

### 3-D modeling of Hanoi, Vietnam

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Hanoi, the capital of Vietnam, is one of the fastest-growing cities in Southeast Asia. Before the 19th century, the city contained many lakes and ponds which were relict lakes of Red River. In the early 20th century, however they disappeared almost completely from the map. Two key points have influenced urban transformation in Hanoi. One is that Vietnam was under French rule in the late 19th century. Urban planning by the French government had a profound influence on the urban development of Hanoi. The second is the geography of Hanoi and its natural environment. Hanoi is located in a floodplain of Red River, the average elevation being less than 10 meters. It has faced repeated flooding for a long time. According to the map drawn by the French government, there was already a large-scale dike in the late 19th century. This is one of the most important points to consider the topographical changes in Hanoi. However, it is difficult to describe the topographical changes using two-dimensional (2D) analyses only. Yonezawa (2009) suggested a three-dimensional (3D) urban model consisting of three elements: aboveground data, topographical data, and subsurface data. Such a model can be expected to be the basis data of various area studies. The present study focuses on the topographical changes of Hanoi in the 19th and 20th centuries. To analyze the relief of terrain and micro-topography for such an urban transformation, we need to use elevation survey data to generate a digital elevation model (DEM), a digital representation of ground surface and the most important element of topographical analysis for urban transformation, providing evidence for old rivers, lakes, fills and land subsidence. Consequently, two patterns of DEM of Hanoi (2005 and 1950) were generated. By comparing them, the areas of fills and lands subsidence can be visualized. This will be useful for studying urban transformation, because it is difficult to estimate how many lakes and ponds disappeared by using only 2D spatial analysis.

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