Governing systemic and cascading disaster risk in Indonesia: where do we stand and future outlook

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Abstract

Purpose – This paper aims to identify key factors for a contextualised Systemic Risk Governance (SRG) framework and subsequently explore how systemic risks can be managed and how local institutional mechanisms can be tweaked to deal with the complex Indonesian risk landscape.

Design/methodology/approach – Using a case study from Palu triple-disasters in Central Sulawesi, Indonesia, the authors demonstrate how inland earthquakes in 2018 created cascading secondary hazards, namely tsunamis, liquefactions and landslides, caused unprecedented disasters for the communities and the nation. A qualitative analysis was conducted using the data collected through a long-term observation since 2002.

Findings – The authors argue that Indonesia has yet to incorporate an SRG approach in its responses to the Palu triple-disasters. Political will is required to adopt more appropriate risk governance modes that promote the systemic risk paradigm. Change needs to occur incrementally through hybrid governance arrangements ranging from formal/informal methods to self- and horizontal and vertical modes of governance deemed more realistic and feasible. The authors recommend that this be done by focusing on productive transition and local transformation.

Originality/value – There is growing awareness and recognition of the importance of systemic and cascading risks in disaster risk studies. However, there are still gaps between research, policy and practice. The current progress of disaster risk governance is not sufficient to achieve the Sendai Framework for Disaster

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Risk Reduction (2015–2030) unless there is an effective governing system in place at the local level that allow actors and institutions to simultaneously manage the interplays of multi-hazards, multi-temporal, multi-dimensions of vulnerabilities and residual risks. This paper contributes to these knowledge gaps.

Keywords Systemic risk governance, Multi-hazards, Palu, Indonesia

Paper type Research paper

Introduction

Economic and social science scholars have long been concerned with the risk of globalisation, which has increasingly created the world as a "global village". As the world system has become more connected and integrated through financial, banking, transportation and Internet networks, contagious effects of a hazardous event such as an economic crisis and/or a pandemic can create a far-reaching unprecedented impact in different parts of the world. Therefore, it is no surprise that economic scholars have coined the term "systemic risk" to suggest the need to understand some phenomena where an event can trigger cascading effects that lead to widespread disruptions of services, trade and catastrophe. In the last two decades, some economists have defined "systemic risk" as a framework to understand the agential power of a hazardous event that cascades and propagates through a set of interconnected systems (Rochet and Tirole, 1996; De Brant and Hartmann, 2000).

Risk and disaster studies scholars have recently adopted such a framework as they see the merits of "systemic risk" framework to both understand the reality of the empirical world and structure disaster risk governance (e.g. Schweizer and Renn, 2019; Aven and Renn, 2020). Unlike the conventional risk governance framework, the systemic risk approach highlights the interconnected nature of risks, including their interconnected drivers, impacts and vulnerabilities. Moving beyond the multi-hazards concept, the systemic risk approach allows us to understand that the reality of disaster risk is multifaceted, interrelated, context-dependent and sometimes produces nonlinear effects (IRGC, 2017, 2018; UNDRR, 2019).

Sendai Framework for Disaster Risk Reduction (SFDRR) 2015–2030 highlights the need for systematic interventions that drive disaster risk reduction (UNISDR, 2015 para. 15 and 36c). However, in an increasingly vulnerable, uncertain, complex and ambiguous world, managing disasters and risk reduction to achieve the SFDRR target by 2030 will be tremendously difficult given the polycentric nature of authorities that structure their ways of governing (Lassa, 2011).

There is an increase in global awareness of systemic and cascading risks. Nevertheless, we identify gaps within the current disaster risk governance frameworks where efforts to govern disaster risk and build resilience through the four priorities of SFDRR on the ground have been increasingly disconnected. Therefore, we predict that the existing model of disaster risk governance potentially will fail to achieve SFDRR targets by 2030.

We argue that there is a need to create new governing systems at the local level that allow actors and institutions to simultaneously manage the interplays of single and multi-hazards, multi-temporal, multiple dimensions of vulnerabilities, poverty reduction, unplanned urbanisation, environmental degradation and other residual risks. The unprecedented pandemic coronavirus disease 2019 (COVID-19) has revealed our inability to understand the root causes of risk, and thus it stressed the need to understand how to manage systemic risks at local levels.

Meanwhile, in practice, governments and civil society are also not well aware of the importance and benefits of perceiving risk from the systemic approach, which causes the issue of implementation (including processes and outcomes) on the ground. We identified several disabling factors hampering the governability of systemic risks that are mainly dealing with risk perception and communication, including the lack of systemic risk

awareness, understanding of root causes of vulnerability (and risk), risk communication, coordination, mainstreaming in policy and regulation, consideration of future uncertainties in planning and resources (see Paton and Sagala, 2018; Djalante *et al.*, 2017).

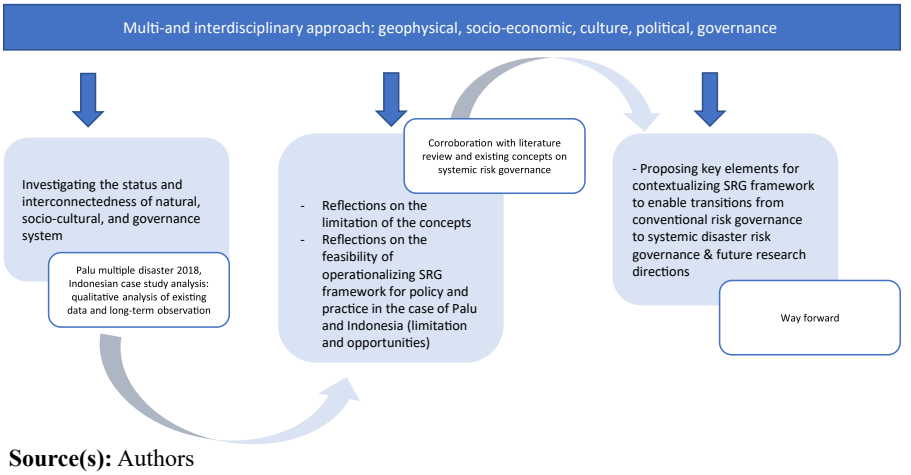
The rise of systemic disaster risk in the Indonesian context is observable. Unfortunately, how institutions and organisations are designed, mandated and equipped to deal with such systemic risk is becoming more fragmented (Renn, 2020). Therefore, there is an increase in gaps between the nature of risk that becomes increasingly complex (Lucas *et al.*, 2018) and the institutional frameworks devised to deal with those risks.

We use a case study from Palu's multiple disasters in Central Sulawesi, Indonesia, to demonstrate how inland earthquakes in 2018 created cascading secondary hazards, namely tsunamis, liquefactions and landslides, caused unprecedented disasters. Those hazards interact with floods and residual risks such as conflict over natural resources, religious conflicts, gender-based violence, displacements and terrorism in the last 20 years. It is also well acknowledged that geologically, Palu is laying on the Palu-Koro fault, which should be free from human activities. Against these backgrounds, a more systemic approach to govern systemic risks is needed. We argue that there is a need to create institutional mechanisms that are adaptive and amendable to meet the targets of SFDRR and Sustainable Development Goals at local levels.

The paper hypotheses that conventional risk governance is unfit and needs to be generated from the local context to represent socio-cultural characteristics and/or place-based to address more systemic disaster risks. A new framework of risk governance is needed. Informed and inspired by a growing literature on the topic of systemic risks in disaster studies and other fields, we will propose several important elements to produce a contextualised Systemic Risk Governance (SRG) framework for the case of Indonesia to explore how systemic risks and their interaction with residual risks and other existing problems can be managed, and how local institutional mechanisms can be tweaked to deal with the complexity of such a risk landscape.

Methods

To reach our objectives, we applied a three-step approach (see Figure 1 below).



Source(s): Authors

Figure 1.
Research design

We first start with investigating the case of Palu's cascading disaster risks in 2018 and analyse the three interconnected systems, including natural, socio-cultural history and governance systems. Second, we conducted a systematic literature review using the Scopus database to take stock of various SRG frameworks and juxtapose the appropriateness to apply to Palu's case. We also investigate the feasibility of operationalising the existing frameworks in the current governance system in Palu and Indonesia in general. Third, based on the juxtaposition, we highlighted the way forward by presenting the lessons learned and points for attention to improve the development of the SRG approach in Palu and Indonesia.

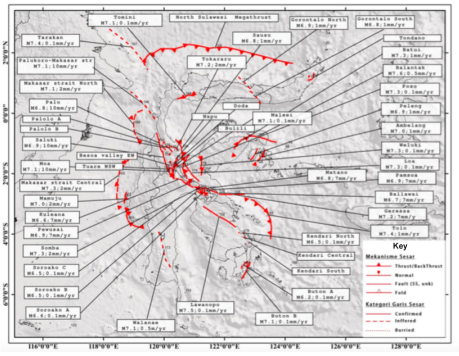
We utilised the data (primary and secondary) obtained from the ongoing research conducted in Palu collected by authors through a long-term observation between the period 2002 until 2020.

We have foreseen the limitation of the methodology, understanding that approaches toward systemic disaster risk governance are contemporary. However, the framework has long been applied and assessed in the financial sector. Therefore, we have been challenged in identifying representable practices to benchmark. On the other hand, we found it useful to reflect on the reality through Palu's case and observe to what extent a systemic approach to risk governance is realistic. The nature of this paper is mainly descriptive, which opens the possibility of highlighting future research directions, including empirical contributions.

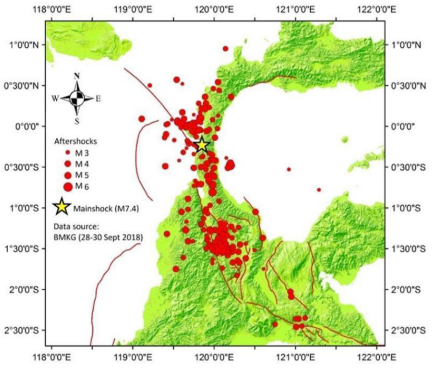
Disaster risk context in Central Sulawesi: the interconnectedness between natural, social and governance system

The 2018 Palu disaster and its cascading impacts

Sulawesi is located in the Sunda block adjacent to three plates; the Australia plate, the Philippine plate and the Pacific plate, known as the triple junction. This triple junction caused a complex tectonic in Sulawesi, accommodated by strike-slip faulting and thrust faulting. In 2017 PuSGeN considered 50 active fault segments in Sulawesi and the Sulawesi Megathrust north of Sulawesi (Figure 2). The Central Sulawesi region is tectonically active. Historical destructive earthquakes along the Palu-Koro fault zone occurred in 1907, 1909, 1937 and 2012. A paleoseismology study was conducted by Daryono (2016) and obtained that previous earthquakes occurred in 1,909, 1,468 and 1,338. Abendanon (1917) concluded that the 1907 earthquake was followed by a more destructive earthquake two years later, in 1909. The 1909 earthquake mostly destroyed houses that survived during the 1907 earthquake.



Source(s): PuSGeN (2017)



Source(s): PuSGeN (2019a)

Figure 2.
Left: Active fault in Sulawesi as in the National Earthquake Source and Hazard Map launched in 2017, Right: Epicentres of the Palu earthquake 2018 (M7.4) and the aftershock distributions (red dots) along the Palu-Koro fault in Central Sulawesi

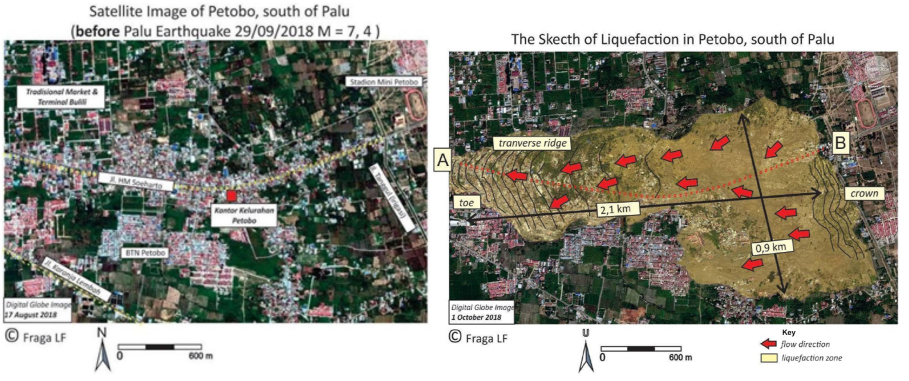
The damage runs along Saluki up to the Donggala region. Abendanon reported a considerable cracking of 7 km with an uplift of 1.0 m. Trenching in Omu Village on the Saluki segment shows evidence of sinistral slip of 1.5 m and vertical slip of 1.5 m. Daryono (2016) suggested a plausible recurrence interval of 130 years in Palu-Koro.

The 2018 Palu earthquake occurred on Friday afternoon, 28 September 2018, at 18:02:44 local time (Central Indonesia Time, WITA) with a magnitude of Mw 7.4, centred 26 km North of Donggala, Central Sulawesi (Figure 3). The earthquake was caused by The Palu Koro fault zone, spanning from the northern part of eastern Donggala through Palu Bay, passing Palu City to the south as far as 75 Km (PuSGeN, 2019a,b; Gunawan *et al.*, 2020; Natawidjaja *et al.*, 2021). The earthquake has caused strong shaking, generated a tsunami that hit the City of Palu, in Palu Bay, and massive liquefaction, especially in Petobo, Balaroa, Jono Oge areas and in Sibalaya of Palu City and Sigi Regency. BMKG automated modelling indicates the intensity of VI-VIII in the City of Palu and Donggala Regency, Central Sulawesi. BMKG updated the ShakeMap two days after correction based on modelling, data instrument and macroseismic survey of 30 September 2018, and released the intensity of IX-X in the City of Palu, meaning extensive damage in Palu City.

The secondary hazards

A large surface deformation was observed by PuSGeN (2019a, b) field survey, PuSGeN (2019a, b) field survey conducted in early October 2018 and satellite imagery by USGS/NASA Landsat-8 JAXA. Horizontal offset was found as large as 4–6 m and vertically offset up to 30–50 cm running through the City of Palu from South to North. Ground shaking was observed. The significant rupture and ground shaking cascade into secondary hazards of inland landslides and submarine landslides, rapid tsunamis and massive liquefaction (PuSGeN, 2019a; Gunawan *et al.*, 2020; Natawidjaja *et al.*, 2021).

The tsunami was preliminary thought to be triggered by a submarine landslide induced by the fault rupture in the sea floor of Palu Bay. This event has proven new scientific evidence that strike-slip fault can generate a large tsunami, contrary to the previous understanding that presumes strike-slip faulting is insufficient for triggering large tsunamis. Socquet *et al.* (2019) and Bao *et al.* (2019) has argued that the supershear characteristic of this long rupture has caused the seafloor displacement that generates tsunami (Elbanna *et al.*, 2021) that built up a computational framework whose result showed that supershear ruptures propagating along strike-slip faults, traversing a narrow and shallow bays, are prime candidates for



Source(s): PuSGeN (2019a)

Figure 3.
Liquefaction-induced lateral spreading at Petobo village

tsunami generation, regardless of the submarine landslide. The event triggered a tsunami warning but did not reach the communities in time. The extremely short lead time, the foreshock that occurred a few hours before created a false sense of security, and collateral damages, including electricity shut down, also affected the failure of the tsunami warning to save lives (UNDRR-UNESCO IOC, 2019). These findings have called for a global re-evaluation of tsunami risk from strike-slip faulting in the bay or offshore and how it affected the effectiveness of risk reduction measures, including warning systems.

The geotechnical impact of this event includes ground cracking along the road near the coastline and mountainous areas after the earthquake, including on the airport runway. The two significantly interesting phenomena are a liquefaction-induced ground failure in Balaroa, massive lateral spreading in Petobo villages, and Jono Oge Village and Sibalaya village (Gallant *et al.*, 2020) (see also Figure 3). These hazards buried those four villages. Based on the Center for Groundwater Resources and Environmental Geology research, most of the Palu area has a very high potential for liquefaction with a liquefaction potential index of > 15 with a shallow ground water level of around <12 m. However, no previous document nor the Risk Assessment document of Palu City mentioned massive liquefaction could occur. However, the locals named it "Nalodo", meaning "the land that turns into mud and slide".

Human–nature interactions in liquefaction risk in Palu

The 2018 tsunami in Palu has caused cascading effects on the economic, ecological and social systems. More than 4,100 people lost their lives. Based on an assessment of the National Agency for Disaster Management (BNPB), United Nations Development Program (UNDP) and Local Agency for Disaster Management (BPBD) on 26 October 2018, the significant economic losses and damage were approximately identified as around IDR18,48 Trillion or about USD 1,3 Million in four regions of affected places those are Palu, Donggala, Sigi and Parigi Moutong (Kementerian PPN/BAPPENAS and Pemerintah Provinsi Sulawesi Tengah, 2018). It is the second devastating tsunami after the 2004 tsunami in Aceh (Athukorala and Resosudarmo, 2005).

Extensive agricultural infrastructure, including the primary irrigation system, namely Gumbasa, has collapsed, leading to severe loss and damage to the agricultural system. It has disrupted the farming activities of 7,356 hectares of areas located in Sigi, Palu and Donggala. There are about 7,000 farmers directly affected, and the farmers are losing their livelihood and have fewer alternatives to generate income. The irrigation system was built in the colonial era in 1931 and rebuilt in 1976 by the Indonesian Government through the Ministry of Public Works.

A study by Watkinson and Hall (2019) also mentioned that the density of irrigation infrastructure itself is built in the seismically active location in Palu. This infrastructure may proxy for shallow water infiltration, undermining very gentle slopes, thus enhancing liquefaction and landslides' susceptibility. The Gumbasa Irrigation system covers five sub-districts in Sigi District and Palu City to support the 8.180,65 hectares of farmland upgraded in 2016 from 4,731 hectares (Puslitbang KemenPUPR, 2019). The disaster caused severe damage to the water system from upstream to downstream, so the water supply for agricultural sectors stopped after the disaster. The recovery of the agriculture system needs more innovation in terms of the solution of the water management system and agriculture variety to cope with water scarcity.

The tertiary hazards

The earthquakes compromised the slope stability around Sigi Regency. Following the earthquakes, heavy rainfall occurred in the upstream Bangga River, triggering a high-magnitude flash flood in several areas in the Sigi Regency (Tunas *et al.*, 2020) (see Plate 1).

Source(s): Tunas *et al*. (2020) (CC-BY 4.0)

Plate 1.
Impact of flashflood in Bangga River

Flash floods had impacted agricultural and plantation sectors as well as fatalities at the local level. A recent study reveals that the long duration of 8 h of heavy rainfall is the main factor that triggered the landslides upstream of the watershed initially triggered by the earthquake (Tunas *et al.*, 2020).

Residual risks from past disasters and conflict

If there is one exceptional place to name, so intricate and at the same time profoundly embedded in a long history of disasters, it would be Palu City, Central Sulawesi province in Indonesia. Palu today is a vibrant multicultural urban city. However, the town was also repeatedly shaped by massive earthquakes, devastating tsunamis, fatal volcanic eruptions and prolonged social conflicts.

Palu has a diverse socio-economic and cultural background since it is growing as one of the most developed cities in Central Sulawesi. Palu is inhabited by the local ethnic population, namely Kaili (21,60%) as the majority, followed by other local ethnicities (40,6%) and currently mixed with other ethnic groups from other islands of Indonesia (37,80%). The intense development in Palu has attracted numbers of migrants living in the City following the history of the transmigration program (population redistribution across the country) since the 1970s in Central Sulawesi.

Empirical documentation of historical disasters can be traced back to Dutch colonialism and missionary interventions at the end of the 19th century and the beginning of the 20th century. During the time, Palu, Sigi and Parigi Moutong were merely a tiny part (*onder afdeling* or sub-district) of the two great lands (*afdeling* or district): Poso and Donggala. Several West European scientists observed the areas' natural and geological phenomena and ethnological observations, documented by Wichmann, Abendanon, AC Kruyt, Nicholaus Adriaani and Waltern Kaudern. Abendanon, for example, noted earthquake events in 1907 and 1909 during his expedition. Most of these events were published in national newspapers in the Netherlands. For the less literate local communities, the earthquakes, tsunamis and liquefaction events were documented through oral stories and practices kept alive and circulated in Palu, Sigi, Donggala and Parigi districts.

The events were also captured in the toponymy of the places affected, suggesting extreme events that were significant enough to rename and memorise places. A few examples are the name of district Kaombona (the collapsed land) in Palu, the district Duyu (landslide), Tagari Lonjo (the liquefied soil), Beka village (wretched/ruptured) and Rogo village (damaged or devastated). The local communities adopted these past events into indigenous languages and terminologies; Lingu in Kaili language for earthquakes[1], Bombatalu or Lembotalu (which literally means the three big waves) for tsunamis, and Nalodo for liquefactions[2]. The Kaili communities, the largest ethnic group in Palu, shaped their imagined future risks by establishing a safe area named Kinta, which is believed to be safe from liquefaction phenomena in Petobo Palu City. It was later proven that the Kinta within the Petobo sub-district survived in the 2018 giant liquefaction. The houses in Kinta's proximity were only mildly affected and were not exposed to significant damages and losses.

Naming places with natural hazards remains in the communities' daily conversations. Moreover, the name Palu means lifted soil which is strongly related to the historical account of large-scale hazard events. However, that information is well acknowledged only by historians and yet commonly could shape the risk perception of the local people.

In general, there are two different perceptions of tsunamis. Most of the urban communities in Palu who are migrants, particularly along Palu Bay, are less aware of the risk of the tsunami. Still, they recognise that Palu is prone to earthquakes (LIPI, 2019). The domination of migrants in Palu is related to the function of Palu as one of the transmigration programs where thousands of families from Java and Bali, the most populated islands, move and live permanently in Central Sulawesi (as well as some other provinces across Indonesia). People have information about the latest tsunami in Aceh. Unfortunately, they perceived Palu Bay as safe from tsunamis because it is away from the ocean.

The inter-generational knowledge loss is a vivid example of tsunami risk ignorance in Palu Bay. The elderly who either experienced or were informed of the devastating earthquake in the past perceive that similar events only occur recurrently after a couple of decades; thus, there is no continuous passing of information to the younger generation. The younger generation in the City has limited information on historical tsunami events. Only a few know that the City is located along the Palu-Koro faults along the City, even though two significant tsunamis have hit the City and its surroundings in the last 100 years.

In contrast, in the Labean Village community, Donggala District preserved local knowledge of disaster preparedness, which successfully avoided catastrophes in 2018 tsunamis. The awareness was raised based on the tsunami in 1938 and 1968, called a story of three waves or in the local language as *bombatalu* or *lembotatu* and constructed by the native tribe of Kaili in Palu (Reksa, 2020). The story's message is about the 15 m of waves that cause catastrophe in the villages. The local community is automatically aware that after the earthquake, it will be followed by three high waves, so the people have to go to the highest place.

One of the significant earthquake-induced tsunamis occurred on 1 December 1927 in Palu Bay. The event was later followed by the 20 May 1938 massive earthquakes and tsunamis in two different coastal plains; the Makassar Strait in the west part of Palu and Donggala and the Tomini Bay in the north of Parigi and Poso. In July 1983, the Colo volcanic eruption in Una-Una island, approximately 180 km from Palu, yet strong enough to devastate the great land, and impacts stretched to the south of Sulawesi island. Stories suggest that there were at least 7,000 displaced people due to the eruption, with poor quality of barracks and permanent housing and failures in response governance in general, leaving lingering mocks of the narrated PUMA among themselves, abbreviated from "Pengungsi Una-Una Masuk Ampana" (the Una-Una survivors are entering Ampana district). Many chose to return to their old settlements.

Historically, Central Sulawesi also has had a traumatic communal conflict, particularly in Poso, a neighbouring city of Palu. Just after the reformation in 1998, for almost three years, the conflict has caused nearly a hundred thousand people to become refugees in the surrounding areas and a depth of traumatic experiences among the people. Inequality and power relations are considered the underlying factors of racial conflict. At the end of 2001, the Peace Agreement, namely the Malino Agreement, was signed to build reconciliation between the groups, but the violence persisted. The immense challenges to extinguish the embedded social problem were worsened by corruption practices, terrorism and criminal acts, forcing the establishment of Presidential Instructions No. 34/2005 on the Comprehensive Management of Poso Conflict. The local government had faced the most extended period of management of displaced people they have ever experienced.

Two years after the ignited conflict, another earthquake occurred on 4 May 2000, bringing a 3 m tsunami that devastated neighbouring communities in Banggai islands, resulting in 26,682 people being recorded as Internally Displaced People (IDPs) scattered in different places, inhabiting informal settlements. There were intentions to preserve the memory of the tsunami event in the Totikum sub-district, Banggai Islands, which the village's name by "Kampung Tsunami" or tsunami village. But similarly, in the case of Una-Una communities, the local communities in Banggai resettled their devastated land again (Muhammad *et al.*, 2020).

One would assume that the following 2005 earthquake that devastated Palu could have been a wake-up call on risk governance inspired by the 2004 Indian Ocean tsunami. The earthquake occurred on 24 January 2005, shortly after the mega-tsunami event. Narratives of the Aceh-Nias catastrophe through the media shaped dreadful imaginations and raised anxieties that a tsunami would also attack Palu bay. The massive public evacuation occurred without plans on where to go and how long. Some abandoned their houses and ran against the coastline, to the hills, or even approached the earthquake's epicentre in Bora, within the Donggala district. At least there were three casualties and several infrastructure collapses and failures.

In 2012, another destructive earthquake occurred with the epicentre close to Lindu lake in the Sigi district. The tremors were felt in Palu, in the afternoon, during the last day of Ramadhan fasting month. The earthquake was significant enough to cut the main and only road network that links Palu with the other four neighbouring districts: Lindu, Kulawi, South Kulawi and Pipikoro. Limited logistics were dropped by helicopters. At least six fatalities reported from this event led local communities to recall the tragic 2005 earthquake. The three latest earthquake events in 1996, 2005 and 2012 were tied by one active fault: Palu Koro. Until the latter, no local disaster management agencies were in place. Table 1 and Figure 4 summarise historical events related to social changes in Palu.

Governance system and relevance of systemic risk governance as a diagnostic tool

Governance reflects the steering action to reduce disaster risk (Lassa, 2013), avoid new risks (UNDRR, 2017) and find opportunities to deal with future disasters. However, the effectiveness of governing efforts to reduce risk relies on "the goodness of fit" of governance structure (actors and institutions), policy instruments (financial, infrastructure, legal and communication), synergies between the structure and instruments in responding to certain disaster risks.

Indonesia has adopted decentralised governance mechanisms to allow the central government to distribute some authorities, responsibilities and resources to the sub-national levels. In practice, decentralisation remains challenging due to a lack of capacity/resources at the local level and lack of coordination. On top of that, some argue that it is simply difficult to brush off the "centralisation" culture with the domination of national authorities that have

Table 1.
Historical events related to social dynamics in Palu, Central Sulawesi

Year	Event(s)		Source
1927	Earthquake	Tsunami waves reached 15 m, 15 died and 50 injured	Omira *et al.* (2019), Pakoksung *et al.* (2019)
1 December	Tsunami		
1938	Earthquake Mag 7.6	Houses and coconut trees along Mamboro in Donggala were washed away by 2–3 m of tsunami waves. 18 died, 942 houses destructed	Prasetya *et al.* (2001)
19 May	Tsunami		
1968	Earthquake Mag 7.8	200 villagers on the Tambu coasts were washed away and devastated. 800 houses destroyed. Inundations in Tuguan island 300 m inland, with 8–10 m runups	
10 August	Tsunami		
14 August	Earthquake Mag. 7.4	A village named Mapaga vanished due to the earthquake Tuguan island and its population vanished entirely	
	Tsunami		
1978–1994	Growing urbanised Palu	From very few houses built by the Palu river in the 1900s to 1952, approximately 40–50% growth of housings in 1973–1978, and 60–70% in 1978–1994. Increase in migrants residing in (90% coming from South Sulawesi, some occupied illegal urban lands and working in informal sectors), along with the development of infrastructures and trade areas around and near the river	Fachruddin, 2010
1930s–2016, or still occurring	Long history (3 generations) of communal conflict between Nunu and Tavanjuka clan/village	Both are from the same ethnicity (Kaili), and the same religion (Moslem) includes the same religious affiliation. Identities are relatively homogeneous. Reasons for conflict are varied, shaping cultures of violence	Junaidi and Marzuki (2016)
1996	Earthquake	10 fatalities, over 60 injuries and building damages	Gomez *et al.* (2000), Jena *et al.* (2020)
1998	Inter-religion, communal violence and ethnic conflicts	Internally displaced people due to conflict: 93,254 people, death 1,129, destroyed houses 1,754	Aragon, 2001, Rismawati (2011)
24 December–May 2000 to December 2001, excess conflict still occurring			
2018	Earthquake Mag. 7.4	4,100 loss of lives, 1,016 were unidentified. 110,000 houses destroyed. Internally displaced people: 63,359	UNDRR-UNESCO IOC (2019)
28 September	Liquefactions		
	Tsunami		
2020–2021	Global pandemic COVID-19	Difficulties with social distancing in temporary housing and housing qualities and sanitation problems. Several positive cases in the temporary shelters/housing are unknown	Reksa (2020)

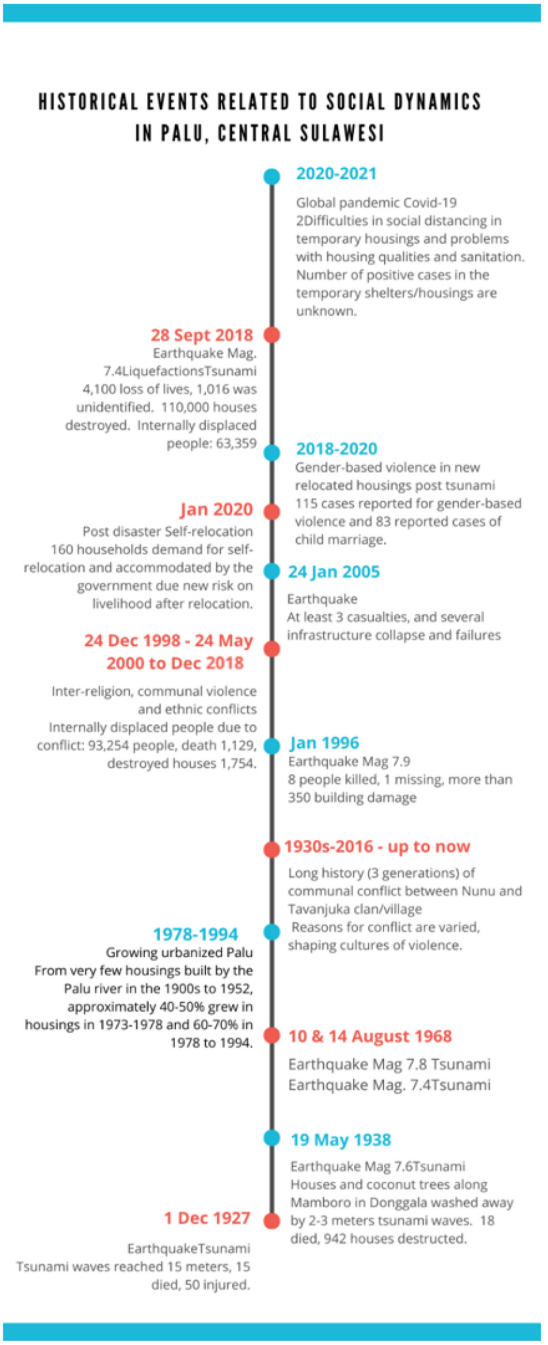


Figure 4.
Historical events related to social dynamics in Palu, Central Sulawesi

been long embedded in Indonesia (see also Trias and Cook, 2019; Putra and Matsuyuki, 2019). While decentralisation has, to some extent, allowed diversification of actors and introductions of new actors in decision-making processes, in practice, it has yet to fully enable participation, especially local participation (Sofyan *et al.,* 2020; UNDRR, 2022, p. 97). These problems are also applied to disaster governance in Indonesia. Disaster management in Indonesia was only institutionalised in 2008 when the National Disaster Management Agency was established as mandated by Law 24/2007 on Disaster Management.

We will briefly discuss the disaster risk governance challenges and opportunities during pre-disaster, emergency response and post-disaster stages.

Pre-disaster phase is a very crucial phase in disaster management. This is the phase where the capacity for preparedness is cumulated. It includes the cumulation of knowledge (e.g. risk assessment, scenario and forecast model) and the responding policies to prepare for future disasters. In this phase, it is crucial to enhance the detailing of scientific uptake for evidence-based policymaking for Central Sulawesi districts before the 2018 earthquake followed by tsunami and liquefaction. The Disaster Risk Assessment (DRA) documents are available for Central Sulawesi, Palu City and Donggala District for 2016–2020, followed by Sigi District for 2017–2020. Those three areas in Central Sulawesi were affected the most during the tsunami of 2018. The risk index comprises hazards, vulnerability and capacity at the district level, with the unit of analysis at sub-district levels. From 1910 to 2015, at least ten types of hazards, namely floods, extreme wave-abrasion, epidemic and pandemic, technology failure, drought, eruption, extreme weather, landslides and flash floods, have happened in Central Sulawesi. The 2015 DRA uses historical disaster data as a baseline and added tsunami and forest fire as potential hazards, but the document did not mention liquefaction. Instead of assessing multi-hazards, the DRA is a single hazard-based assessment. Reflecting on the Palu earthquake case, several gaps we found include limitation in understanding tsunami hazards, failure to incorporate flow-liquefaction potential, limitation in understanding the size of earthquake rupture and precise location, failure to predict its cascading and compound risk, and limitation in incorporating the detail build environment to the risk assessment, including the existence of irrigation channel. The DRA of Palu City has mentioned the high level of earthquake and tsunami hazard, high level of vulnerability, and low level of capacity, without clarifying potential tsunami characteristics, estimated lead time people have, and no mention that the City lies on the Palukoro fault (PuSGeN, 2019a, b). Field investigation has revealed that the Palukoro fault location lies precisely on the location of the trenching investigation before the 2018 earthquake in the southern part of Palu City (Natawidjaja *et al.*, 2021). Yet, in Palu City, the surface rupture is found 1 km to the west of the mapped fault (PuSGeN, 2019a, b). The corridor along surface rupture of 10 m is now categorised as a red zone, in which no buildings are allowed, as well as tsunami impacted are and flow-liquefaction areas.

The complexity as a feature of risk is still unrecognised in the assessment, and the knowledge inputs are still incomplete and dominated by specific disciplines that focus more on natural hazards and physical assets. For example, the vulnerability assessment document is limited to the measured indicators directly related to the population, namely demographic characteristics (population density and vulnerable group), productive land and GDP per sector, health and critical facilities, and environmental aspect (forest, mangrove). Although it contains socio-cultural, economic, physical and environmental aspects, it does not capture the complex social realities ranging from social power, histories, and actors' socio-cognitive, cultural perspectives and political economy. The exposures of the built environment are not well assessed and captured by the DRA document. For example, 1,299 schools damaged by the earthquake in Central Sulawesi (Hanifa *et al.*, 2019) were not anticipated prior, also the case for hospitals and most other infrastructures. Institutional aspects are also not considered in the vulnerability assessment, and social conflict issues are identified as potential disasters.

These issues have contributed to the lack of awareness of the community of the tragedy that they might face in the future (see Sofyan *et al.,* 2020; UNDRR, 2022, p. 97).

In addition, there is a low priority and lack of capacity of the government to manage the disaster. The City has enacted a contingency plan to respond to the tsunami, but it is not a priority in the development program. The authority argues that the limited local budget is insufficient to implement the contingency plan. The dissemination of the preparedness through evacuation drills has been conducted, however, without accurate simulation but rather as a formalisation of the activities. Most local policymakers have no information and understanding of the respective documents; therefore, there is no appropriate implementation or disaster preparedness.

However, it is essential to mention that the training for the community conducted by the Local Agency for Disaster Management in 2017 in Palu had sporadically engaged local and religious leaders. People involved in the activities are aware but have no clear and precise information about the evacuation route. The fatalistic evacuation behaviour during the 2018 tsunami suggests a lack of preparation from the authorities to inform the local community about the evacuation route and effective response during a disaster. This was also added by the failure of the tsunami warning system to reach out to communities within minutes due to the atypical underwater landslide tsunami. Local knowledge from past experiences existed primarily in suburban areas, while in the urban Palu, most communities were caught by surprise (UNDRR-UNESCO IOC, 2019).

The neglect of risk can be seen in the development of the Waterfront City project in Palu and the promotion of Palu Bay as the centre of tourism destination, which led to massive development along the coast without significant proper evacuation information. The modern city concept has neglected local knowledge on the tsunami risk even though some studies have informed the risk of geological hazards on the Palu Koro Fault. At the same time as the 2018 tsunami in Palu, a scholar from a local university published a book on the Palu Koro fault movement, which explicitly describes the high risk of Palu to tsunamis triggered by the fault's activity. Scholars and practitioners on disaster have informed respective risks to the local authority. Still, there is no follow-up to reduce risk but rather focus on the City's attraction as a tourism destination.

Regarding the emergency-response *phase*, the shelter provision faces several concerns regarding timeline, process, quality and maintenance. Social inequality has risen regarding the absence of standardisation of shelters. There are supports from non-government organisations, civil society and private sectors to provide shelters with the minimum standards from the government. Still, it is difficult to control in the implementation stage as lack of coordination is another issue. Yet, several social concerns include security issues, sexual abuse, and an unsafe environment for children.

It is also reported that no leadership was shown by the local governmental authorities right after the disaster struck Palu in 2018. Some argued that this happens due to the lack of ownership by the local government to handle a disaster of this large scale. The 2018 tsunami in Palu causes a cascading risk to the communities. It has left a story of chaos in the first three days of the disaster, including the massive looting in many places. Not only in the places of basic needs supply but also the despoilment of many assets across the City in many areas (LIPI, 2019).

This, again, touched upon the decentralisation issues manifested in the dependency on the national government and limited capacity of the local governments (see also Paton and Sagala, 2018) to deal with multi-disasters in their administrative jurisdictions (Putra and Matsuyuki, 2019).

Post-disaster interventions include rehabilitation and reconstruction stages which consist of infrastructure, social, economic and cultural aspects. Based on the timeline provided by BAPPENAS, the socio-economic recovery started after three months of emergency response.

Unfortunately, the affected communities have limited alternatives to recover after the disaster. After the tsunami destroys all sources of their livelihood, farmers, fishers and employees with short-term contracts, informal workers are the most severe groups in terms of economic impact. No sufficient social protection could provide better recovery except for appropriate external support (LIPI, 2019).

In terms of rehabilitation, the priority is still on infrastructure rehabilitation. There is also a social assistance programme (i.e. in the form of cash assistance) provided by the government and relief organisations (Lassa *et al.*, 2022). The cash assistance program is useful for people who have lost their livelihood and economic assets. However, yet to reach out to all affected communities. More programmes can involve more participation of affected communities, including shelter and public facilities construction. It is important to consider integrating infrastructure and socio-economic rehabilitation to support the transition build back better (LIPI, 2019).

A study conducted by LIPI (2019) found that fishing communities along the coast were also affected severely by the disaster and lost almost all their livelihood assets. Only after the government provides boats to a fishing community can they start fishing. In addition, the informal workers along the coast also lose their livelihoods without social protection and have less exit strategy. The slow recovery process of the economy has forced many survivors to return to the coastal areas prohibited from human activities and places for living just to start economic activities. This strategy is bringing them back to a new risk condition.

In terms of risk perception of tsunami risk in Palu, it is mainly related to the misperception of the risk, leading to the mismanagement of disaster preparedness until post-disaster. In addition, the recovery stage also faces a challenge in considering the chance to rebuild the areas. The risk mapping raises controversy as many local communities have returned to their original place as livelihood is one of the most reasons to neglect the relocation away from the coast. Relocation areas are also hazard-prone areas, and this issue is still under debate among policymakers, scholars and disaster risk practitioners.

Two years after the catastrophe, shelter issues remain a big challenge. The problems during the post-disaster stage have created a new risk on top of the pandemic to the people already at risk of disasters. Limited basic shelter facilities are one example of problems in the transition of rehabilitation stages and the challenge of shelter provision. The delay in providing shelter started after the emergency response period when the survivors had to stay in tents as temporary shelters for more than three months. Some even stayed in the shelters for more than three years. Moreover, the quality of shelter varies depending on the organisation, including the lack of minimum standard of sanitation and access to health and education facilities (LIPI, 2019). There is a standardisation from the national government, but it is less likely to be fulfilled without integrated coordination and clear and transparent regulation.

Disaster risk reduction strategies to build back safer

In the previous sections, we have explained disaster risk governance based on the three phases of conventional disaster risk management. However, we noticed that to understand disaster risk governance from a systemic risk perspective, one should incorporate an integrated understanding of the interconnectedness of the three phases. On paper, disaster risk reduction concepts address this siloed thinking by aiming to prevent new and reduce existing disaster risks and manage residual risk, all of which contribute to strengthening resilience and, therefore, achieving sustainable development (UNDRR, 2019). DRR strategies focus on policy objectives with concrete timelines and procedures by reducing risk and at the same time aiming at strengthening economic, social, health and environmental resilience.

One of the strategies considered to reduce disaster risk and increase socio-ecological resilience in Palu is the ecosystem approach. The coastal ecosystem of Central Sulawesi is covered by 40,083 hectares of mangrove forest and 608 coastal villages (BPS, 2019). Mangrove forest has continuously decreased as the City urbanised fast. In 2010 about 50% of it was seriously damaged (e.g. 5,652 hectares out of 7,387 hectares and 605 hectares out of 762 hectares in Pagiman). Based on the KITLV's documentation, the picture of Palu city shows a mangrove forest from Kale (Layana) until Mamboro sub-districts that have been utilised as residential areas (Kompas, 2019). The local community mentions that the land use change occurred massively in the 1980s, and in the 1990s, Palu Bay was developed as one of the tourist destinations, including reclamation projects.

The rehabilitation of mangrove forests in the Palu coastal area was first started in 2015 (BPS, 2019). The role of mangroves as a strategy to mitigate the City and its surrounding from disasters is revealed in the UNDRR resilience scorecards assessment conducted in December 2020 (interview, 2021). The evaluation, however, has also revealed that monitoring such a strategy still lacks a structured plan, and there is no action to control the environmental quality regularly. Moreover, there is only limited identification and recording of ecosystem assets which causes a challenge to be considered in the spatial plan.

Mangrove ecosystems along the coast are natural protectors against coastal disasters (Triyanti *et al.*, 2017), including tsunami waves (Ismail *et al.*, 2012). One of the areas along the Palu Bay, Kabonga District, has been claimed to be saved by the mangrove forest (See also Goda *et al.*, 2019). The village only experienced 10 damaged houses and one death of people. The critical role of mangroves in Palu Bay has been modelled based on tsunami inundation modelling reveals that adding 0.072 ha of mangrove forest could reduce 2858,8658 ha of inundation along with the East Palu (Novitarima and Saputri, 2019). The local knowledge allowed wisdom in preserving mangrove beds and their ecosystem for decades, particularly in the Donggala district. Unfortunately, political-economic drivers continue to convert the coastal ecosystem as one media recently reported that the "Tsunami fort in Donggala cleared to turn into a fishpond" (Kumparan, 2022) – suggesting a setback in the ecosystem approach in the province.

Sendai Framework for DRR addresses "build back better" as one of the priorities to reduce disaster risk. The transition from emergency response to recovery and reconstruction plays a significant role in supporting the success of reducing underlying and driver risk. Nevertheless, the concept of transition as a process still lacks consideration.

The master plan of rehabilitation and reconstruction after the disaster of Central Sulawesi addresses the importance of the mangrove forest, urban forest and greenbelts as natural protectors against tsunamis. The master plan provides land utilisation direction along the coast and the City to prioritise ecosystem-based solutions as one of the mitigation strategies for disaster (Kementerian PPN/BAPPENAS and Pemerintah Provinsi Sulawesi Tengah, 2018). However, the sea dyke construction as a solution to protect risk areas from tsunamis has raised pros and cons among scientists and practitioners as it tends to constrain the plan to implement an ecosystem as the priority in development planning. Moreover, from the local people's side, the sea dyke has raised a new challenge for them to observe the change around the sea to indicate the upcoming disaster.

Perhaps the most challenging, underlying problems in disaster risk governance in Indonesia are related to asymmetric power relations. After all, the governance process in disaster risk reduction is expected to facilitate different actors and institutions but at the same time also deal with managing vested interest. For example, in the case of the growing role of international donors in emergency response and recovery in Indonesia. Presidential regulation (Perpres) number 22/2008 has provided a basis to regulate the national and local disaster management budget (national and local) which consists of stages of pre-disaster, emergency and post-disaster stages. Social assistance resources are available from national loans.

Regarding the case of Palu, the contingency budget is limited, and it became a challenge, especially to implement the contingency plan (LIPI, 2019). In addition to the Perpres 22/2008, The Head of BNPB regulation (Perka BNPB) 22/2010 regulates the contribution of International donors during emergency response. Some prerequisites are needed, primarily to ensure sovereignty, respect and trust.

In the case of Palu, Indonesia has tightened its role compared with the case of Aceh. International humanitarian actors and donors no longer can freely enter the disaster-affected areas without local assistance and should avoid visiting with the attendance of their nation's army. This case needs further exploration. For example, to what extent the governmental authorities could play a coordinating role in managing the donors and international support in the emergency and recovery process? What would be the most effective control mechanism?

In addition, as occurred elsewhere, despite progress in the national and local legislative reform and institutional development as a result of Hyogo and Sendai imperatives, disaster risk governance is not yet programmatic. Local governments are still occupied by short-term political goals that run in political cycles. For example, in Indonesia, there are cases where local elected leaders focus on their tenure and do not prioritise the continuity and sustainability of disaster management policies (LIPI, 2019), among many crucial sustainable development agendas.

Despite the dominance or preference for more centralised modes of governance, several practices of self-governance have been reported at the local level. For example, through social movements, by initiating petitions to challenge certain disaster-related policies in responding to the Palu 2018 disaster. This type of practice should be seen as an opportunity for incremental transformation.

Systemic risk governance framework as therapeutic tools

After identifying the systems in Palu, we reflect on several existing concepts from our literature review on SRG and its assessment frameworks. Our preliminary literature review shows a shortage of studies on systemic risk and potential strategies to govern such risk within the disaster risk reduction body of literature. We found two practical concepts to increase our understanding of SRG and its components. *First* is the notion of systemic risk. The definition of systemic risk has been first coined through the economic system perspective. It is defined as "the risk that an economic shock triggers, through panic or otherwise, either the failure of a chain of markets or institutions or a chain of significant losses to financial institutions, resulting in increases in the cost of capital or decreases in its availability and substantial financial-market volatility" (Schwarcz, 2008). When expanded to more comprehensive systems beyond the economy, systemic risks have been studied through different lenses. OECD published a report in 2003 mentioning five types of emerging interrelated risks in the 21st century, including disasters, industrial accidents, infectious diseases, terrorism and food safety (OECD, 2003). These are risks produced by global changes, including increasing population, global environmental change (i.e. climate change), technological development and competition (OECD, 2003, pp 30–31).

The Global Assessment Report produced by UNDRR in 2019 (UNDRR, 2019) has provided new insights on understanding systemic risk in disaster risk reduction contexts. It further describes risk topology by understanding and realising the multiple and interconnected root causes, context and risk drivers. These perspectives widen our understanding of systemic risk beyond the economic and financial systems and consider socio-ecological systems, including environmental degradations and causal relations with poverty and poor governance.

Second is the concept of SRG. Understanding the systemic nature of risk is only a first step. Next, knowing how to deal with this type of risk is crucial. The governance concept is

essential here as it reflects how we steer our actions. Governance can be defined as a process of more or less institutionalised interaction between public and/or private entities, ultimately achieving collective goals (Lange *et al.,* 2013). The SRG concept further contextualises the specific governance feature, including actors, institutions and mechanisms needed to deal with and manage systemic risks (IRGC, 2018).

Several characteristics laid the normative considerations to govern systemic risk. It includes uncertainty, complexity and ambiguity (van Asselt and Renn, 2011). These are additional characteristics to the dynamics, diversity and scales commonly used in socio-ecological system studies (see, for example, Chuenpagdee and Jentoft, 2013). In addition, SRG studies have also incorporated the inclusive governance approaches, focusing on the involvement and participation of wide-range actors beyond government, including non-governmental organisations, civil society and private sectors (see, for example, Schweizer and Renn, 2019).

Several studies have also suggested a framework to assess such a SRG system in terms of operationalisation and assessment. The IRGC Guidelines for the government of systemic risks 2018 (IRGC, 2018) are one of the commonly known frameworks, especially in disaster risk reduction (see also UNDRR, 2019). It listed seven steps of guidance, including (1) explore the system, (2) develop the scenario, (3) determine goals and level of tolerability for risk and uncertainty, (4) co-develop management strategies, (5) address unanticipated barriers and sudden critical shifts, (6) decide, test and implement strategies, and (7) monitor, learn from strategies implementation, review and adapt. The framework has attempted to define specific actions required, expected outcomes and success factors to follow each step.

We observed six essential elements to be emphasised in several steps of the SRG framework for the case of Palu. *First*, to explore the system and obtain a systemic understanding, more attention should be given to conducting a *social scanning* to get a complete overview of the local context, including local culture and social capital, which will affect the sustainability of risk reduction efforts. It is also essential to highlight the complexity that drives the inability of a system (social and natural) to synergistically function. In addition, it is imperative to clearly understand different risk typologies, including multi-, compound, cascading and residual risk. These are concepts that are interchangeably used and difficult to be defined. *Second*, the development of scenarios should incorporate multiple time horizons. Longer time horizons would enable the effect of the reflectiveness and learning process over time. *Third*, expert judgement can be a valuable means to determine goals and level of risk tolerability. Diversification of expertise is also important, primarily to ensure the meaningful participation of diverse scientific disciplines and policy actors. *Fourth,* the local context should be considered when deciding, testing and implementing strategies. For example, during the recovery process, one should consider ensuring the sustainability of local livelihood and shelter quality. *Fifth*, cognitive aspects should be taken as parameters to measure success in terms of monitoring, learning, review and adaptation. This includes the aspect of risk perception, self-efficacy and self-evaluation. *Finally*, it is vital to set the normative as a "yardstick" to guide the implementation of a SRG approach. It includes norms of social justice, transparency, accountability and appropriateness.

Limitation and opportunities for systemic risk governance: broader reflections

While the SRG framework has helped diagnose the empirical phenomenon in Palu, we believe that it is still challenging to be operationalised and used by the disaster managers and stakeholders on the ground. Based on our analysis, we argue that disaster risk governance in Palu – especially reflecting on the multiple disaster events of tsunami and liquefaction in 2018 – is still using a conventional approach. The governance system in Palu could not move towards a probability risk approach, let alone a systemic approach. Several limitations are hampering the efforts to incorporate a systemic approach:

(1) The highly dynamic and complex social and ecological systems. This is manifested in the typology of risks and disasters becoming more complex, compounded, nonlinear, systemic, and unpredictable.

(2) The limitation in the current risk assessment. There is a strong need for improvement in risk assessment processes and models anticipating more dynamic and complex socio-ecological systems and risk. This will also require a comprehensive and regular risk assessment update and incorporating local and indigenous knowledge.

(3) Unmatched political and planning process. The systemic disaster risk governance approach's efforts and continuity depend primarily on the current political and planning cycle (5-year plan). In addition, there are asymmetric power relations due to vested interests, which lead to a lack of meaningful and coordinated participation of non-state actors in disaster risk reduction efforts.

(4) Inappropriate governance systems. To ensure a systemic and coherent approach, there is a need for more inter-agency coordination. In the case of Palu and Indonesia, governance systems should be transformed.

(5) The contingency plan foresaw the tsunami close to reality in 2018. It provides the scenario of a 7.4 earthquake magnitude followed by a tsunami along Palu Bay. However, there are lacking priorities to follow up on the contingency plan. It is found that there is no follow-up by distributing action plans to related local agencies across the city government.

(6) Limited protection/disaster reduction strategy options, including degradation of coastal ecosystems, lead to reduced capacity of coastal ecosystems to provide services for climate regulation and protection (e.g. degradation of mangrove, reducing its services as a barrier to reduce the impact of tsunami).

(7) Post-disaster focuses on building back better by considering shelter as a process rather than physical infrastructure *per se*.

Despite the limitations, several opportunities can bring Palu a step forward to a more SRG approach.

(1) Indonesia has already had long experiences of disasters and has shifted its disaster management paradigm. The current law number 24/2007 on disaster management has provided mandates to govern disasters in Indonesia, including establishing the Local Disaster Management Agency (BPBD), budget allocation and support from international donors. There is a window of opportunity for taking the first step to adopt a more SRG approach by emphasising and enhancing collaboration among related stakeholders to address the high complexity and uncertainty of future disaster risk.

(2) Lessons from Central Sulawesi in 2018 suggest the need to consider disaster risk from a systemic risk framework perspective.

(3) Ecosystem service-based solutions have been mentioned in the master plan for rehabilitation and reconstruction, but they need to fit with the spatial program and risk-based development pathway.

(4) Local knowledge identification. Palu has various local knowledge dictionaries to recognise disaster risk. More ambitious documentation and sharing of local knowledge are needed.

Conclusion and recommendations

This study has attempted to investigate the systemic characteristics of disasters in Central Sulawesi multiple disasters in 2018. We explained the different systems in play, including the complex interaction of histories of natural hazards, socio-cultural and social-historical development (vulnerability and capacity), and institutional and governance systems.

We concluded that Indonesia has yet to incorporate a SRG approach through the case of Palu. Political will is required for Indonesia to adopt more appropriate risk governance modes that promote the systemic risk paradigm (see Djalante *et al.,* 2017). A fit-for-purpose SRG framework contextualised and adjusted to country conditions is needed for further exploration and operationalisation in the policy domain. However, such an SRG framework needs to be informed by further research, investigation, reflective action, and a creative approach to co-design, co-develop and co-produce a policy and a relevant and contextualised SRG framework with governmental authorities and societal stakeholders.

Finally, we recommend that the focus of SRG should be directed towards productive transition and local transformation. However, for Indonesia, incremental change through hybrid governance arrangement, balancing informal and formal, self- and horizontal and vertical modes of governance (see Lassa, 2019, 2022) is deemed more realistic and feasible.

References

Abendanon, E.C. (1917), "Expedition de la celebes centrale - voyages geologiques et geographiques a travers la celebes centrale (1909-1910), Volume II", *Leyde, Librairie et Imprimerie ci-devant E*, J. Brill.

Aragon, L.V. (2001), "Communal violence in Poso, Central Sulawesi: where people eat fish and fish eat people", *Indonesia* No. 72, pp. 45-79.

Athukorala, P.C. and Resosudarmo, B.P. (2005), "The Indian Ocean tsunami: economic impact, disaster management, and lessons", *Asian Economic Papers*, Vol. 4 No. 1, pp. 1-39.

Aven, T. and Renn, O. (2020), "Some foundational issues related to risk governance and different types of risks", *Journal of Risk Research*, Vol. 23 No. 9, pp. 1121-1134.

Bao, H., Ampuero, J.P., Meng, L., Fielding, E.J., Liang, C., Milliner, C.W., Feng, T. and Huang, H. (2019), "Early and persistent supershear rupture of the 2018 magnitude 7.5 Palu earthquake", *Nature Geoscience*, Vol. 12 No. 3, pp. 200-205.

BPS (2019), *Statistik Sumber Daya Laut Dan Pesisir Indonesia 2019*, BPS, Jakarta.

Chuenpagdee, R. and Jentoft, S. (2013), "Assessing governability–What's next", in Bavinck, M., Chuenpagdee, R., Jentoft, S. and Kooiman, J. (Eds), *Governability of Fisheries and Aquaculture: Theory and Applications*, Vol. 7, Springer Netherlands, pp. 335-349.

Daryono, M.R. (2016), "Paleoseismology tropis Indonesia (dengan studi kasus di Sesar Sumatra, Sesar Palukoro-Matano, dan Sesar Lembang)", Institut Teknologi Bandung, PhD dissertation.

De Brant, O. and Hartmann, P. (2020), "Systemic risk: a survey", Working Paper 35.

Djalante, R., Garschagen, M., Thomalla, F. and Shaw, R. (2017), "Introduction: disaster risk reduction in Indonesia: progress, challenges, and issues", in Djalante, R., Garschagen, M., Thomalla, F. and Shaw, R. (Eds), *Disaster Risk Reduction in Indonesia*, Springer, Cham, pp. 1-17.

Elbanna, A., Abdelmeguid, M., Ma, X., Amlani, F., Bhat, H.S., Synolakis, C. and Rosakis, A.J. (2021), "Anatomy of strike-slip fault tsunami genesis", *Proceedings of the National Academy of Sciences*, Vol. 118 No. 19, e2025632118.

Fachruddin, P.A. (2010), "The characteristics of inhabitants Palu Rivers flood basin", *Ruang*, Vol. 2 No. 1, pp. 56-71.

Gallant, A.P., Montgomery, J., Mason, H.B., Hutabarat, D., Reed, A.N., Wartman, J., Irsyam, M., Simatupang, P.T., Alatas, I.M., Prakoso, W.A. and Djarwadi, D. (2020), "The Sibalaya flowslide initiated by the 28 September 2018 MW 7.5 Palu-Donggala, Indonesia earthquake", *Landslides*, Vol. 17 No. 8, pp. 1925-1934.

Goda, K., Mori, N., Yasuda, T., Prasetyo, A., Muhammad, A. and Tsujio, D. (2019), "Cascading geological hazards and risks of the 2018 Sulawesi Indonesia earthquake and sensitivity analysis of tsunami inundation simulations", *Frontiers in Earth Science*, Vol. 7, p. 261.

Gomez, J.M., Madariaga, R., Walpersdorf, A. and Chalard, E. (2000), "The 1996 earthquakes in Sulawesi, Indonesia", *Bulletin of the Seismological Society of America*, Vol. 90 No. 3, pp. 739-751.

Gunawan, E., Widiyantoro, S., Supendi, P. and Nishimura, T. (2020), "Identifying the most explainable fault ruptured of the 2018 Palu-Donggala earthquake in Indonesia using Coulomb failure stress and geological field report", *Geodesy and Geodynamics*, Vol. 11 No. 4, pp. 252-257.

Hanifa, N.R., Mujaki, J., Rudyanto, A., Pamumpuni, A., Gunawan, E., Pradipta, G. and Rasyidi, A. (2019), *Spatial Assessment of Schools Damage Due to Palu Earthquake 2018, Assessment On Palu Earthquake 2018, Indonesia*, National Center for Earthquake Studies, Research and Development Agency of Ministry of Public Work and Housing, 978-602-5489-14-3.

IRGC (2017), *Introduction to the IRGC Risk Governance Framework, Revised Version*, EPFL International Risk Governance Center, Lausanne, doi: 10.5075/epfl-irgc-233739.

IRGC (2018), "Guidelines for the governance of systemic risks. Lausanne: international risk governance center (IRGC)", doi: 10.5075/epfl-irgc-257279.

Ismail, H., Abd Wahab, A.K. and Alias, N.E. (2012), "Determination of mangrove forest performance in reducing tsunami runup using physical models", *Natural Hazards*, Vol. 63 No. 2, pp. 939-963.

Jena, R., Pradhan, B., Beydoun, G., Alamri, A.M. and Sofyan, H. (2020), "Earthquake hazard and risk assessment using machine learning approaches at Palu, Indonesia", *Science of the Total Environment*, Vol. 749, 141582.

Junaidi, M. and Marzuki, M. (2016), "Konflik Komunal Nunu dan Tavanjuka di Kota Palu: Meniti Jalan Panjang Menuju Perdamaian", *Etnohistory*, pp. 199-210.

Kementerian PPN/BAPPENAS and Pemerintah Provinsi Sulawesi Tengah (2018), *Rencana Induk Pemulihan Dan Pembangunan Kembali Wilayah Pascabencana Provinsi Sulawesi Tengah*, Kementerian PPN/Bappenas, Jakarta.

Kompas (2019), *Mangrove Forest Reduces the Impacts of Tsunamis on 28 September 2018 in Palu Bay, Central Sulawesi*, Kompas Cetak, (accessed 15 January 2019).

Kumparan (2022), "Benteng tsunami di Donggala Dibabat untuk Dijadikan Tambak, Kumparan" 14 February 2022, available at: https://kumparan.com/paluposo/benteng-tsunami-di-donggala-dibabat-untuk-dijadikan-tambak-1xVEjZkliGH (accessed 25 July 2022).

Lange, P., Driessen, P.P., Sauer, A., Bornemann, B. and Burger, P. (2013), "Governing towards sustainability—conceptualising modes of governance", *Journal of Environmental Policy and Planning*, Vol. 15 No. 3, pp. 403-425.

Lassa, J.A. (2011), "Institutional vulnerability and governance of disaster risk reduction: macro, meso and micro scale assessment (with case studies from Indonesia)", University of Bonn, PhD Dissertation.

Lassa, J.A. (2013), "Disaster policy change in Indonesia 1930-2010: from government to governance?", *International Journal of Mass Emergencies and Disasters*, Vol. 31 No. 2, pp. 130-160.

Lassa, J.A. (2019), "Negotiating institutional pathways for sustaining climate change resilience and risk governance in Indonesia", *Climate*, Vol. 7 No. 8, p. 95.

Lassa, J.A., Nappoe, G.E. and Sulistyo, S.B. (2022), "Humanitarian ecosystem for cash transfer programming: understanding institutional and operational constraints in post-disaster governance in Indonesia", *Journal of Disaster Studies*, Vol. 14 No. 1. doi: 10.4102/jamba.v14i1.1046.

LIPI (2019), *Laporan Kaji Cepat Penanganan Pasca Bencana di Palu, Sigi, dan Donggala:Pemulihan Tempat Tinggal dan Penghidupan*, LIPI. Jakarta, 978-623-90973-0-1.

Lucas, K., Renn, O., Jaeger, C. and Yang, S. (2018), "Systemic risks: a homomorphic approach on the basis of complexity science", *International Journal of Disaster Risk Science*, Vol. 9 No. 3, pp. 292-305.

Muhammad, C., Gogali, L., Herianto, M., Lapasere, M.R., Muhidin, N., Lamasitudju, N. and Gayathri, T.R. (2020), "Menyemai Perubahan - Catatan Rekonstruksi Berbasis Komunitas Empat Desa di

Sulawesi Tengah, Labuan Toposo, Lemusa, Soulowe, Toaya", *Penerbit Indonesia Untuk Kemanusiaan*, 978-602-61287-3-7.

Natawidjaja, D.H., Daryono, M.R., Prasetya, G., Liu, P.L., Hananto, N.D., Kongko, W., Triyoso, W., Puji, A.R., Meilano, I., Gunawan, E. and Supendi, P. (2021), "The 2018 M w7. 5 Palu 'supershear earthquake ruptures geological fault's multi segment separated by large bends: results from integrating field measurements, LiDAR, swath bathymetry and seismic-reflection data", *Geophysical Journal International*, Vol. 224 No. 2, pp. 985-1002.

Novitarima, A. and Saputri, T.W. (2019), "Reducing tsunami wave Energy by mangrove ecosystem based on tsunami inundation model in Palu Timur, Indonesia", *Conference: Hokkaido Indonesian Student Association Scientific Meeting*, Japan, Sapporo.

OECD (2003), "Emerging Systemic Risks", Final Report To the OECD Futures Project, OECD, Paris, France.

Omira, R., Dogan, G.G., Hidayat, R., Husrin, S., Prasetya, G., Annunziato, A., Proietti, C., Probst, P., Paparo, M.A., Wronna, M. and Zaytsev, A. (2019), "The 28 September 2018, tsunami in Palu-Sulawesi, Indonesia: a post-event field survey", *Pure and Applied Geophysics*, Vol. 176 No. 4, pp. 1379-1395.

Pakoksung, K., Suppasri, A., Imamura, F., Athanasius, C., Omang, A. and Muhari, A. (2019), "Simulation of the submarine landslide tsunami on 28 September 2018 in Palu Bay, Sulawesi Island, Indonesia, using a two-layer model", *Pure and Applied Geophysics*, Vol. 176 No. 8, pp. 3323-3350.

Paton, D. and Sagala, S. (2018), *Disaster Risk Reduction in Indonesia: Environmental, Social and Cultural Aspects*, Charles C Thomas Publisher, Springfield, IL.

Prasetya, G.S., De Lange, W.P. and Healy, T.R. (2001), "The Makassar strait tsunamigenic region, Indonesia", *Natural Hazards*, Vol. 24 No. 3, pp. 295-307.

PuSGeN (2017), *Earthquake Source and Hazard Map of Indonesia 2017*, Indonesia National Center for Earthquake Studies, Research and Development Agency of Ministry of Public Work and Housing, 978-602-5489-01-3.

PuSGeN (2019a), *Assessment on Palu Earthquake 2018, Indonesia*, National Center for Earthquake Studies, Research and Development Agency of Ministry of Public Work and Housing, 978-602-5489-14-3.

PuSGeN (2019b), *Report on the Progress of Confirmation of the Palukoro Fault Prone Zone Post-Palu Earthquake*, Indonesia National Center for Earthquake Studies, Research and Development Agency of Ministry of Public Work and Housing, 978-602-5489-20-4.

Puslitbang Sumber Daya Air Badan Penelitian dan Pengembangan Kementrian Pekerjaan Umum dan Perumahan Rakyat (2019), *Pemulihan Sumber Daya Air Pascabencana Gempa Padagimo, Sulawesi Tengah*, Kementrian PUPR, Jakarta.

Putra, D.I. and Matsuyuki, M. (2019), "Disaster management following decentralisation in Indonesia: regulation, institutional establishment, planning, and budgeting", *Journal of Disaster Research*, Vol. 14 No. 1, pp. 173-187.

Reksa, A.F.A. (2020), *Trapped Populations: Menangani Pandemi COVID-19 Untuk Penyintas Bencana di Kota Palu*, Jurnal Kependudukan Indonesia, pp. 101-104.

Renn, O. (2020), "New challenges for risk analysis: systemic risks", *Journal of Risk Research*, pp. 1-7.

Rismawati, R. (2011), "Bertahan Hidup di Pengungsian Kaum Janda Korban Konflik Poso", *Academica*, Vol. 3 No. 1, pp. 593-614.

Rochet, J.C. and Tirole, J. (1996), "Interbank Lending and systemic risk", *Journal of Money, Credit and Banking*, Vol. 28 No. 4, pp. 733-762.

Schwarcz, S.L. (2008), "Systemic risk", *Geo. Lj*, Vol. 97, p. 193.

Schweizer, P.J. and Renn, O. (2019), "Governance of systemic risks for disaster prevention and mitigation", *Disaster Prevention and Management: An International Journal*, Vol. 28 No. 6, pp. 862-874, doi: 10.1108/DPM-09-2019-0282.

Socquet, A., Hollingsworth, J., Pathier, E. and Bouchon, M. (2019), "Evidence of supershear during the 2018 magnitude 7.5 Palu earthquake from space geodesy", *Nature Geoscience*, Vol. 12 No. 3, pp. 192-199.

Sofyan, I., Erdiyansyah and Royfandi, M. (2020), "Participative disaster management: post-disaster Renewal of Palu city", *Technium Social Sciences Journal*, Vol. 13, pp. 25-34.

Trias, A.P.L. and Cook, A.D. (2019), "Recalibrating disaster governance in ASEAN: implications of the 2018 central Sulawesi earthquake and tsunami", RSIS Special Report.

Triyanti, A., Walz, Y., Marfai, M.A., Renaud, F. and Djalante, R. (2017), "Ecosystem-based disaster risk reduction in Indonesia: unfolding challenges and opportunities", in Djalante, R., Garschagen, M., Thomalla, F. and Shaw, R. (Eds), *Disaster Risk Reduction in Indonesia*, Springer, Cham, pp. 445-467.

Tunas, I.G., Tanga, A. and Oktavia, S.R. (2020), "Impact of landslides induced by the 2018 Palu earthquake on flash flood in Bangga River basin, Sulawesi, Indonesia", *Journal of Ecological Engineering*, Vol. 21 No. 2, pp. 190-200.

UNDRR (2022), *Scoping Study on Compound, Cascading and Systemic Risks in the Asia-Pacific*, United Nations Office for Disaster Risk Reduction, UNDRR, Geneva.

UNDRR & UNESCO-IOC (2019), "Limitations and Challenges of early warning systems: a case Study of the 2018 Palu-Donggala tsunami", United Nations Office for Disaster Risk Reduction (UNDRR), Regional Office for Asia and the Pacific, and the Intergovernmental Oceanographic Commission of United Nations Educational, Scientific and Cultural Organization, IOC Technical Series N° 150.

UNDRR (2017), "Terminology", available at: https://www.undrr.org/terminology/ (accessed 19 July 2022).

UNDRR (2019), *Global Assessment Report on Disaster Risk Reduction*, UNDRR, Geneva.

UNISDR (2015), *Sendai Framework for Disaster Risk Reduction 2015-2030*, UNISDR, Geneva.

Van Asselt, M.B. and Renn, O. (2011), "Risk governance", *Journal of Risk Research*, Vol. 14 No. 4, pp. 431-449.

Watkinson, I.M. and Hall, R. (2019), "Impact of communal irrigation on the 2018 Palu earthquake-triggered landslides", *Nature Geoscience*, Vol. 12 No. 11, pp. 940-945.

Further reading

BMKG (2019), *Katalog Gempabumi Signifikan Dan Merusak 1821-2018*, BMKG, Jakarta.

CARE, BPBD Palu, Kota Palu and Lingkar (2020), *Penilaian Ketangguhan Kota Palu Terhadap Bencana*, CARE, Palu.

Daswati, D., Samad, M.A. and Wekke, I.S. (2020), "Collaborative governance in the management of integrated community shelters post disaster (ICS) in the city of Palu", *Politik Indonesia: Indonesian Political Science Review*, Vol. 5 No. 2, pp. 229-242.

Geotechnical Extreme Events Reconnaissance (2019), "Geotechnical Reconnaissance: the 28 September 2018 M7.5 Palu-Donggala, Indonesia Earthquake", GEER Association Report - Version 1.0, 3 April 2019.

O'Brien, K., Pelling, M., Patwardhan, A., Hallegatte, S., Maskrey, A., Oki, T., . . . and Mimura, N. (2012), "Toward a sustainable and resilient future", in Field, C.B., Barros, V., Stocker, T.F. and Dahe, Q. (Eds), *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, pp. 437-486.

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