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The role of spatial planning in reducing exposure towards impacts of global sea level rise case study: Northern coast of Java, Indonesia

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ABSTRACT

Spatial planning is expected to facilitate climate change adaptation by directing future spatial and infrastructure developments away from zones that are exposed to climate-related hazards. This study attempts to confirm this understanding by mapping the effects of the various spatial plans on the northern coast of Java, Indonesia. First, the study maps the extent of coastal hazards for the baseline year of 2010 using a GIS-based inundation model. An overlay in GIS demonstrates the influence of spatial plans for the projection year of 2030. This allows for calculating the economic losses of the planned developments. The case study shows that the current provincial spatial plans direct land use conversions along the northern coast of Java to continue to occur in the future. This could significantly decrease the regional capacity in dealing with the exposure to coastal inundation. The analysis also demonstrates that a total area of 55,220 ha of land prone to inundation, consisting of protected area (1488 ha), fishponds (32,916 ha) and agricultural land (20,814 ha), is planned to be converted into industry (13,399 ha) and settlements (41,821 ha). Thus, these areas will be also prone to inundation in 2030. This change would potentially lead to an economic loss of 246.6 billion USD. The spatial plans issued by the national and provincial governments for regulating the future land use on the northern coast of Java have not integrated measures against hazards related to global sea level rise. Meanwhile, many existing developments have already been affected by coastal inundation. Rather than reducing the exposure towards coastal flood hazards, the case study shows that spatial plans could even increase the risk of climate-related hazards and cause higher economic losses. These findings provide a different perspective on the role of spatial planning for climate change adaptation than what is stated in the literature.

1. Introduction

Issues related to global climate change have dominated our day-to-day life ranging from purely scientific discussions and political debates to price instability of agricultural commodities in the markets. Following up on the Conference of the Parties (COP) 13 of UNFCCC in Bali in 2007, the mitigation of, and adaptation to, global climate change have become an important agenda in Indonesia. Since then, the government of Indonesia has begun to mainstream climate change mitigation and adaptation into its development planning system. Law No. 17 Year 2007 on 2005–2025 Long-Term Development Plan (GOI, 2007) clearly states that Indonesia's long-term sustainable development will face threats from climate change. To elaborate this law, in November 2007, the Indonesian government published *RAN-MAPI* (National Action Plan in Facing Climate Change), which contains guidelines to coordinate multi-sectoral efforts in climate change adaptation and mitigation. In July 2008, *Bappenas* (National Development Planning Agency) also published a document titled "National Development Planning: Indonesia's Response to Climate Change". This document, besides being specially designed to sharpen and strengthen the 2004–2009 Mid-Term Development Plan (RPJM), also served as input for the 2010–2014 RPJM in the context of climate change adaptation. Furthermore, following up on President Susilo Bambang Yudoyono commitment to reduce greenhouse gases (GHGs) emission at the G-20 Meeting in 2009, in Pittsburgh, USA, the government issued Presidential Regulation No 61 of 2011 on National Action Plan for Reducing GHGs emission. In the context of adaptation, the Indonesian government has also published the National Action Plan on Climate Change Adaptation in 2014. Recently, the Nationally Determined Contribution (NDC) has been enforced, as part of the 2015 Paris Agreement, which has been ratified through Law No. 16 of 2016. It consists of adaptation and mitigation measures towards climate change. The mitigation target of NDC for Indonesia is the reduction of emission up to 29% if using domestic resources and 41% if there is support from the international community compared to business as usual condition by 2030.

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1.1. Background

In the context of integrating climate change mitigation and adaptation into planning in Indonesia and to further elaborate the various climate change related policies mentioned above, *Bappenas* has published the "Indonesia Climate Change Sectoral Roadmap or ICSSR" in March 2010. This document contains a sectoral roadmap program of Climate Change Mitigation and Adaptation for a 20-year period to mainstream climate change issues into the 2010–2014 Mid-Term Development Plan (RPJM) onward, and into related Strategic Plans of ministry and non-ministerial agencies. One of the Bappenas (2010) main recommendations is to plan the future land use of the northern coast of Java to control land conversion into urban areas, from either agriculture or forestry. However, the National Spatial Plan and several further implementing plans such as the spatial plans of Java contain policies for further concentrating major investment along the northern coast of Java. Jakarta, Semarang, and Surabaya are appointed as "Center for National Activity (CNA)" based on Government Regulation (GR) 26/2008 on the National Spatial Plan and Presidential Regulation (PR) 28/2012 on the Java-Bali Island Spatial Plan.

Similarly, GR 26/2008 and PR 28/2012 designate their surrounding urban areas, called *Jabodetabek* (**Jakarta**-Bogor-Depok-Tangerang-Bekasi), *Kedungsepur* (Kendal-Demak-Ungaran-**Semarang**-Purwodadi), and *Gerbangkertosusila* (Gresik-Bangkalan-Mojokerto-**Surabaya**-Sidoarjo-Lamongan), as National Strategic Urban Regions. In effect, for an example, the Spatial Plan of Central Java 2009–2029 allocates the northern coastal corridor of Kendal-Semarang-Demak as an industrial zone. Similarly, the spatial plan of East Java 2011–2031 designates the coastal zone of Gresik, Surabaya, and Sidoarjo as an industrial area. These provincial plans, as a follow-up of the national policy, will accelerate regional economic development through urban expansion. However, such allocation could increase exposure to Global Sea Level Rise (GSLR) hazards as the existing land use of this coastal corridor is dominated by fishpond areas and mangroves.

Coastal systems constitute a dynamic interaction among sub-systems of natural processes and socio-economic, which have changed in form in reaction to geomorphological and oceanographical processes. Climate change is believed to influence the characteristics of climate parameters, which in turn change external marine and terrestrial influences (IPCC, 2007). Such global change has been seen to impose hazards that are mainly related to an increase in surface temperature, precipitation change, an increase in frequency and intensity of extreme weather events, and sea level rise, which is further exacerbated by environmental degradation.

Neumann et al. (2015) argue that coastal development, land use change, and urban expansion are important factors influencing an increase in exposure towards a combination of current hazards and sea level change. The urban expansion along the coastline has brought economic benefits. However, such development trend also further burdens coastal ecosystems causing serious environmental degradation as emphasized by Curran et al. (2002) that the function of coastal ecosystems as an ecological services provider, is not always compatible with other competing multiple uses of settlements, industries, and fishponds. On the other hand, for example, mangroves, which constitute 25 percent of tropical coastlines, could function as a buffer to reduce the threats from natural hazards such as storms and tsunamis as well as to provide nutrients for sustaining marine life (AAAS, n.d.). Therefore, coastal ecosystem degradation reduces its capacity to withstand hazards caused by both geological factors (e.g. tsunamis) and climate-related disasters such as global sea level rise.

This paper discusses the reinforcing trends that have been taking place in the urban centers and their surroundings along the northern coast of Java. Major investment, occurring for example in Jakarta, Semarang, and Surabaya have brought high economic growth, which in turn caused a high rate of migration, putting further pressure on the coastal ecosystems. In addition, anthropogenic climate change could further escalate the magnitude of coastal hazards. These hazards could offset the economic benefit of the developments in the region.

The northern coast of Java has been classified as the main economic corridor of Indonesia (Dardak, 2012). This is supported by Kuncoro (2013), who concluded that the share of employment and the output value of large and medium industries of Greater Jakarta and Greater Surabaya, which locate most industries along the northern coast of Java, are respectively 53.3% and 64.3% of the total for the whole of Java. According to Tan et al. (2016), the contribution of the secondary sector into the GRDP in Java in 2011 reached 36.48% and the tertiary sector was 52.06%. Regarding the secondary sector, the manufacturing industry is mostly located in Bekasi, Cikarang, and Tangerang (see Fig. 2), but also in East Java, e.g. the shipping industry in Surabaya. The main transportation occurs through road and rail networks along the northern coast of Java, which requires maintenance costs of around IDR 1.8 Trillion per year (Tan et al., 2016). The international seaports of Tanjung Priok, Tanjung Perak, and Tanjung Mas are also located along the northern coast of Java.

Given the above issues, the questions to be addressed in this paper are:

(1) To what extent do the coastal hazards at the baseline period (2010) threaten existing development?
(2) To what extent would the projected coastal hazards threaten planned land use in the future (2030)?
(3) To what extent do the current spatial plans reduce the exposure towards coastal inundation and how much is the potential economic loss of the damage exposure?

1.2. Global sea level rise and its impacts on coastal development

Global warming is considered to cause sea level rise (SLR) which could stem from the thermal expansion and the melting of glaciers and ice in the North and South Poles. IPCC (2007) reports that thermal expansion contributed about 0.42 mm per year (1961–2003) and ice melting contributed 0.68 mm per year (1961–2003), a total increase of 1.1 mm per year in the period of 1961–2003. Furthermore, from 1993 to 2003, thermal expansion added around 1.6 mm per year and ice melting 1.2 mm per year. Therefore, the total climate change contribution to SLR was 2.8 mm per year in the period of 1993–2003 (IPCC, 2007). In addition, IPCC (2014) reports that the average rate of global sea level rise was 1.7 mm/year from 1901 to 2010 and 3.2 mm/year from 1993 to 2010.

Several recent researches show an accelerating process of ice melting along with intensifying global warming. SLR due to global warming is projected to reach 35–40 cm in 2050 relative to the year 2000 (Bappenas, 2010), and by using IPCC-AR 5 modeling reaches up to 48 cm in 2050 (Sofian, 2015). Based on a scenario of RCP 8.5 in the period of 2081–2100, the rate of SLR would be 8 to 16 mm/yr (IPCC, 2014). Along with the increasing global warming, the frequency of ENSO (El Niño and La Niña) also increases (Timmermann et al., 1999). Bappenas (2010) projected that the frequency of ENSO in Indonesia from 2000 to 2020 will increase to every 2 years, based on sea surface data of the Java Sea and IPCC modeling.

According to Aldrian et al. (2012) based on NOAA's record from 1970 to 2009, there have been 4 (10%) strong El Niño (1972-73, 1982-83, 1991-92, 1997–1998) and 3 (8%) strong La Niña (1973-74, 1975-76, 1988-89) occurrences. Cai et al. (2014), using climate modeling data, project the frequency of extreme El Niño events due to greenhouse warming to double. Major forest fires mainly occurring in Sumatra in 2015 is correlated with extreme El Niño. Similarly with the smoke haze disaster in 1997/1998, which partly was reinforced by a prolonged drought related to extreme El Niño (Tangang et al., 2010). Similarly, during a La Niña event sea level rises as high as 20 cm, causing floods along coastal regions (Sofian, 2015). Moreover, referring to Wilson and Piper (2010), climate change impact along coastal areas is a