International Journal of Disaster Risk Reduction xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: www.elsevier.com/locate/ijdrr

A predictive model to assess spatial planning in addressing hydro-meteorological hazards: A case study of Semarang City, Indonesia

Imam Buchori[a,*], Agung Sugiri[a], Mussadun Mussadun[a], David Wadley[b], Yan Liu[b], Angrenggani Pramitasari[c], Istiqomah T.D. Pamungkas[c]

[a] Department of Urban and Regional Planning, Faculty of Engineering, Diponegoro University, Indonesia
[b] School of Earth and Environmental Sciences, The University of Queensland, Australia
[c] Centre of Geomatics' Applications for Sustainable Development, Central Laboratory and Services, Diponegoro University, Indonesia

ARTICLE INFO

Keywords:
Spatial planning
Hydro-meteorological hazard
Rob
GIS

ABSTRACT

Global warming has negatively influenced the quality of life of many people, especially those who live in coastal areas. Sea-level-rise in northern Java, Indonesia, has impacted coastal cities prone to flooding and inundation. This study reports the extent to which spatial planning, mandated by the Indonesian Law 26/2007 to minimise the risk of people and improve their resilience, has taken into account hydro-meteorological hazard of Semarang City in northern Java. Geographic Information System (GIS) based spatial analyses were used to predict the anticipated vulnerability of the area based on the combined effect of two processes, namely, a tendency towards land subsidence and an increase in sea level. Further, by overlaying the current and projected vulnerability maps to the year 2031 with the planned land use of the city in the same timeframes, results show that most precincts with anticipated flooding and inundation are residential, industrial, and commercial areas, indicating that the current spatial land use plan has not adequately accounted for the hazard. The methodology employed in this study should prove of use for other cities on the littoral.

1. Introduction

Global warming has been an important issue for at least the last three decades. The melting ice in the Arctic has significantly increased the volume of global sea water, prompting sea level rises (SLR) by 0.5–2.3 m at the end of the century [1]. Consequently, inundation in many coastal cities could become more severe in future.

Coastal cities face new or aggravated stresses from climate impacts [2], owing to change in both the marine and the terrestrial environments [3]. Over time, coastal land will be more severely affected by SLR, storm surge and wave height, whereas inland changes include alterations in river flow regimes [4]. About 600 million people and two-third of the world's major cities located in coastal areas have been influenced by SLR [5]

With one of the longest coastlines in the world, the archipelago of Indonesia has many cities located in coastal areas. They link regional trading activities between their hinterland and other cities beyond their island at all scales ranging from local to international. Given rapid growth, their nearby coastal areas have also become attractive places for settlement, fishery and tourism.

Natural disasters frequently occur in Indonesia [6–8]. Given its tropical climate, the nation often faces extreme weather, temperature and wind effects. Such climatic conditions, along with the growth in human activities and environmental degradation, tend to worsen and lead to an increasing incidence and intensity of natural disasters, in particular, hydro-meteorological hazards such as floods, landslides, tropical cyclones/storm and drought. According to Nied et al. [9], the characteristics of floods are affected by hydro-meteorological conditions. The flood types are linked to soil moisture and weather patterns, primarily determined by the season, the presence of snow, and atmospheric conditions in the build-up period. Flooding events also vary among the seasons.

In northern Java's coastal cities, inundation has been worsened by SLR, which causes *Rob,* a local term for this hydro-meteorological hazard. Technically, *Rob* refers to both inundation that permanently occurs and flooding that appears temporarily in an area, both of which are caused by the sea water overflow. In areas being affected by *Rob*, many people live unsafe. The more economically capable inhabitants can often move to safer areas. However, many others decide to stay in place for various reasons, including financial restrictions, the need to be close to workplaces, as well as other historical and cultural influences. Despite their attempts to adapt *in situ*, they are vulnerable to such

* Corresponding author.
E-mail address: i.buchori@undip.ac.id (I. Buchori).

https://doi.org/10.1016/j.ijdrr.2017.11.003
Received 6 April 2017; Received in revised form 23 October 2017; Accepted 1 November 2017

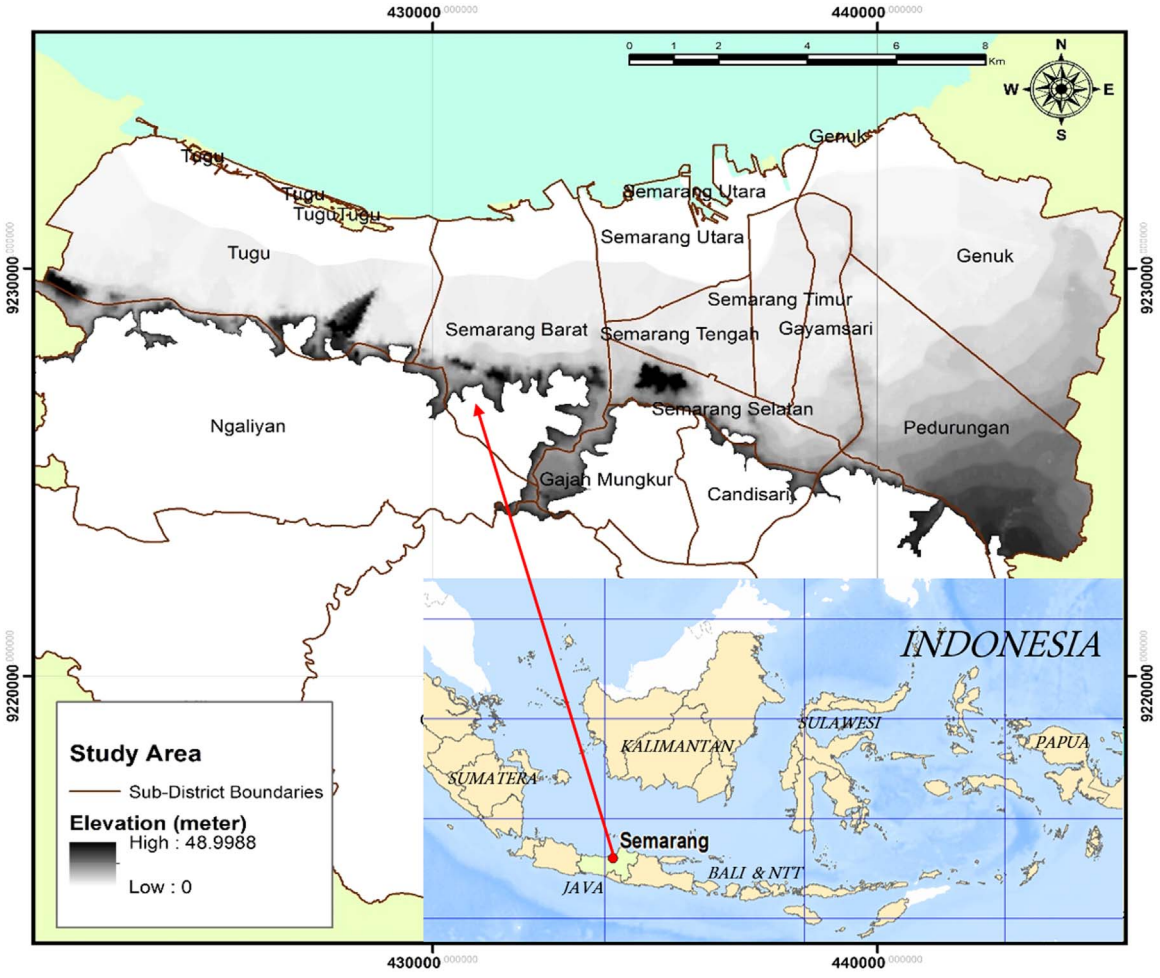

Fig. 1. The study area of Semarang in Central Jawa, Indonesia.

hazard.

There is extensive literature on the scale of SLR in various locations around the world. Nicholls and Mimura [10], for example, estimated that sea level will increase by 10–25 cm by the end of the 21st century. Huq et al. [11] predicted that the rise would vary from around 18–59 cm depending on location. Overall, sea level could rise by 50 cm [12], with a one percent possibility of 100 cm [10]. In Indonesia, the extent of SLR in the coastal area of Makassar can amounted to 8–10 mm per year according to Hidayat [13]. This estimate concurs with Julzarika [14] which predicts that sea level around Semarang will rise between 50 and 100 cm in the following decade. A more recent study by Ismunarti, Satriadi, and Rifai [15] show a much large rate of 14.2 mm/year based on data from the Indonesian Agency of Meteorology, Climatology and Geophysics' data (*Badan Meteorologi, Klimatologi dan Geofisika*/BMKG) from 1995 to 2014.

Research on coastal development has featured strongly in the literature, leading to improved understanding of its: impact, risk and vulnerability assessment [3,6,16–20]; management, planning and sustainable adaptation [4,21]; and hazard mitigation planning [22]. Seaboard cities need to pay special attention to community awareness of, and resilience toward, hydro-meteorological hazards, especially around themes of climate change. Human settlement has long been drawn to coasts, which provide many resources and trading opportunities, but also expose residents to various hazards [5]. A wide range of climate change and hazard impacts can afflict metropolitan coastal areas where a dynamic and complex interaction of natural and socioeconomic systems occurs in highly heterogeneous contexts [23]. Adapting to climate change is therefore an essential part of ensuring that cities remain desirable places to live and work.

Spatial planning is a common instruments for disaster risk reduction [4,6,24–28]. Concomitantly, Indonesian Law No. 26/2007 on Spatial Planning determines that disaster mitigation should be part of a spatial land use plan. The Indonesian National Spatial Plan (*Rencana Tata Ruang Wilayah Nasional*) consists of both a Spatial Structure Plan (*Rencana Struktur Ruang*) and Spatial Pattern Plan (*Rencana Pola Ruang*). The Spatial Structure Plan determines the hierarchy of service centres and relationships among different spatial units, while the Spatial Pattern Plan regulates land uses such as conservation, cultivation and built-up areas. In principal, the Spatial Pattern Plan should take into consideration, among other matters, hydro-meteorological hazards, particularly in planning the land use in the coastal regions to reduce negative impacts of disasters before, during, and after their occurrence [11,29,30] and improve local resilience [31]. Spatial planning strategies can vary from avoiding potential direct impacts, relocating vulnerable people to less risky locations, and modifying environmental design, to maintaining good spatial management [32]. However, previous studies show that current local spatial plans in Indonesia have neither considered this factor nor had this factor adequately addressed in practice [33–38]. A study of Maulana and Buchori [36] assessing the current land use of Semarang shows its incompatibility with the Spatial