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Politicising land subsidence in Jakarta: How land subsidence is the outcome of uneven sociospatial and socionatural processes of capitalist urbanization

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ABSTRACT

Jakarta is sinking dramatically because of land subsidence, which in turn increases its vulnerability to tidal flooding. The explanation of land subsidence's causes and the design of solutions is led by geoscientists and engineers, who tend to treat it as largely a technical problem. This paper takes issue with this. It sets out to contribute to politicizing land subsidence by analysing it as part of the sociospatial and socionatural transformations that characterize processes of urbanization. We propose an approach that allows showing how subsidence happens through urbanization's interconnected moments of horizontal concentration, vertical extension, and differentiation – the weight of the built environment, the expansion of deep groundwater wells, and the remaking of the city (and beyond). By investigating the sociospatial correlation between land subsidence and the development of buildings, and the temporal correlation between land subsidence and the increase of groundwater wells we illustrate how land subsidence is intrinsic to (post-) New Order capitalism (1965–1998 and 1998-now). We also show that it proceeds in uneven ways: those who cause subsidence are not the ones who suffer most from it. Through a serious treatment of soil–water dynamics, our socionatural theorization also helps appreciate how urbanization is always co-shaped by interactions between human and non-human processes.

1. The sinking city: politicising Jakarta's land subsidence

A new type of flooding is occurring in Jakarta: tidal flooding. It is a form of flooding that was first observed in November 2007, when sea tides hitting the northern part of Indonesia's capital city caused existing dikes to overflow. Sea water inundated the northern part of the city, leaving low income neighbourhoods flooded for almost a month. The flood also forced the closure of the highway connecting the city to its airport (Kompas 2007). According to hydrologists (Brinkman and Marco, 2009) the occurrence of higher tides for the period of 2005–2010 can be explained by this period's correspondence to the phase in which the moon orbits more closely around the earth, exerting a strong gravitational pull. Yet, while happening in cycles of 18.5 years, tidal floods had not previously caused the city to flood. The 2007 vulnerability of the city to tidal flooding was caused by land subsidence: the fact that the city was, and still is sinking below sea-level.

Land subsidence is increasing flood vulnerability not only in Jakarta, but also in many other coastal cities (Syvitski et al. 2009; Nicholls et al. 2021). This is why subsidence is a growing concern of policy makers, ever more often making its appearance on climate adaptation agendas. In Jakarta, the attempts of critical scholars to politicise the cause of this phenomenon largely follow the explanations of the biophysical process as given by geoscientists' and engineers' (see, van Voorst and Hellman (2015); Padawangi and Douglass (2015); Colven (2017); Wade (2018); Sheppard (2018); Saputra (2019)). Critical social scientists have shown how the issue of land subsidence is used to support the development of giant infrastructure (Octavianti and Charles 2018); how it is enmeshed within the uneven socionatural transformation of the city (Goh 2019); and how the "invisibility" of groundwater makes it difficult to assess its relation to subsidence (Colven 2020). We respect how these scholars seek to make sense of the causes of land subsidence, and seek to build on their analyses and join their political motivations. Yet we aspire to take existing critical analyses of land subsidence as a socionatural phenomenon one step further. We do this, first of all, by showing how

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groundwater in Jakarta, taken by Colven (2020, 17) as "invisible", is in fact multiple and plural. Waters under the ground of Jakarta's built environment are differentiated between the shallow and the deep, and this matters for how land subsidence occurs. We also open up the cause of land subsidence, summarized as "uncontrolled urban development" by Goh (2019, 251) by more specifically tracing how two widely accepted causes of land subsidence (the extraction of groundwater and the construction of building) are linked to the political-economic particularities of (post-) New Order Indonesia.

In fact, the on-going conversation about land subsidence in Jakarta among engineers and geoscientists revolves around identifying the relative importance of the two most important causes of land subsidence: the weight of buildings and the extraction of groundwater. The two are interrelated. The over-extraction of deep groundwater increases the 'compactability' of the soil, exacerbating the consolidating effect of the weight of buildings. In Jakarta, there is a clear divide between geoscientists and engineers who identify the weight of buildings as the primary cause (the Jakarta Mining Agency as quoted in Rukmana 2008; Ramdhan and Hutasoit 2008), and those who identify the extraction of groundwater as the leading cause of land subsidence (Abidin et al. 2001; Ministry of Public Works 2011; NCICD Master Plan 2014; Deltares 2016a). Proposals to stop or slow land subsidence tend to be limited to technocratic or infrastructural measures or calls for regulation (see, Nicholls et al. 2021). Therefore, although the explanations of engineers and geoscientists recognize urbanization or "urban development" as a cause of land subsidence (Abidin et al. 2011), they dedicate little effort to further understanding or specifying the type or moments of urbanization which are causing groundwater over-extraction and the development of ever more buildings. Instead, they seem to take "urban development" for granted.

In this article, we take issue with this. This is because leaving analyses and calculations of the causes of subsidence to 'the natural' or 'engineering' domains, considering these as separate and separable from the 'social' or 'human' domains is a distinct act of "technification (rendering technical)" (Joy et al. 2014, 7; Li 2007) contributing to the de-politicisation of floods and their management (Joy et al. 2014). Treating subsidence as a more or less naturally occurring phenomenon in need of a technical solution makes it difficult to recognize how it is part of and entangled with uneven processes of urbanization, with those who are most responsible for causing subsidence often not themselves being most vulnerable to the risks of flooding. With this line of argumentation, we subscribe to the desire articulated by Wang to thematise subterranean geopolitics (Wang 2020). Yet, our main aim in this article is not so much to further theorize the politics of the underground. Instead, we mobilize insights of critical geographers about 'the political (or social) of the natural and technical' (Joy et al. 2014; Swyngedouw 1996; Brenner and Schmid 2015) in order to further politicise explanations of land subsidence in Jakarta.

Our strategy for doing this is based on ontologically re-defining subsidence as a problem that is simultaneously technical, social and political. This is importantly inspired by the concept of socionature (Swyngedouw 1996). Joy et al. (2014, 9) explain how for water more generally, (re-)politicisation "implies understanding the complex social-environmental processes and socio-political relationships that constitute and surround" water. Joy et al. (2014) emphasize how doing this requires interdisciplinary approaches, and thus our effort to (re-)politicize subsidence in Jakarta consists of two interconnected and interdisciplinary moves. First, we insert land subsidence in sociospatial and socionatural theories of urbanization to explain how the sinking of soils in Jakarta is a distinct and specific part of (post-) New Order capitalism. Doing this shows how solving or dealing with subsidence necessarily entails asking questions about the form of capitalism and the processes of uneven urbanization it generates and relies on. Second, we critically engage with the knowledge (tools, maps) about subsidence as produced by engineers and geoscientists, both to open up their explanations and analyses for critical scrutiny and to help understand how processes of subsidence can be traced and linked to ongoing processes of uneven urbanization.

The premise of the first part of our analysis is that a city like Jakarta, as Harvey (2007, 5) puts it, is a "thing" that comes about through processes of "urbanization". We set out to show how land subsidence is intrinsic to such processes, with the phenomenon as well as current solutions to it being produced by and themselves productive of unevenness. Hence, our politicisation of Jakarta's land subsidence consists of explaining it as the product of particular entanglements between nature, urbanization, and a specific form of capitalism. To do this, we rely on historical data showing how the rate of Jakarta's land subsidence started to accelerate and become problematic from 1975 onwards (JICA 2017, 22), precisely with the advent of Indonesia's New Order regime (1967–1998) and beyond (1998-now), or (post-) New Order – a specific form of state capitalism consisting of a mixture of centralized social, political, and economic power led by general Suharto (Hiariej 2003). (Post-) New Order capitalism rested on and promoted urban agglomeration in and around the core of Jakarta (Kusno 2013).

The city of Jakarta is governed as a special capital region (DKI, *Daerah Khusus Ibukota*). Similar with the land subsidence which become problematic under the New Order regime, Jakarta's population, according to Batubara and Handriana (2021, 58) increased distinctly under the New Order regime. In 1930, Jakarta's population was 533,015. It increased to 2.9 million in 1961. In 31 years the population grew by 2.4 million. In 1990, Jakarta population was 8.2 million; which means in 29 years (from 1961), the population grew by 5.3 million. On the ground, it is difficult – and illogical – to separate the DKI itself from the urban agglomeration of Jabodetabek, whose name is taken from the initial letters of cities of Jakarta, Bogor, Depok, Tangerang and Bekasi. In 2010, the total population of Jabodetabek was around 28 million (Rukmana 2013). By systematically tracing how land subsidence is entangled with and part of this agglomerating process, we aspire to open up the broad category of 'the social' or "human activities" as figuring in many analyses of sinking delta cities around the world (Syvitski et al. 2009, 681). In particular, by showing how land subsidence is historically embedded in Jakarta's capitalist urbanization, we specify which processes and whose activities are to be held responsible for fundamentally transforming the city, its water and rocks.

Where the first part of our politicisation of land subsidence consists of opening up 'the social', the second part of it entails opening up 'the technical' (or 'the natural'). Our effort here resonates with an emerging stream of critical physical geography scholarship which calls for "unsettling" (Lave et al. 2014, 4) the monopoly of engineers and natural scientists in producing data about and explaining everything categorized as biophysical. Instead of treating subsidence as something that merely provides the 'natural' or 'biophysical' context to the unfolding of uneven urbanization, we aspire to instead treat the sinking of soils as a distinct form of "agency" (Bakker 2012, 621) co-shaping the form and direction of urbanization processes. Critically but seriously engaging with the knowledge produced by engineers and geoscientists about subsidence – their descriptions, model, predictions – is central to this effort. We note here how the acknowledgement of the agency of nature in creating land subsidence is in line with the expanded conception of capitalism proposed by some scholars (most notably Fraser 2014; Moore 2015), with land subsidence appearing as a manifestation of the 'natural' limits to Jakarta's capitalist growth-urbanization trajectory.

We narrate our story by engaging with Brenner and Schmid's (2015) three forms of urbanization (concentrated, extended, and differential) to identify-two mechanisms of urbanization: the horizontal concentration of the city, and the vertical expansion of groundwater wells as well as the unevenness in and through which they are entangled. To think through the (post-) New Order Indonesia while appreciating the agency of non-human nature, as well as to show how it is inseparable from the human nature in urbanization, we put Brenner and Schmid's (2015) sociospatial theory of urbanization in conversation with Swyngedouw's (1996) socionatural theory of urbanization.

2. Sociospatial and socionatural theories of urbanization

Our overall analysis takes inspiration from and makes use of sociospatial urbanization theory as developed by Brenner and Schmid (2015). Critiquing definitions of urbanization as consisting of the growth of cities, their "new epistemology of the urban" instead theorizes urbanization as the sociospatial processes through which the urban is produced under contemporary (1980′s onwards) capitalism. They distinguish three interrelated moments of urbanization. The first moment of Brenner and Schmid (2015)'s urbanization theory is concentrated urbanization, referring to the spatially coming together or clustering of the means of production and labor power. This type of spatial concentration, according to others (see: Marx (1982), 772–81; Smith (2008), 60–8; Harvey (2012), 3–66; Merrifield (2013), 74), makes the exploitation of surplus-value and surplus easier for capitalism. The second, extended urbanization, refers to how ever more people and resources outside of (or indeed under) the city are mobilized to make concentrated production within the city possible. And thirdly, differential urbanization is the uneven outcome of concentrated and extended urbanization together. It refers to the creative destruction of existing sociospatial arrangements to allow for the acquisition of new spaces that enable a new round of capital accumulation.

We mobilize this categorization in three moments of urbanization as a useful heuristic device to tell the different yet interconnected stories of land subsidence in Jakarta. A first story is about the subsidence caused by soil compaction, which happens as part of concentrated urbanization: the horizontal spatial growth of Jakarta, extending into the urban agglomeration of Jabodetabek. A second story is that of the subsidence caused by the increase in the number of groundwater wells. This form of subsidence happens as part of a vertical form of above- (Saitluanga 2017; Liong et al. 2020) and below-the-ground (Wang 2020) extended urbanization, needed to sustain above-the-ground processes of surplus extraction. Lefebvre (1991, 325) already pointed to the "underground" as part of the capitalist production of space. Extended urbanization in terms of water therefore does not just happen in a horizontal direction, by taking water from hinterlands that are spatially far from the city (Gandy 2002; Swyngedouw 2004; Kaika 2005; 2006), but it also happens vertically, or what Van Noorloos et al. (2019, 862) identified as "volumetric urbanism". Finally, the moment of differentiation relates to how incidences and rates of subsidence as well as solutions to it are distributed across the city and beyond. It also crucially entails identifying who are behind land conversions or the intensification of groundwater extraction, and showing how their actions are part of and produce deeply uneven social relations.

We complement Brenner and Schmidt's theoretical proposal with Swyngedouw's (1996) concept of socionature to allow better appreciating the role of non-humans – in our case complex soil–water dynamics – in co-causing land subsidence. Swyngedouw proposed the term socionature to remedy the tendency of Marxist analyses to prioritize the wage-labour process in explaining the production of surplus-value under capitalism. According to him, capitalist processes are also importantly shaped and marked by 'nature' or non-wage-labour (for example: care, land, water). To denote the inseparability of the social and the natural under capitalism, Swyngedouw and others mobilize the term socionatural transformation (Swyngedouw 1996; Heynen et al. 2006; Tzaninis et al. 2020). The terms socionature and socionatural transformations help make 'nature' integral to the analysis of the linkages between urbanization and land subsidence in a way that does not force nature back into a separate and separable ontological entity, one that remains outside of 'the political'. Rather than explaining 'natural' behaviours by referring to 'natural' qualities and 'social' behaviours by referring to 'social' qualities, the term socionature forces attention towards how the social and the natural always form 'hybrids'.

For us then, we see the specific political economic context of our analysis ((post-) New Order Indonesia) as also constituted and shaped by sociospatial and socionatural urbanization. As urbanization processes reconfigured spaces and human-nonhuman relations in (Kenichiro 2001; 2015) and beyond (Kusno 2013; Batubara et al. 2022) the city of Jakarta, the components, materials, actors and cronies (Leaf 2015) within the state capitalism (on the relation between state and capitalism see: Hiariej 2003; Sangadji 2021) of (post-) New Order Indonesia were shaped and emerged.

3. Methodology: operationalizing socionatures

How to translate and operationalize the theoretical insights explained above into a methodology that enables representing and understanding land subsidence as the outcome of deeply entangled social and natural processes? We decided to use engineering and geophysical maps of land subsidence as our empirical starting points. We used these maps to proceed in a step-by-step approach to establish the sociospatial correlation between land subsidence and the development of buildings as well as the temporal correlation between land subsidence and groundwater extractions. We then mobilized these correlations to trace the people behind the buildings (and groundwater extractions) that primarily cause subsidence, to see if and how subsidence relates to the particular operations of (post-) New Order capitalism in Jakarta.

As for the first, analysing how the growth of the built environment and land subsidence are sociospatially connected, we modelled Jakarta's land subsidence on the basis of published GPS-measurements. Provided by Abidin et al. (2008), these measurements were gathered through eight surveys of elevation from 26 locations over the period of 1997–2005. Abidin et al. (2008) calculate land subsidence rates by subtracting consecutive measurement data. For example, the total land subsidence in one particular location/station is calculated by subtracted the second (29–30 June 1999) from the first measurement (24–26 December 1997). Iteratively repeating this same process seven times, allowed them to come up with the difference between the second and first measurement, between the third (31 May – 3 June 2000) and second, etc. all the way to the difference between the eighth (21–25 September 2005) and the seventh measurement (21–26 December 2002). They published the outcomes of this exercise in the form of a table and separate maps (Table 2 and Figure 8 of Abidin et al. 2008, 27 and 29). We used this data set to map subsidence rates (as measured in cm/time) over 1997–2005, for each of the 26 stations. Using *ArcGIS* to digitize the station's locations (in Figure 3 of Abidin et al. 2008: 25), we then plotted the total elevation differences (land subsidence) in each station and interpolated the total land subsidence values to generate a contour map of land subsidence. Our intention behind this interpolation is to connect the different parts of the city that have similar total land subsidence values. The map represents these connections in different colours (map at Fig. 1). In this way, the map shows the spatial pattern of land subsidence.

To illustrate the link between this spatial map of land subsidence to ongoing processes of capitalist urbanization of the (post-) New Order regime, we used *OpenStreetMap* and *World Imagery* maps to connect differential rates of land subsidence with the spatial growth of buildings within the city. Here, we took land conversions and the development of the built urban environment as manifestations of capitalist urbanization. We draw on existing data sets – historical data from secondary sources and news articles (Fig. 2) – that show that it is primarily members of the New Order regime network of crony capitalists who built on hydrologically sensitive lands. They are, thereby, identifiable as the causers of land subsidence.

The second component of our methodological puzzle was to link land subsidence to aquifer depletion. We did this by tracing the temporal correlation between groundwater extraction and the New Order regime. We identified how the total registered number of groundwater wells increased under the New Order regime, making use of secondary material. Kagabu et al.'s (2012) graph of 1879–2007 registered groundwater wells in Jakarta allows identifying the number of registered groundwater wells under the New Order regime. Since Kagabu et al.'s

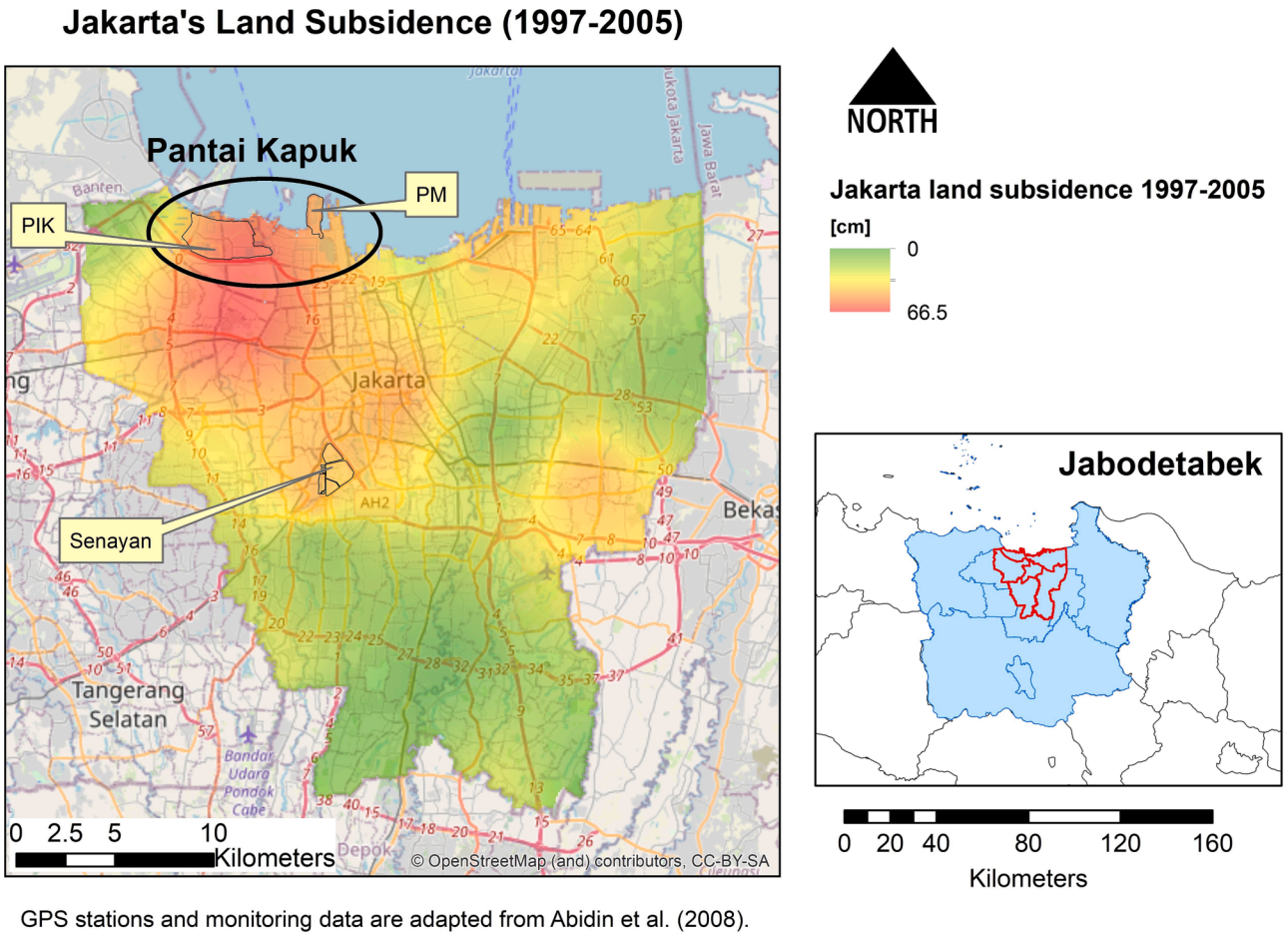

Fig. 1. Jakarta's land subsidence (1997–2005).

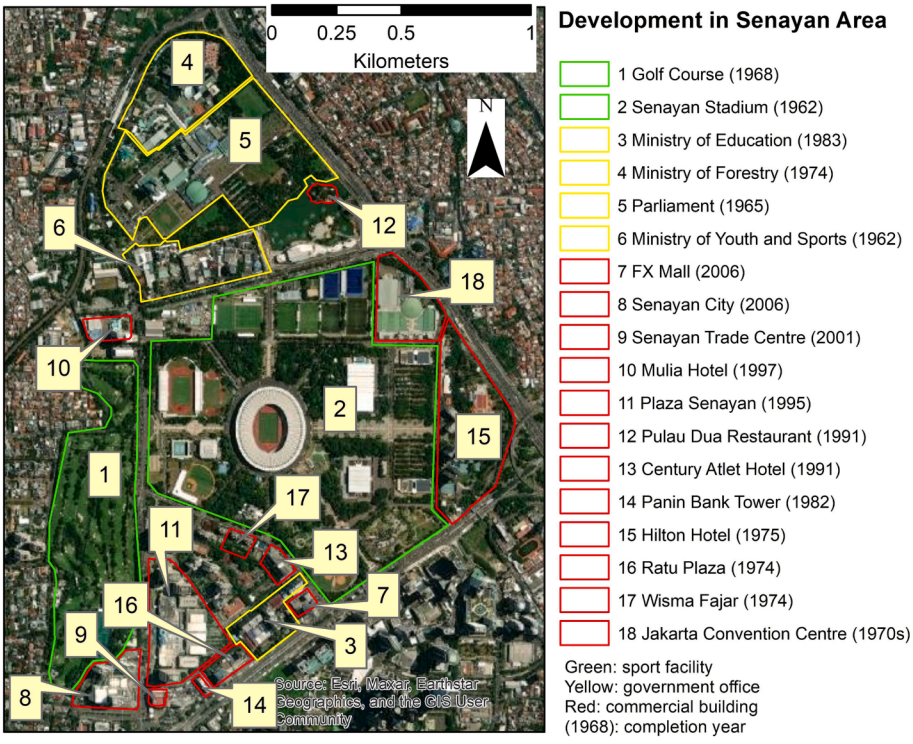

Fig. 2. Development in Senayan area.

(2012) graph does not publish the exact number of wells, we extracted it by means of *getdata-graph-digitizer* software.[2]

We compare deep and shallow groundwater in terms of the extracted volume, cost of making, total number of wells, and how they cause land subsidence to understand vertical unevenness. Here, we make use of data produced by the DKI Jakarta Water Agency about the volume of extracted shallow and deep groundwater. The official data notoriously under-report actual extracted volumes of water, as they ignore the myriad of unregistered wells in Jakarta. We therefore compared the government's data to estimates made by non-governmental organizations. We also compared the costs of making deep groundwater wells – with data obtained from secondary sources and through interviews with a well driller from our on-going research in Semarang, the capital of Central Java Province – with that of constructing shallow groundwater wells – with data obtained through interviews with shallow groundwater users. We interviewed Jakarta based engineers about the total number of groundwater wells in the city, and discussed problems in monitoring groundwater extraction with them. In addition, we used geological reports and publications to understand how the specific characteristics of Jakarta's soils and aquifers co-shape patterns and rates of land subsidence.

4 Weight. of the built environment: concentrated capitalist urbanization

Tracing those who were behind the conversion of hydrologically sensitive areas (green and blue belt) into large scale commercial land development is a first way to illustrate the connection between (post-) New Order capitalism and subsidence. Jakarta's 1985–2005 Spatial Plan clearly marks specific land areas as critical for water retention and catchment, therefore delineating them as protected areas. The implication is that these are areas should not be used for real estate development. Yet, Rukmana (2015) documents how around 4,000 ha of land in these hydrologically sensitive areas were used for the development of supermarkets, luxurious settlements, hotels, apartments, malls, schools, and hospitals. We zoom in on two specific locations in our attempt to follow the relative north–south spatial distribution of land subsidence in our map (Fig. 1) and to capture the details of how buildings in these areas came about, focusing on how they are linked to the workings of the (post-) New Order regime: the Pantai Kapuk (PK, circled in map at Fig. 1) development in the north-west part of the city and the Senayan development in the city centre.

The PK in northwest Jakarta, within which the Pantai Indah Kapuk (PIK) development now stands, used to be a mangrove forest (Padawangi 2008, 52). The forest provided a water retention area, able to retain up to 16 million m^3 of water (Majalah Tempo 2007, 108-109). In the early 1990 s, this area was transformed into Pantai Indah Kapuk (PIK), consisting of a golf course (76.2 ha), sport and recreation facilities (20.43 ha), a park (86.5 ha), housing (368.34 ha), industrial warehousing (17.48 ha), a business area (88.18 ha), and others (57.5 ha) (Kompas 1993). To make this possible more than 700 ha of the mangrove forest had to be drained and filled. The main figure behind this conversion was the renowned Chinese-Indonesian property developer Ciputra (Leaf 2015), who is closely linked to Sudono Salim, the right hand of New Order leader, Suharto (Robison 2009 [1986], 271–322; Borsuk & Chng 2014). Still at the PK, to the east of PIK, one finds the Pantai Mutiara (PM) luxury residential areas, covering 110 ha (Properti.kompas.com, 2010). This land was developed in the 1990s through land reclamation. In this case, property development was led by Intiland, a company owned by Suhargo Gondokusumo, a member of Yayasan Prasetiya Mulya (Kompas 1993a), a foundation led by Sudono Salim (Aditjondro 2006, 201-202; Borsuk and Chng 2014, 240-247). Both developers, Ciputra and Suhargo Gondokusumo, and their guru, Sudono Salim, are at the core of Suharto's New Order capitalism (Hiariej 2003, 64).

The relations between these two developments and land subsidence is similar: the weight of the new buildings caused the compaction of the alluvial soils. Our land subsidence map (Fig. 1) indeed clearly illustrates that the areas of PIK and PM sunk around 60 cm and 50 cm respectively (land subsidence values and the total sinking between 1997 and 2005 are taken at the centre of polygons). We conclude that this form of land subsidence is the product of and integral to a horizontal form of concentrated urbanization of the (post-) New Order. This is not just a sociospatial process, but also a socionatural one in how it irreversibly transforms the density of the soil, making it sink and changing its water retention capacities.

Moving now to the second area (Fig. 2) in the city centre, the Senayan development. In 1962, in the early days of Indonesia's independence this area of 279 ha was protected from development through its designation as a national heritage site. This is why the group with most legitimate claims to be Jakarta's native population, the Betawi, who lived in this area were forcefully evicted (Yuliastuti 2015, 44-5; Ahmady et al. 2010, 129). The area both had a recreational function by serving as a sporting area, and an ecological function: the huge green area helped intercept and absorb rainwater. However, following the change in the political regime from the nationalist-left of Sukarno to the pro-capital New Order Suharto in 1965, land in the greenbelt was slowly converted into commercial real estate. At present, only 40 ha of green area are remaining.

Many developments in Senayan area (Fig. 2) can be directly traced to New Order regime crony capitalists. The iconic superblock of the Hilton Hotel and the Jakarta Convention Center were for instance developed in the 1970′s by PT Indobuildco. This is a company owned by Ibnu Sutowo (Kompas 1974; 1992; 2007), a former army general appointed by Suharto as the director of Pertamina, the state-owned oil company that funded the army during the early phase of New Order consolidation (Crouch (2007)1978, 275). The superblock of Plaza Senayan was developed in the 1990′s by PT. Aditya Wirabakti, the joint company of Suharto's fourth daughter, Titi Prabowo and her brother in-law Hashim Djojohadikusumo (Kompas 1995). Members of the Suharto family, namely his third son Bambang Trihatmojo, also figured in the development of the adjacent Mulia hotel in 1997 (Kompas 1998; Yuliastuti 2015). Not only did the Mulia Hotel violate the horizontal spatial regulations of the city by building on a cultural heritage site and green space, it also violated the vertical regulations, with its building height far exceeding permissions (Kompas 1997). Also here, the relation between new real estate development and subsidence is undeniable: our map (Fig. 1) shows that the Senayan area has sunk around 44 cm.

These two stories provide an important empirical foundation for our suggestion that explaining Jakarta's land subsidence requires going beyond geology. Although understanding it does entail a serious engagement with engineering and geoscientific data, to understand why subsidence occurs such data need to be complemented with, and inserted into, a critical understanding of processes of urbanization. Doing this reveals how subsidence is a specific manifestation of a form of capitalist urbanisation that is highly uneven. The case of the Senayan city centre is a particularly stark illustration of how subsidence is deeply political: first, native people living in this area were evicted to make place for green and blue lands, only to later allow members of the network of New Order crony capitalists to appropriate it for commercial developments. The increased weight eventually caused the compaction and sinking of the soil.

It is important to emphasize that land conversions in the north-west and centre of the city do not just consist of sociospatial, but also of socionatural or socioecological transformations, in which soils and waters interact in specific ways with human interventions to co-determine the character and direction of urbanization. This happens in three different but interrelated ways. First, more buildings reduce the soil's

[2] The software is available at: https://getdata-graph-digitizer.com/download.php; (accessed: February 5th, 2018).

water absorption capacity, thereby also reducing water stored in the ground. This in turn, empties the pores of some strata of underground rock formations, making them more vulnerable to compaction and subsidence. Second, their weight together with, third, the extraction of groundwater from the contained aquifer, both lead to further compaction and subsidence. In the following section we examine in more detail how the extraction of groundwater from the contained aquifer can be temporally traced to the workings of (post-) New Order capitalist urbanization, and is useful to further understand the materiality of the non-human in the uneven production of land subsidence.

5. Extraction of groundwater: extended capitalist urbanization

The extraction of groundwater from the contained aquifer below Jakarta is the second significant cause of subsidence, and therefore a second important way in which sociospatial processes of urbanization are simultaneously socionatural. Biophysically, the hollowing out of the aquifer that happens when removing water increases its 'compactability' (Ramdhan and Hutasoit 2008). In what follows, we describe examples of groundwater extraction and soil compaction processes as a specific vertical form of extended capitalist urbanization. In doing this, we once again highlight that the relation between the extraction of groundwater and subsidence illustrates the distinctly socionatural character of urbanization. First, available quantities of groundwater change through the development of the built environment because of how buildings reduce recharge and the soil's water retention and absorption capacity. Second, also the biochemical properties of groundwater change because of how industrial and domestic wastewater and runoff negatively affects groundwater quality, increasing the amount of contaminants (Martosuparno et al., 2014). Reversely, humans are affected – importantly in terms of health – by changes in groundwater's physical, biophysical, and biochemical properties. In Jakarta, 60 % of the population are not connected to the piped water network of the private sector concession operating the city's water supply, and the majority of them rely on groundwater for daily use (Furlong and Kooy 2017; Hidayat and Lin 2018).

A second and more indirect way in which society co-evolves with nature has to do with the tension between the difficulty to monitor extraction rates and the ease of extraction. Hydrogeologists have long tried to model Jakarta's aquifer (see, Deltares 2016a for a review), with the objective of using the model as a tool for better monitoring extraction and governing groundwater. However modelled representations so far inherently fail to accurately capture the complexities of reality. The most widely accepted model (Fachri et al. 2002) divides the approximately 250 m of sedimentary deposit of the aquifer into 4 layers: from the depth of 0–40 m is the shallow uncontained aquifer; 40–140 m is the thick aquitard (aquifer with low water content); 140–230 m the second layer of contained aquifer, and; for the depth of more than 230 m another layer of aquitard. Yet, this representation of aquifer layers ill captures spatial variations across the city. There are for instance places where there are no discrete layers, but rather "intercalated" small sand "lenses", making it "almost impossible to trace specific clay or sand layers" (Deltares 2016a, Deltares 2016b, 12).

In contrast to the difficulties of modelling and knowing the aquifer characteristics, the extraction of groundwater is relatively easy for those with the capital to afford pumping technology and energy costs. This ease of extraction has led to an increase in groundwater use (Kagabu et al. 2012, 5), particularly since the New Order. In 1879 there were only 42 groundwater wells in Jakarta, while there were 352 in 1968. Hence, in 89 years the number of groundwater wells grew with 310, or 8.3 times. The number of registered groundwater wells increased even more sharply (10 times) during the 30 years period of the New Order regime, from 352 in the 1968 into 3,626 in the 1998 (Kagabu et al. 2012, 5). Kagabu et al. (2012) do not specify whether the counted registered wells are deep or shallow wells. After the New Order regime, between 1998 and 2016 the reported increase in registered wells is smaller, amounting to a total of 4,551 registered wells. Of these, 1,945 are shallow wells with an annual extraction of around 1.2 million cubic meter and 2,606 are deep wells with much higher extracted volumes of around 5.9 million cubic meter of groundwater annually (DKI Jakarta Water Resources Agency/WRA 2017, unpublished data). Deep groundwater wells extract five times more than shallow groundwater wells. The small increase in terms of the total number of groundwater wells after the New Order regime, however, is not likely to be caused by a reduction in the number of people starting to drill wells. It is more likely to be explained by the fact that owners simply did not register their wells, to avoid paying tax, and avoid the setting of volumetric limits to extraction[3] (see also Wahyono and Wardiat (2012)). An engineer working at the DKI Jakarta Industry and Energy Agency estimates the total number of wells in the city to be at least 15,000![4]

Given the high number of unregistered wells, it is almost impossible to accurately measure the total volume of water extracted from the contained aquifer. Based on 2016 registered wells data, the government reported that the groundwater extracted by both deep and shallow wells was 7.1 million m^3 (DKI Jakarta WRA 2017, unpublished data). This is bound to be a massive under-estimation. Research conducted by civil society groups calculated the total water needs of the city and compared this with the volume provided through centralized piped supply. Based on this calculation, they came to an estimated annual volume of groundwater extraction of 548.2 million cubic metre (Tifa and Amrta Institute (2013)).

This groundwater extraction is vertically uneven, which is related to the cost of making a well. Extracting deep groundwater (from $>$ 40 m depths) requires a lot more money than extracting shallow groundwater ($<$40 m). In Jakarta, deep well development can cost a billion of Indonesian Rupiah/IDR (see Hidayat and Lin 2018).[5] Development of a shallow groundwater well, meanwhile, costs only around IDR 1.5 million.[6]

Unsurprisingly, those primarily responsible for extracting cleaner deep groundwater from the contained aquifer are industries, as well as those belonging to the political and social elite. Prominent deep groundwater users are factories, government-offices, foreign embassies (Malaysia, Netherlands, Switzerland, Poland, England, and Saudi Arabia), and the houses of elites such as that of the 1998–9 President of Indonesia, B.J. Habiebie (Indonesia's Corruption Eradication Commission/KPK 2017, unpublished data) and that of the 2017–8 DKI Jakarta deputy governor (Sandiaga Uno), who ran as a candidate for vice president in the 2019 presidential election (The Jakarta Post 2018), and is now appointed as the Minister of Tourism and Creative Economy (2020-now). In addition, the vast majority of the new real estate development discussed in the previous section rely on groundwater that is pumped up from the deep aquifer through privately paid for infrastructure (Rusdiyanto and Pratomo 2007; JICA 2017, 47). In contrast, Jakarta's urban poor residents rely primarily on the more contaminated shallow groundwater.

[3] Interview with DKI Jakarta Industry and Energy Agency (June 5th, 2017).

[4] This estimate is based on the total number of buildings in the city. It's a common practice in Jakarta, even though a building has connection to piped water network, people still drill their own wells (JICA 2017, 47; KPK 2017, unpublished data) to anticipate if the flow in the pipes is down.

[5] Hidayat and Lin (2020) interviewed an engineer who mentioned the cost of making recharge deep wells to inject water into deep aquifer. We predict the cost of developing deep groundwater wells to pump water out from aquifer is not so much different. As a matter of comparison, in Yogyakarta, a city in the central part of Java, the cost of making a deep groundwater well is about IDR 400–500 million (Amrta Institute 2017, 2); in Semarang, the capital of Central Java Province, the cost of making a deep groundwater well is about IDR 200 million (interview with a deep groundwater driller in Semarang, 12 and 13/8/2019).

[6] Interview with user in Jakarta's urban poor settlement of Bukit Duri, September 2016.

As discussed and shown, there is a direct temporal relation between groundwater extraction and land subsidence: both increased under the New Order period. Yet, subsidence is caused by more-than-human factors; also rock and geological characteristics come into play. The rock in the northern part of the city has the highest percentage of sand vs clay, which means that the sub-surface water storage capacity here is larger (Deltares 2016a, 8-14). When groundwater continues to be sucked out, it is these sand layers (or lenses) that will be compacted the most. Hence, the distinct material characteristics of nature – here the composition of the rock, the distribution of sand layers, and the resulting water storage capacities – importantly co-determine the pattern and rate of land subsidence.

Groundwater is over-extracted from the deep aquifer when the rate of extraction exceeds that of recharge. This is how the deep aquifer in the northern part of Jakarta has been transformed, from an area of "seepage" in 1900 into a "sink" in 1992: water which used to flow upwards, from the deepest layer of the aquifer to the top, now flows downwards, from the shallow uncontained layer to the bottom (Deltares 2016a). The technical meaning of this is that the deep aquifer is hollowed-out, and compacted. We already discussed that those primarily responsible for doing this are those who are able to invest large amounts of money in the drilling of deep wells to obtain access to cleaner water. The shallow groundwater wells, used by the urban poor, extract less clean water and do not have as big an impact on compaction and subsidence. New models of the aquifer flow system predict that stopping land subsidence will require another 10–25 years after – if – extraction of groundwater is completely stopped, immediately.[7]

6. Conclusion/discussion: re-imagining more sustainable and just ways

In this paper we contribute to the politicisation of land subsidence, emphasizing that it should be considered as a more-than-natural phenomenon. We show why it is dangerous to leave the analysis of and the design of solutions for land subsidence to engineers and geo-scientists, as this renders invisible both the processes of urbanization causing it, and the individuals benefiting from these processes. Our proposal to politicize land subsidence uses the case of Jakarta to show how subsidence can be interpreted as intrinsic to a particular form of urbanization consisting of intertwined sociospatial and socionatural transformations. Interactions between land conversions, the development of buildings and deep groundwater extraction made possible by the combined works of political economic relations of the (post-) New Order regime network of crony capitalists on the one hand and hydro(geo)logical processes on the other are effectively destroying the city of Jakarta and its subterranean space, producing water-related risks both above and below ground. Those primarily responsible for causing this destruction remain systematically less vulnerable to these risks than Jakarta's urban poor (as we show through the case of flooded low income neighbourhood at the opening section), even when plans to tackle subsidence often entail their re-location.

We have argued and shown that subsidence is 'more-than-natural', but at the same time we also emphasize that it is 'more-than-social' (or political). This latter argument stems from our concern that critical analyses which implicitly go along with and accept engineers' and geoscientists' explanations about the causes of land subsidence by treating it as consisting of primarily 'natural' or 'biophysical processes'. The effect of this is that land subsidence figures either as the 'background', appears as an 'elsewhere' or 'context', or is theorized in terms of resources of limited supply. This makes it difficult to recognize how nature itself (re-)acts and behaves, and of how processes of capitalist urbanization are shaped by continued interactions and entanglements between the 'natural' and the 'social'. Our theorization of land subsidence as a socionatural process in which the continuous interactions between humans and non-humans are treated as internal to capitalist urbanization allow making visible how also nature – in our case the behaviour of 'underground' rocks and waters (the 'sand vs clay' composition, the spatial distribution of aquifer layers, the relative 'compactability' of soils when water is taken out and when they are under heavy weight, the relative reduction in water percolation rates when soils are compacted) – co-shapes patterns and rates of land subsidence.

We operationalized our theorization by developing a methodology for tracing and mapping the connections between processes of land subsidence and human behaviours, in our case focusing particularly on the actions and investments of members of the (post-) New Order crony capitalist network. We collected, re-arranged, re-interpreted and visualized existing data on subsidence, combining this with data on land conversions, which we could link to particular investors and members of Jakarta's political and economic elite. We showed the sociospatial reconfigurations that happened by clearing protected green areas from its former inhabitants to make place for New Order capitalist cronies, and traced how this land conversion not only deteriorated the land's water retention and absorption capacities, but the weight of the new buildings developed also irreversibly compacted the soil. Reliance on extracting water from ever deeper layers of the aquifer to provide clean water to the users of these new edifices, increased the soil's 'compactability' and causing it to sink even further. Identifying how subsidence is caused by particular processes, and individuals within the processes, allows for its politicization. Making actors and decisions visible makes it then possible to hold them accountable for Jakarta's increased vulnerability to floods that is the effect of subsidence, instead of blaming residents of urban poor settlements.

While land subsidence can be interpreted as posing one of the limits to Jakarta's capitalist growth-urbanization trajectory, the currently favoured solution to subsidence – the re-location of the capital city to Kalimantan/Borneo Island, announced by the President in 2019 – is one that will only allow capital accumulation to further accelerate, producing yet another round of uneven sociospatial and socionatural transformations. The total cost of moving the capital is of IDR 466 trillion (almost 30 billion Euro), involving around 254,142 ha of land (this is according to the newly enacted law on the relocation of capital, Law number 3/2022) that will be 'developed' mainly by the non-state investors. Hence, one again the property developers and land concession holders are the ones who stand to benefit most, at the expense of the communities who currently live where this new capital will be erected (Johansyah et al. 2019).

In this way, these new plans only serve to underscore our main message: it is dangerous to treat floods and land subsidence as primarily technical problems and follow analyses or the design of solutions proposed by geoscientists and engineers. Rather than solving, techno-managerial solutions will only intensify the uneven socionatural problems, or in Kaika's words (2017, 98), such solutions only work to make people and environment "able to take larger doses of inequality and environmental degradation in the future". Just like the plan to relocate the capital, proposed solutions such as the construction of giant flood protection infrastructures (see, Colven (2017)) or deep artificial recharging wells will further strengthen capitalist urbanization and its protagonists – causing further socioecological damage and injustice in the process.

Our analysis instead points to the critical importance of questioning the very logic of capitalist urbanization that makes deeply uneven sociospatial and socionatural transformations appear as 'progress'. Questioning, and redressing processes of capitalist urbanization, and therefore land subsidence, include taking action against deep groundwater extraction. For practical solutions, the government can begin to investigate the depth and volumetric extraction of deep groundwater wells, as well as push for the expansion of piped water network coverage

[7] Engineer's presentation at *Knowledge Stakeholder Open Workshop* at Ministry of Public of Work office, Jakarta (June 7th, 2017).

managed by the privatized city's water company. Since its privatization in 1998, the centralized water network distribution system has not been expanded to cover more areas/residents of the city (Ardhianie, 2021), while the private companies who own the water concession are generating a huge profit (Lako and Ardhianie, 2012; Karunananthan, 2021). Rather than glorifying members of powerful political and economic elites who are responsible for causing these transformations as heroes of progress, a more political socionatural analysis of subsidence can help hold them accountable for their damage, and serve as the basis for re-imagining societal dealings with land and water in more sustainable and just ways.

CRediT authorship contribution statement

Bosman Batubara: Conceptualization, Methodology, Data curation, Investigation, Validation, Formal analysis, Project administration, Funding acquisition, Visualization, Writing – original draft, Writing – review & editing. **Michelle Kooy:** Supervision, Writing – review & editing, Funding acquisition, Project administration. **Margreet Zwarteveen:** Supervision, Funding acquisition, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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