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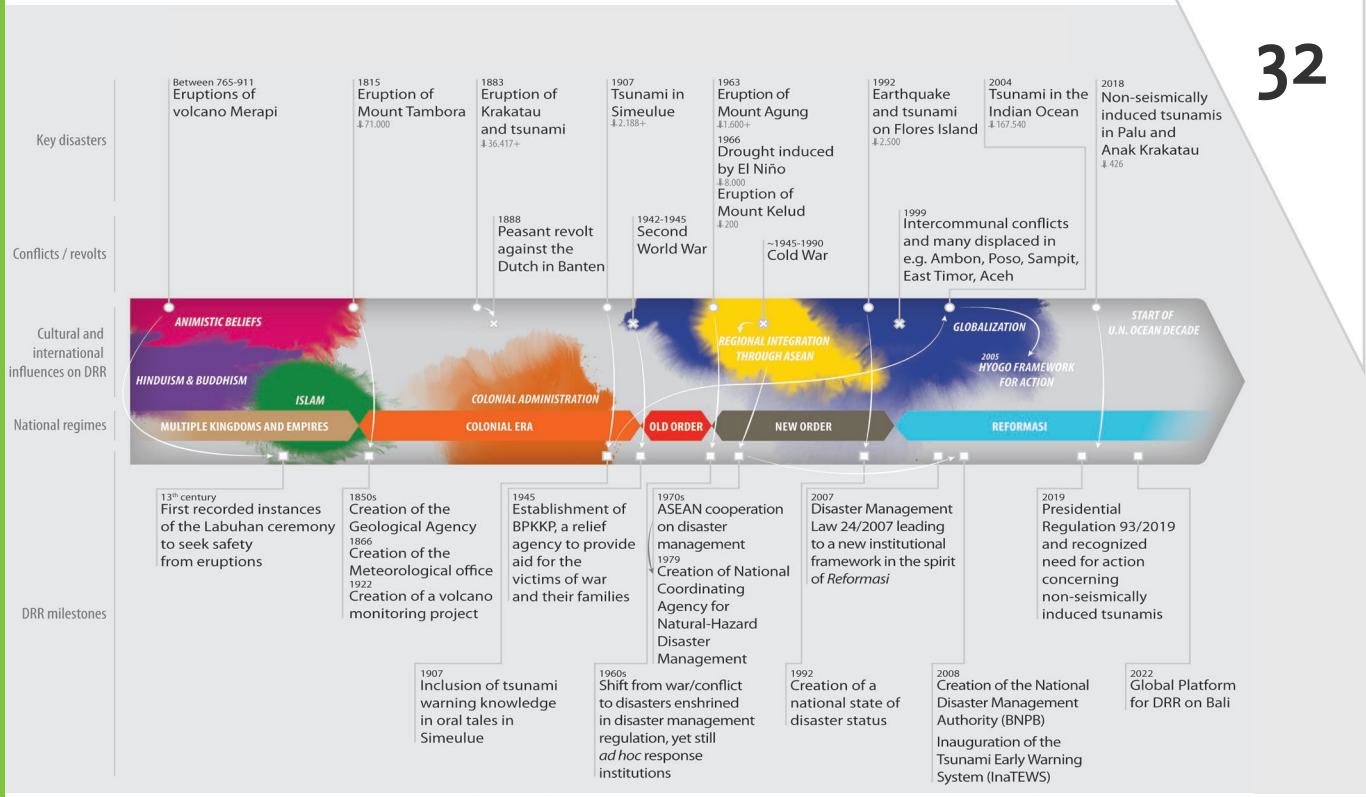

Disaster*Cultures – Indonesia and its Tsunami Warning System

Isabelle Desportes, Dr.
Wicak Wicaksono
Martin Voss, Prof. Dr.

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Katastrophenforschungsstelle (KFS)
Freie Universität Berlin
FB Geowissenschaften
Carl-Heinrich-Becker-Weg 6-10
12165 Berlin

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ASEAN	Association of Southeast Asian Nations
BAKORNAS	*Badan Koordinasi Nasional Penanggulangan Becana Alam* / National Coordination Board for Natural Disaster Management (BPBD precursor, known at times BAKORNAS-PB or BAKORNAS PBP)
BATAN	National Nuclear Energy Agency of Indonesia
BIG	*Badan Informasi Geospasial* / Agency for Geospatial Information
BMKG	*Badan Meteorologi, Klimatologi, dan Geofisika* / Agency for Meteorology, Climatology and Geophysics
BNPB	*Badan Nasional Penanggulangan Bencana* / National Agency for Disaster Management
BPBD	*Badan Penanggulangan Bencana Daerah* / Subnational Disaster Management Agencies
BPPT	Agency for the Assessment and Application of Technology
BRIN	*Badan Riset dan Inovasi Nasional* / National Research and Innovation Agency
CSO	Civil Society Organizations
DRR	Disaster Risk Reduction
EOC	Emergency Operations Center
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
InaTEWS	Indonesian Tsunami Early Warning Systems
IDSL	Inexpensive device for sea level monitoring
JICA	Japan International Cooperation Agency
NTWC	National Tsunami Warning Center
PMI	*Palang Merah Indonesia* / Indonesian Red Cross

POLRI	*Kepolisian Negara Republik Indonesia* / Indonesian Police
PVMBG	*Pusat Vulkanologi dan Mitigasi Bencana Geologi* / Centre for Volcanology and Geological Hazard Mitigation (also known as CVGHM)
TNI	*Tentara Nasional Indonesia* / Indonesian Military
UNDRR	United Nations Office for Disaster Risk Reduction
UNESCO-IOC	Intergovernmental Oceanographic Commission of the United Nations Educational Scientific and Cultural Organization
USAID	United States Agency for International Development

Abstract

Much literature on the disaster-culture nexus focuses on tangible elements such as demograpics or geography and adopts an anthropocentric Western and positivistic mindset. In contrast, this Working Paper applies an epistemological 'disaster*cultures' approach to Indonesia. We put the onus on construction processes, interpreting and finding meaning rather than on identifying set patterns, and highlight how culture does not refer to 'exotic' processes that can only be studied at the community level. Researchers, practitioners and policy-makers all approach disasters and risks through their own specific (disciplinary) lenses. The first part of thiw Working Paper will introduce our disaster*cultures-approach. Subsequently, analysing academic literature in English and Bahasa Indonesia, but also poems, art, toponyms, grey literature and selected exchanges conducted with Indonesian tsunami scientists and disaster management officials in 2022 as part of the TSUNAMI_RISK research project, we review the socio-historical ways through which multiple disaster*cultures have formed in Indonesia. The remainder of the Working Paper details the main disaster stakeholders, policies and practices at play in Indonesia today, particularly in regard to the Indonesian Tsunami Warning System (InaTEWS) and efforts to detect non-seismically induced tsunamis. As such, we aim to provide disaster scholars and practitioners with a holistic overview of the Indonesian contexts in which they operate, and to facilitate more socio-culturally sensitive technology and warning system development.

Keywords: Culture, Disaster, Indonesia, History, Tsunami, Warning System

Zusammenfassung

Publikationen zum Zusammenhang von Katastrophen und Kultur konzentrieren sich meist auf messbare bzw. quantifizierbare Größen wie Demografie oder die von Menschen gestaltete Umwelt und nimmt eine anthropozentrische, westliche und positivistische Denkweise an. Im Gegensatz dazu wendet dieses Arbeitspapier einen epistemologischen 'Katastrophe*Kultur'-Ansatz auf Indonesien an. Wir legen den Schwerpunkt auf Konststruktionsprozesse und die Interpretation von Bedeutung, anstatt auf das Identifizieren von festgelegten Mustern. Wir heben hervor, dass Kultur in erster Linie nicht 'exotische' Prozesse bezeichnet, die nur auf Gemeinschaftsebene untersucht werden können. Forscher, Praktiker und politische Entscheidungsträger nähern sich Katastrophen und Risiken jeweils durch ihre eigenen spezifischen (disziplinären) Perspektiven, die ihrerseits aus einem kulturellen Konstruktionsprozess hervorgegangen sind. Im ersten Teil des Arbeitspapieres stellen wir unseren Ansatz der Katastrophen*Kulturen vor. Durch die Analyse akademischer Literatur in Englisch und Bahasa Indonesia, aber auch von Gedichten, Kunst, grauer Literatur und ausgewählten Gesprächen mit indonesischen Tsunami-Wissenschaftlern und Katastrophenmanagementbeamten im Jahr 2022 im Rahmen des TSUNAMI_RISK-Forschungsprojekts überprüfen wir anschließend die sozio-historischen Wege, auf denen sich in Indonesien multiple Katastrophen*Kulturen gebildet haben. Der restliche Teil des

Arbeitspapiers beschreibt die wichtigsten Katastrophenakteure, -politiken und -praktiken, die heute in Indonesien eine Rolle spielen, insbesondere im Hinblick auf das indonesische Tsunami-Warnsystem (InaTEWS) und Bemühungen zur Erkennung von nicht-seismisch verursachten Tsunamis. So wollen wir Katastrophenforscher*innen und -praktiker*innen einen Zugang zu einer sozialwissenschaftlich reflektierten, kultursensitiveren Perspektive ebnen, einen umfassenden Überblick über die indonesischen Kontexte geben, in denen sie tätig sind und die Entwicklung von sozio-kulturell sensiblerer Technologie und Warnsystemen erleichtern.

Schlüsselwörter: Kultur, Katastrophe, Indonesien, Geschichte, Tsunami, Warnsystem

1 Introduction

This Working Paper stems from two observations. First, culture matters to prevent and respond to disasters. In line with a constructivist approach to risk and disasters, studies have for instance found how the relationship between levels of risk perception and risk preparedness is not straightforward (Appleby-Arnold et al. 2021). People might have been confronted with disasters and be aware of risk, yet not take preventive action. They may receive a tropical storm warning, yet not evacuate (Paul and Dutt 2010). Something called 'culture' is mediating the relationship, referring to an array of factors ranging from social cohesion to trust in authorities over norms and values. Second, culture is not sufficiently taken into account in current disaster risk reduction (DRR) and response (Krüger 2015). This also applies to new disaster risk management processes and technologies, such as warning systems, which are too often rolled out without due attention to the specific context and the multiple socio-historically formed ways through which societies perceive and engage with their surroundings.

Our research contributes to the cultural turn taking place in disaster studies – a turn which is by far not new (see for instance Carr 1932, Douglas and Wildavsky 1982, Bankoff 2003, Voss 2008, Voss and Funk 2015), yet struggles to pick up pace. Two main caveats are frequently observed when it comes to literature on the disaster-culture nexus. The first is a focus on the tangible elements of culture. As noted by Appleby-Arnold et al. (2021, 666), works exploring the risk perception-culture nexus "often still refer back to demographics, including ethnicity, geography, and socioeconomic factors, rather than cultural aspects, such as values and traditions, worldviews, power relations, and attitudes towards authorities". Second, most studies on disasters and culture adopt an anthropocentric, Western and positivist mindset according to which many things are taken for granted (Voss, 2008, Voss and Funk 2015). This is reflective of broader trends within disaster studies: The domain is mainly characterised by an over-reliance on positivistic epistemologies (Goodall, Khalid, and Del Pinto 2021, 3), English language literature, and overwhelmingly consists of Western scientists studying processes in the Global South (Gaillard 2019). The vocabulary and concepts the scientists bring in often do not fit local language and perceptions (Chmutina et al. 2020). For example, the separation of nature and society is not only not compatible with the worldview of some indigenous groups, who tend to consider nature and society as intertwined (Maton-Mosurska cited in Goodall, Khalid, et Del Pinto 2021, 11). Many cultures do not distinguish at all or in a comparable manner. But, even where this culture-nature divide exists, this separation is being construed in each socio-cultural context in a singular way.

To help bridge overcome these caveats, we argue for an epistemological disaster*culture approach[1] according to which what science commonly calls 'disasters' should be studied without pre-conceptions

[1] Terminology plays a central role in an epistemological approach to disasters, and so does naming the topic of inquiry in itself. Hesitating between ´disaster cultures´, ´culture of disaster´ and many more, we finally settled on 'disaster*culture' to highlight how culture is all-encompassing and how terming specific processes ´disasters´ is a cultural meaning-giving process in itself.

(Voss 2008, Voss 2022, Voss and Funk 2015). While some scholars find that we are both part of, as well as shaped by cultures, we place ourselves in the tradition of Geertz (1983), who has defined culture as a "self-webbed web of meaning". The disaster*culture approach introduced and applied here to the case of Indonesia puts focus on interpreting and ´finding meaning´ rather than on identifying set patterns. Our review of the socio-historical ways through which multiple disaster*cultures have formed in Indonesia rests on the key principles summarised in Box 1. We analyse academic literature in English and Bahasa Indonesia, but also poems, art, grey literature and selected exchanges conducted with Indonesian tsunami scientists and disaster management officials in 2022 as part of the TSUNAMI_RISK project. Indeed, an epistemological disaster*culture approach highlights that culture does not refer to 'exotic' local processes that can only be studied at a community level. Researchers, practitioners and policy-makers all approach disasters and risks through their own specific (disciplinary) lenses. As such, this Working Paper follows a double aim: (i) develop the disaster*culture approach, and (ii) pragmatically provide disaster scholars and practitioners with a holistic overview of the Indonesian contexts in which they operate, so as to facilitate more socio-culturally sensitive technology and warning system development.

The Working Paper is structured in four sections. We present the Indonesian setting, whereby 'risk' and the nature/culture divide are epistemological approaches amongst others. Then, we review key socio-historical phases which have contributed in shaping the Indonesian disaster management policy over time. The third and fourth sections include a more traditional presentation of the main disaster stakeholders, policies and practices at play in Indonesia today, particularly concerning the Indonesian Tsunami Warning System (InaTEWS) and non-seismically induced tsunamis. By ways of conclusion, we reflect on the entanglements and evolutions of disaster*cultures in contemporary disaster practice in Indonesia.

Box 1: Key principles for an epistemological approach to disaster*culture.

- Approach disaster studies without preconceptions and question everything, including the framework. Goodall et al. (2021) refer to this as taking the attitude of a learner;
- Be clear on one´s own intellectual foundations, if possible with the help of an external perspective;
- Be cognizant of plurality, also within science;
- Refrain from drawing hierarchies between different meanings;
- Be cognizant of the intermeshing and evolutions of meanings and types of knowledge.

The TSUNAMI_RISK research project

TSUNAMI_RISK (2021-2024) „Multi-risk and cascade effects analysis in cooperation between Indonesia and Germany – common research on volcanic- and landslide-induced tsunamis" aims for a better understanding of the geophysical and socio-political processes surrounding non-seismically induced tsunamis in Indonesia.

The disaster*culture working package is conducted by the Disaster Research Unit at the Freie Universität Berlin, in close collaboration with Universitas Indonesia and the Indonesian National Research and Innovation Agency (BRIN).

TSUNAMI_RISK is led by the Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum (GFZ) (Helmholtz Centre Potsdam – German Research Centre for Geosciences); the Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR) (German Aerospace Center); the Technische Universität Braunschweig (TU-BS) (Technical University of Braunschweig), Leichtweiß-Institut für Wasserbau und Wasserressourcen, Abteilung für Hydromechanik, Küsten- und Seebau (Leichtweiß-Institute for Hydraulic Engineering and Water Resources, Department of Hydromechanics, Coastal and Ocean Engineering); the Technische Universität Berlin (TUB), Fachgebiet für Ingenieurgeologie (Technical University of Berlin, Department of Engineering Geology); the Bundesanstalt Technisches Hilfswerk (THW) (Federal Ageny for Technical Relief) sowie die Erdbeben- und Tsunami-Warnsystem entwickelnde GmbH Gempa (Earthquake and tsunami warning system developer Gempa GmbH).

A wide range of Indonesian research and disaster management institutions co-engaged in the research. Project funding is provided under the Client II Fund by the German Ministry of Research and Education, BMBF Funding reference number 03G0906A.

2 An archipelagic landscape, a diverse population

The Republic of Indonesia is a country of geographical superlatives. Spanning a distance of 5,000 km and counting 17,000 islands in the Indian and Pacific Ocean, Indonesia constitutes the largest archipelagic state in the world (Lassa 2013). Barrow (1990, 78) describes it as one of the countries where "the degree of marine influence over its climate, environment, settlement, communications and development of resources [is] considered unmatched in any other part of the world" (cited in Bankoff 2003, 19). The country, with its coastline adding up to 80,000 km, does not only count 14% of the global coastal length (Triyanti 2019, 81), but, it is also situated on top of the Pacific Ring of Fire where the Eurasian, Indo-Australian and Pacific tectonic plates collide (see Figure 1), a location with 10% of the world´s volcanoes. There are 128 active volcanoes in Indonesia today (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 26).

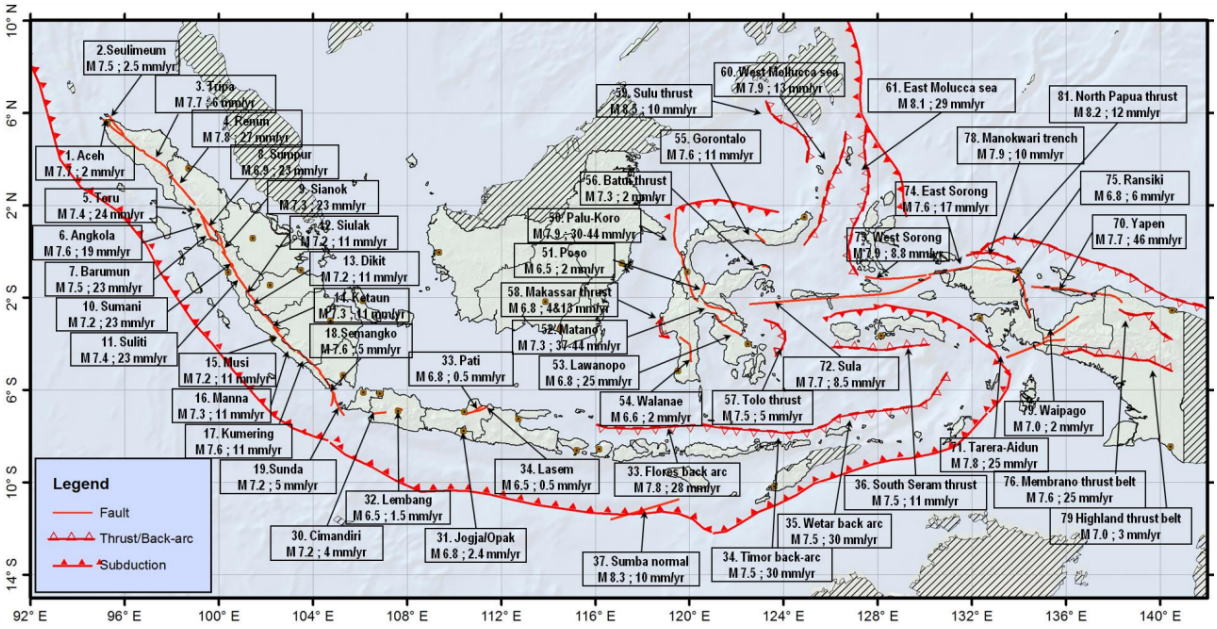

Figure 1. Active fault lines in Indonesia (Irsyam et al. 2017).

2.1 Risks and vulnerabilities

The geography leaves the population of more than 270 million (Statistics Indonesia 2021), two thirds of which live in coastal areas, highly exposed to hazards such as earthquakes, volcanic eruptions, tsunamis, floods and coastal erosion. Between 1900 and 2015, it is estimated that almost 29 million people have been injured, internally displaced or otherwise affected by disasters. Over the same time period, close to 240 000 people were killed as a result of disasters (Djalante and Garschagen 2017, 21). Hydrometeorological disasters are the most common and are rising in frequency due to climate variability and change, with a 20-fold increase between 2002 and 2016 according to the National Disaster Management Authority (see Figure 2; *Badan Nasional Penanggulangan Bencana* (BNPB) 2022). Earthquakes are less frequent, but as they also lead to secondary disasters such as tsunamis, 70% of all disaster deaths since 1900 can be attributed to this hazard. Tsunamis are particularly deadly and have

claimed 160,000 lives (Djalante and Garschagen 2017). In relation to volcanoes, Indonesia has "the greatest confluence of volcanic explosivity, population density, and documented fatalities in the world" (Cottrell 2015, 11).

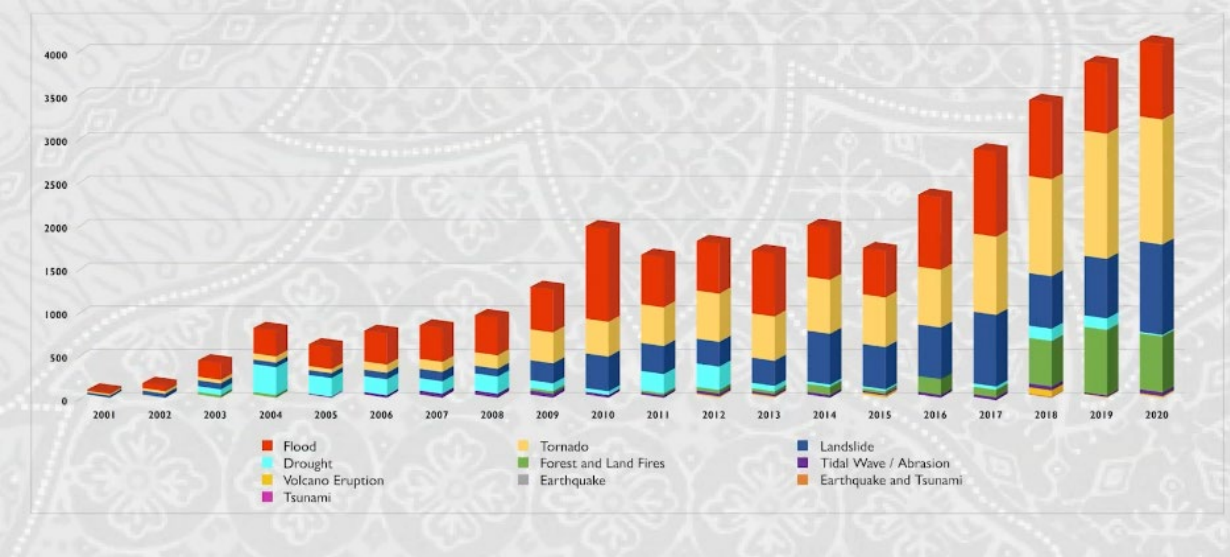

Figure 2. Evolving amount of disasters in Indonesia over the 2001-2020 period (BNPB 2022)

The diversity in landscapes is matched by the diversity in population and vulnerability levels. The presence of more than 700 different languages is only one aspect of the "multiplicity of viewpoints and cultures" present in Indonesia (Birkmann, Setiadi, and Fiedler 2015, 246). Cultural diversity is further compounded by the presence of around 300 ethnic groups- each with their own agrarian, marine and/or urban livelihoods, traditions and relation to their wider environment, to name but a few distinguishing factors. Overall, vulnerability is increased by unplanned urbanization and authorities' lack of resources and capacities as well as high poverty and inequality levels. While Indonesia is considered a low middle-income country, with agriculture accounting for only 14% of Gross Domestic Product (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 21), more than 27% of children under five suffer of stunting prevalence and chronic malnutrition (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 11). "Socioeconomic status and infrastructure" which are very unequally developed across the archipelagic state, "gender, age and population growth" as well as family structure have been identified as key drivers of disaster vulnerability (Siagian et al. 2014). Disaster Management Law 24/2007 prescribes special attention to vulnerable groups, defined as "children, pregnant and lactating women, disabled persons, and the elderly" (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 11). High levels of poverty, which e.g. limit the possibilities to build two-story houses or to flee other than by foot, likewise influence people´s vulnerability (Gaillard et al. 2008). In Aceh following the 2004 tsunami, most victims were women who were in their homes doing household chores, taking care of their children or "did not know how to swim, dive or climb trees" to protect themselves from the tsunami wave (Gaillard et al. 2008, 16). Conflict contributes to vulnerability, as it may lead to distrust of state institutions and/or make fleeing to inland mountains unsafe due to occupation by armed groups (Gaillard et al. 2008).

At the regional level, in comparison with the ten other members of the Association of Southeast Asian Nations (ASEAN), Indonesia is 4th amongst member states described as lacking capacity to deal with disasters, after Cambodia, Laos and Myanmar (The ASEAN Secretariat 2021). Based on the risk index published in the World Risk Report and compounding exposure, vulnerability and capacity elements, Indonesia ranks 2nd on the list of countries most at risk from disasters (Bündnis Entwicklung Hilft 2023, 54).

2.2 The nature / culture divide in Indonesia?

Risk is one angle from which to approach the relationship between the diverse Indonesian population and the physical environment. Yet, not all would call what science terms a 'disaster' a disaster, or perceive their environment as 'risky', even when they live at the foothill of a volcano.[2] In the National Museum of Indonesia in Jakarta (2022), disasters are described as an "inevitable part of life for Indonesian people since ancient times". A photography by Ahmad Samsudin, displayed at the National Museum of Indonesia in 2022, shows pupils continuing their school activities in a flooded classroom and illustrates how disasters are integrated into daily life, at least in some circumstances. Some Indonesians also live in risky areas by choice. For the villagers living on the slopes of Mount Merapi- the most active Indonesian volcano, erupting every four years on average and located close to Yogyakarta- the volcano has a positive side: it supports life by fertilizing the soils, provides blessings, and purifies itself and humans (Voss 2008). Recently, 'volcano tours', whereby destroyed villages can be visited by tourists, offer additional revenues (Nazaruddin 2022). Residents are forced to evacuate every time the mount erupts, but keep coming back to live their life. Both 'giving' and 'taking' happen periodically and routinely, they are part of the population's life cycle. Residents 'live with the risk', integrating the volatility of the volcano in their lives and livelihoods (Maarif 2013, 5). According to community wisdom, the eruptions of Mount Merapi therefore do not constitute a disaster in themselves. The ability to overcome the possible dangers posed by the volcano must always be developed by the community itself: disasters begin and end with humans' inability to eschew the threat (Maarif 2013, xi). Similarly, on the eastern edge of Java, people's livelihoods are tightly interlinked with the volcano: it provides sulphur resources and a source of income for many villagers (ZDF 2021). As counter-example, the fisherfolk of Madura are less positively inclined towards the nearby volcano: Its ashes prevent them going out on sea to fish. For them, flooding is a danger during the rainy season, but the wind and waves on sea are rather interpreted as joys and "moods of the ocean".

This last quote evoking the "moods of the ocean" underlines the various epistemological approaches to one's environment. Citing Rigg (1997, 46-48), Bankoff (2003, 24) notes the use of two distinct words referring to 'environment' in the Indonesian language: *Taman* refers to a "nature tamed and manipulated for human interests", while *hutan* connotes a "wild, rustic and untamed space that is often associated with evil spirits and that should only be entered with care". In line with the first approach (*taman*), the environment can be approached as an economic space and a reservoir of resources. Bankoff (2003, 24) refers to the Indonesian state's 'resource frontier' discourse and associated practices,

[2] In the following, the term disaster should thus be understood as put into bracket: 'disaster'.

according to which populations could simply move to a new area when resources were depleted, making sustainable use of resources less relevant. Resource extraction has increased through European colonialism as well as after political independence, making Indonesia "one of the principal sources of export-oriented commercial resource extraction [(such as palm oil)] in the world and precipitat[es] human-induced environmental changes on an unprecedented scale" (Bryant and Parnwell 1996: 4–8 cited by Bankoff 2003, 19). This goes hand in hand with changing risk levels. Reviewing the meanings attached to the ocean in the Indonesian fishing village of Boe Manes, Schenk (2020, 2) likewise observes that the sub-discipline of maritime anthropology has mainly approached the Pacific Ocean as a "biomass, a resource-container, and a territory of national and international political and economic interest".

In line with the second approach (*hutan*), the ocean can and already has been approached as a socio-cultural space and a space where people´s perception, (sensual) experiences and meaning making are central (Schenk 2020, 71). Indigenous people would see the sea as "distinct bodies of waters of different qualities, paths and boundaries" (Schneider 2012, 195) and perceive the ocean "where it does not appear physically" (Schenk 2020, 71). In that sense, water is not what separates islands and people; it connects them. At the National Museum of Indonesia (2022), the sea is described as "unifying the nation". According to the museography, agrarian and marine ecosystems and livelihoods go "hand in hand" and "support each other"; thus, the "archipelago concept sees Indonesia as an integrated and inseparable territory that consists of land, sea and their air space above it". Fishing communities face particular dangers amidst unpredictable waves, currents, winds and rock relief. Knowledge of sea navigation, Austronesian ship building techniques and map reading is particularly important to ensure safety whilst on sea. In addition, faith in supranatural forces and the "belief in the sacred" help cope with uncertainty (National Museum of Indonesia 2022). The sea, as illustrated by associated practices such as ship building, boat-making and thanks-giving rituals, is a sacred space where one has to "mind how one behaves" (National Museum of Indonesia 2022). Needless to say, the sea also inspires countless works of art.

Extractive and socio-cultural-spiritual approaches to the environment can be interlinked. For instance, most of the indigenous people in Maluku are living on small islands prone to extreme weather, droughts and high tidal waves. The people practiced *sasi*, a strategy passed on from generation to generation involving barring entrance to, taking of resources or making use of a certain area for a period of time. *Sasi* thus served to locally regulate the use of natural resources, but was also linked to lengthy and sacred traditional ceremonies involving local leaders such as *kewang* (customary police), *raja* (king/head of village), as well as *saniri* (members of customary council) (Marasabessy 2018). Government Law 5/1979 established standards for the governance of every village and thus forced customary change – including the practice of *sasi*. Nowadays, most of *sasi* is practiced through church, providing it a new meaning (such as prohibiting theft) and shifting the way the custom is perceived (Barus 2014).

Schenk (2020, 73) finds that concerning the fishing village of Boe Manes, a "relational thinking between people and environment is not beneficial": "mobility and practical / occupational / economical / social / emotional entanglements 'with the environment' are so routinely and continuously inherent in everyday life". Similarly concerning the Bandanese, Gosh writes (2021, 36) citing Liboiron (2021, 7):

> *"the landscapes of their islands were places of dwelling that were enmeshed with human life in ways that were imaginative as well as material; the land did not exist solely to produce nutmeg and mace. It was not land but Land, which is, in the words of Indigenous scientist and thinker Max Liboiron, 'the unique entity that is the combined living spirit of plants, animals, water, humans, histories and events …' "*

Both authors thus put into question the nature-culture divide, which has also been thematised by disaster scholars (Goodall, Khalid, and Del Pinto 2021).

3 Socio-cultural and historical pathways

We now turn to the socio-cultural and historically grown ways through which disasters are perceived, thought about and acted on in Indonesia. We review the influence of key socio-cultural factors: livelihoods and a social group's relation to the environment and hazards, religion and spirituality, as well as the major political phases of multiple kingdoms, colonialism, the 'Old Regime', 'New Regime' and *Reformasi*. Moreover, disasters have played a main role in influencing DRR paradigms and approaches, most notably the Tambora volcanic eruption in 1815, the Krakatau volcanic eruption and tsunami in 1883, and the 2004 Indian Ocean tsunami. Figure 3 presents the main processes and events in the form of a timeline, whereby the past 'colors' the ways disasters are perceived and interacted with in the present, like oil drops falling into water.

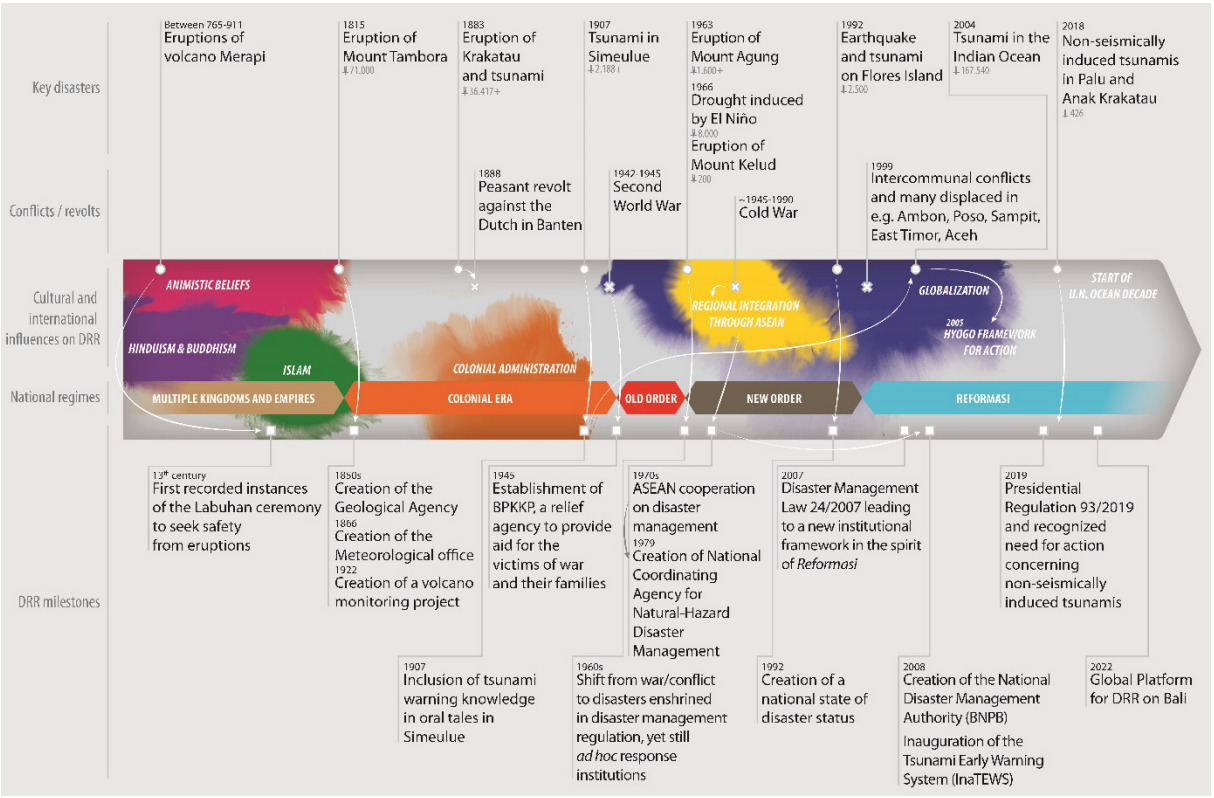

Figure 3. A multiplicity of socio-historically grown disaster*cultures in Indonesia. Source: Desportes and Wicaksono 2022, graphic design by Emmanuel Dahan.

The Figure illustrates some of the ways in which deeper cultural factors, disaster-related processes and events influence each other. For instance, century-old religious belief systems shape what coastal residents consider as 'risky situations' or 'safe' areas today. Or, the Dutch colonial disaster approach and the violence of World War II led Indonesian disaster policy to focus on foreign invasions following its independence, rather than disasters triggered by natural hazards. The upcoming sub-sections shed light on some of these intricate interrelationships.

3.1 A MULTITUDE OF KINGDOMS, LIVELIHOODS, LANGUAGES … AND DISASTER*CULTURES

Prior to the 20th century Indonesian nation-building project into 'one nation united in diversity' and notwithstanding colonial attempts to crush independent political entities[3], Indonesia consisted of a wide multitude of kingdoms and empires (Walsh 2000). Archaeological excavations indicate the Indonesian archipelago has been inhabited for at least 1.5 million years by Homo erectus. Modern humans (Homo sapiens) reached Indonesia approximately 40,000 to 50,000 years ago. With Hindu and Buddhist influences, the Srivijaya naval kingdom flourished from the 7th century onwards. The island of Java was subsequently home to the agricultural Buddhist Sailendra then Hindu Mataram dynasties. Andreastuti (2006) advances the hypothesis that the latter kingdom probably moved from Central to Eastern Java because of repeated eruption of Mount Merapi between 765 and 911. In the late 13th century, the Hindu Majapahit kingdom stretched across most of Indonesia. The presence of Islamised populations can be traced back to the same century, and were first located in northern Sumatra. Islam is described as having spread through the archipelago peacefully through the *para wali* guardians, its values merging with Hindu-Buddhist religious influences and preserving local cultures (National Museum of Indonesia 2022). By the end of the 16th century, Islam was the dominant religion on Java and Sumatra.

EFFECTS FELT TODAY

It can be debated to what extent certain values are integral to 'Indonesian culture' at large. 'Community approaches' and 'fatalism', especially as opposed to 'Western culture', were cited by several Indonesian participants of a workshop on disaster*cultures (8.6.2022). The faith that 'all will turn out well in the end', or that a situation is beyond one's control, might be reflected in the title of a giant sculpture which is placed in front of the National Museum of Indonesia. It seems (through a 'Western eye'?) to show human figures lost inside the spiral of a tsunami, yet the sculpture is titled "I am confident I will reach my destination" (see Figure 4). As presented inside the National Museum of Indonesia (2022), the principle of reciprocity and practices of mutual cooperation became central to Indonesian peasant culture as livelihoods shifted from hunting/gathering to settled agriculture. In the villages, families worked the land in turns, a process called *gotong-royong*, and the harvest was communally used and stored in barns called *lumbung*. This way of life has shifted with the advent of commercial farming; the size of individual barns has become a symbol of hard work and an object of prestige (National

[3] The Sultanate of Mataram, last major independent Javanese kingdom, was colonised and broken up by the Dutch in 1755 (Dove 2010).

Museum of Indonesia 2022). Such shifts between more individualistic and communal ways of living are relevant from a disaster management perspective, as they may impact preparedness levels (Cornia, Dressel, and Pfeil 2016).

Figure 4. Sculpture entitled "Ku yakin sampai di sana" (I am confident I will reach my destination) by I Nyoman Nuarta, displayed in front of the National Museum of Indonesia (Desportes 2022).

Cultural diversity translates into different disaster sub-cultures, which take expression in a diversity of built environments, livelihoods, myths, traditions and languages. Some, as the Omo Nias on Nias (see a model of their housing on Figure 5) and the Bajau in coastal Sulawesi, have integrated varying environmental conditions and hazards into their daily life. According to Mulyati, Najib, and Burhany (2017), the extensive local knowledge and degree of interrelation with the local environment of the Bajau is reflected in their settlements: The Bajau live on stilt houses above sea water, floor heights are determined based on highest tides and roof slopes are custom-shaped to harvest rainwater which is to be used for drinking and cooking. Notably, the Bajau tribes do not have specific inland open spaces for social interaction, the sea is their 'playground' instead (Mulyati, Najib, and Burhany 2017).

Figure 5. Traditional housing on Nias displayed in the National Museum of Indonesia (National Museum of Indonesia 2022).

Local myths, legends and traditional ceremonies provide insight into the distinct meanings populations assign to disasters. Mount Merapi, for instance, is personified and referred to as *mbah* (grandfather) Merapi: he is scary, but also full of love for the villagers (Voss 2008, Widodo and Hastuti 2019). The *Labuhan* ceremony (Figure 6) is still conducted at Yogyakarta palace[4] to both express gratitude and seek safety from its eruptions (Permana 2019; Dove 2010). The people of Mentawai likewise refer to earthquakes as grandfather with the word *teteu* in their language. *Teteu* is the subject of a song, which is commonly used during celebrations and special occasions, such as a party to celebrate a newly built house (Rafliana 2015). The lyrics of the song are provided in Box 2; they include both a description of the earthquake event, the cause of it happening (the evil spirit of the seashell), and an indication of people's actions (here, running away). The song conveys the relationship of proximity and respect that the people of Mentawai have with the natural phenomena of earthquakes. They may feel fear at the onset of a quake, but would call out to 'grandfather' and remain able to act with clarity and good judgement, thereby minimizing the earthquake impact (Sutton et al. 2021). Across the myths and songs, the two-sidedness of volcanoes and what they represent forms a recurrent theme: on one hand, they offer spiritual protection, fertility and life, on the other hand, they are dangerous.

Figure 6. Labuhan Merapi ritual as an expression of gratitude and asking for protection from God (Kementerian Pendidikan dan Kebudayaan 2016, 178).

[4] The town of Yogyakarta and its palace are the center of Javanese culture and the seat of the reigning Sultan of Yogyakarta. Their hereditary title and position as hereditary Governor of the Special Region of Yogyakarta are formally recognised by the Indonesian Government (Republik Indonesia 2012).

Box 2: Mentawai's Teteu (earthquake) song (Rafliana 2015).

Original lyrics	Translated
Teteu amusiat loga	Grandfather (earthquake), the squirrel is singing
Teteu katinambu leleu	Grandfather (earthquake), the noise comes from the top of the hills
Teteu girisit nyau'nyau'	Grandfather (earthquake), there is a landslide and destruction
Amagolu' teteu tai pelebuk	The Grandfather (earthquake) of the spirit of the seashell is angry
Arotadeake baikona	Because the Baiko tree has been cut down
Kuilak pai-pai gou'gou'	The kuilak bird is singing
Lei-lei gou'gou'	The chickens run away
Barasita teteu	There comes Grandfather (earthquake)
Lalaklak paguru sailet	And people are running away

In regards to both verbal and non-verbal uses of language, Nazaruddin (2022) describes the non-verbal means of communication that elders living on the slopes of Mount Merapi have with their volcano. *Ilmu titen*, literally the "knowledge to recognise the patterns of relations" is embedded in cultural memory and has been passed on through generations (Nazaruddin 2022, 190). According to *ilmu titen*, a natural phenomenon, such as a shift in air temperature or certain animal behavior, signifies the occurrence of another. Moreover, the environment is seen as inhabited by "unseen spirits" with whom there are a "magical system of relationships based on reciprocity, coercion, equivalence and obligation" (Nazaruddin 2022, 196). However, not all people are equipped to decode and convey these signs; villagers therefore turn to *juru kunci*, the elder who functions as the volcano caretaker, for evacuation and other instructions (Voss 2008).

As highly visible indicators of various disaster*cultures, different words are used to describe what scientific epistemologies term as being a 'disaster'. Box 3 lists some of the key vocabulary and highlights to what extent different words are used to describe the perceived phenomena. Strikingly, at least six different words refer to what is scientifically denoted as tsunami. The term *smong*, used by the Simeulue on Sumatra island, presents a particularly interesting example. According to Sutton et al. (2021), *smong* encapsulates the tsunami phenomenon in a broader sense, from the generative earthquake, the receding sea and the devastating waves. This points to a more holistic understanding of tsunamis, including the processes that provoke it. A *smong* song was created by Simeulue survivors following the 1907 earthquake-induced tsunami to pay tribute to deceased family members and transmit the story and traditional knowledge about tsunami warning signs. The word *smong* and the cultural practices, such as oral tales, that surround it have attracted many researchers (Rahman and Sutton 2018). For Gaillard et al. (2008), the case of Aceh province, which was particularly strongly hit by the 2004

Indian Ocean tsunami, is a telling example of differing disaster*cultures and their effect on post-hazard behavior. Different ethnic groups displayed very distinct behaviors, leading to massively differing death toll numbers. Of the Acehnese and Minangkabau people, about 170,000 died because of the 2004 tsunami. On the Simeulue island situated near the earthquake epicenter, 44 casualties is the highest cited estimate (Gaillard et al. 2008). Nearly 100 years after the 1907 earthquake, the Simeuluen had themselves spotted warning signs and quickly ran towards the mountains. This was not the case for most Acehnese and Minangkabau people, of which about a quarter had settled in the coastal area less than 10 years before. Rahman et al. (2018) interviewed one Simeuluen who lived in Meulaboh on Aceh mainland. The interviewee described his experience of screaming the word *smong* when he was on the beach, yet failing to warn people around him to run away. From the told experience, the word *smong* was merely recognised by people who were culturally and emotionally rooted in the Simeuluen community: The vast majority of people in Meulaboh failed to grasp the meaning of the word as they had never heard the story of *smong*. In 2005, the United Nations Office for Disaster Risk Reduction (UNDRR, previously UNISDR) awarded the Simeuluen people with the UN Sasakawa Award in appreciation of and to encourage their efforts in building what they termed a culture of preparedness (UNISDR 2005). *Smong* has been internationally recognised to highlight the role of local knowledge in reducing risk, as declared in the Sendai Framework for Disaster Risk Reduction 2015-2030 (UNISDR 2015). National recognition was given as well: the word *smong* has been officially included in the Indonesian dictionary since 2016 (Badan Pengembangan dan Pembinaan Bahasa 2016; Rahman and Sutton 2018).

Box 3. Same phenomenon, different words.

danger *= Bahaya (can also mean emergency)*

earthquake = *Gempa (id)/ Lindu (Java)/ Teteu—grandfather (Mentawai)/ Tana goyang (Maluku)*

liquefaction = *Likuifaksi (id)/Nalodo (Palu)*

tsunami = *Air turun naik (Maluku)/ smong (Simeulue)/ ie beuna (Aceh)/ ae mesi nuka (East Nusa Tenggara)/oloro – galoro (Nias) / Bomba talu (Palu), Palu)/ kalembak (Banten)*

the pyroclastic flows = *Wedhus Gembel*

flash floods = *Galodo (Minangese)*

Moreover, local disaster knowledge is reflected in the toponomy of geographical places. Around Palu for instance, an area impacted by earthquakes, landslides and tsunamis, the population refer to places through names evocative of past events:

> *"district Kaombona (the collapsed land) in Palu, the district Duyu (landslide), Tagari Lonjo (the liquefied soil), Beka village (wretched/ruptured) and Rogovillage (damaged or devastated)"* (Triyanti et al. 2022, 9).

The name *nalodo*, meaning "the land that turns in mud and slides", even points towards a risk which is absent in the official risk assessment document of Palu City: that of massive soil liquefaction (Triyanti et al. 2022, 7).

3.2 Religion and spirituality

Religious belief, faith and/or spirituality as well as other forms of rationalizing pure existence fundamentally construe how phenomena – addressed as 'disasters' in scientific discourse – are perceived and engaged with all around the globe. Amongst the general population, basic understanding supports that something like a disaster exists independent from beliefs, religious or spiritual forces. But this understanding implies the objective existence of a material world independent from socio-culturally construed perceptions – an assumption that derives from a western positivistic scientific perspective which we simply cannot take for granted. It is only by use of a Western scientific lens and very specific concepts that it is possible to observe the social order of 'disasters' as experienced by objectively existing 'individuals' through their own 'religious' or 'spiritual' lens. Yet in Western societies, these terms and concepts have come to existence and further evolved only within the last three centuries, as described by French Historian and philosopher Michel Foucault (1971). He argues that we cannot understand the social order and meanings assigned by people in the Middle Ages today, because we are applying analytical categories – such as 'disaster' – which did not exist then. Providing another example concerning the super-imposition of scientific concepts upon different contexts, Marie et al. (2018, 25) find that "the concept of resilience is under-researched in Arabic and Islamic regions". Instead, studies found that *sumud* was central to Islamic faith and culture: an approach which underlines the need for steadfastness, perseverance and dignity at an individual but especially also at a collective level (Atallah, 2017 and Marie et al. 2017, cited in Hammad and Tribe 2021, 137). While the concept of *sumud* has already been studied in some contexts, e.g. Afghanistan and Palestine, Indonesia-based studies are still lacking.

For an Indonesian illustration of how religion 'influences' the meanings and practices attached to disasters, Donovan (2010, 118) cites the case of the 1963 volcanic eruption of Mount Agung on Bali, which is perceived to be a home of deities both evil and kind. More than 2,100 people were killed, several hundreds of which as they advanced towards the lava flows, believing that these "represented their gods descending from the summit" (Donovan 2010, 118). As explained in the National Museum of Indonesia (2022), the Hindu goddess of rice herself, who goes by different names in various parts of Java, Bali and Sulawesi, stands for life prosperity and fertility, but also for 'disasters' including 'disastrous' floods, droughts, pests and diseases. At times of planting and harvest, farmers persuaded the goddess to "side with them" through ceremonies involving specific chants, instruments and dances, but also farming traditions. For example, on Java, farmers showed respect towards the paddy goddess by cutting rice with specific wooden tool called *ani-ni* or *hetam*. The National Museum of Indonesia (2022) displays a quote from Geertz, according to whom this practice is not only spiritual: relying on this tool slows the harvesting process and provides labor opportunities for more smallholders and landless peasants. In this way, spirituality and socio-economic motivations seem to intertwine.

Even more so centuries ago than today, disasters were interpreted as Godly punishments all the way from Germany to Indonesia. For example, the 1815 volcanic eruption of Tambora, largest to date in modern history, is remembered as an act of divine retribution according to the folk tale *zaman hujan* told on the island of Sumbawa. From a scientific point of view, the Tambora eruption caused a tsunami, major (global) atmospheric and ecological changes as well as socioeconomic impacts including a famine, diseases and lack of clean water. The eruption wiped out the Tambora population group and language (de Jong Boers 1995). De Jong Boers (1995, 38) interprets efforts to make sense of the massive eruption through a folk tale still told today. According to him, the tale provided *meaning* to losses that would otherwise be unexplainable:

> *"[t]he ruler of the small princedom of Tambora had allegedly called down Allah's wrath upon himself and his princedom by giving a hadji, a pious Muslim who had performed the pilgrimage to Mecca, (impure) dog's flesh to eat and killing him afterwards. This local interpretation of the event explains the factually unexplainable, namely the reason why natural disasters[5] occur. The story clarifies the cause of the violent eruption of Mt. Tambora by saying that it was a punishment from God for godless behavior. The eruption is thus made comprehensible and logical, as it were".*

Effects felt today

As stated in the 2018 census (Kementerian Agama Ri 2020), 86,7% of the Indonesian population are Muslim, the remainder being Protestant (7,6%), Catholic (3,12%), Hindu (1,74%), Buddhist (0.,77%) and Confucian (0,03%). Animistic beliefs, while present and sometimes superposing with other beliefs, are not officially acknowledged by the Government of Indonesia (Badan Pusat Statistik 2013). It should there be noted that a specific Indonesian Ministry 'regulates' religious dynamics and limits the number of formally recognised religions (Rosyadi 2020).[6] Regarding the ongoing importance of religion and spirituality for the way disasters are perceived, interpreted and interacted with, Birkmann, Setiadi and Fiedler (2015, 246) state that religious beliefs significantly impact risk perceptions; "nothing is seen to happen without God's will". Similarly, Donovan (2010, 118) finds that

> *"Indonesia is a nation that has an intense cultural relationship with volcanoes and hazards. Indonesians have a diverse, complex and deeply devout connection with*

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[5] This quote also illustrates how strongly occidental scientific knowledge structures and influences even research that approaches cultural processes from a supposedly reflective, cultural-scientific perspective. There is a completely unreflected reference here to "natural disasters", expressing the idea that there is a "true", namely scientific knowledge that can explain the event, whereas the indigenous population is faced with a pure mystery that allows them to fall back on mystical interpretations.

[6] Critical debate on how the government rules religious practices (e.g. all citizens must declare their religion by choosing between one of the six officially recognised religions, including indigenous tribes which are thus 'forced' to embrace an official religion, and religious appurtenance is printed on national identification card) has been ongoing (Jazila 2018; Rosyadi 2020).

> *the environment and as a consequence often rely on their traditional, animistic beliefs during a crisis".*

A majority of Indonesian would hold the transcendental belief that risk levels would 'harmonise themselves out' as part of the general workings of the universe; this would lead them to feel secure even in hazard-prone areas (Gusti Ayu Ketut Surtiari, personal communication, 1.11.2022). Continuing with the topic of volcanoes, Bubandt et al. (2017, 131) argue that on Java, a volcano is almost always "a spiritual as well as a geothermal entity – a vengeful and an angry geospirit". Geoscientists conducting fieldwork on the island note that

> *"volcanoes are considered connected to human society to achieve a universal harmony between society, nature and the cosmos... Although most Javanese people are aware of scientific explanations for natural phenomena, they usually prefer to draw on explanations that relate natural events to their social world"* (Troll and et al. 2015, 140).

Interestingly, Kasim et al. (2021, 68) find that in the conflict-affected Aceh province, conflict and natural-hazard linked events are assigned completely different meanings, even when the population today calls them both 'disasters'. People have suffered from the conflict and associated murders, kidnapping, rapes and torture for decades. Vengeance is sought when families are attacked. In contrast, their stance towards tsunamis is fatalistic: the wrath of tsunami is perceived as destiny and will of Allah. A study carried out in Padang highlights how belief systems and religious leaders can serve both as a hindrance to and as a promotion of tsunami preparedness strategies (Birkmann, Setiadi, and Fiedler 2015). It relays the words of a community member explaining how religious teachings influence the decision to evacuate:

> *"Some religious perceptions still influence the people's behaviour: if we do good deeds, we will be protected. If we run away, it means we are afraid or not faithful – this makes people ashamed to evacuate immediately"* (cited in Birkmann, Setiadi, and Fiedler 2015, 246).

As shown by this quote, evacuating may be interpreted by some as a lack of faith, while fatalism demonstrates one's religious beliefs (Voss 2008). Birkmann, Setiadi and Fiedler (2015, 247) moreover describe behaviors of people seeking refuge at mosques or cemeteries where famous religious leaders are buried following tsunami warnings, not considering if these areas are at higher elevation placed nor if they are more remote of the coastline. This exemplifies the different understandings and the vast influence of religion concerning what makes a place ´safe´.

3.3 Colonialism

Djalante and Garschagen (2017) note that few studies have examined the Portuguese, Dutch and Japanese colonial periods in Indonesia[7] from a disaster perspective. Their analysis of post-1900 EM-DAT data shows that in Indonesia, most disaster deaths occurred during the colonial period. The violent Dutch colonial project, along with its focus on resource extraction (Bryant and Parnwell 1996: 4–8 cited by Bankoff 2003, 19), highly increased vulnerabilities and thus disaster risk for the Indonesian people. Indonesian 'commoners', then slaves, were at the very bottom of the social strata (National Museum of Indonesia 2022). In certain areas, the colonisers took control of the harbors, extended their settlements along the coast and pushed the indigenous population further inland, thus exposing them to new environments and increasing their vulnerabilities. In other areas, they 'imported' people for a cheap labor force, into the coastal deltas, exposing them to further risks by breaking up pre-existing social networks and long-term (economic) safety nets. This was the case in Palu, where the coastal population maintains a relationship to the sea from a distance until today (Mahid, Sadi, and Arisyanto 2009). In addition to destroying lives and livelihoods, the colonisers imposed their own scientific and mechanistic view of a nature separate from 'culture', a natural world that had to be subdued (Gosh 2021). According to Schrikker (2016), the Dutch colonial government approached disasters in a mostly reactive and *ad hoc* fashion. The colonial regime endorsed the ´Regeling op de *Staat van Orloog en van Beleg´* in 1939, which allowed the general governor to activate a state of emergency without consulting legislative bodies (Lassa 2013). The *Regeling* aimed at handling war situations and external threats, not disaster situations. Following repeated eruptions of Mount Kelud, a flood tunnel and volcano-monitoring project established in 1922 are amongst the first known disaster prevention projects implemented by the colonial government (Schrikker 2016).

The response to the 1883 Krakatau eruption and the subsequent tsunami formed the "largest emergency relief operations in the Dutch colonial government period" (Lassa 2013, 136). Camps for internally-displaced peoples were established and members of the European community of Jakarta (then Batavia) set up a fund to assist European victims only (Djalante and Garschagen 2017). Similarly, following the massive earthquake which occurred in Padang Panjang in 1926, the Dutch colonial government foremost assessed the number of casualties, damages and losses affecting colonial officers and Europeans (Riskianingrum 2013). Riskianingrum (2013) describes the response measures to the 1926 earthquake taken by the Dutch colonial regime. Following the tremors, the Padang Resident[8] sent a telegram to the central colonial government in Bogor. The *algemene secretarie (*a secretariat organization under the Governor General) distributed the Padang Resident's report to relevant *diensts* (departments), mainly to the *binnenland bestuur* (department of home affairs), *leger* (Army), *burgerlijke openbare werken* (Department of Public Works), and *gouvernement bedrijven* (state-owned companies) for them to coordinate the earthquake response. International relief and aid came from Sweden and Sydney, domestic solidarity emerged from e.g. the *Studiefonds Kota Gedang Tjabang Betawi*

[7] The first Portuguese and Dutch ships arrived in the 16th century, the colony of the Dutch East Indies were formed in 1800 and occupied part of the territory of what today is known as Indonesia. Indonesia declared its independence in 1945, which was formally recognised by the Netherlands in 1949. Japanese occupation lasted from 1942 to 1945.

[8] Official assigned by the Dutch colonial regime to the area.

(Minangese people in Jakarta) and religious and local media *fonds gempah* (charity funds). The Dutch government moreover rehabilitated public facilities and sent volcanologists to assess the cause of the earthquake.

Following the Yogyakarta earthquake of 1943, this time with Indonesia under the rule of the Japanese colonial regime, volcanologists including Dutch Dr. van Bemmelen, familiar with local geological conditions, were sent to the area to understand the earthquake causes (Riskianingrum 2013). 213 people lost their lives and about 2,800 buildings were destroyed by the earthquake. The research in Batu Retno village, one of the most impacted, revealed poor building conditions as major factor of vulnerability. The Japanese colonial government later sent *gunseikanbu* (military government staff*)* as representatives to express sympathy and condolences.Overall, and as visible on Table 1, the Dutch colonial regime has set up numerous institutions and promoted research on natural and social sciences, particularly on volcanology and seismicity, biology in the 1850s, meteorology in 1866, as well as customary law and culture (Riskianingrum 2013). The Ambon 'spice islands' in eastern Indonesia, on which many Dutch settlements were concentrated, have been the subject of much geological research. Harris and Major (2016) mention a catalogue which remains largely unknown to the scientific community, compiled by Arthur Wichmann. Wichmann studied the geology of Indonesia and compiled 350 years of observations of earthquakes and tsunamis, mostly based on records kept by the Dutch East India Company of Indonesia.

We could find less literature on disaster action by the indigenous authorities and population, and on how the actions and priorities of Dutch disaster efforts were perceived by the Indonesian population. Exceptions to this are the attention and condolences provided by the Yogyakarta Sultanate to the people affected by the 1943 earthquake. Accompanied by his courtiers, the Royal Highness of Yogyakarta visited the most impacted areas in Yogyakarta, Bantul and Purwokerto, specific attention focused on supporting the survivors in their mourning (Riskianingrum 2013). Research also highlights how various revolt movements against the Dutch colonisers were likely triggered by disasters. The 1825-1830 revolt of the Yogyakarta prince, Diponegoro, against the Dutch was reportedly preceded by "famine, cholera epidemics, and volcanic eruptions" (Adas 1979) . The 1888 peasant revolt against the Dutch in Banten was preceded by human and cattle epidemics, earthquakes and the eruption of Mount Krakatau in 1883 (Kartodirdjo 1966) .

Effects felt today

Colonial impacts do not stop when the colonial regime leaves; that is true for disaster management as well. Just like Bahasa Indonesia contains loan-words from e.g. Arabic, Javanese, Mandarin, Portuguese Sanskrit and Sundanese (National Museum of Indonesia 2022), language and vocabulary used today in the Indonesian administration and governance bear a Dutch imprint. Examples include *schorsing/skorsing* (suspension), *garnizoen/garnisun* (garrison), *failliet/pailit* (bankruptcy), *toeslag/tuslah* (allowance). Disaster-specific examples are less frequent. There, key terms have their own etymology, free of European influences (see Box 3). It is however worth noting that the word *risico* in Dutch (risk in English) has the same meaning as *risiko* in Bahasa Indonesia itself – an indication of the 'idea' of risk itself being less present or completely absent before the colonial era? The word 'tsunami' itself is composed of the Japanse *tsu* (meaning harbor), and *nami* (meaning wave) (UNDRR 2017b). Conversely, words travel out from Indonesia to the rest of the world. The term *lahar* originates from Bahasa

Indonesia and refers to volcanic mudflow, a hyper-concentrated mixture of rock debris and water that engulfs everything on its passage and are as such even more dangerous than lava flows. It has been internationally recognised and is listed on the United States Geological Survey (2022). Yet, even if a similar word is to be found in another language, the meaning may differ widely, resulting from different socio-historical evolutions and embedded in different socio-cultural orders.

When	What
17th century	Rumpius, a Dutch researcher, marks the beginning of research activities by the Dutch in Indonesia, conducted botanical research in Ambon. Valentijn conducts research about Batavian (Jakarta) society and Indonesian biodiversity.
24 April 1778	Establishment of *De Bataviaasch Genootschap van Kunsten en Wetenschappen* – the Batavian Society of Arts and Sciences, and association of scientists funded by the Dutch government.
1820	Establishment of the *Natuurkundige Commisie* – the Dutch East Indies Commission of Natural Science. The Dutch government funded various researchers to explore natural resources, including in zoology, botany, geography, volcanology, and seismicity.
1845	Junghugn, member of the *Natuurkundige Commisie,* publishes data on 37 volcanoes in Indonesia, 10 of which have disappeared since then.
19 July 1850	Establishment of the *Natuurkundige Vereeniging* – Natural Science Institute, funded by the Dutch Government, which mainly focuses on earth science, volcanology and seismicity.
1 January 1866	Establishment of the *Koninklijk Magnetisch en Meteorologisch Observatorium te Batavia*, tasked with meteorological observation, climate and long-term weather forecast. In 1867, the observatory broadens its scope to observe the earth's structure, magnetic fields, and seismology. Micro-seismic and photographic seismograph are used starting 1898 to detect earth's tremors and seismic waves.
1942 - 1945	The meteorology and geophysics observatory changes to *Kisho Kauso Kusho* due to Japanese occupation. Under Japanese administration, the data recording has become less effective and poorly managed.

Postcolonialism >1945	Under Indonesian administration, the *Kisho Kauso Kusho* is divided into two. One body under the Meteorological Bureau in Yogyakarta serves the air force, reporting to Indonesian military. The other body is the meteorological and geophysical office in Jakarta, under the *Ministry of Public Works*.

Table 1. The development of research institutions during the Dutch colonial regime (Riskianingrum 2013, 8-11).

Certain interviewees (Indonesian geoscientist #1, 2.6.2022, and #2, 7.6.2022) note an over-reliance on high-tech disaster management processes and interpret this as an element of Japanese influence. As a rich country with a focus on the high-tech industry, Japan maintains highly innovative and technologically advanced disaster management systems. Today, the Japan International Cooperation Agency (JICA) has offices on the last floor of the BNPB building in Jakarta, sharing a room with staff funded by the United States Agency for International Development (USAID). JICA funded technology following the 2004 tsunami and current Indonesian research programs, such as a project on virtual reality devices to increase community risk awareness.[9]

Box 4. Influences from abroad – and their rejection (National Museum of Indonesia 2022).

This proposed design of the Indonesian state symbol is an example of how colonial influences remain present, and rejected. As explained in the National Museum of Indonesia (2022), this particular design refused "by the government and parliament largely because it included the image of sun rays, which was considered to be an influence of Japan".

One could argue that the rejection of foreign influence (see Box. 4 for an example) and more specifically Western liberalism (a "continuing theme of Indonesian political discourse since before the birth of the nation") (Morfit 1981, 841), is a lasting effect of colonialism. Similarly, concerning tsunami-related technology, the Indonesian government also wishes to retain control. Yet, this counters the predominant perspective that only considers national sovereignty assertions normal for countries of the Global North. The "nativeness of tsunami science" and a sense of pride in "red and white technologies" (referring to the colours of the Indonesian flag, but also the buoy system put in place by the Indonesian government to monitor sea level after earth- and seaquakes) are some of the discourses

[9] A practice already common in Japan, personal communication with an Indonesian social scientist #2, 7.06.2022.

surrounding the Indonesian Tsunami Early Warning System processes (Rafliana 2022). Research and technology developed by foreigners are less readily accepted and implemented. For instance, concerning the development of Early Warning Systems at a regional level- as coordinated by the Intergovernmental Coordination Group of the United Nations Educational, Scientific and Cultural Organization (UNESCO) since 2005- it was "clear from the beginning [...] that all Indian Ocean countries wanted to operate their own national warning centres and did not want to rely on the information of one or more dedicated warning centres for the Indian Ocean" (Lauterjung et al. 2010, 2625).

Overall regarding research on the Indonesian territory, the government of Indonesia has recently launched new research permit granting processes including the obligation to co-publish results with Indonesian scientists. It also plans to put tougher penalties in place for foreign researcher who do not respect the regulations. Following the 2018 Palu tsunami, some geoscientists have complained that the research permit processes are too lengthy and complex, delaying or even preventing time-critical research following a disaster. Geographer Gaillard (Schiermeier 2018) however defends the restrictions and locally-led research overall:

> *"No one knows and understands the context and local concerns, including research needed to enhance disaster risk-reduction policy and practice, better than the Indonesians. [...] This does not mean that foreign researchers should be excluded. But local researchers, supported by local institutions, should take the lead in designing relevant and culturally appropriate research projects".*

3.4 The 'Old Order' under President Sukarno (1945-1966)

For the first twenty years following Indonesia´s independence, emergency management continued to center on threats of foreign invasion. Post-WWII logic and lack of major disasters during this time promoted the approach (Lassa 2013) and several laws pertaining to the management of war, conflict and separatism were endorsed under President Sukarno. Emergency management National Law 6 was drafted in 1946 with the influence of civil bureaucrats and civil society organizations (CSOs) including prominent Islamic organisations (Lassa 2013). Explicit demands were made to not solely involve the military in emergency management, rather placing authority in a National Defence Council consisting of the Prime Minister, relevant ministries, three CSO representatives and a military commander instead (Lassa 2013). Nevertheless, Law 30/1948 transferred full authority to the President in case of dangerous situations.

State focus was on building the nation state, legislation and institutions. Key symbols were enshrined following independence, such as the national device *Bhinneka Tunggal Ika* (unity in diversity), the red and white flag (red standing for the bravery of those who fought against the colonialists, white for the pure intentions of the national heroes), and the state symbol *Garuda* (National Museum of Indonesia 2022). The last of these depicts the half-hawk half-human manifestation of the Hindu god Vishnu, one of the three "keepers of the universe" showing how Indonesia is a "strong state and nation" (National Museum of Indonesia 2022). The national ideology of *Pancasila* was presented as a "traditional philosophy of life" immanent to Indonesian society and articulated around "the historical experiences of the Indonesian people" (Morfit 1981, 841). It consists of five pillars:

1. Belief in one supreme being;
2. Commitment to internationalism (i.e. non-alignment to one of two or more political blocs[10]), or according to a more literal translation "just and civilized humanitarianism" (i.e. "to treat with others, even foreigners, in a fair manner, free from suspicion, exploitation, and oppression" (Morfit 1981, 840);
3. Commitment to the unity of Indonesia;
4. An emphasis of "the idea of a people led or governed by wise policies arrived at through a process of consultation and consensus", which does not necessarily imply Western liberal democracy (Morfit 1981, 840);
5. Commitment to social justice.

State building efforts led to radical change in organizational and institutional cultures, including leadership styles and bureaucracy, as well as a high level of institutional discontinuity. For example, the Geological Agency that deals with geological risks and is tasked with conducting a volcanological survey was assigned to nine different ministries (e.g. Public Works, Wealth, Wealth and Industry, Economy, Trade and Mining etc.) over the 1947-1992 period (Lassa 2013). In terms of scientific research, Lassa (2013, 139) points out that research concerning disasters connected to geological hazards was scarce. A rare exception was a UNESCO mission studying risks associated with volcanoes in Indonesia in 1966 (Tazieff, Marinelli, and Gorshkov 1966). Risk prevention was not high on the global agenda in general, and thus Indonesia suffered from discontinuing support for the disaster management institutions founded and funded by the Dutch colonial regime, including the Geological Agency.

Effects felt today

According to Lassa (2013, 145), public discourse today promotes the important role of the military as bearer of (human) resources and as the primary disaster responder. The Indonesian military, *Tentara Nasional Indonesia* (TNI), has maintained a central position throughout successive disaster management regimes (Center for Excellence in Disaster Management & Humanitarian Assistance 2021). This was visible during the 2004 tsunami response, where the Indonesian military took a lead role. Overall, there is a high trust in leadership and respect of hierarchy (personal communication by Indonesian social scientist #2 and #3 during a disaster*cultures workshop on 8.6.2022).

Youth, which played a prominent role in Indonesia's nation building[11], are active participant of disaster-related initiatives today. Youth unions (*Karang Taruna*) have been established at the village level and are involved in community welfare programs. Youth are supposed to play an active role in the community empowerment organizations (*Lembaga Pemberdayaan Masyarakat*) which occupy a coordinating and decision-making role in rural areas. While these bodies only loosely relate to disaster

[10] Indonesia held a key place in the non-alignment movement, prominently as founding Bandung Conference host in 1955 (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 16).

[11] Youth played a key role in the fight for independence and nation building, with key resolutions taken amongst others during the Youth Congresses. The Youth Pledge made at the end of the second Youth Congress in 1928 proclaimed the idea of one motherland, one nation and one language, using the term 'Indonesia' (Ricklefs 1986).

prevention and response, another type of youth organization is the *Taruna Siaga Bencana* (*Tagana*) or disaster preparedness youth, a volunteer-based organisation established by the Ministry of Social Welfare in 2009. The latter specifically focuses on disasters (Mulyasari and Shaw 2012, see a more detailed entry on the *Tagana* in stakeholder mapping section 3). More than 25 000 schools implemented the "disaster-safe schools" programme rolled out by the government and NGOs in 2013 (Ministry of Education and Culture, 2015 cited in Amri et al. 2017, 597).

The extent to which the *Pancasila* ideology remains present in today's disaster management is a subject for further research. In a context of increased demographic and economic pressure, Indrastuti and Prasetyo (2020, 7) argue that Indonesian environmental policy has not been marked by a *Pancasila* perspective, which would rather aim at developing community welfare and "patterns of harmony, harmony and balance both in meeting physical and spiritual needs".

3.5 The 'New Regime' under President Suharto (1967-1998)

Suharto came to power in 1967 following a bloody political transition involving the death of more than 500,000 people. Lasting until 1998, his rule was characterised as militaristic and Indonesia was considered by some as "the most centralist" country in the world (Mietzner, 2014, cited in Srikandini 2018, 23). Regional governments had little influence, filling the role of "policy executors of Jakarta" (Srikandini 2018, 23). This contrasts with some of the institutional disaster management trends reported in literature. The National Coordination Team for Disaster Management was created in 1967 immediately following largescale droughts and the Bengawan Solo floods which occurred in Suharto´s birthplace. The National Coordination Board for Natural Disaster Management (BAKORNAS) was created in 1979 and was led by the Ministry of Welfare. It constituted "an important step in the recognition of multi-stakeholders and multi-agencies coordination for dealing with the increasing impacts of disasters" (Djalante and Garschagen 2017, 41). Nonetheless, laws were still in place to transfer full authority to the President during times of national emergency.

In Indonesia between 1970 and 1996, poverty decreased by 34%, infant mortality by 60%, the education gap between boys and girls diminished significantly and primary school enrolment increased to 90% (Lindsey 2021). The United Nations Food and Agriculture Organization rewarded Indonesia for achieving rice self-sufficiency in 1985 (Jordan and Muslimah 2013). However, while the Suharto era was characterised by social progress in some areas and exponential economic development, it was further marked by rising inequality and changing risk profiles. Djalante and Garschagen (2017, 41) present the rapidly expanding industrial palm oil production as a prime example of economic processes leading to new risks and increased vulnerability. As part of the 1969-1999 `transmigration program´, indigenous people were forcibly displaced to leave room for agriculture (Down to Earth No. 76-77 2008). Although many projects failed due to political interests, corruption, kickbacks, and nepotism, 40 to 50 million hectares of forest areas were cut and burnt to grow palm oil as well as to construct rubber, pulp wood and rice plantations, leading to nearly annual massive wildfire events particularly in Borneo/Kalimantan and Sumatra.

Under Suharto, Indonesia integrated into global markets and institutions. Lassa (2013) argues that the creation of the ASEAN group as well as the Cold War further influenced Indonesian disaster

management: the United States funded bodies such as USAID and ASEAN to keep the spread of communism in check in Asia, and disasters were a common theme to USAID and the ASEAN members. ASEAN made a joint Declaration on Mutual Assistance on Natural Disasters in 1976. The Declaration (1976) states that disasters are "retarding the pace of development". As a result, economic rationales for disaster action were brought to the foreground, even though one could also consider that a specific form of development, leading to higher vulnerability, led to disasters in the first place. That same year 1976, one of the first recorded multi-disciplinary disaster risk management workshops was held in Jakarta, with as attendees including: the National Development Planning Ministry, the Health Department, the Finance Minister, the Office of Meteorology and Geophysics, the Geological Survey, the Indonesian Red Cross, and international players such as the United Nations Development Program and USAID—one of the main sponsors of the ASEAN agreement (Lassa 2013, 140).

ASEAN workshops and stronger national-international interaction thus contributed to a more systematic disaster approach in Indonesia. Along with other notable influences from abroad, Lassa (2013, 141) cites a publication by Cuny and Abrams (1983) to emphasise the linkages between disaster and development and the disaster cycle.

Effects felt today

Export-led growth, rapid deforestation, population growth and urbanization took off during the Suharto era and continued after his removal from power (Down to Earth No. 76-77 2008). Many Suharto development projects have left significant legacies, with hazard-prone river banks and coastal areas inhabited still today (Djalante and Garschagen 2017, 40). Certain risk-related practices and knowledge were lost in the process of rapid urbanization (Gaillard et al. 2008), however, new practices and knowledge did of course emerge simulatenously (see van Voorst (2016) and her work on flood risk behaviour in Jakarta´s flood-prone informal settlements). Current concentrations of decision-making, power, experts and resources on the island of Java was further cemented during the New Regime era. A "centralisation culture", "domination of national authorities" and limited role of local participation remains a prevalent characteristic of Indonesian government today, despite the decentralisation efforts of the 1990s (Triyanti et al. 2022, 13). A discourse centred on the economic damages inflicted by disasters remains present, although this by no means a phenomenon unique to Indonesia.

3.6 The initial *Reformasi* period (1998-2004)

1998 marked the fall of the Suharto regime, with massive student demonstrations and violence leading to numerous internally displaced persons (IDPs). At the same time, separatist, ethnic and religious conflict was playing out in Aceh, Ambon, Poso, Sampit and East Timor, turmoil that caused increasing calls for disaster management to pay more serious attention to IDPs (Lassa 2013). BAKORNAS-PB was renamed BAKORNAS-PBP (*Badan Koordinasi Nasional Penanggulangan Bencana dan Penanganan Pengungsi*, or National Coordination Board for Disaster and 'Displaced' People Management) as part of Presidential Decrees 3/2001 and 111/2001 (Djalante and Garschagen 2017, 42).

1998 constituted an important "stepping stone for Indonesian democracy", students occupied the legislative building demanding: 'new reform' (*reformasi*), the right of free expression and the government

to partner with civil society to achieve development goals (Srikandini 2018, 114; Lindsey 2021). The post-1998 *Reformasi* era is thus an era of reform, including within the sector of disaster risk management. The Decentralisation Law of 2001 had a profound impact. While the Vice President was given direct responsibilities, the shift from a government sole in charge of disaster response towards disaster governance involving a broader set of actors by law was substantiated. First, disaster management organisations, policy frameworks and budgets were set up at national but also provincial and regency/municipal levels. In case of disaster, the lowest level is to be active first, with higher levels providing support in case local capacities are overwhelmed (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 35). Second, the Decentralisation Law explicitly named non-state actors as involved in disaster governance. Lassa (2013, 142) quotes a statement made in 2003 by the then Minister of Social Welfare for the opening of the "International Seminar and Workshop on Tsunami: In Memoriam 120 Years of Krakatau Eruption—Tsunami and Lessons Learned From Large Tsunamis": "Disaster is our responsibility. Not merely government responsibility but also that of the private sector and society".

Several quotes from the early 2000s indicate that tsunamis were recognised by some as real and serious threats, especially by those who correctly considered that 60% of Indonesia's coastal cities were situated in earthquake-prone regions. Arguably, political will to reduce tsunami risk was there, although perhaps rarer at local level[12]. Political speeches promoted the need to integrate the three approaches of "integrated coastal zone management, integrated fisheries management, and integrated coastal hazard management" in order to lower the risk of tsunami impact (Lassa 2013, 142–43); however, policy instruments to transform this will into action was mostly lacking.

3.7 The shaping effect of disasters themselves

While the above described how socio-historical phases, processes and events fostered specific disaster perceptions and actions, trends in disaster management were also influenced by the frequency and severity of disasters themselves. Indeed, the 1960s were marked by several high-impact disasters, amongst them the 1963 Mount Agung eruption which killed approximately 1,600 people on Bali, the 1966 drought which caused around 8,000 deaths, and the 1966 Mount Kelud eruption which killed approximately 200. This likely pushed the Old Order Sukarno government to include disasters caused by natural hazards in their emergency management, and led to the establishment of the first institutions explicitly focus on disasters triggered by natural hazards in 1966.

In contrast with the disaster-intense 1960s, the 1970s were marked by only few earthquakes, volcanic eruptions and smaller-scale cyclones. Moreover, these disasters occurred in places remote from the centres of power, primarily identified as the island of Java and the Indonesian capital Jakarta. Lassa (2013, 141) describes disaster institutions as "partially dormant" during the 1970s, although the

[12] After a fatal earthquake, the governor of Bengkulu Province noted several priorities for action: more earthquake-resistant construction structures, no more building on known fault lines, updating risk analysis and mapping and increasing awareness on post-disaster behaviour (Lassa 2013, 144).

National Coordinating Team for Natural-Hazard Disaster Management (*Tim Koordinasi Nasional Penanggulangan Bencana Alam*) was upgraded into BAKORNAS to include offices at provincinal levels in 1970 (*Badan Koordinasi Nasional Penanggulangan Becana Alam*) in 1979.

In 1992, a tsunami caused large-scale devastation in Flores, leading the then Minister of Finance to state that "Flores goes back to the predevelopment era before 1970" because of the event; infrastructure and people´s assets constructed over the course of the previous 25 years were destroyed (cited in Lassa 2013, 142). That same year, the government created the possibility to invoke a 'national state of disaster' following a catastrophe.

The 2004 Indian Ocean tsunami: a 'wakeup call' and 'window of opportunity'?

No other disaster has influenced the Indonesian disaster management system more strongly than the 2004 Indian Ocean tsunami, provoked by an earthquake of a 9.3 magnitude. As stated by WillitsKing (2009, 7), the "initial national response was overwhelmed by the scale of the tragedy". Civilian authorities as well as a multitude of international aid actors came to help, with the Indonesian military playing the key response and coordination role. Some argue that the moment at which the tsunami occurred- Christmas time and amidst the global 'War on Terror'- supported a trend of international donating and long-term support. Western Christian societies, the act of giving has a central mening at Christian time, and might also explain the high level of donations. Military attacks and anti-Islamic prejudice went hand in hand with the 'War on Terror' and thus may have spurred guilty feelings towards "Muslims and other non- Christians" suffering from the effects of the 2004 tsunami (Lewis and Lewis 2017, 31). Coordination efforts of both Indonesian institutions and the United Nations were poorly managed, leading to inappropriate aid practices at times. In the aftermath of the tsunami, 167,700 people lost their lives, more than half a million were displaced and three quarters of a million (partially) lost their livelihoods (Willitts-King 2009, 7). By Presidential Decree, a national day of mourning was added to the declaration of the national state of disaster.

Literature generally describes the 2004 tsunami as a wake-up call, not only at the level of Indonesia and the other 15 countries impacted, but also globally (Djalante and Garschagen 2017, 43). Shortly after the tsunami, in 2005, the Hyogo Framework for Action was adopted as the first international DRR framework. The framework placed DRR higher on the global agenda and set trends such as bottom-up DRR processes. In Indonesia itself, the 2004 tsunami opened a 'window of opportunity' to transform the emergency management system and put in place a holistic disaster management system covering disaster mitigation, prevention, response, recovery and reconstruction (Djalante et al. 2012). In effect, a Tsunami Rehabilitation and Reconstruction Board (BRR/*Badan Rehabilitasi dan Rekonstruksi*) was formed, coordinating finances and technical support received from national and international agencies. Additionally, BAKORNAS PB was given the mandate to coordinate disaster management according to Presidential Decree 80/2005 (Djalante et al. 2012, 43). A new institutional framework was set up in 2007, consisting of the new Disaster Management Law 24/2007 and the creation of national and local disaster management organizations. As highlighted in Figure 7, these organizations are tasked with knowledge management, monitoring and observation, warning dissemination and organizing the preparedness and response to a variety of risks: earthquakes and tsunamis, volcanic eruptions, landslides, floods, extreme weather events, droughts, wildfires and health epidemics. Spahn et al. (2010) refer to the new framework emerging from Law 24/2007 as a "new paradigm" which put

the focus on DRR, including tsunami preparedness, and shifted responsibilities towards sub-national institutions, in particular, the provinces, districts and municipalities. Yet, these responsibilities were more often perceived as "burdens without adequate additional resource allocation", nor clear mandates and sufficient capacities (Spahn et al. 2010, 1412).

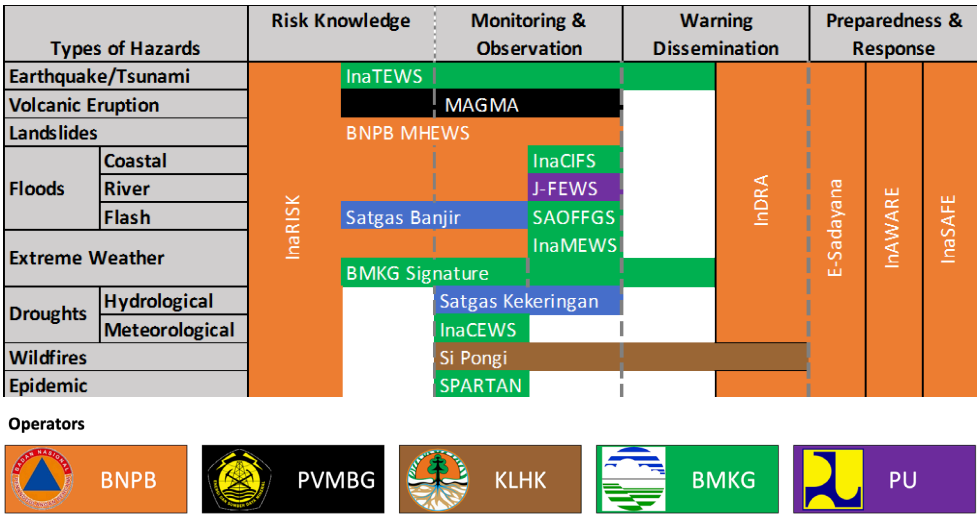

Figure 7. Various platforms exist to support the Multi-Hazard Early Warning System (Global Facility for Disaster Risk Reduction 2020).

On the one hand, post-2004-tsunami policy focuses on technology including Tsunami Early Warning Systems. The Republic of Indonesia invested several hundred millions of USD in the Indonesian Tsunami Early Warning Systems (InaTEWS), "a nation-wide network of seismic sensors, GPS (Global Positioning System) and tide gauge stations [...] [and] a satellite communication network to connect to all remote field stations" (Lauterjung and Letz 2017a, 6). Regional and international cooperation played an important role to support the development of the InaTEWS. Bilateral initiatives with China, France, Germany, Japan and the United States of America likewise contributed to the development of the InaTEWS (Harjadi 2008), with activities and investments coordinated by BMKG, but also by members of the 45-million EUR German Indonesian project 'Tsunami Early Warnings System' (GITEWS) running 2005-2011 (Jörn Lauterjung, personal communication, 3.11.2022). The GITEWS project resulted amongst others in "the first Tsunami Early Warning System in the world operationally using real-time GPS" (Lauterjung and Letz 2017b, 18), with the aim to deliver quick forecast information with precise inundation heights for specific coastal ranges. Installation of seismic stations in and outside of Indonesia, of a satellite communication network as well as development of the seismic software package SeisComP3 which unifies the various seismic, GPS and oceanographic parameters into a single processing scheme, were key (Lauterjung and Letz 2017b). The follow-up 'Project for Training, Education and Consulting for Tsunami Early Warning Systems' (PROTECTS, 2011-2014) then put the onus on capacity building, through for example TEWS training modules. Through the Indonesia-China Digital Network, China was involved in developing seismic monitoring systems, situation centers, telecommunications and capacity building. Japan has likewise supported the seismic monitoring system through the real time Japan-Indonesia Seismic Network, established situation centers and conducted capacity building via JICA. France provided support in upgrading the existing seismic network. Via

USAID, the United States were involved in sea level monitoring and capacity building, including workshops and study missions.

Internationally, the 2005 Hyogo Framework provides the basis for tsunami EWS around the world and mandated the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (UNESCO-IOC)[13] to coordinate the set-up of an ocean basin wide warning structure in the Indian Ocean region, building on national EWSs (Lauterjung et al. 2010, 2623). The UNESCO-IOC developed and operationalised "monitoring instrumentation (seismic, tide gauges), tsunami modelling, risk assessment and interoperability" (Lauterjung et al. 2010, 2624). Consisting of 28 member states from around the Indian Ocean, the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG-IOTWMS) was formally created in 2005 as a subsidiary organization to UNESCO-IOC (UNESCO 2022). UNESCO moreover provided support in terms of infrastructure, capacity building and technical assistance through the International Tsunami Information Center (Harjadi 2008).

Following the 2004 tsunami, scientific, policy and political discourse underscored the importance of the 'last mile' to ensure warnings are followed by action by the population at risk. In 2006, the then Indonesian Minister of Technology Dr. Kadiman stated that Indonesia needs "to build [a] structure and culture to respond to tsunamis" (*Jakarta Post* cited by (Birkmann, Setiadi, and Fiedler 2015, 241). Through educational campaigns and public evacuation drills, raising awareness and local capacity building would help foster resilience and preparedness (Birkmann, Setiadi, and Fiedler 2015, 241). Today, the will to build a culture of preparedness down to the local level is made tangible all around the country through the organization of events and drill exercises for the annual National Disaster Preparedness Day in April and the International DRR awareness day in October. Schools are a key locus to hold activities to raise awareness and train the younger generation (Amri et al. 2017, 597).

In the spirit of *Reformasi* and the decentralisation agenda as well as global trends such as a multi-hazard approach, disaster governance, inter-scalar linkages, bottom-up disaster management and community-level empowerment (see the Hyogo and Sendai Frameworks (UNISDR 2007; 2015), civil society is considered key in achieving these objectives. Several multi-stakeholder platforms consisting of both governmental and non-governmental stakeholders were set up at different scales following the 2004 tsunami, amongst which:

> *"PLANAS, Indonesian Civil Society for Disaster Management [Masyarakat Peduli Bencana Indonesia, MPBI], Indonesian Expertise on Disaster Management [Ikatan Ahli Bencana Indonesia, IABI], the University Forum [Forum Universitas], the Regional DRR Forum [Forum Peduli Bencana Daerah], and the Village DRR Forum [Forum Peduli Bencana Desa])"* (Srikandini 2018, 114).

This gives an indication of the wide array of stakeholders formally and informally involved in today´s InaTEWS, which we discuss in the next section.

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[13] The UNESCO-IOC had already coordinated the Pacific EWS efforts over the last 40 years (Lauterjung et al. 2010, 2623).

4 The InaTEWS system today

Following the 2004 Indian Ocean Tsunami and with the above described support of partner organizations and countries including UNESCO, Germany, France, China, Japan and the United States, the Government of Indonesia officially inaugurated the InaTEWS in 2008 (Harjadi 2008). Figure 8 presents the subsequent milestone developments of the InaTEWS, including the evolution of warning mechanisms (from fax-based to telegram-app-based warning dissemination modes, highlighting the rising importance of social media if raising awareness and propagating disaster information), as well as identifying key institutional developments, which will be further thematised below.

While Law 24/2007 set up the groundwork for current disaster risk management institutions in Indonesia, (with its focus on prevention, creation and involvement of national and sub-national institutions, see section 2.7 and (H. Spahn et al. 2010), Regulation 93/2019 (Karnawati 2020) outlines the current roles and functions of the currently relevant government institutions. Figure 9 illustrates how the InaTEWS is presented as composed of a 'structure' and a 'culture' component, with a multitude of agencies involved in each:

- The structure component is coordinated by the Agency for Meteorology, Climatology, and Geophysics (BMKG). The Agency as well as the National Tsunami Warning Center (NTWC) operate the monitoring, data processing and dissemination system. Various technology (see Table 2) is deployed all around the country's territory to monitor earthquakes and tidal levels, with further monitoring of undersea volcanoes planned in the future.
- The culture component is coordinated by the BNPB, who is responsible for preparing and implementing the appropriate actions based on the received warnings.

The warning chains part of the culture component are examined in greater detail in Figure 10. There are three types of (non-binding) warning chains according to the BMKG regulations (BMKG 2013; Triyono 2020):

1. Four-level warning messages disseminated by BMKG (symbolised by the red arrows);
2. Local government providing directives and/or instructions to the community at risk: from the perspective of BMKG, local government is the one responsible for deciding and ordering evacuation (green arrows);
3. BNPB, the military and the police disseminating instructions to support the emergency response preparation and evacuation process (black arrows).

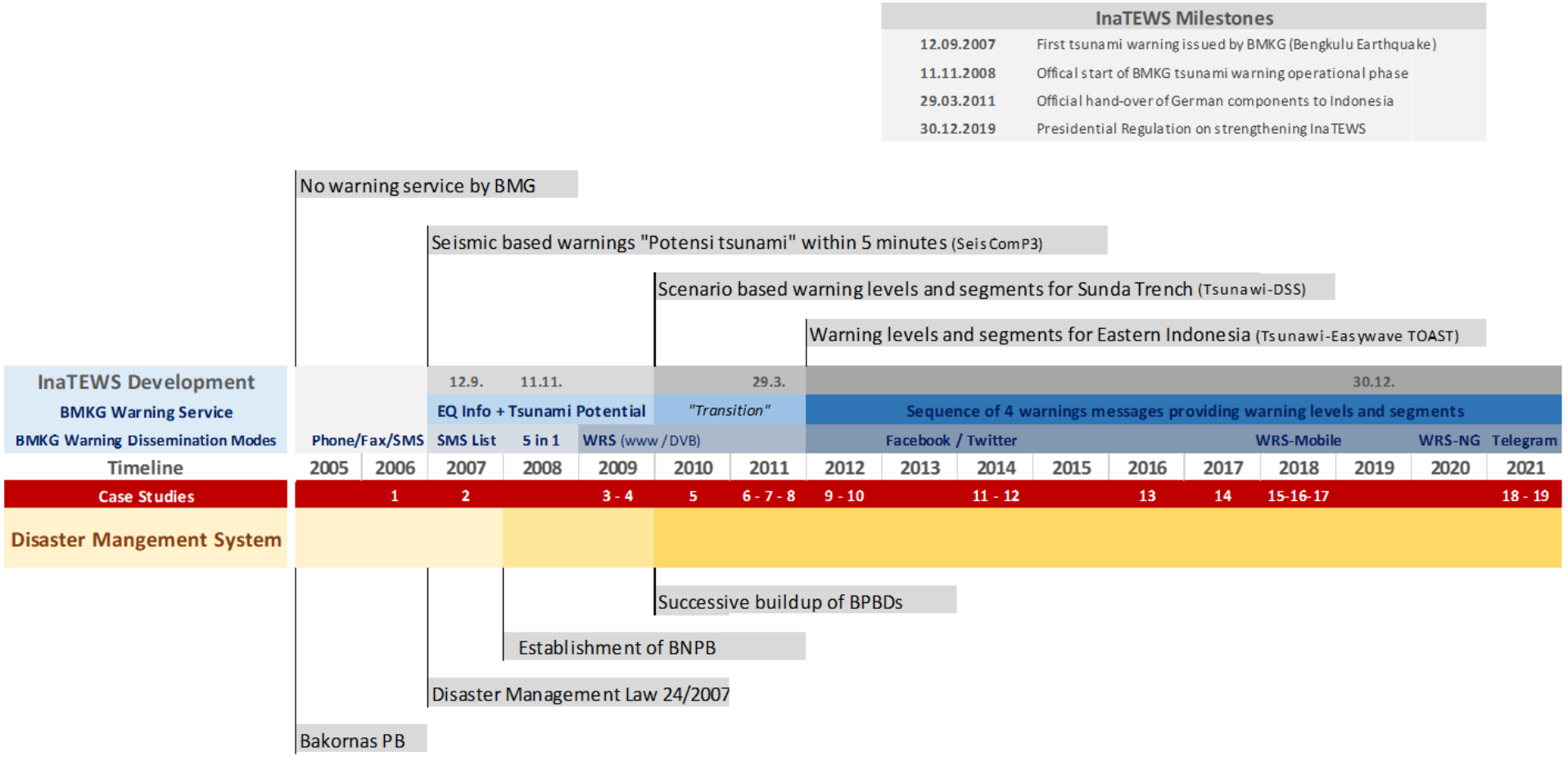

Figure 8. Evolution of tsunami warning services and disaster management in Indonesia since 2005 (Harald Spahn, Rafliana, and Wicaksono 2022).

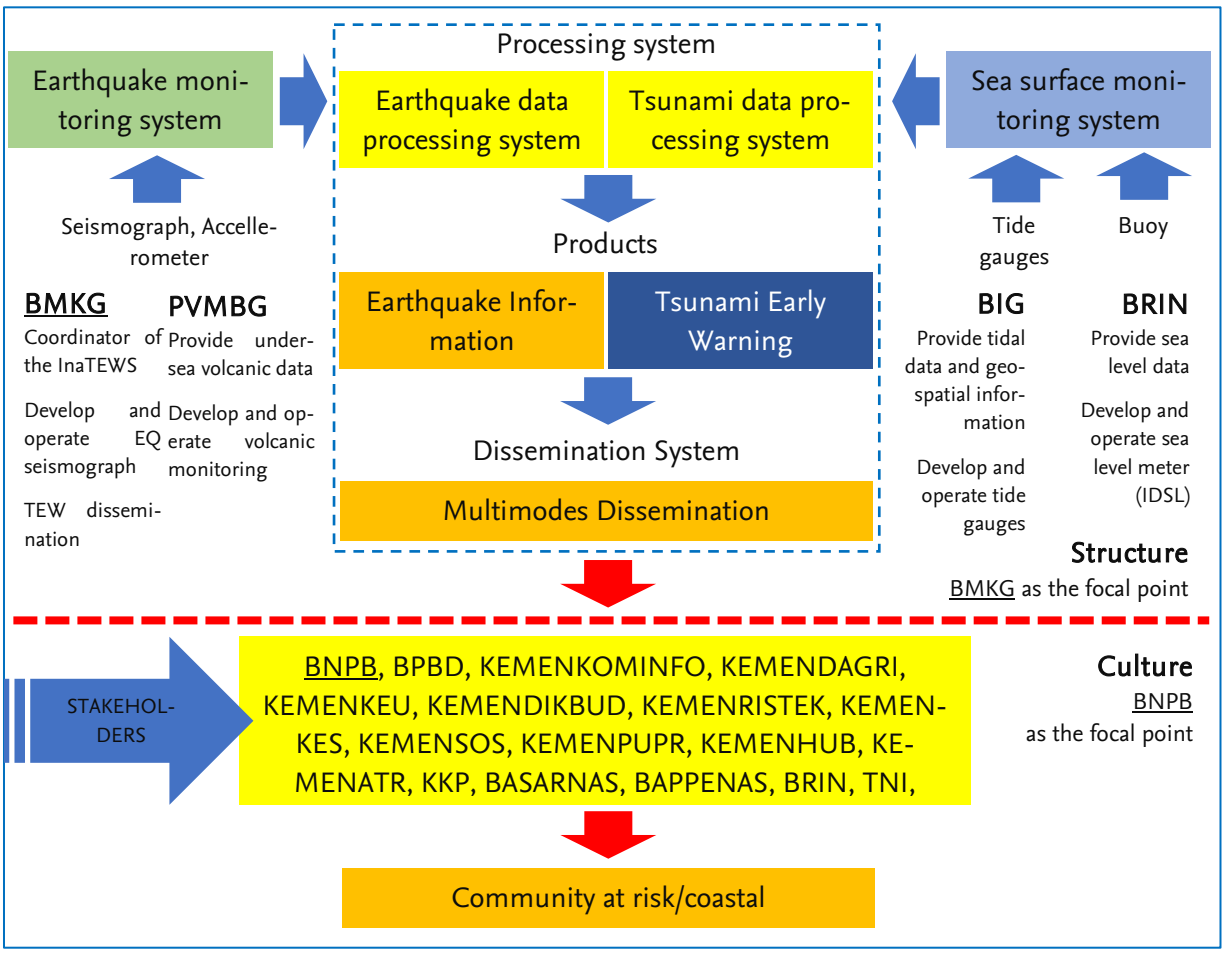

Figure 9. InaTEWS Grand Design 2020-2024: The structure and culture components of the InaTEWS (based on Karnawati 2020).

Communication between both the structure and culture components is important; however, also complex and sometimes open to interpretation. While the binding Presidential Regulation 93/2019 precisely describes the division of responsibilities of the 18 government institutions involved in the structural and cultural components of InaTEWS, the regulation leaves some ambiguity as to which institution exactly, at national and/or local government level, is responsible to decide and order community evacuation. It merely specifies that:

- Local Government is responsible for coordinating the communities' actions in responding to the tsunami early warning information: *"mengoordinasikan tindakan respon masyarakat terhadap informasi peringatan dini tsunami..."* (Article 39d).
- BNPB must ensure the 24/7 operation of *Pusdalops* (i.e., Emergency Operations Center, EOC) following the earthquake information and tsunami early warning with lifesaving action to the community*(Article 33e);*
- BNPB is mandated with a similar responsibility to the Subnational Government (PEMDA) [Article 39 (d)], to coordinate communities' actions in responding to the tsunami early warning information (Article 33f).

Equipment	Quantity	Operator	Description	Source
Seismograph	568	BMKG		(Karnawati 2020)
Accelerograph	336	BMKG		(Daryono 2020)
Tide Gauge	159	BIG		(Syafi'i 2020)
Tsunami gauge	5	BMKG		(Karnawati 2020)
Ina Buoy Tsunami	13	BPPT / BRIN	2020-2024 timeframe	(Anantasena 2020)
Ina Cable-Based Tsunameter (CBT)	7	BPPT / BRIN	2020-2024 timeframe	(Anantasena 2020)
Ina Tomographer	3	BPPT / BRIN	2020-2024 timeframe	(Anantasena 2020)
Continuously Operating Reference Station (CORS)	187	BIG		(Syafi'i 2020)
Global Navigation Satellite System (GNSS)-controlled tide gauge	31	BIG	Additional 89 planned until 2024	(Syafi'i 2020)
Tsunami radar	4	BMKG	To monitor the Anak Krakatau area	(Husrin et al. 2021a)
Inexpensive Device for Sea Level Monitoring (IDSL) / PUMMA	8	KKP / MMF		(Husrin 2020)
Tsunami scenario modelling	18000	BMKG		(Karnawati 2020)
Warning receiver system	315	BMKG		(Daryono 2020)
Tsunami sirens	35	BMKG		(Syafi'i 2020)

Table 2. InaTEWS equipment (existing and planned) (Karnawati 2020; Daryono 2020; Syafi'i 2020; Triyono 2020; Anantasena 2020; Husrin et al. 2021a; Husrin 2020).

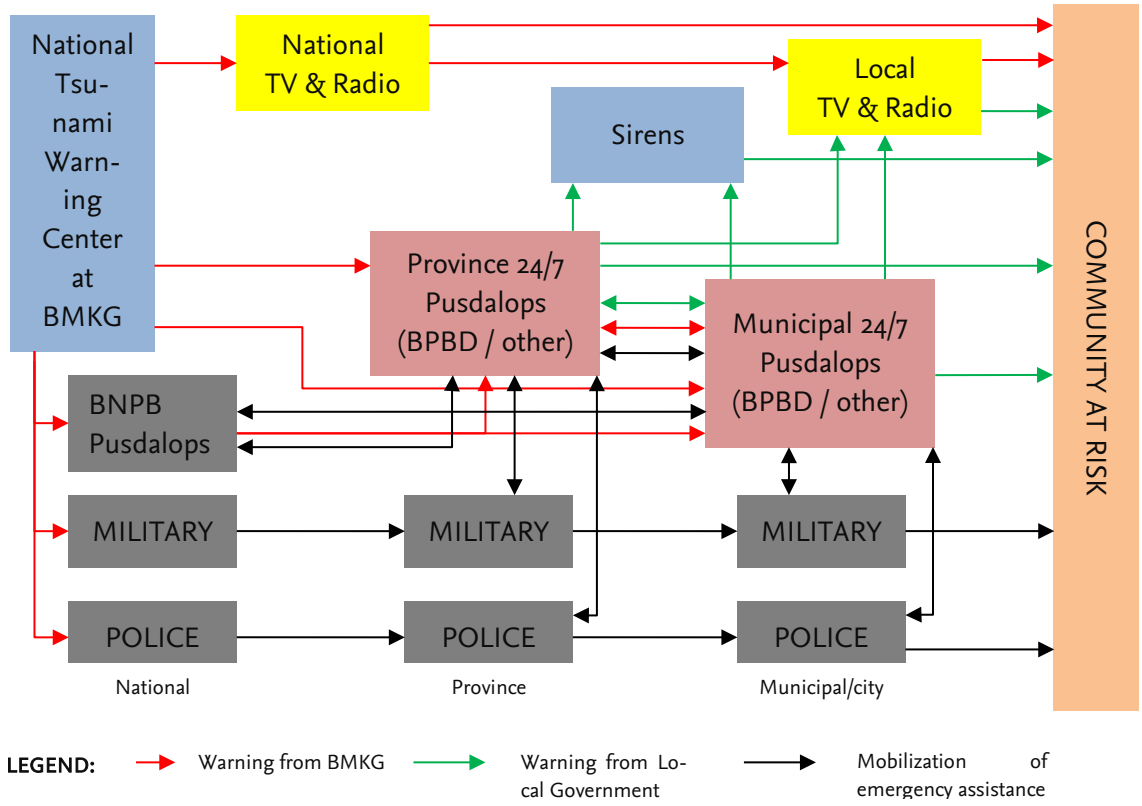

Figure 10. Tsunami warning chains (Triyono 2020).

4.1 Stakeholder mapping: Key formal actors

The official mandates, practical responsibilities and more recent developments will now be detailed for seven key institutions, with an overview provided on Table 3. It is worth noting that main governance levels in Indonesia are the national level, province (led by Governors), regency, municipal, district and sub-district levels (Japanese Ministry of Land, Infrastructure, Transport and Tourism 2017). Some formal institutions are tasked with taking decisions (e.g. BMKG decides if an earthquake can potentially trigger a tsunami or not; BNPB at the national and Subnational Disaster Management Agencies (*Badan Penanggulangan Bencana Daerah* BPBD) at the provincial level to decide on the emergency response). Some institutions are tasked with implementing decisions (e.g. BNPB disseminates warning messages); however, other institutions play a central role in creating and transferring knowledge (e.g. the Indonesian research agency BRIN develops technology and works to integrate it into the InaTEWS system at BMKG).

Actors	Roles & Responsibilities					
	Risk Analysis	Monitoring & Warning	Dissemination of Warning	Evacuation	Response	Awareness Raising
BMKG - Meteorology, Climatology, and Geophysics Agency		IMP	DM			KT
PVMBG - Center for Volcanology and Geological Hazard Mitigation		IMP				
BRIN - National Research and Innovation Agency	IMP	IMP				KT
BIG - Agency for Geospatial Information	IMP	IMP				
BNPB - National Disaster Management Agency	IMP		IMP		DM	IMP
PEMDA - Subnational Government	IMP		IMP	IMP	IMP	IMP
BPBD - Subnational Disaster Management Agency	IMP		IMP	IMP	DM	IMP

Table 3. Roles and responsibilities of key actors in InaTEWS. Note: DM = Decision Maker, IMP= Implementer, KT = Knowledge Transfer (Authors' analysis of Presidential Regulation 93/2019).

BMKG – Agency for Meteorology, Climatology and Geophysics

The Indonesian Agency for Meteorology, Climatology, and Geophysics - *Badan Meteorologi, Klimatologi, dan Geofisika* (BMKG) is headed by a minister-level Director General who reports directly to the President of Indonesia. BMKG hosts Indonesia's National Tsunami Warning Centre (NTWC), a back-up center is set up on Bali (Lauterjung and Letz 2017a, 15). BMKG currently uses the Tsunami Observation And Simulation Terminal (TOAST) as basis for tsunami modelling, which integrates and shares real-time data with the SeiscomP3 seismic system developed in the years 2000s to rapidly evaluate strong earthquakes (Hanka et al. 2008). Moreover, BMKG acts as the Regional Tsunami Services Provider for the Indian Ocean Countries (Pribadi 2014). Its new website format has increased data access and readability for the receiving countries.

In addition to the mandate, mentioned below, BMKG conducts community-level capacity building to improve awareness and preparedness. It routinely conducts Geophysics Field Schools for local governments, the media and community groups. It also maintains equipment installed at the village level.

Official Mandate in InaTEWS according to Regulation 93, 2019

1. Coordinate the structure component.
2. Develop and operate the earthquake and tsunami observation systems.
3. Provide and disseminate information of tectonic earthquake and tsunami early warning.
4. Maintain equipment for earthquake and tsunami observation.
5. Research, develop, assess, and apply technology to enhance the earthquake information system and tsunami early warning.
6. Report to the President on the structural component strengthening and development of earthquake information system and tsunami early warning.
7. Coordinate the collection of integrated observation data for earthquake information system and tsunami early warning, covering:
    a. Seismograph and accelerograph
    b. Continuous global positioning system
    c. Tide gauges
    d. Deep sea level tsunami
    e. Ocean bottom unit
    f. Tsunami radar.
8. Ensure the availability of seismic waveform data and readiness of the TEWS communication network in real-time 24/7.
9. Conduct real-time 24/7 observation, management, and service of the earthquake information and tsunami early warning.
10. Become the crisis center of the structure component in the event of disaster caused by earthquake and tsunami.
11. Disseminate tsunamigenic earthquake information within a maximum of five minutes after the beginning of the earthquake.
12. Disseminate earthquake parameters, including location, depth and magnitude.

13. Disseminate information of tsunami potential including the area of impact, estimation of the time of arrival, and estimation of tsunami height.
14. Conduct scheduled communication tests.

Recent Developments

The national medium-term development plan 2020-2024 includes the strategic priority to speed up dissemination of earthquake information from BMKG to the public from five to just three minutes after the earthquake occurrence (Republik Indonesia 2020). The Indonesia Earthquake Early Warning System (InaEEWS) detects the primary so-called 'P wave' in advance (Karnawati 2020).

BNPB – National Board for Disaster Management, including Pusdalops and Pusdatinkom

The BNPB was founded in 2008. It is headed by a 3-star military general who reports directly to the President of Indonesia. BNPB governs all disaster management aspects in the country and is supported by five deputy-head consist of a deputy for systems and strategy, a deputy for prevention, a deputy for emergency response, a deputy for rehabilitation and reconstruction and a deputy for logistics and equipment.

BNPB's Emergency Operations Centre (Pusdalops) operates in a sophisticated monitoring room with various warning receiver systems, communication devices and several teams who:

(1) Work on hazard and disaster monitoring 24/7, including the operation of radio communication and monitoring from various web-based applications such as InAWARE[14], BMKG Signature, ESDM Magma, Sadewa, Modis and BMKG's Warning Receiver System.
(2) Make situation analysis reports with maps and graphic information as well as oversee the process of developing risk assessment at a district level.
(3) Contact center 117 which operates 24/7 to provide the public information regarding policies applied in disaster emergency (e.g. provide information on VAT exemptions for international aid imports, repatriation procedures, quarantines).

In the event of a tsunami warning, *Pusdalops* establishes communication with the provincial and/or municipal disaster authorities) in the (potentially) impacted areas. It informs and clarifies the warnings and assists as necessary.

BNPB also has a Center for Data, Information and Disaster Communication (*Pusdatinkom*) which gives clear information about disasters and their impacts through press releases and other media activity- such as through BNPB's social media channels- to the public. DIBI and InaRisk count amongst the

[14] InAWARE was specifically developed since 2014 to ease information sharing between national and provincial governance levels. It is based on the Pacific Disaster Centre's DisasterAWARE platform, and integrates hazard information from international and national sources (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 51).

multiple databases (BNPB 2022). While DIBI is primarily used by government officials from the different governance levels, who can add, validate and store data, InaRisk is a web-based platform also available as smartphone application developed with the United Nations Development Program for the population to directly visualise risk assessments (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 51–52). In both English and Bahasa Indonesia, users can "overlay risks, vulnerabilities, and capacities with specific threat types, including floods, volcanic eruptions, and even COVID-19 outbreaks" (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 51).

Interestingly, the ASEAN Coordinating Centre for Humanitarian Assistance on disaster management (AHA Centre) secretariat is hosted on the 13th floor of the BNPB building. The AHA Centre is an intergovernmental organization which aims to facilitate cooperation and coordination among ASEAN Member States and with the United Nations and international organizations for disaster management and emergency response in ASEAN region.

Official Mandate

According to BNPB Regulation 04/2019, BNPB has a specific Directorate of Early Warning tasked to coordinate the development and implementation of technical policy, as well as plan, monitor, analyze, evaluate and execute in the field of early warning:

1. Coordinate the culture component.
2. Report to the President regarding progress of the culture component in strengthening and developing of the earthquake information system and the tsunami early warning.
3. Provide guidelines and directions for the development of disaster management plans for earthquake and tsunami.
4. Provide guidelines for education and training on earthquake and tsunami preparedness as well as disaster response.
5. Provide detailed scale risk mapping for earthquakes and tsunamis.
6. Provide other relevant guidelines for local government in enhancing earthquake and tsunami disaster prevention and preparedness.
7. Ensure the *Pusdalops* (Emergency Operations Center) at BNPB is operating 24/7 to enable immediate follow up from earthquake information and tsunami early warning.
8. Coordinate community responses to earthquake information and/or tsunami early warnings delivered by the government.

Recent Developments

The division of roles between the Directorate of Early Warning and *Pusdalops* is not clearly established. However, BNPB published a masterplan document for multi-hazard early warning systems in 2019. This document covers earthquakes, tsunamis, floods, volcano eruptions, ground movement, droughts, extreme weather, forest and land fires, epidemics, and nuclear disasters. The Masterplan is partly based on a World Meteorological Organization concept (World Meteorological Organization 2018).

In 2020 and running until 2024, BNPB initiated a USD 160 million World Bank-loan funded project called Indonesia Disaster Resilience Initiatives Project (IDRIP). It aims to improve the preparedness of national government and selected local government concerning risk management system and emergency response and includes investments in multi-hazard early warning system. Both BNPB (focus on the 'downstream') and BMKG (focus on the 'upstream') act as project management units.

BNPB has recently demanded that all districts conduct risk assessments by 2024 (BNPB 2022). A newly established national pool of risk assessment experts will support these endeavors. Guidelines for risk assessments have existed since 2012. On paper, the agency channels funding towards district governments who are then responsible to conduct the assessment in cooperation with various experts. In practice, risk assessments have only been conducted by 245 districts (less than 50% of the total amount) in the last 10 years. While assessment updates should be regular, only two districts have thus far engaged in this process.

Key ministries part of the BNPB Steering Committee

Several ministries are part of the BNPB Steering Committee and engage before, during and/or after disasters: The Ministry of Home Affairs, Planning, Health (e.g. establishes Health Crisis Centers), Public Works and Housing (e.g. constructs evacuation roads and sites pre-disaster and increases access to disaster zones), Transportation (e.g. opens and closes transportation hubs in case of a disaster), Energy and Mineral Resources (see below on PVMBG), Social Works and Foreign Relations (Center for Excellence in Disaster Management & Humanitarian Assistance 2021). The last two are involved in the coordination of societal stakeholders introduced in Section 3.2.

The Ministry of Home Affairs – *Kemendagri* is led by a Minister who reports directly to the President. *Kemendagri* oversees the implementation of the Minimum Service Standards on Disaster Management (*Kemendagri* Regulation 101/2018). According to the regulation, municipal level governments are to allocate (financial) resources for basic disaster management services, including early warning services. *Kemendagri* provides a policy framework and supervises local government, ensuring all basic services are delivered adequately. As such, it ensures fulfilment of the minimum disaster management service standards in coordination with BNPB, provides capacity building on the safety and rescue from earthquakes and tsunamis in accordance with the minimum service standards, and measures the performance of local government in the implementation of disaster management. It therefore plays a significant role in ensuring the delivery of early warning services by the local government to the community at risk, even though it has no specific responsibility concerning the InaTEWS.

BAPPENAS is a ministerial level agency accountable to the President. It oversees government affairs in the field of national development planning according to Presidential Decree 65/2015. Through the formulation of 5-year medium-term National Development Plans and as coordinated with the long-term (20 years) and annual Development Plans, BAPPENAS translates the elected President's visions into development priority programs and targets. This includes a macro-economic framework and investment decisions. The current long-term plan runs from 2005 to 2025 and is entitled a "self-reliant, progressive, just and prosperous Indonesia" (Law 17/2007, (Japanese Ministry of Land, Infrastructure, Transport and Tourism 2017). BAPPENAS is involved in disaster risk management through the preparation of macro-economic frameworks (directing investments) and national spatial plans (with zoning

decisions). Following a major disaster, BAPPENAS will assist local government in developing a rehabilitation and reconstruction plan. The plans frequently involve programs and funding for 'building back better', as well as improvements to early warning systems.

PVMBG – Center for Volcanology and Geological Hazard Mitigation

The center for volcanology and geological hazard mitigation - *Pusat Vulkanologi dan Mitigasi Bencana Geologi* (PVMBG) is an echelon II unit under the Geological Agency of the Ministry of Energy and Mineral Resources (*Kementerian Energi dan Sumber Daya Mineral*). The latter is responsible for general energy provision and mining, but also provides and manages data on geologic hazards including volcanoes and landslides. As such it is involved in risk monitoring and post-disaster assessments, as well as providing alert level recommendations (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 38).

The Multiplatform Application for Geohazard Mitigation and Assessment in Indonesia (MAGMA) presents updated volcanic activity levels and early warning information including recommendations since 2015 (see Figure 11 for a screenshot).

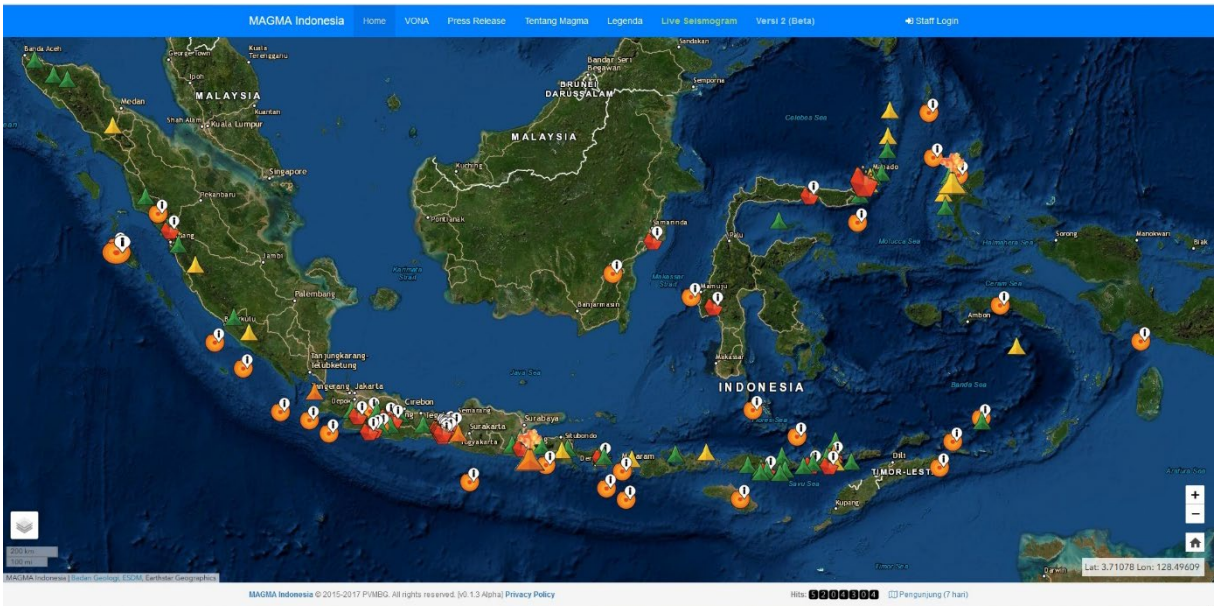

Figure 11. MAGMA Indonesia user interface (Ministry of Energy and Mineral Resources 2022).

Official Mandate

1. Integrate the undersea volcanic earthquakes observation data in real-time 24/7 with the tsunami early warning system hosted by BMKG (11.a).
2. Conduct scheduled tests regularly on communication and emergency (11.b).
3. Ensure data availability of volcanic observation and readiness of the communication network (11.c).

Recent developments

Since Presidential Regulation 93/2019, PVMBG is obligated to share volcanic monitoring data with BMKG/the InaTEWS.

BRIN – National Research and Innovation Agency

The National Research and Innovation Agency – *Badan Riset dan Inovasi Nasional* (BRIN) is headed by a chairman appointed by and reporting to the President of Indonesia. It acts as the sole national research agency.

In addition to the below mandate, BRIN develops guidelines and provides education and public campaigns.

Official Mandate

1. Integrate the observation of deep-sea level tsunami with the TEWS hosted by BMKG in real-time 24/7.
2. Conduct technology innovation on earthquake observation, deep sea level tsunami, cable based tsunameter, and other marine observation equipment.
3. Conduct scheduled communication tests.
4. Ensure the availability of deep-sea level tsunami data and readiness of the communication network.
5. Conduct research and assessment on earthquake and tsunami.
6. Develop guidelines and provide education and public campaign support for safe spaces where residents can exchange and share their local knowledge.
7. Provide Short Leadtime Tsunami-Earthquake technology.
8. Conduct improvement on ocean literacy on the maritime disaster risk reduction, including earthquake and tsunami.
9. Assist local governments as required in conducting earthquake and tsunami risk assessment.
10. Ensure the availability and readiness of satellite data and communication networks.
11. Provide technical assistance on remote sensing images.
12. Provide surveillance support using unmanned aerial vehicles or drones.

Recent Developments

In 2021, all Indonesian national research agencies including the Indonesian Institute of Sciences (LIPI), the Agency for the Assessment and Application of Technology (BPPT), the National Nuclear Energy Agency of Indonesia (BATAN) and the National Institute of Aeronautics and Space (LAPAN) were merged into BRIN in accordance with Presidential Regulation 78/2021. BRIN's responsibilities cover all those of the named previous institutions.

For the 2020-2024 period, BRIN (particularly the section that previously was BPPT) targets to deploy and operate new buoys and ocean sensors (see Figure 12), funded by the state in value of IDR 728.69 billion:

- Tsunami buoys in 13 locations.
- Tsunami Coastal Acoustic Tomography (TCAT) in three locations.
- Indonesia Cable-Based Tsunami-meter (Ina-CBT) in seven locations.

Figure 12. Site plan for the sea-level monitoring 2020-2024 by BPPT/BRIN (Anantasena 2020).

BIG – Agency for Geospatial Information

The Agency for Geospatial Information – *Badan Informasi Geospasial* (BIG) is responsible nationally for geospatial information and coordinating the implementation of the One Map Policy laid out in Presidential Regulation 09/2016. As such, it provides the basemap used as reference by all other institutions involved in developing thematic maps. The head of BIG reports directly to the President.

Official Mandate

1. Integrate the observation data from tide gauges and continuous global positioning system (cGPS) with the TEWS in real-time 24/7 (14.a).
2. Conduct technology innovation on tide gauges and cGPS for the provision and dissemination of earthquake information and tsunami early warning.
3. Conduct scheduled communication tests.
4. Ensure data availability and operational state of cGPS, tide gauges, and communication network of the earthquake information system and tsunami early warning.
5. Develop a 1:5000 basemap which will be used as a basis of reference for earthquake and tsunami-based spatial planning.

6. Develop a 1:10,000 coastal mapping / tsunami prone areas as bathymetry data on Indonesian coastal environment map.

Recent Developments

As of 2020, BIG is managing 170 tide gauges station as part of a system called Ina-Tides, illustrated on Figure 13 (Husrin et al. 2021b). The system, operational since 2015, consists of radar gauges, pressure gauges and float gauges that continuously feed the InaTEWS with real-time data.

BIG also operates Indonesia's Real-Time Global Navigation Satellite System (GNSS). The multi-satellite positioning system involves GPS and several other navigation satellites such as GLONASS, Galileo, BeiDou, QZSS, and IRNSS. BIG manages 213 real-time GNSS stations across Indonesia as part of the InaCORS (Indonesia Continuously Operating Reference Stations) framework. InaCORS[15] provides geospatial reference for mapping and monitoring the earth's crust movements.

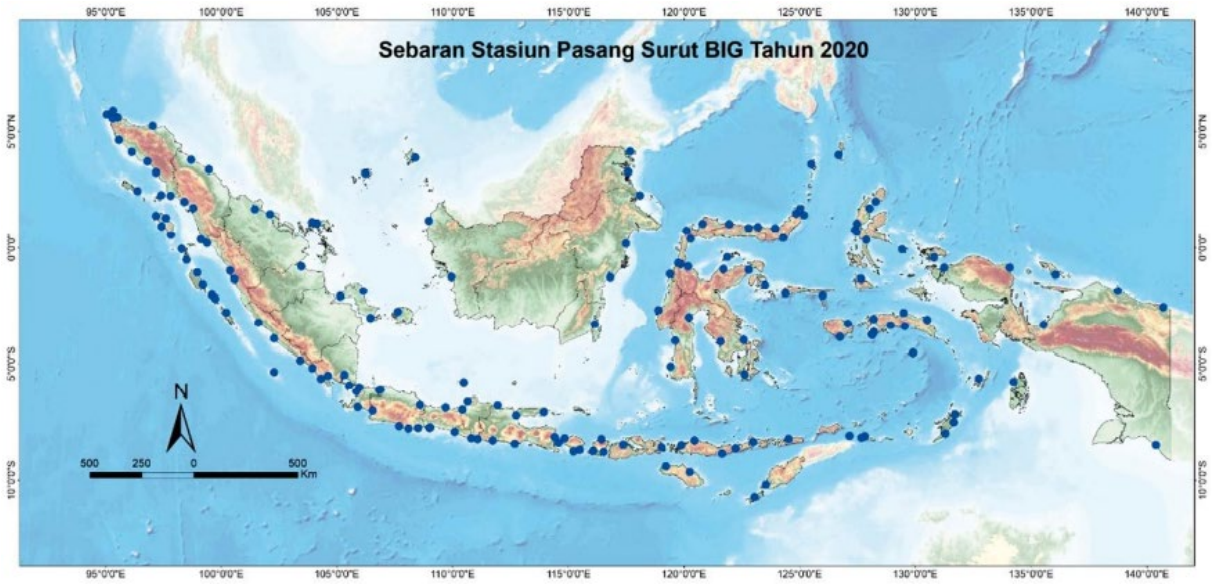

Figure 13. Location of tide gauge stations managed by the BIG (BIG 2022).

BPBD – Subnational Disaster Management Agencies

BPBDs are mandated to undertake disaster management functions in their respective jurisdictions. They are mandatory at the province level but optional at the municipal level. At municipal level, there are two institutional BPBD forms, depending on each local government's needs and resource availability:

[15] Online data can be provided by BIG upon request at the following addresses: http://srgi.big.go.id/srgi2/jkg and http://nrtk.big.go.id/.

- Type A is led by an echelon II government official: this type has more authority in command and coordination and involves bigger organizational structures.
- Type B is led by an echelon III government official.

Due to the decentralization process, no official regulation explicitly states who should call for evacuation at the local (provincial or municipal) level. Each local government should compromise, take decisions and develop their own mechanism in issuing the evacuation order. However, until now, few BPBDs have established such regulations and procedures. Stepping up at local level is further made difficult as capacity and funding varies significantly per BPBDs, even though BNPB is authorised to manage 'on-call-budget' to respond to major disasters (BNPB 2020). This budget has fluctuated between 1.3 trillion Indonesian Rupiah[16] and 14.5 trillion Indonesian Rupiah between 2015 and 2020 (BNPB 2020).

Most BPBDs disseminate BMKG information to the community using radio communication (see the details on RAPI and ORARI in the 'Media' sub-section below) and loudspeakers operated from vehicles.

The BPBD of Bali Province provides certifications for hotels which practice preparedness for earthquakes and tsunamis. Preparedness and response capacity to tsunami early warnings are part of the assessment scoring. However, such a certification process is only implemented in Bali and not standardised at the national level.

Official Mandate

Coordinate other local government agencies for the implementation of the culture component (20.3).

Recent Developments

BNPB is currently developing a local disaster management capacity measurement tool, which aims to assess the institutions, performance and quality of services of BPBDs at the municipal level.

TNI – The Indonesian military

According to Law 34/2004, the Indonesian national army has a limited role in what concerns internal affairs, yet it is also mandated with civic missions, in particular to support the government in managing disaster emergencies. The Center for Excellence in Disaster Management & Humanitarian Assistance (2021, 41) points out that although TNI support must legally come at the request of civilian authority, its members are often amongst the first responders.

The military´s responsibilities regarding tsunami early warning services and response are detailed in Presidential Regulation 93/2019:

[16] 1.3 trillion Indonesian Rupiah are worth approximately 90 million Euros.

- Ensure the security of equipment related to earthquake monitoring and tsunami early warning.
- Support the provision and update bathymetry data.
- Support dissemination of earthquake information and tsunami early warning; help and secure the evacuation process.
- Assist in the delivery of logistics.
- Support humanitarian action, in particular IDPs.

The military has a different governance structure than the general government, yet local government such as governors at provincial level are positioned at the same level as the military resort commander (the KOREM). Mayors and regents, however, situated respectively at the municipal and district level, are at the same level as the military district commander (the KODIM). In line with Law 34/2004, the military can mobilise all military personnel within a civil mission jurisdiction following official request from the head of local government (i.e., from the governor to the chief of KOREM, or from the Mayor/Regent to the chief of KODIM).

POLRI – The Indonesian police

The mandate of the Indonesian police (*Kepolisian Negara Republik Indonesia* POLRI) is to protect people, assets and their environment from disturbances and disasters; specific disaster roles are detailed in POLRI Regulation 17/2009 (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 40). In case of an emergency, POLRI sets up evacuation routes and Field Control Commands to save victims, with BNPB/BPBD taking over once civilian command is established. POLRI also helps with the dissemination of disaster early warning information (earthquakes and tsunamis) and secures the infrastructure through which early warning systems operate.

4.2 Stakeholder mapping: Key informal and/or societal actors

In addition to government actors with formal disaster management mandates, a multitude of informal and/or societal actors are involved in disaster prevention and response. These are increasingly refered to as 'Pentahelix' entities in Indonesian disaster policy and practice.

UNESCO-IOC and ICG/IOTWMS

BMKG functions as an approved Tsunami Service Provider of the Indian Ocean Tsunami Warning and Mitigation System, which in turn is integral part of the Global Tsunami Warning and Mitigation System established and coordinated by the UNESCO-IOC. The Jakarta Tsunami Information Centre was established as the information hub for the Indian Ocean region. The Centre was upgraded to Indian Ocean Tsunami Information Center (IOTC) in 2011 at the 8th session of the Intergovernmental Coordination Groups for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) in

2011. This Information Centre focuses on capacity building and gathering information and resources, in particular to study the prevention of, preparation for and mitigation of tsunamis across the Indian Ocean region (UNESCO 2022).

PMI – The Indonesian Red Cross

The Indonesian Red Cross - *Palang Merah Indonesia* (PMI) was founded in 1945 and operates according to humanitarian principles: it helps victims without any ethnic, tribal or political discrimination. As every National Society Part of the Red Cross Red Crescent movement, it is closely linked to the state. The current PMI chairman is Jusuf Kalla, who served as vice president of Indonesia twice (2004-2009 and 2014-2019). PMI's official mandate is regulated by Law 01/2018 and Red Cross Government Regulation 07/2019. Given Indonesia's high disaster risk, the disaster management field is amongst its priorities. For its emergency response operations, PMI works under coordination of BNPB and the BPBDs.

As part of its ongoing activities, PMI provides health and social services to communities, including blood donation and training of volunteers, for instance in first aid. It also conducts community preparedness projects to improve risk awareness. This involves risk mapping and the development of participatory rural appraisals and contingency plans. In 2020, PMI conducted community-based disaster risk reduction projects in 37 village and 28 schools at 28 municipalities in seven provinces (Palang Merah Indonesia 2021). In times of emergency, PMI volunteers support the community evacuation process under coordination of local authorities including BPBD, the military and the police. The organization is moreover involved in search and rescue operations, supports logistics with its warehouses, and sets up IDP camps.

Resource-wise, PMI funding comes from public donations as well as funding or in-kind support from the International Federation of the Red Cross Red Crescent, the International Committee of the Red Cross, as well as Red Cross Red Crescent societies from other countries. The Society (Palang Merah Indonesia 2021) disposes of approximately 460,000 volunteers distributed across 34 provinces and more than 400 district branches (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 44). PMI moreover manages seven educational and training centers, one located in each province, as well as one Red Cross public hospital in Bogor.

Civil society organisations such as Tagana - the disaster preparedness cadets

Youth, women and faith-based groups play a major role in disaster risk reduction (see Table 4) for an overview) and response. They are involved in raising awareness, drills, information collection and communication, livelihood support initiatives, evacuation and humanitarian volunteering.

The 39,004 disaster preparedness cadets —*taruna siaga bencana* (*Tagana*) consisting of mostly youth are a structural network of officially registered and trained volunteers established to support the community with disaster management (Kementerian Sosial Republik Indonesia 2020). *Tagana* was created

in every province since 2009 and reports to the Director of Social Protection for Disaster Victims at the Ministry of Social Affair (Mulyasari and Shaw 2012, 137). The members of the network conduct disaster risk reduction and preparedness activities, as well as early detection of potential occurrence of disaster to the community. In times of emergency, *Tangana* supports community evacuation under coordination of BPBD. The volunteers are involved in disaster rescue, temporary shelter, communal kitchen, logistics, and psychosocial aspects.

The Women Welfare Associations (TP PKK/Tim Penggerak Pemberdayaan Kesejahteraan Keluarga) work independently yet are subsidised by the government (Mulyasari and Shaw 2012). Leaders of faith-based groups are usually highly influential within their community. Their collaboration is crucial for preparedness activities and evacuations to be successful.

	Integration into development planning	Capacity development	Decentralization	Public-Private partnership	Community participation
Women's Welfare Associations	Evaluating the disaster management plan with ward and sub-district officers	Disaster awareness courses	Collection and communication of risk data at wards	Micro-credit and soft-loan system for women-headed households	Cultural events organised for fundraising purposes
Youth Unions	Mobilizing youth in the participation of disaster management plan reviews	Youth disaster drills	Set-up disaster unit office within the ward government	Engagement of the private sector for young entrepreneurs	Mobilization of youth volunteers
Faith-Based Organizations	Engage the community in the participation of disaster management plan review	Training of Trainers for community safety campaign	Collective cooperative schemes at ward level	Linkage of rehabilitation and reconstruction subsidy	Informal community gathering for planning

Table 4. Civil society organisations for disaster risk reduction (Mulyasari and Shaw 2012, 143).

Non-governmental organizations

Nearly each municipality hosts various local, national, as well as international NGOs. These often play a crucial role in building effective early warning systems, and are often involved in the community preparedness, evacuation, emergency response and rehabilitation, and reconstruction processes (H. Spahn et al. 2014). In 2021, 36.1 million USD of humanitarian support went to Indonesia, with the most important donors being, in order of spending, the United Arab Emirates, Japan and the United States (United Nations Office for the Coordination of Humanitarian Affairs 2022). Most international NGOs

have offices in cities such Jakarta, Medan, Makassar and Denpasar, while local NGOs are primarily established at the place where they directly operate. As one of many examples, *Komunitas Siaga Tsunami* (KOGAMI, translates as tsunami prepared community) is an NGO established in Padang city with the aim to build a system of tsunami preparedness together with communities and local government.

According to the Government Regulation 23/2008 regarding the Participation of International Institution and Foreign Non-Government Institution in Disaster Management, the main role of NGOs is to support and strengthen the efforts of disaster risk reduction and emergency management in order to reduce suffering and accelerate recovery. For international assistance, prerequisites are "sovereignty, respect and trust" (Triyanti et al. 2022, 13). Following the 2004 tsunami, Indonesia tightened its control of international actors, who are requested to enter disaster-affected areas with local assistance only. All NGOs are required to submit a proposal, establish a memorandum of understanding or agreement and receive agreement to the work plans. In consultation with the Ministry of Foreign Affairs (*Kementerian Luar Negeri*), which is the "primary contact for international assistance requests and offers" and "acts as entry point for required resources", BNPB is the focal point for funders wishing to make donations and NGOs wishing to establishing disaster management cooperations (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 38). BNPB moreover follows projects over the course of their implementation.

Academia

Universities are coordinated by the Ministry of Education, Culture, Research and Technology. Indonesia also has a Forum of Higher Education for Disaster Risk Reduction (FPT PRB – *Forum Perguruan Tinggi untuk Pengurangan Risiko Bencana*). The Forum developed a guideline of DRR Thematic Community Service, which includes proposals on how to develop a community-based early warning system (Forum Perguruan Tinggi untuk Pengurangan Risiko Bencana 2018).

Research-wise, universities produce knowledge and technology which can be useful and can be further developed in cooperation with government agencies or other actors. Although research is ongoing, and findings and practical applicability still need to be tested further, one interesting prototype developed is the earthquake early warning system developed by the University of Gadjah Mada, which reportedly can provide warnings three days before earthquakes actually happen (Ramadhan 2021). The University of Gadjah Mada also introduced an earthquake early warning system which would be based on radon gas concentration (Pratama et al. 2021). Telkom University is working on a prototype of earthquake early warning based on geomagnetic signals (Elrizki, Irawan, and Setianingsih 2020).

Education-wise, while disaster management themes are part of many curricula, few universities have established specific majors on disaster management. Exceptions include the University of Indonesia who established a master's programme in 2021, as well as the University of Gadjah Mada.

Both academics and university students may partner with government agencies or work directly at the community level. For instance, this may be done as part of a community service program for which study credits can be earned. University community service programs usually work on specific thematic subjects in a selected village.

The media

According to Law 31/2009 about BMKG as well as the Ministry of Communication and Information's Regulation 20/2006 regarding early warning systems, the media must halt any regular broadcasting in order to share tsunami early warning information immediately upon receiving the information from BMKG, in form of a 'Stop Press' message with breaking news and running text. From a rapid assessment of InaTEWS effectiveness to the Wharton Basin Earthquake 2 March 2016, Bersema (2017) identified 11 national television stations that installed web-based warning receiver systems in their master control rooms. However, only four of them broadcasted the 'Stop Press' message. Moreover, social media has rapidly developed since Law 31/2009, which focuses on official media providers and television only. Indonesians are more likely to hear of a disaster through Facebook, Twitter or WhatsApp, sometimes in sensationalist terms (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 50–51).

Some of the Indonesian telecommunication companies owning Base Transceiver Station towers permit tsunami sirens to be placed on their towers. For example, several Telkomsel towers in the city of Padang have been equipped with electromechanics sirens which get their power from the same electric supply as the Base Transceiver Stations. The sirens are remotely controlled for activation/deactivation/testing by the BPBD office. Indosiar TV stations at the top of Gado-Gado hill in Padang count several repeater devices for radio communication, further supporting the warning dissemination process.

As a specific media type, RAPI (*Radio Antar Penduduk Indonesia)* and ORARI (*Organisasi Amatir Radio Indonesia)* are citizen-based band radio organizations. Individuals who hold radio communication devices for personal use are required to get a license which can be acquired from either of those two organizations. RAPI and ORARI usually cooperate with local governments, which allows for transmission of information on major events such as general elections, festivals or disasters. In times of emergency, RAPI and ORARI support the dissemination of tsunami early warnings. Registered RAPI and ORARI members usually monitor the frequencies used by BMKG and BPBD to get information and will further disseminate it to their respective community.

The private sector

The private sector includes state-owned companies, local government-owned companies, cooperatives, and private companies who have their legal entity and operations in Indonesia. Its engagement in every phase disaster management is regulated by BNPB Regulation 22/2014, companies engaging in disaster management need to have memorandum of understanding with BNPB or BPBD first. The overall aim is to ensure the safety of surrounding communities, the environment, as well as preserve private business operations during disaster impact. According to Government Regulation 21/2008, the private sector is one of the institutions that must implement government directives following government-issued early warnings. This might require the private sector to mobilise their own resources in order to support emergency responses.

In addition, the private sector contributes with its own initiatives. For instance, the Bali Hotels Association installed their own radio and internet operations room so that they can receive tsunami early warnings directly from BMKG 24/7. The operators then disseminate the earthquake and/or tsunami information via SMS to subscribing member hotels and associates. Moreover, several member hotels serve as potential tsunami evacuation areas.

4.3 Identified strengths and challenges of the InaTEWS

Several strengths and challenges of the InaTEWS were already thematised above. Here follows a more concrete list of each as reported in the literature, although far from exhaustive.

Strengths identified in the literature

- InaTEWS is embedded and contributes to a "system of systems" within the Indian ocean, proving forecasting information to other states´ Tsunami Warning Focal Points as well (Sakalasuriya et al. 2020, p. 436).
- The Service Guidebook for InaTEWS provides guidance for national and local stakeholders, public and private sectors. There is a hierarchy and mandate definition (who provides info, who disseminates etc.) provided by BMKG, who is sole sender of a tsunami warning to other stakeholders (Sakalasuriya et al. 2020, p. 436). The coordination between national actors is perceived as "adequate and effective", particularly within BNPB divisions (Sakalasuriya et al. 2020, 437).
- There are established Memorandum of Understanding (MoUs) to operationalise the InaTEWS in cooperation with additional actors such as nuclear energy inspector BAPETEN and BATAN.
- The decentralised local decision-making mechanisms on actions to follow centralised warnings is compatible with the geography of Indonesia, a huge physical area with at least 6,000 populated islands and varied situational circumstances (Sakalasuriya et al. 2020, 438).
- There is a proactive approach in training local actors, including on bulletins and standards. The established national early warning standards[17] are in line with international standards (Sakalasuriya et al. 2020, 438).
- The system is designed for seismically induced near-field tsunamis which are predominant in the region (Lauterjung, Münch, and Rudloff 2010; Lauterjung and Letz 2017b), as long as these are not significantly shorter than 30 minutes of warning time. The InaTEWS can handle multiple earthquakes occurring within short period of times (personal communication with Harald Spahn involved in the development of the InaTEWS during numerous German-Indonesian

[17] National standard 8840-1:2019 concerns Disaster early warning system – part 1: general hazards, SNI 8841-2:2020 specifically concerns tsunamis.

projects, 31.10.2022), although some debate the accuracy of this (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 52).

- 22 tsunami warnings have been issued by InaTEWS since its inauguration in 2008, with only two referring to tsunamis with a wave height above one meter: the Mentawai tsunami of 2010, and the Palu tsunami of 2018 (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 51). While some have still had a devastating impact, analysis of these cases results in ´lessons learned' (Sakalasuriya et al. 2020, 439)

Challenges identified in the literature

- An increasing fragmentation of organizations tasked with specific mandates is not conclusive to dealing with systemic risk and compound disasters (Triyanti et al. 2022, 4), especially when the institutions send each other the ball for the next steps. In particular, the national level agency BNPB has no authority over the BPBD sub-national agencies; they are under management of the Ministry of Internal Affairs. This translates in different assessments of what constitutes an 'extreme event' and to identify disaster scales and impacts (Gusti Ayu Ketut Surtiari, personal communication, 1.11.2022).

- The Service Guidebook for InaTEWS is not always clear and does not define the roles of BNPB, EOC and BPBD, even though they are significant in practice to disseminate information and activate local evacuation orders (Sakalasuriya et al. 2020, 436). This leads to coordination issues between national agencies (e.g. BMKG and BNBP), between national and local actors, (e.g. between BNPB and BPBD due to "misunderstandings of the warning command chain", (Sakalasuriya et al. 2020, 437) and between different local agencies (e.g. local BPBDs have different mechanisms and guidelines for giving evacuation orders). This is especially true at local levels, where different stakeholders (mayor, governor, deputy governor, military commander and chief of police) decide on evacuations, yet do not have time to meet and consult within the necessary timespan (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 53).

- Funds are lacking to extend (local) services 24/7, and for technological investments such as fiber optic cables which would allow to relay information from pressures gauges and underwater seismometers.

- Funds are also lacking for maintenance for the buoy system, which is frequently vandalised by fishermen.

- Linked to the lack of funding and training: Human capacity limitations in terms of "interpreting information on tsunami warning and using equipment and tools" is visible at local level also; officials may for instance not activate warnings because they do not understand warning bulletins and the associated procedures (Sakalasuriya et al. 2020, 438).

- Decentralisation is not advised when funding and capacities are inadequate, as several Indonesian examples such as the 2018 Palu earthquake and tsunami (Triyanti et al. 2022) and 2018

Sulawesi earthquake (Sakalasuriya et al. 2020, 438) substantiate. In Palu, the BMKG early warning was not received and the siren and SMS sending to the population did not operate because of earthquake-induced power shortage. Importantly, the EWS local government had failed to maintain the BPBD backup generator and uninterrupted power supply in working order (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 53).

- There have been cases of misinformation, leading to cases of people fleeing in absence of a disaster, or lack of evacuation in spite of the disaster, as happened during the 2018 Sulawesi earthquake (Sakalasuriya et al. 2020, 439). Participation in past tsunamis and drills may lead to a false sense of security. For instance, no siren and no SMS were received by the Palu population in 2018. While many had felt the earthquake, they assumed it was not followed by a tsunami wave (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 53).
- Less than half of districts have completed risk assessments, with only two districts having updated their risk assessment (BNPB 2022).
- Risk management sometimes falls behind economic interests. For instance, Palu Bay is massively developed as a tourism center, with little attention to existing risks and dissemination of proper evacuation information (Triyanti et al. 2022, 14). Private sector involvement in disaster management is still perceived as a welcome form of charity, disaster management thus is not yet 'everybody's business".
- Current early warning policy and practice still focuses on hard sciences, allocating little space to social dimensions. Disaster recovery often focuses on infrastructure aspects, with neglect of social assistance programs (e.g. cash assistance, livelihood reconstruction or reconversion). This can have maladaptation effects, e.g. people have no choice but to resume their economic activities at the coast, even though these are prohibited post-disaster (Triyanti et al. 2022, 15).
- Technical and human errors in the system (2012 and 2016 tsunamis), unpredicted rapidity of the tsunami and technical failure (2018 in Sulawesi) remain present. As currently designed, the InaTEWS does not take into account submarine landslides, nor non-seismically-induced tsunamis (Adam Switzer from the Earth Observatory in Singapore, cited in (The Sydney Morning Herald 2018). According to the Center for Excellence in Disaster Management & Humanitarian Assistance (2021, 52) for instance, "data flexibility or analytical/communication capacity" is rather fit for "tsunamis that arrive in 20 minutes or more".

5 Not seismically-induced tsunamis and cascading events: the new frontier?

The recent tsunamis in Palu (28 September 2018) and Anak Krakatau (22 December 2018) had large-scale impacts: the deaths of 4,316 and displacement of 33,719 people due to the two 2018 events combined (BNPB 2018). These devastating disasters created renewed importance of further developing the InaTEWS, including the technology and procedures for population warning and evacuation, and of detecting non-seismic tsunamis triggers.

Needless to say, the geological phenomena of not-seismically induced tsunamis is no novelty (see Table 5).[18] According to the BMKG tsunami catalogue (2019, 3), the first ever recorded tsunami in Indonesia occurred in the year 416 following a volcanic eruption. Soloviev and Go (1974, 225) describe the same tsunami by referring to the 'Book of Kings' (*Pustaka Raja* / *Pararaton*), the Javanese historical narratives of the royal dynasty that ruled Java between the 13th and 15th centuries. Following the 'Book of Kings', Mount Kapi, believed to be the current Krakatau volcano, erupted and caused massive waves that inundated and separated the islands of Sumatra and Java. As listed on Table 5, at least 18 non-tectonic induced tsunamis, the majority of which were induced by volcanic eruptions or volcano flank collapse, have been recorded in Indonesia since 1659. In six cases, the specific tsunami trigger is still unknown. The 2018 Palu-Donggala tsunami is suspected to have been triggered by an underwater landslide. In addition, Soloviev and Go (1974, 241, 255, 256) recorded several small localised events which occurred in the Sunda Strait area with unknown cause in the year of 1851, 1883 (two months after the Karakatau eruption) and 1889.

As visible in Figure 9, the InaTEWs is primarily shaped as an earthquake-centric warning system; it mainly detects earth fault motions that may trigger tsunamis. Non-tectonic tsunami sources are considered in the sense that PVMBG provides some undersea volcanic monitoring. However, as highlighted by an Indonesian geoscientist (#1, 2.6.2022), PVMBG considers only the volcano itself, not the water around it. If there is no population situated within 5 kilometers of the possible eruption, the institution considers nobody to be at risk. Presidential Regulation 93/2019 does not explicitly mention non-tectonic tsunami sources (Karnawati 2020; Republik Indonesia 2019b), yet the InaTEWS Grand Design 2020-2024 takes into account non-tectonic tsunami triggers and various government institutions are currently working to fill the gaps and develop technology to address non-tectonic tsunamigenic sources (Husrin et al. 2021a). For instance, a BRIN researcher has been experimenting with Inexpensive Devices for Sea Level Measurement after he exchanged with international research colleagues during the 2018 Palu International Tsunami Survey Team. This device can monitor sea level data in locations close to volcanoes, as opposed to the tidal monitoring conducted by BIG further away, and primarily used to support maritime navigation. (Geoscientist #1, 2.6.2022 and 4.11.2022). BMKG

[18] Early volcanic research in Indonesia, such as the 1966 UNESCO-supported mission (Tazieff, Marinelli, and Gorshkov 1966), did not make the link between volcanic phenomena and tsunamis. Tazieff et al. (1966) primarily study the Java island volcanoes from the angle of geothermal energy.

is currently developing detection technology for non-tectonic tsunami sources which relies on sea surface elevation changes. The subject of non-seismically induced tsunamis is getting traction, including as part of the German-Indonesian Tsunami Risk project (Tsunami Risk Consortium 2021) and Ina2Core project.

Date	Tsunami trigger	Location
11 November 1659	Mount Teon	Maluku
20 May 1673	Mount Gamkonora	North Maluku
28 November 1708	*Unknown*	Maluku
11 November 1717	*Unknown*	North Maluku
1 September 1763	Mount Gamalama	North Maluku
10 April 1815	Mount Tambora	West Nusa Tenggara
14 February 1840	Mount Gamalama	North Maluku
14 April 1855	*Unknown*	East Nusa Tenggara
2 March 1856	Mount Awu	North Sulawesi
3 March 1871	Mount Ruang	North Sureguesi
26 August 1883	Mount Krakatau	Lampung
20 June 1891	*Unknown*	Maluku
14 August 1928	Mount Rokatenda	East Nusa Tenggara
26 October 1957	*Unknown*	East Kalimantan
2 April 1969	*Unknown*	North Maluku
18 July 1979	Flank collapse Mount Ile Werung	East Nusa Tenggara
22 December 2018	Flank collapse Mount Anak Krakatau	Lampung
28 September 2018	Palu bay landslide	Central Sulawesi

Table 5. List of non-seismic triggered tsunami recorded in Indonesia (Karnawati 2020, 7–8).

Internationally, the UN Decade of Ocean Science for Sustainable Development starting in 2021 provides additional impetus to advance research and implement better protection from ocean hazards, including tsunamis (UN 2022). What is referred to as the 'Ocean Decade' aims to develop technology and observational tools for better tsunami detection and warning. The need to enhance community preparedness (referred to as '100% tsunami ready') is stressed as well (UN 2022). Concerning multi-hazards, the UNDRR (2017a) has stressed the importance of "considering interrelationships between natural hazards, including hazardous events occurring simultaneously, in cascades, or cumulatively over time"; more and more research is done in this direction, the British Geological Survey for instance compiled inventories of landslides triggered by the M7.8 Nepali earthquake in 2015 (Gill and Bullough 2017, 2). "Better assess the risk associated with cascading, compounding hazards and complex crises" is listed among the objectives of the Bali Agenda for Resilience summarizing the main outcomes of the Global Platform for Disaster Risk Reduction which took place in Indonesia in May 2022 (UNDRR 2022). Alexander and Pescaroli (2019) have termed 'cascades' as new disaster paradigm. In terms of hazards but also vulnerabilities and disaster impacts, simple linear models are contradicted. Interdependencies, overlaps and escalation points all contribute to increasingly complex crises, which are more and more understood as such.

One question that remains open is in regard to how cascading disasters and atypical tsunamis are already part of local disaster*cultures and how this local knowledge and local practices might support the development of the InaTEWS. Conversely, existing disaster*cultures surrounding tsunami warning signs might be counter-productive in the case of atypical tsunamis: if they focus on feeling the earthquake or wait for warning from the InaTEWS which presently does not include this type of tsunamis, they will not be able to act in time.

6 Final observations on entangled and evolving disaster*cultures

Authors warn of relying on static and simplistic interpretations concerning disaster meanings and discourses. Disaster narratives are always socially constructed and can be contentious subjects (Venugopal and Yasir 2017), just as disaster memory processes are multiple and contested (Fuentealba 2021). The Sidoarjo mudflow provides an Indonesian example, whereby the question whether the disaster was due to an earthquake on the island of Java, or to drillings linked to the extractive gas industry, is debated until today (Lewis and Lewis 2017). Communities themselves are heterogeneous across lines of gender, religion, origin, status and much more, whereby different understandings co-exist. Padang for instance is home to Muslims but also to Buddhists and Christians, some of which came from China, Nias or Northern Sumatra, and to Indigenous groups with animistic faiths (Birkmann, Setiadi, and Fiedler 2015, 246–47).

Belief systems, as well as processes of assigning meaning to and making sense of disasters evolve with time and within socio-cultural contexts. Presently, key evolution drivers are the increasing use of social media (leading to different ways of communicating and perceiving risks and disasters), the recent coronavirus pandemic (which led to a rise of poverty, malnutrition and hunger), and climate change. Indonesia is and will further be at the forefront of climate change impacts. The current 20-year development plan thus incorporates climate change mitigation and adaptation elements, specific policies including "optimal use of land, water, and natural resources, conserving rainwater, developing early warning systems for extreme weather events, protecting coastal zone, making infrastructure more resilient, and better urban planning" (Center for Excellence in Disaster Management & Humanitarian Assistance 2021, 8). Nature-based disaster management solutions are currently high on the international agenda, as reflected in the 2022 Global Platform for Disaster Risk Reduction gathering (UNDRR 2022). Notwithstanding its extensive coastline, such approaches would seem relatively new to current policymakers, who would have 'turned their back' in the past decades (personal communication by Indonesian social scientist #2 during a disaster*cultures workshop on 8.6.2022).

At a local level, belief systems, assigning meaning and making sense of events evolve under the influence of disasters and official disaster management interventions. In Padang, community members could perceive tsunami awareness raising activities as showcasing a lack of faith and 'an invitation to more disasters. Yet, the efforts by disaster management actors including civil society actors were increasingly recognised as valid measures to increase capacities (Birkmann, Setiadi, and Fiedler 2015). Similarly, Donovan (2010, 122) recounts how during one research workshop conducted in a village at

the foot of Mount Merapi, the youngest participants, who had received hazard training by government authorities and CSOs, showed frustration as the elders centered the discussion on traditional tsunami warning signs. This shows how authorities´ presence gradually impact local belief systems. Nazaruddin (2022) converges with this finding, describing how community members have gradually abandoned the idea that their villages would be "safe" as protected by spirits. Yet she also stresses that the scientific knowledge and official warning systems do not simply replace the traditional meaning-making and communication systems: "People still believe that the eruption is a magical event, however they perceive that they are not able to communicate with the spirits" (Nazaruddin 2022, 201). They also do listen to information they receive from authorities, but interpret them according to their own circumstances (Nazaruddin 2022, 203). Thus, the different meaning making systems are in "dynamic tension" with one another. To overcome gaps in meaning making, CSOs have involved religious leaders or even told religious stories to increase disaster awareness. For example in Padang, one CSO promoted the idea of evacuating to another community higher up the hill by linking it to the story of the Prophet Muhammad and his followers, who had been welcomed by a community in Medina as they fled from Mecca (Birkmann, Setiadi, and Fiedler 2015, 248).

Belief systems and ethnic aspects intertwine with socio-economic and political factors. The safety of housing styles may decrease with modernization as traditional housing on Bali, Palu and Nusa Tenggara Barat (Lombok) is more earthquake-resistance than modern constructions in line with building codes (Gusti Ayu Ketut Surtiari, personal communication, 1.11.2022). Nazaruddin (2022) highlights how people's perception of time itself has shifted under additional evolutions such as growth-oriented capitalism. While recurrent eruptions were part of life cycles when subsistence-oriented livelihoods prevailed ("normal – crisis (eruption) and back to normal"), the new livelihoods and accumulating wealth were inscribed in a linear perspective ("normal – crisis (eruption) – growth after the crisis – crisis (eruption) – more growth") (Nazaruddin 2022, 195). The eruptions had brought about settlement changes, a shift from corn culture to dairy cattle grazing on newly dense meadows and the possibility of disaster tourism, from which economic growth could be derived. Material factors influence decisions such as evacuation. Villagers living at the foothill of Mount Merapi may refuse to evacuate without traditional warnings, but also because their village had been spared during past eruptions and because they were afraid of abandoning their livestock (Donovan 2010, 124).

To conclude, the documentary "Land of the fire mountains: Indonesia" (Zweites Deutsches Fernsehen 2021) provides an evocative illustration of disaster*cultures and knowledge systems intermeshing with each other. In a Balinese village at the foothills of Mount Agung, where an eruption killed more than 1,000 people in 1963 and where about 140,000 people were preventively evacuated and the international airport closed in 2017, a volcanologist is posted to monitor the latest development. The volcano is also a holy place according to the Hindu religion, the eruptions are perceived as a work of God and accompanied by prayers. In the documentary, a priest sticks rice on the volcanologist's brow, symbolizing the gifts of nature, cleansing and protection. As the documentary voiceover states: "even the volcanologist believes in the power of prayer".

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Editor

Katastrophenforschungsstelle (KFS)
Freie Universität Berlin
FB Geowissenschaften
Carl-Heinrich-Becker-Weg 6-10
12165 Berlin

Title picture

The authors

Dr. Isabelle Desportes is a research fellow at the Disaster Research Unit, Freie Universität Berlin. She has worked on climate change and disaster governance for institutions ranging from the International Institute of Social Studies, Erasmus Universiteit Rotterdam, to the International Federation of the Red Cross Red Crescent and the Red Cross Red Crescent Climate Centre.

Wicak Wicaksono is a master's graduate from the Disaster Management program at the School of Environmental Sciences, Universitas Indonesia. As development practitioner, he works on projects related to disaster management, early warning systems and climate change adaptation.

Prof. Dr. Martin Voss is University Professor for Crisis and Disaster Research at the Institute of Geographical Sciences in the Department of Geosciences, Freie Universität Berlin, and Head of the Disaster Research Unit.

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Katastrophenforschungsstelle (KFS)
Freie Universität Berlin

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