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RESEARCH

Responding to sea level rise: challenges and opportunities to govern coastal adaptation strategies in Indonesia

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Abstract

Coastal cities in parts of Indonesia are subject to many compounding pressures, including increasing population and industrial agglomeration, and are experiencing greater levels of relative sea level rise (SLR) given the impacts of climate change and large-scale subsidence. The sustainability and resilience of many coastal cities is being tested as they struggle to integrate many socio-technical, political and ecological dependencies within the city with the surrounding coastal environment. Governments at all levels have implemented a diversity of strategies to arrest relative sea level rise, but given the 'wicked' nature of this problem, both policy solutions, proposed and implemented, have rarely achieved the outcomes needed. To a large extent, this is attributed to the ineffective governance framework which has led to policy failure, with multiple actors being motivated by different legislative, political, financial and social interests who prioritize specific beneficiaries and solutions. This article examines the governance challenges associated with sea level rise through case studies in Semarang and Demak, Indonesia. It highlights significant barriers that impede effective coastal adaptation including (1) the policy and motivations of differing levels of government. This includes a national government that emphasizes mega-infrastructure projects, a regional government that lacks the capacity and resources to address groundwater extraction and a local government that seeks low-cost hybrid engineering solutions given their financial and budgetary constraints; and (2) ipso facto a lack of coordination across scale, jurisdiction and sectors. This article also highlights several opportunities for community and civil society participation in nature-based solution (NBS) practices and implementation. This article finds that effective adaptation strategies in coastal areas require an integrated governance framework to improve policy implementation and coordination.

Highlights

Addressing SLR needs coordination of governance of all levels among sectors and between jurisdictions affected.
Appropriate measures need to combine top-down and bottom-up approaches.
Local governments lack the capacity to address SLR and land subsidence problems.
Overlapping and conflicting laws hinder effective implementation in addressing SLR.

Keywords Adaptation options · Wicked problem · Sea level rise · Governance · Nature-based solutions

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Introduction

The coastlines of East and Southeast Asia support 71% of the global coastal population (that is situated below 10 m above sea level), and their vulnerability to sea level rise (SLR) and subsidence are set to intensify (Nicholls et al. 2021). The compounding effects of SLR and coastal subsidence associated with soil compaction and water extraction is particularly evident in many coastal regions along Indonesia, with areas such as Central Java retreating rapidly (Sarah and Soebowo 2018; Triyanti et al. 2017; Winterwerp et al 2020). Relative SLR represents a wicked, complex and unstructured problem (Rittel and Webber 1973; Termeer and Dewulf 2019; Hisschemöller and Hoppe 1996). Finding solutions to address the causes and effects remains elusive, not least because of the number of actors involved and affected. Current efforts to address these issues are focused primarily on urbanized areas, such as Semarang, rather than rural areas, like the adjacent Demak. This reflects a deeper inequity that prioritizes larger-scale mega projects in urban areas at the expense of projects within poorer and marginalized communities. Such actions reinforce the economic ascendency of cities and concurrently disadvantage regional and poorer communities (Bhattachan et al. 2018).

From this context, understanding the systems of governance is critical as it highlights the failings of existing solutions and can offer new models of decision-making. Increasingly, decision and policy makers are required to collaborate with non-government organisations, including community organisations and businesses, to form 'hybrid' or polycentric governance (Toxopeus et al., 2020) to improve their decision-making capacity. Climate-resilient cities must adapt existing governance systems to address relative SLR (Hinkel et al. 2019; Oppenheimer et al. 2019; Ramm et al. 2017) . A governance perspective highlights the inherent tensions and complexities of those making decisions and for whom, particularly when responding to wicked problems (Rittel and Webber 1973).

This paper examines the governance approaches to coastal adaptation to address relative SRL and how they involve and impact various stakeholders. Using a case study approach, this analysis focuses on the governance arrangements in Semarang, Indonesia, and the adjoining regional town of Demak, Indonesia. The governance approaches represent a bifurcation of government interest and approaches; an integrated sea wall and toll road mega project (Crompton 2010) proposed by the national government; and smaller-scale, nature-based projects (such as hybrid engineering sediment traps and mangrove plantings) conducted by local government, civil society and community groups (Termeer, and Dewulf 2019; Noordegraaf et al. 2019). This paper finds the potential to utilize a hybrid governance approach (Kooiman et al 2008; Torfing et al. 2012, Kooiman and Bavinck 2013) which can improve the effectiveness and implementation of climate change adaptation projects.

The governance of climate change adaptation

Climate change is a global issue. However, devolving decision making to local levels allows adaptation strategies to reflect local realities, including social, economic and environmental realities and cuts across government levels, sectors and societal domain (Bauer and Steurer 2014). This approach is endorsed internationally within Article 4(e) of the *United Nations Framework Convention on Climate Change* (UNFCCC), which requires States to adapt and 'develop and elaborate appropriate and integrated plans for coastal management' as part of their adaptation planning. This governance arrangement is designed to ensure that there is capacity, capability and willingness to invest and act on climate change (Long & Rice 2019), and points to the utility of frameworks to manage complex and ever-changing systems (Liu et al. 2007). Moreover, it responds to UN SDG 13 Climate Action and Target 13.1 to strengthen resilience and adaptive capacity to climate-related hazards and natural disasters (United Nations 2015).

Accordingly, there are two broad approaches to the governance of climate change policy involving local decision makers: a top-down approach where national programs are implemented at the local level, and the stakeholder-centred, bottom-up approach in which priorities are set and implemented at the local level (Bauer and Steurer 2014). Hybrid governance has demonstrated their potential for strengthening justice elements though the inclusion of different views and actors. For climate governance to be inclusive, socially just, sustainable and adaptive, different perspectives need to be reconciled (Leonardsson et al. 2021) to improve the decision-making capacity. In practice, hybrid governance involves the collaboration and coordination between different levels of government (national and local) and other stakeholders (e.g. NGOs, academics, private interests and local community members) to deliver certain policy outcomes, such as adaptation to relative SLR. Hybrid governance requires extensive community consultation and genuine participation, and aim to achieve solutions which address not just economic objectives, but also co-benefiting social and environmental outcomes.

The IPCC suggests that adaptation options need to address complexities of social and ecological systems (IPCC 2019). Therefore, framing climate change adaptation requires a mixture of social and institutional responses rather than the sole implementation of technical solutions (Hinkel et al. 2010). This integrated framing challenges a more traditional decision-making process that places the technical

outcome driven by a narrow definition of expert knowledge against a more inclusive and community-involved process. In a technical decision- making approach, science and technology intersect more tangibly with the political domain because the issues and solutions have greater visibility and relevance to the public (Collins and Evans 2002: 236). However, in the last two decades, the emergence of greater stakeholder involvement within the decision-making process is gaining social consensus, especially in relation to addressing urgent societal–environmental problems, such as climate change (Munaretto et al 2014).For relative SLR in particular, the IPCC Special Report on Cryosphere and the Oceans (Oppenheimer et al. 2019; IPCC 2022) has identified that the issue presents a profound governance challenge and difficult social choices, reflecting its status as a wicked policy problem.

All types of responses to relative SLR have a synergistic relationship, including the protection of the land and physical assets, impact on housing, ecosystem-based adaptations and the advance and retreat of shorelines. Hard engineering–based protection may be effective and economically efficient in most urban contexts facing land scarcity, but can lead to increased exposure to longer term risks where natural disasters exceed the levels of protection that form an explicit part of the engineering design. Ecosystem-based adaptation can reduce coastal risks and provide multiple additional benefits, yet may lack technical, ecological, social and political certainty. Adaptation experience to date illustrates that using a locally appropriate combination of decision analysis, land-use planning, public participation and conflict resolution approaches can help to address the governance challenges faced in responding to relative SLR (Oppenheimer et al 2019; IPCC 2022), within which there is likely to be a combined, technical and ecological, response.

The concept of adaptive and interactive governance (Torfing et al. 2012, Kooiman and Bavinck 2013) can be useful to diagnose ranges of governance issues and how to design appropriate governance strategies. This is especially true for the case of a wicked, complex and uncertain problem such as climate change and coastal adaptation (Triyanti et al. 2017; 2020). Interactive governance consists of three orders of governance. The first-order governance deals with day-to-day affairs where people and their organisations interact to solve societal problems and create new opportunities. Second-order governance focuses on institutional arrangements within which first-order governing take place. 'Institution' denotes the agreements, rules, rights, laws, norms, beliefs, roles, procedures and organisations that are applied by first-order governors to make decisions. Meta or third-order governance evaluates the governing exercise (Kooiman et al 2008). In addition, it is useful to also examine climate governance through a structural lens: self-, co- and hierarchical governance. Self-governance refers to situations in which actors take care of themselves, outside the purview of government. Co-governance occurs when parties collaborate and stake their identities and autonomy to govern. Hierarchical governance is the most classical mode, and is characteristic for the interactions between a state and its citizens. It is a top-down style of intervention, expressing itself in policies and law (Kooiman et al 2008).

In this paper, we will use these concepts, especially modes of governance, to examine the problem and responses to relative SLR in Semarang and Demak. As this article will advocate, despite the availability of enabling international law and frameworks, Indonesia lacks a climate policy designed to integrate the activities of government and others from the national to local level. In part, this is emblematic of wider trends that have seen the responsibilities to tackle climate change transferred to lower government levels, while environmental issues remain within the jurisdiction of the national government (Gupta 2007).

Methodology

This research triangulates data from a review of grey and published literature with qualitative interviews of stakeholders at the local level who are involved in coastal management in Indonesia. This paper has chosen Tambak Lorok, Semarang and the villages of Sriwulan and Bedono in Demak, located on the west coast of Central Java. These locations have been chosen for the purposes of this study for both the impacts that they face to relative SLR (Yuwono et al. 2018), and the different policy approaches taken to address the same coastal issue. As demonstrated in Table 1, government officials, NGOs, academics and local communities have been interviewed via in-depth interview, workshop(s), training event and focus group discussion in 2018.

A central issue of this study is governance networks and how they interact to impact the effectiveness and implementation of climate adaptation strategies. To integrate this issue into the research methodology and highlight the collaboration (or lack thereof) between key stakeholders, this study has employed a purposive or chain-referral (i.e. 'snowballing') sampling technique as part of the interview process. This technique involves a primary data source (i.e., an interviewee) to nominate another potential data source (i.e., other interviewees) to generate data samples and gain a bigger picture of the stakeholder environment. This process was undertaken to identify key individuals within the decision-making process that may relate to an individual's expertise, authority or influence. In doing so, this study aims to explore each stakeholder's perspective on policy options taken to address relative SLR and evaluate their modes of governance and challenges.

Table 1 List of key interviewees and organisations

	Number of interviewees
National government	
Ministry of Public Work and Housing/BBWS	2
Provincial (local) government	
Marine Affairs and Fisheries Central Java Province (DKP)	4
Regional Disaster Management Agency, Central Java Province BPBD	2
Environmental Agency, Central Java Province	2
City- and municipal-level government	
Marine Affairs and Fisheries, Semarang and Demak City	2
Environmental Agency, Semarang and Demak City	2
NGOs	
Wetland International Indonesia	2
Bintari (NGO)	1
OISCA	1
Community members	
Local communities Tambak Lorok, Semarang	15
Local communities Bedono village, Demak	5
Local Communities Sri Wulan village, Demak	3

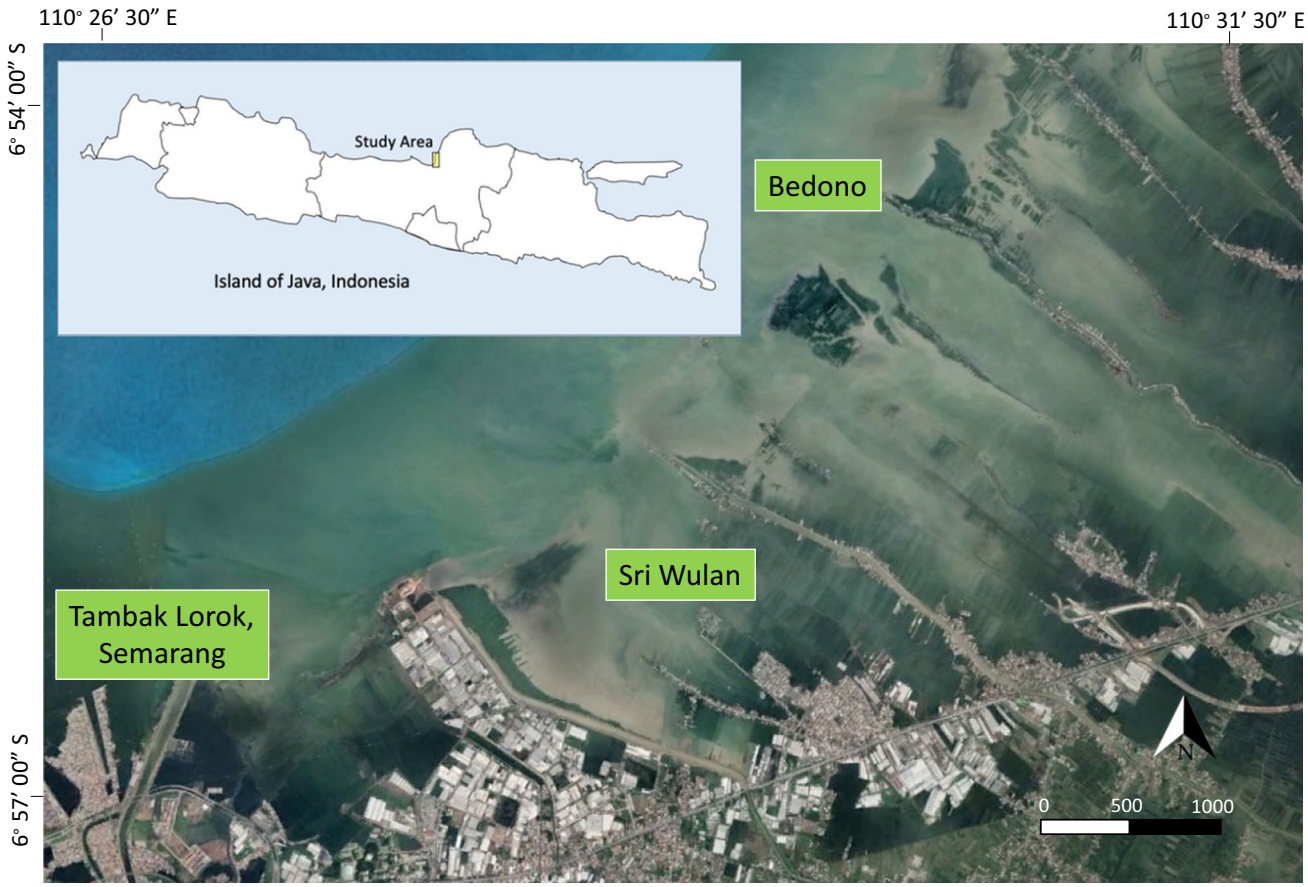

Fig. 1 Map of villages as case studies in Semarang and Demak. Source: Google Earth, 2020

For the analysis of the interview data, responses were organised according to the level of government (central, provincial and municipal) and by location, Semarang and Demak. Data on the policy changes and actions by every institution was then cross checked and analysed against published records.

Coastal subsidence and SLR in Semarang and Demak, Indonesia

The dual pressures of subsidence and SLR are present in many parts of the world, particularly in cities that are built on deltas (Erban et al. 2014; Nichols et al. 2021) and unconsolidated sediments, such as the neighbouring cities of Semarang and Demak, Indonesia (Fig. 1). These cities have reported land subsidence and rising water levels since the mid-1990s, and the impacts are getting worse as the process of global climate change intensifies. Globally, SLR is occurring at approximately 3.1 mm/year (Lindsey 2019). For Semarang and Demak, land subsidence is far greater, up to 80–120 mm/year, highlighting the immediacy and magnitude of this issue (Yuwono, et al. 2018). Relative SLR for Samarang and Demak therefore brings into focus adaptation issues likely to face global coastlines under mid- and high-emission scenarios (IPCC 2022).

The cause of land subsidence in Semarang and Demak is attributed to several factors including the physical characteristics of the alluvium soil in coastal areas but is driven mostly by anthropogenic impacts such as excessive groundwater extraction by industries (Abidin et al. 2013; Saputra et al. 2017). The implications of climate change further exacerbate and contribute to the issues caused by excessive groundwater extraction. The driving forces for groundwater extraction are a lack of alternative surface water sources for the city, illegal extractions, and the capital costs to provide this additional water security (Semarang City Government 2016). Not surprisingly, mapping of land subsidence in Semarang and Demak has revealed greater rates along the coastline underlain by alluvium sediments. As shown in Fig. 2, the coastline across the region has been progressively retreating since 1994 at an average rate of 25 m per year (Muskananfola and Febrianto 2020) and this has led to greater impacts of coastal erosion and permanent inundation and has exacerbated the pre-existing flooding problems caused by climate led SLR.

The physical impact of land subsidence in Semarang and Demak is substantial. According to data from the Marine Affairs and Fishery Agency in Semarang, land subsidence in Semarang is occurring across four districts (West Semarang, Tugu, North Semarang and Genuk)

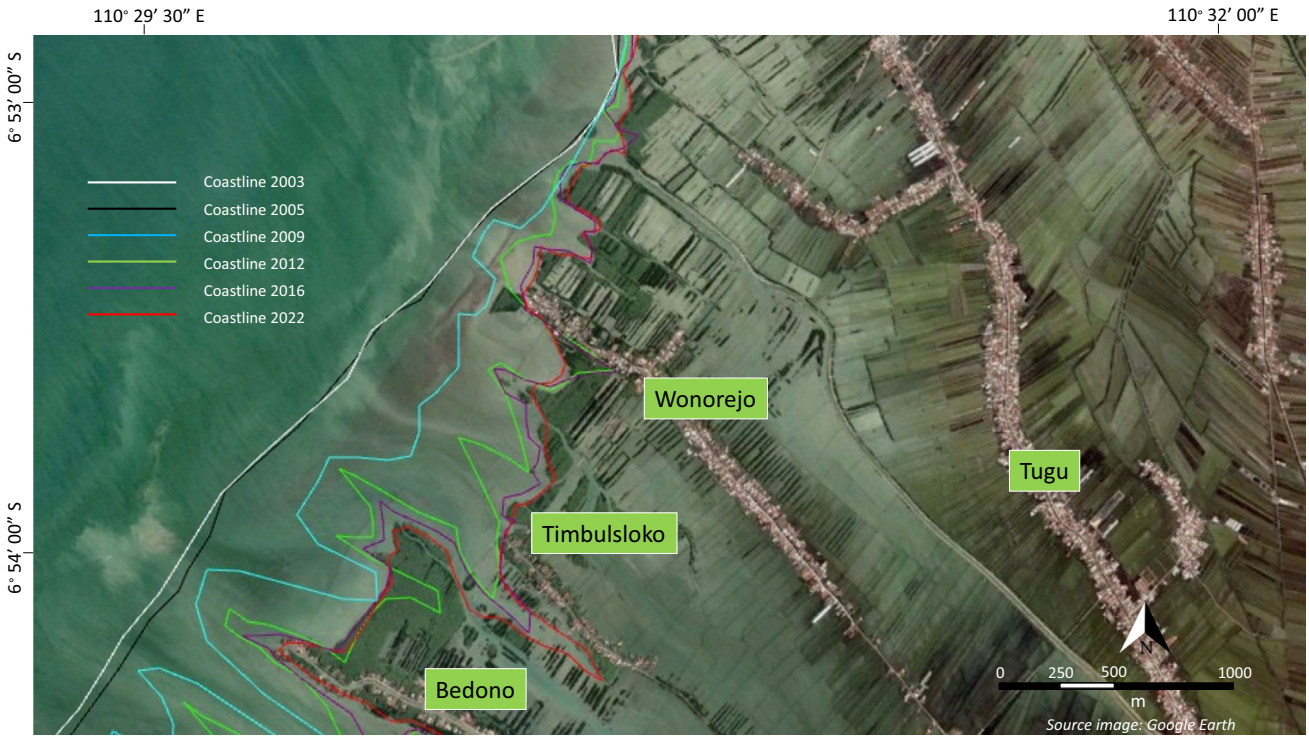

Fig. 2 Changing of shoreline in Demak from 2003 to 2022. The figure shows the erosion happened over time in villages in coastal areas in Demak. Source: Wetland international Indonesia, 2022

totalling 902,920 ha with the combined area subject to coastal flooding totalling 422,223 ha. In Demak, two districts (Sayung and Wedung) and four villages (Sri Wulan, Bedono, Timbulsloko and Babalan) are affected by land subsidence, erosion and coastal inundation with some areas permanently inundated. The socio-economic impacts of these changes have been occurring for 20 years and have had direct and negative effects on property, livelihood and the culture of these coastal communities. The residents have lost, or are incrementally losing, their houses and land, their sources of income and the enabling infrastructure to access their villages, such as roads. These vital resources are under continued threat of damage or have disappeared altogether. Despite ongoing and albeit variable efforts to manage the impacts, migration and displacement from these areas has been inevitable. In Demak alone, according to the interview with local officials, 798 ha of land has been lost due to permanent inundation, resulting in the migration of 1200 people from the Sri Wulan village, while 800 people living in the Bedono village have been forced to migrate.

Policy responses for addressing relative SLR in Semarang

In the race to save coastal Java from inundation, adaptation efforts to address relative SLR in Semarang and Demak demonstrate the different framing of adaptation options by central and local governments. To date, most of key policy options are more addressing SLR rather than the land subsidence problem. As a means of simplifying these typologies, these have been divided in terms of a top-down approach or hierarchical governance that is driven by the national government, which is more engineering and capital intensive in nature, as typified by the mega project proposals. In contrast, there are smaller-scale, ecologically orientated bottom-led approaches enabled through self-governance or co-governance which are smaller in budget and scale (Table 2).

The top-down approach or hierarchical governance is exemplified by two proposed hard infrastructure projects: an integrated sea wall and toll road along the Semarang and Demak coastline by the National Government's Ministry of Public Work and Housing and a marine tourism village in Tambak Lorok Semarang supported by the state government. At the other end of the spectrum, two community-led or co-governance initiatives involving NGOs and local government are provided involving a nature- based mangrove planning program and a hybrid ecological engineering solution to manage coastal erosion.

Hierarchical governance and top-down approaches

Sea wall and toll road integration

To improve logistics and transportation, and protect Semarang and Demak from relative SLR and coastal inundation, the national government has proposed a 27-km toll road and sea wall (Fig. 3). This initiative is being coordinated by the Ministry of Public Works and Housing (Decision No. 355/KPTS/M/2017). The project forms one of several mega projects under the National Capital Integrated Coastal Development (NCICD) Policy and has been included as a national priority within the Long-Term National Development Planning (RPJMN) Policy. From a national government perspective, the scale of this project reflects the geographic and jurisdictional extent of relative SLR and the consequent need for a coordinated multi-city approach to adapt to climate change.

The sea wall and toll road integration project are not without controversy nor is it uniformly supported by the public and other stakeholders at the local level. There are many different stakeholders' perspectives that question the effectiveness of this technical solution and its impact on the community and coastal environment. In the interviews held with selected local, provincial, municipal and national government officials, most doubted that the mega sea wall project could solve land subsidence issues. This mirrors the concerns and eventual abandonment of the proposal for a giant sea wall project in Jakarta (CNBC 2021). Some of the strongest criticism comes from academics, environmental activists and NGOs who argue that this solution does not address the most pressing issue of relative SLR, being land subsidence (Kompas 2022). In our research, interviewees from environmental NGOs Bintari and OISCA expressed concern with the potential environmental and social impacts of the project, particularly its negative impacts on mangrove areas despite the EIA document that promised to use best available technology to minimize these impacts. It is expected that there would be relocation of 46 ha of mangrove areas in Semarang and Demak because of this project. In addition, during interviews with the Bintari NGO, there was a concern that the project benefits will not be fully realised in Demak, with several areas of affected villages not being protected by the sea wall. The NGO also expressed concern that an area that falls outside of the sea wall would experience significant changes to current sea patterns, and waves are likely to damage and erode other areas nearby, such as the Bedono and Timbulsloko villages in Demak. In addition, there is a perspective that companies who own the land near coastal areas will be advantaged as the land will emerge again after the establishment of the sea wall and toll road integration. Land speculation has emerged with

Table 2 Key policy options for adaptation in Semarang and Demak

Policy options	City	Strength	Weaknesses	Lead agency or institution/s
Sea wall and toll road integration. This is a strategic long-term project to provide safe transportation and logistics from Jakarta and West Java to other regions in central Java and East Java	Semarang, Demak	Protect a majority of Semarang's coastal areas from flooding and coastal inundation Ease traffic congestion and improve transportation and logistics	Protects only small parts of Demak and other parts of the coastline which will be further deteriorated by coastal erosion due to changing sea waves Damage to mangroves and other marine / intertidal biota Access to the sea will be blocked for some local fishing industries High maintenance costs Anticipated accumulation of garbage (gross pollutants) to be collected and landward ponding of water will need to be pumped to sea	The Ministry of Public Work and Housing (national government initiative and funding from loan)
Tourism village (Tambak Lorok) enabled through the creation of sea walls and upgrading the fisherman port. This will require the upgrading and relocation of informal settlements (slums) to inland to vertical housing (apartments)	Semarang	Slum upgrading and protection of coastal flooding	Several residents' object to the forced resettlement to vertical housing and/or selling their land for the project Disconnects communities from the traditional or current location	Ministry of Public Works (national government) and Bappeda Semarang City (local government)
Mangrove planting and rehabilitation (short term and long term)	Semarang, Demak	Cheap and ecologically friendly	Lack of land for planning as most of coastal area is now owned by companies that do not support this approach Some land has been inundated beyond the capacity of this approach Some areas are unable to be planted with mangrove because of strong wave/tide prohibits their establishment Ongoing relative SLR causing mangrove retreat	Provincial and municipal levels including Marine Affairs and Fisheries, Environmental Agency NGOs and INGOs Local communities
Hybrid engineering	Semarang, Demak	More affordable than other 'grey' infrastructure and involve locals in the establishment and ongoing upkeep	Due to strong wave only 70% of this approach has proven to be successful in trapping sediments to support mangroves Ongoing maintenance issues Potential to interfere with sediment redistribution	Wetland International The Ministry of Marine Affairs and Fisheries UNDIP University

Fig. 3 Sea wall and toll road integration track. The figure shows the initial tract of sea wall and that the toll road integration with 8 km is a sea wall with a height of 5 m. It starts near Tambak Lorok Semarang and passes through Sri Wulan and a small part of Bedono village in Demak. Source: Google Earth and PUPR Ministry, 2018

companies purchasing subsidence-prone land at a reduced price from communities. Land speculation is common in infrastructure project in Indonesia. It causes delay in many infrastructure projects due to failure of compensation negotiation between state and the legitimate owners.

Support for the sea wall and toll road was also expressed by interviewees from local communities in Tambak Lorok, Semarang. The main argument in support for the sea wall was the anticipated safety from flooding. However, such optimism was not uniformly shared with one participant from the local community in Sri Wulan, Demak expressing scepticism regarding the efficacy of the sea wall against coastal flooding. A participant from the Energy and Mining Department indicated that the project will not address the core problem of land subsidence in Semarang and Demak, stating that the subsidence is the result of a lack of adequate water supply. According to the participant from the Department of Public Works and Housing (BBWS), the sea wall is likely to incur substantial costs to manage and will require large retention ponds and pumping systems as the wall will block rivers and drainage systems. This will amplify further flooding risk as surface water will be unable to escape from the catchment area effectively.

Sea wall and marine tourism village in Tambak Lorok

To address ongoing flooding due to coastal inundation, the national government initiated the establishment of the marine tourism village. The project builds upon previous sea wall and fisherman port projects coordinated by the Ministry of Public Works and Housing that led to the establishment of tourism villages such as 'Kampung Bahari' in the Tambak Lorok. The Kampung Bahari project transformed a highly densely populated and informal residential community into a marine tourism village that is now protected by the sea wall. However, it also displaced a large number of vulnerable residents and compensation for relocated fishing communities remains an outstanding issue. Moreover, some residents have stated that they were rejected for alternative housing in apartments offered by the local government, with housing that was provided being geographically distant from their work and coastal identity as a fisherman. While the national government posits that the project provides alternative housing, the subsequent loss of community, coastal identity and employment are not adequately recognized or addressed.

Co-governance and local approaches

At the other end of the spectrum, self and co-governance approaches which emphasize the active participation of local communities and governments emphasize scalable solutions that aim to address the social and environmental impacts associated with mega, grey infrastructure projects favoured by the national government. These ecosystem-based adaptation programs can reduce both coastal risks and provide multiple additional benefits, yet may lack technical, social and political certainty. This is revealed through the observations of Wetland International Indonesia that 70% and the existing mangrove is uncertain in the future as it may be damaged by sea wall and toll road integration project or the community or companies who own the land change their mind and remove the mangrove for other uses.

Hybrid engineering: sediment trap

Hybrid engineering has been introduced in Bedono village, Demak, to address coastal erosion and flooding. According to Wetland International Indonesia (Wetlands International 2016), hybrid engineering is a technology adopted from the Netherlands that brings together engineering and NBS. In this example, sediment traps are used as a permeable structure to allow mangroves to grow within the trapped sediments. The development of mangroves then allows the restoration of the natural effects of wave dampening and sedimentation occurring within the mangrove forest. The technology was introduced by Wetland International through their program 'Building with Nature' (Wetlands International 2016) and has been adopted and replicated by several Indonesian Ministries including the Ministry of Marine Affairs and Fisheries and the Ministry of Public Works and Housing. In 2015, the Ministry of Marine Affairs and Fisheries adopted this approach through the Ministry of Marine Affairs and Fisheries regulations No.55 Year 2016, and it has applied across 9 locations (Demak, Cirebon, Brebes, Semarang, Jepara, Pati, Serang, Rembang and Gresik). This was followed by over 10 km of permeable dam construction in 2018–2019 in Indonesia, including another 1.5 km in Demak (Winterwerp et al. 2020).

The permeable sediment traps have been successful in increasing local rates of sedimentation in the short term. The reduction in waves and currents has encouraged the build-up of sediment behind the permeable wall at Trimulyo village (Kurnia and Nugroho 2018), depositing about 81,500 m^3 in 20 months. Two sediment basins created behind permeable dams installed in Demak in 2013 proved effective at promoting local short-term sedimentation, up to 0.6 m of accretion occurring in the 6 months to May 2014 (Winterwerp et al. 2020). However, ongoing monitoring has suggested a long-term lowering of sedimentation rates, with mangroves surviving in only a few of the most protected basins (Winterwerp et al. 2020). The high sedimentation rates were offset by compaction and subsidence, estimated at 0.05 m per year. It is likely that high sedimentation rates are not translating into strong vertical elevation gain due to both upper-level and deep subsidence (Cahoon et al. 1995; Rogers and Saintilan 2021), compromising the effectiveness of sediment trapping as a means of encouraging mangrove restoration.

A further problem with the placement of parallel dams is the potential inhibition sediment transport. Mangroves have formed along the Demak coastline in areas of abandoned aquaculture ponds where sedimentation has increased as a response to the redistribution and redeposition of eroding shoreline sediment. Permeable sediment traps may interrupt the landward 'streaming' of this material when inappropriately placed (Winterwerp et al 2020), leading to sediment starvation and further mangrove erosion. According to a participant from Wetland International Indonesia, the permeable sediment traps are not installed as long-term structures and they are susceptible to deterioration and failure. Of the structures installed, Wetland International indicated that 30% have failed primarily due to strong wave action that is prevalent along this part of the coast. The lifetime of permeable sediment traps is compromised by shipworms, and regular inspection and maintenance is required (Purnaweni et al. 2018). Some have since been modified by the University of Diponegoro and the Ministry of Marine Affairs and Fisheries as part of an adaptation project through the introduction of hard, non-permeable structures that serve to trap sediments and act as wave breakers.

Mangrove plantation and rehabilitation

Mangrove plantation and rehabilitation are undertaken at a local community level. Mangroves are an important ecosystem that can protect coastal areas from erosion and coastal inundation (Ocean Wealth 2019). However, their success and survival are dependent on relative SLR and sediment accretion (Krauss et al. 2014). In Semarang and Demak, these programs are initiated by several government institutions with the support of NGOs and involvement of local communities. In Demak, these projects were initiated by the district level agriculture office with Gerakan Reklamasi hutan dan Lahan (GERHAN initiative) in 2003–2004, and later followed up by local and international NGOs, such as Bintari in Semarang and the Organization for Industrial and Cultural Advancement (OISCA) from Japan in Demak.

As indicated from interviews with NGO Bintari, the key challenge of mangrove planting is finding suitable land, as most of the land in coastal areas has been given as a concession to companies or is owned by local people. In Bedono village, for example, OISCA has planted mangroves

in inundated land or within community land in partnership with residents. No mangrove plantation has occurred in Sri Wulan due to high wave action preventing its establishment. While OISCA has stated that established mangroves have enhanced ecosystem biodiversity and have become an ecotourism attraction and employment generator (including for women), OISCA has expressed that the outcome of any mangrove plantings and subsequent land reclamation may not be universally agreed between the national and local governments, and the commercial interests of local communities and companies which hold the land. The net result is that this ecological nature-based solution that offers success in some areas remains politically and environmentally vulnerable.

Opportunities for successful long-term restoration of mangroves may be limited on the Demak coastline. Over 90% of mangroves occur immediately to the east, southeast or south of cheniers—protective ridges of coarser sediment that have formed in the context of rapid coastal retreat (Winterwerp et al. 2020). These natural structures protect mangroves from the dominant north-west monsoonal winds and waves; however, they are capable of retreating. Cheniers have been known to retreat by up to 100 m in a matter of weeks (Winterwerp et al. 2020), and their failure and alteration can lead to rapid mangrove erosion. While mangrove colonisation of freshly deposited sediment can be rapid (Irsadi et al 2019), the overall pattern along this coast is one of seaward edge erosion and landward re-establishment, consistent with the limited capacity of mangroves to withstand high rates of relative SLR (Saintilan et al. 2020).

Towards hybrid governance: challenges and opportunities

Implementing meaningful public participation between a centralised and decentralised approach

The sea wall toll road integration proposal offers an example of a top-down, centralist approach or hierarchical governance with a focus on larger reforms and bold objectives that often characterize mega infrastructure projects (Flyvbjerg et al. 2003). Interviewees and academics have asserted a deficiency in the project justification and evaluation that under-represents the socio-environmental impacts while inflating the economic benefits. Such criticisms reflect the same concerns levied against many large-scale and mega-infrastructure transport-related projects (Flyvbjerg et al. 2003). Socio-environmental impacts of the project include the legal uncertainty of sinking land and compensation to community and mangrove damage as result of the project. In addition, the sea wall toll road proposal was primarily aimed at addressing traffic issues from Jakarta to East Java. The design then accommodated to include sea wall to prevent relative SLR. This project is part of a NCICD project and reflects the statutory and resource capabilities to manage and implement the project effectively. Financially, the sea wall and toll road projects form a subset of the National Capital Integrated Coastal Development (NCICD) initiative that has to be funded by loans and public private partnerships and through national and regional budgets with the investment value totalling around $USD 1 billion (Natalia 2019). Like many other mega-projects, they have continued to demonstrate poor economic, environmental and social performance outcomes (Flyvbjerg et al. 2003). Yet despite these controversies, the toll road and sea wall project continue to progress.

The mega-infrastructure projects and proposed sea wall also had issues at the Environmental Impact Assessment (EIA) stage. EIAs for large projects have demonstrated uncertainty that the proposed socio-environmental benefits can be delivered (Flyvberg et al. 2003), and that these limitations are not highlighted to decision-makers Ramm et al. 2017). The EIA for the sea wall and toll road integration project was issued by the Environment Protection Agency of Central Java province. This EIA noted that the project will have a negative impact on the environment, specifically on mangroves and other coastal ecosystems, and this will result in further negative social impacts including blocking fishing lanes to local fisherman (Dinas Lingkungan Hidup 2018). Nevertheless, the EIA was approved, subject to conditions that the final designs minimize the negative impacts of the project (Dinas Lingkungan Hidup 2018).

Under this hierarchical governance approach, it is evident that resource priority has been given to Semarang, an industrial city, and not Demak, an agricultural city, despite their proximity (Nurhidayah and Mcllgorm 2019). This is illustrative of a favouritism towards city centres that contribute greater economic outcomes and by virtue of these decisions exacerbates socio-economic inequalities. Some local communities in Demak expressed that this failure to address the negative impacts of relative SLR points to a failure of the decision-making process at both a policy and project level (Ramm et al. 2017). There remains a lack of community participation in the project, and given that the proposed toll road was also implemented to address traffic issues, heavy weighting and consideration has been given to solutions which favour existing urban areas and urban problems. Conversely, local fishermen and rural residents participating in focus group discussions stated that the current development of marine tourism, positioned as an adjunct benefit of project, will benefit only investors and not the local people, highlighting the socio-economic and political complexities of such an approach. These divergent views underscore an inherent tension within a top-down approach when having to reconcile impacts at the local to national scale, whereby

ambitious outcomes are positioned above the concerns of local communities and their interests (Lamb 2014).

There is an opportunity for further improvement under a hybrid governance model which involves active participation between national and local government, local communities members, NGOs and private interests. Given the capacity for national governments to command more resources and identify issues that span across several local and municipal jurisdictions, projects which aim at addressing systemic, widespread issues such as water over-extraction remain a policy problem that is largely unaddressed when responding to relative SLR. Projects which can capture surface water run-off and be used to relieve existing and anticipated water demand and reduce the strain on underground water extraction require extensive hydrological studies and modelling, community input on existing water uses and resources to identify how to increase water capture and storage. In addition, judicial review and advocacy are other means to improve hybrid governance by enforcing statutory rights held by citizens against the national government. There are further means to invoke the ATR/Spatial Planning regulation no. 17/2021 which makes the national government accountable for sinking land through compensation, and using judicial avenues to prevent the use of rehabilitated land for further urban development which can contribute to greater land subsidence outcomes.

Inclusiveness and adaptability

The two small projects premised on NBS in Semarang and Demak are in contrast to larger capital work projects that are being implemented by national and provincial governments. Unlike large-scale engineering projects, local communities are central to these schemes, which create inclusivity, local empowerment and ownership. This, however, needs to be balanced by the often positioned 'experimental' nature of the solutions, which are not always successful. Nevertheless, their scale and cost are such that they can be modified or retrofitted according to varying circumstances, thus presenting a lower financial, social and environmental risk than alternate larger-scale grey engineering capital works solutions. Importantly, NBS may simply offer adaption pathways to a new socio-economic and environmental setting, for example one that can support mangroves establishment and local fishing enterprises. This inbuilt flexibility, adaptability and malleability of design provides a degree of attraction for the community and offers an example of the benefits of a co-governance approach.

However, there remain questions surrounding the jurisdictional support for a co-governance approach, particularly at higher levels of government that remain committed to the tried and tested technical grey infrastructure solutions that offer a socio-technical path of least resistance to change (Geels 2019). What is less certain is where and how either green or grey solutions can offer the long- term social, ecological, economic and political security sought by all levels of government and the communities they serve.

Multi-sectoral approach and coordination

Adaptation requires coordination across different levels of government and sectors. In Indonesia, this is challenging as there is no specific climate change law. In a 2005 study, coastal management had to grapple with the complexities of 14 government agencies, 22 related statutes and hundreds of regulations (Patlis 2005). This complex legal and governance system has resulted in gaps, uncertainty, redundancies and conflicts in the implementation at the local level (Patlis 2005) and remains an issue today.

Under regional Law No. 23/2014, district- and municipal-level governments no longer have any authority to manage coastal areas. Article 14(1) of Law No 23/2014 states, 'the authority and governance of forestry, marine and energy is divided between (the) national government level and provincial level(s)'. Previously, regency- and municipal-level governments had authority to manage this environment up to 4 miles off the coast and, at a provincial level, 4–12 miles. With the new law, provincial-level management assumes responsibility for all 12 miles off the coastal area. Issues of jurisdictional responsibility are further compounded by the fact that these coastal lines are continually evolving given the impacts of relative SLR (see Fig. 2).

Under regional Law No. 23/2014, municipal and regency governments in Demak and Semarang remain uncertain as to whether they can legally use their budget to support mangrove plantings. This is because the area identified for mangrove replanting now falls within the authority of the provincial level of government, being beyond the coastline. Therefore, the hybrid engineering and mangrove plantation solutions to adapt to relative SLR, as favoured by regency and municipal governments, now needs to be implemented, where feasible, by provincial and national governments who remain financially committed to larger infrastructure solutions. Paradoxically, the only budget that can be used to pursue adaptation at the local village level is a village fund based on the law No. 6/2014 which allows every village to receive US$ 71,528 annually from the national government's budget. Arguably, this small allocation has created the need for these lower tiers of government to invest in inventive and community involved NBSs.

Given the legal and budgetary complexities and jurisdictional limits, under a hybrid governance model, there is a need for different levels of government to work together in order to deliver tangible outcomes and NBS projects. The tools available include the use of tied grants by the national government to provincial governments and

multi-government taskforces enable the involvement and input of local governments, communities, NGOs and private interests to deliver mangrove planting or hybrid engineering solutions. Such governance arrangements also enable the use of external stakeholders to monitor implementation and audit both financial and program performance, which are key risks in project implementation. While coordination remains key, clear, targeted policy with measurable outcomes and targets that is genuinely informed by local participation is a key milestone towards policy success. This opportunity reflects the values of an interactive governance model that embraces the different levels of governance that can inform climate adaptation strategy.

Conclusion

Relative SLR is an ongoing reality threatening many coastal communities in Indonesia and in the world (IPCC 2019), which will be worsened by land subsidence that originate from water extraction and other human activities. The challenges of and solutions to relative SLR and land subsidence, to a large extent, are intrinsic to the governance modes suggested by interactive governance concept, i.e. hierarchical, self and co-governance (Kooiman et al 2008; Kooiman and Bavinck 2013) of those who are charged with managing the coastal zone. Each mode has some advantages and limitations. What is evident from this study is that in hierarchical governance, the allocation of resources to develop policy and implement projects depend on national government while self and co-governance engaging in a cooperative inter (vertical) and intra (horizontal) government approach which includes the community. While this research has not explored the costs of an integrated approach, it has revealed the inherent hierarchical governance limitations and complexities that currently exist and that remain captured by varying and often conflicting socio-technical and political interests.

Self and co-governance or bottom-up approaches strongly frame community perspectives within the decision-making process and utilize NBSs as a means to reimagine a future coastal environment. Mangrove plantings, for example, can improve socio-economic and environmental outcomes from their ground-up involvement and action. But their application is context specific and must reflect environmental conditions. Centralist and hard engineering approach, with its high capital costs and a focus on direct economic benefits, can offer a regional perspective but can carry significant social and environmental risks for the local level, not least that it can divide not unify those most directly affected, particularly marginalized groups. From a local and community perspective, there remains a perception that mega projects benefit big business at the expense of local communities as reflected by the participant's interviews for this paper.

There is a need to bring all parties to the table and provide greater visibility and transparency when evaluating the social, economic and environmental impact through the EIA process. An emphasis should also be given to tackle the issue of social justice in coastal adaptation. This process must not be captured or have embedded within it a predetermined outcome based on the framing governance modes. Wicked environmental problems such as illustrated through the case of Demak showcased a strong dynamic characteristic, difficulties to trace the root cause of problems; therefore, it does not have a single solution nor can they easily be directed via a single governance mode. A hybrid approach should be pursued to realize integrated coastal zone management. Thus, it is incumbent on all actors involved or affected by the decision-making processes and outcomes to be involved with and seek complementary not competing solutions. In the context of Indonesia, the national government still plays a key role as legitimate actor to ensure effective coordination and integrated-ness of existing efforts. The challenge is to balance coordination with efforts to embrace redundancy of policies to increase resilience (Craig 2020; Termeer et al. 2015; Folke et al. 2005). This will require diversity of actors (local government authorities, NGOs, private sectors, community organisations) and sufficient capacity to deal with climate adaptation challenges from the local to national level.

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Declarations

Conflict of interest The authors declare no competing interests.

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