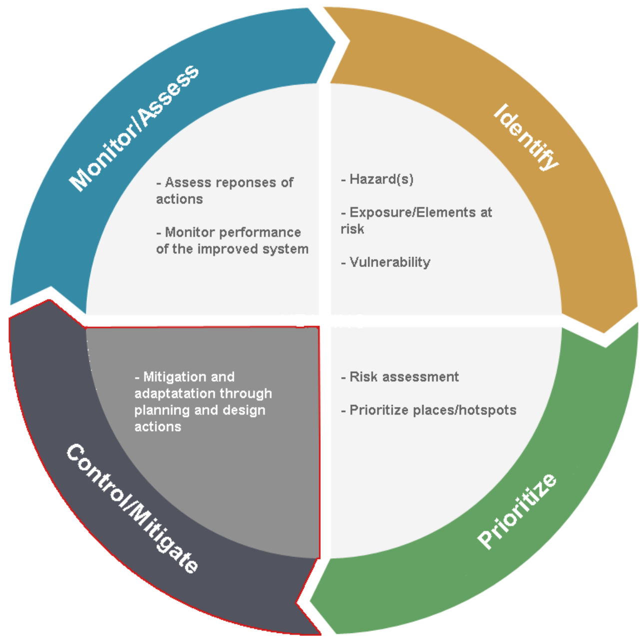

Fig. 1 Risk management cycle is mainly hindered by mitigation and adaptation actions.

Essentially, understanding deprived areas in terms of exposure and vulnerability for the purpose of actions requires more complete characterization of these areas in the context of urban planning and design. Briefly, there is a lack of characterization of the risk by using descriptors or indicators that conforms to urban planning and design. Why is it? Today, with the surge of big data and data science techniques, the Earth Observation (EO) based mapping of urban vulnerability in terms of deprivation as well as the hazards is increasingly powerful that can identify their spatiotemporal patterns directly from raw images (Fig.2). Thus risk identification seems to be reasonably straightforward and as simple as to be the intersection of mapped vulnerability and hazards. However, what is missing is what is actually needed: the interpretation of the mapped patterns of vulnerability and hazards. For instance, with the development of machine learning, especially deep learning techniques, the characteristics of vulnerability and hazards are only describable by abstract image features, which are significantly disconnected from practical context of planning and design, leaving limited room for practitioner to interpret and intervene.

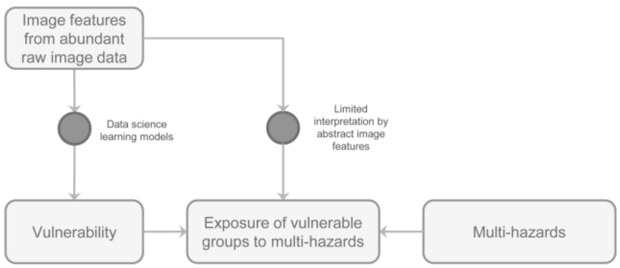

Fig. 2 Widely adopted workflow that maps exposure of vulnerable places such as deprived areas directly from raw imagery data.

2. INTRODUCING A MODIFIED WORKFLOW

Given the missing interpretation in the widely adopted workflow shown in Fig.2, here in this work a modified workflow is proposed. The primary difference between the two workflows is an added component of mapping urban morphology in the modified workflow, where explicit measurements of urban forms in terms of the morphology of basic urban elements such as buildings are derived before mapping urban vulnerable groups such as deprived areas (Fig.3).

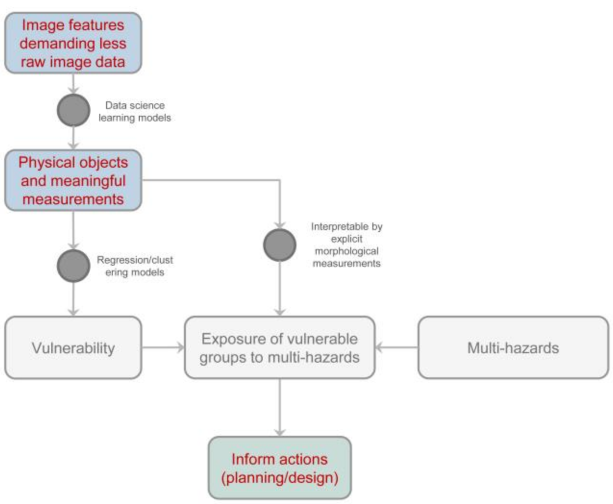

Fig. 3 Workflow modified from Fig. 1

While the overall structure of the workflow seems unchanged, this difference brings significant shift to the workflow in the sense of its concept and operation. First of all, the mapped patterns of vulnerability as well as exposure can be traced back to certain characteristics of urban forms. Thus vulnerability and exposure can be explained by explicit measurements of urban forms that conform to the knowledge applicable in urban planning and design. Essentially, interpretability of vulnerability and exposure patterns contextualizes these patterns in the planning and design practice. Second, the focus of mapping vulnerability is shifted away from raw imagery data leading to a less data demanding workflow as mapping physical characteristics such as urban morphology is less difficult than mapping socioeconomic patterns, which are only partially manifested by physical patterns on satellite imagery data. Last, interpretability along with less data demanding workflow ultimately lead to a more replicable and scientific practice. It is possible to use less expensive and even free image data as the input of the workflow, where human beings are put back into the loop of scientific understanding.

3. TECHNICAL STEPS

Obviously, the added component in the proposed workflow contains two important parts which can reduce to 2 technical steps: (1) EO based mapping of basic urban elements such as building footprints, and (2) deriving explicit measurements of urban forms based upon the morphology of the mapped buildings. In order to make the entire workflow less data demanding and replicable, the freely available Google Earth image data is used in this work along with slightly reengineered and widely adopted Convolutional Neural Networks (CNN) architecture. Specifically, a UNet shaped CNN with ResNet encoder is constructed and applied to Google Earth images for building extraction. An open source Urban Morphology Measuring Toolkit, the MOMEPY (http://docs.momepy.org/en/stable/), is then applied to the mapped building footprints. The metrics are interpretable measurements of the morphology or basic urban elements, such as buildings and streets, such as size, length, density, and alignment. Mapping or representing socioeconomics status such as urban deprived areas would then be interpreted by urban morphological measurements. Consequently, vulnerability and exposure can be explained back into practical context of urban planning and design.

The overall outcome of this proposed workflow can be summarized and visualized as shown in Fig.4, where the vulnerability and exposure can be explained by explicit measurements of urban morphology informing planning and design practice.

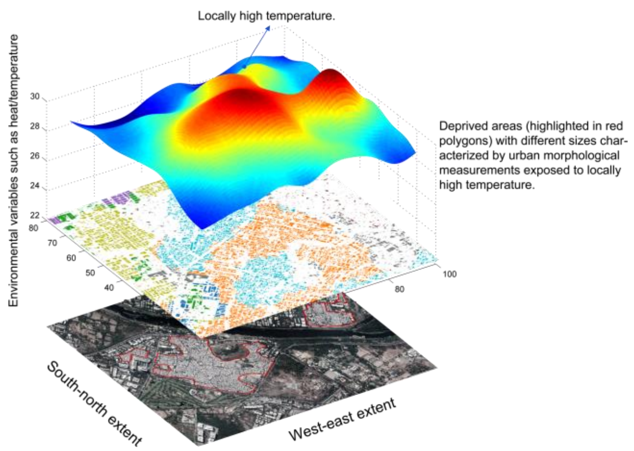

Fig. 4 Interpretable exposure of deprived areas to hazards in terms of building morphology.

4. APPLICATION

In contrast to many of existing similar studies focusing on sub-city scale, this work attempts to apply the workflow at city scale which potentially involve diverse urban patterns in terms of socioeconomic and physical characteristics. The entire city of Nairobi, Kenya is selected as the study area to exemplify and test the proposed workflow (Fig.5).

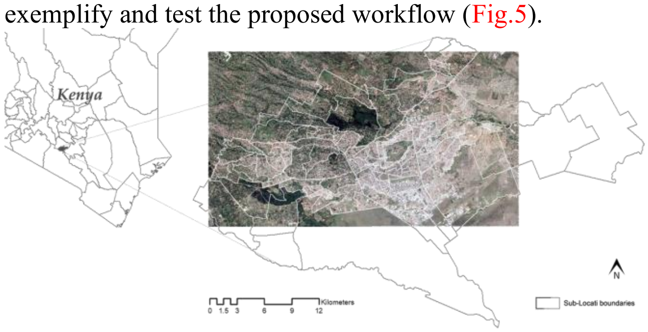

Fig. 5 Study area including the entire city of Nairobi, Kenya

Preliminary finds of ongoing research are visualized in Fig.6, where the exposure of vulnerable groups such as deprived areas to different environmental variables can be explained by the explicit measurements of building morphology that is potentially related to vulnerability. In fact, the pattern of urban deprivation and that of building morphology are already visually similar indicating a potential relationship worth further inspection and interpretation. Thus once the deprived areas are overlaid with different environmental variables such as urban climate (Fig.6(c)) and air quality (Fig.6(d)), the exposure of these deprived areas can immediately be interpreted in terms of their urban forms, which can be translated into practical knowledge of urban planning and design. Upcoming results are to be added.

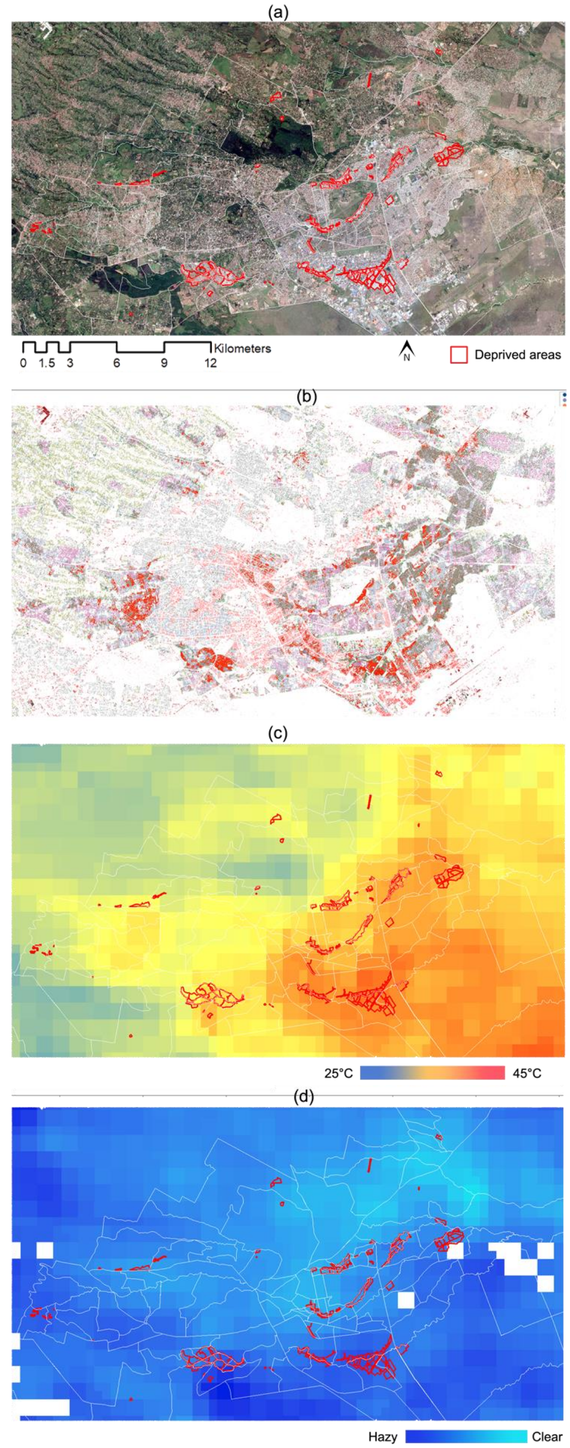

Fig. 6 Preliminary patterns of exposure to different environmental variables that can be explained by the morphology of vulnerable urban areas. (a) Study area with vulnerable deprived areas highlighted by red boundaries. (b) Vulnerability already manifested in morphology patterns that measured by building morphometric clusters. (c) and (d) Exposure of deprived areas to heat and low air quality that can interpreted back into morphological patterns.

Specifically, while the socioeconomic patterns can be explained by the morphological measurements. The morphological characteristics of deprived areas are ready to be inspected for potential urban planning and design guidelines. Zooming into any of the deprived areas as the vulnerable places, the difference of the morphological measurements between the vulnerable places and their neighboring ones, or the rest of the entire city soon provides implications of measurements contributing to the vulnerability and risk. For instance, as shown in Fig. 7, a deprived area representing vulnerable place already displaying its morphological characteristics different from the other places. This area is characterized by high building density (BD), building volume density (BVD), building height (BH), and road density (RD), as well as low sky view factor (SVF), homogeneity of building orientation (BO), building area size (BA), plot area size (PA), and homogeneity of all the measurements.

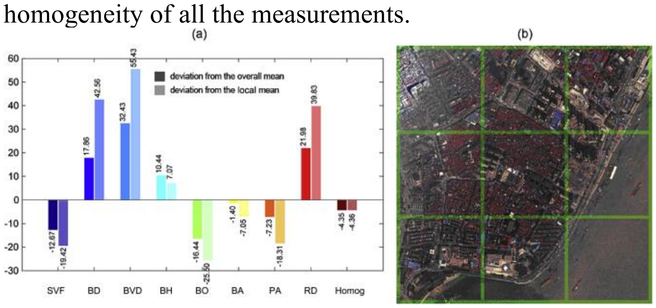

Fig. 7 Morphological characteristics (a) of a deprived area as a vulnerable place (b) is showing different morphology from its neighborhood areas as well as the rest of the city, indicating potential planning and design actions to mitigate the risk and reduce vulnerability.

5. IMPLICATIONS AND ROAD MAP

One of the major implications of the proposed workflow is that the role of EO can be improved from only mapping spatiotemporal patterns of urban processes to facilitating a more interpretable scientific practice. Another implication is a potentially promising research line of deriving abundant explicit and meaningful measurements of urban morphology that captures urban processes and inform practical actions and interventions towards the development of urban sustainability and resilience.

In this work, a proposed workflow has shown promising preliminary findings that how exposure of vulnerable urban groups in terms of deprived areas can be characterized in a meaningful context through the combined strength of EO and spatial morphometrics. This work will continue to further explore the potential of the workflow in:

- Characterizing various urban processes by combining EO and spatial analysis of urban morphology;
- Understanding urban vulnerability and exposure from the perspective of urban morphology;
- Facilitating open science for systematic understanding of urban sustainability and resilience.

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