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The Political Ecology of Groundwater Mining in Yemen

Eingereicht von Robin Dach

Gutachter: Prof. Dr. Jonas Østergaard Nielsen

Prof. Dr. Dieter Gerten

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Abstract

Taking the critical lens of political ecology, this thesis seeks to trace the transformation of hydro-social relations that has culminated in today's 'groundwater crisis' in Yemen. Following an in-depth literature review focusing on water-society relations in rural areas with special regards to irrigated agriculture, it will be outlined how rapid technological and political-economic changes have increasingly undermined local water-management-regimes without leaving a tenable alternative behind. Particularly, it will be argued that these hydro-social changes are intimately related to the unchecked proliferation of deep well technology and the commercialization and expansion of agricultural production, and more broadly to internal political processes and tensions associated with the growth of the fragile and largely patronage-based central state, alongside the persistence and struggles of traditional tribal structures and hierarchies. In this context, a virtually fully deregulated, competitive, and increasingly exclusionary 'groundwater-extraction-regime' has emerged and perpetuated in the absence of viable or effective policy responses, with runaway groundwater depletion, resource capture, and the widespread deprivation of access arguably representing the most salient issues.

Keywords: Political ecology, hydro-social cycle, water scarcity, Yemen

Kurzfassung

Unter dem kritischen Blickwinkel der Politischen Ökologie versucht diese Arbeit die Transformation hydro-sozialer Beziehungen nachzuzeichnen, die die seit mehreren Jahrzehnten andauernde ‚Grundwasserkrise' im Jemen konstituieren. Im Zuge einer ausführlichen Literaturrecherche über Wasser-Gesellschafts-Verhältnisse im ländlichen Jemen - mit besonderem Augenmerk auf die Bewässerungslandwirtschaft - wird aufgezeigt, wie rasante technologische und politisch-ökonomische Veränderungen etablierte lokale Wasser-Management-Regime zunehmend untergraben haben, ohne dass eine vertretbare Alternative zurückgeblieben ist. Insbesondere wird dargelegt, wie diese Veränderungen eng mit der unkontrollierten Verbreitung der Tiefbrunnen-Technologie und der Kommerzialisierung und Ausweitung der landwirtschaftlichen Produktion zusammenhängen. Im weiteren Sinne wird außerdem ausgeführt, wie politische Restrukturierungsprozesse im Spannungsfeld zwischen der Entstehung des schwachen und weitgehend klientilistischen Zentralstaates und dem Fortbestehen traditioneller Stammesstrukturen und Hierarchien auf hydro-soziale Verhältnisse eingewirkt haben. Dabei hat sich insgesamt ein praktisch vollständig dereguliertes, wettbewerbsorientiertes und

zunehmend ausgrenzendes ‚Grundwasser-Extraktions-Regime' herausgebildet, das sich in Ermangelung praktikabler bzw. wirksamer politischer Maßnahmen fortsetzt, wobei die fortschreitende Erschöpfung des Grundwassers, die Vereinnahmung von Wasserressourcen und ausgeprägte Zugangs- und Verteilungskonflikte die wohl hervorstechendsten Problematiken darstellen.

Stichwörter: Politische Ökologie, hydro-sozialer Kreislauf, Wasserknappheit, Jemen

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1 Introduction

Yemen, once known for its elaborate systems of water management and irrigated agriculture, is facing a severe water crisis that has unfolded since the 1970s. In many parts of the country, runaway groundwater 'mining' has been overexploiting aquifers over decades, provoking severe declines in water levels, adverse alterations of local and regional water regimes, and related to that, a multitude of health, livelihood, and social issues including water and food insecurity, the spread of water-borne diseases, distributional conflicts, and the impoverishment and marginalization of large tracts of the rural peasant population (cf. Ward et al. 2007, Moore 2011, Ward 2015, Weiss 2015, Varisco 2019). Although Yemen is characterized by a largely arid to semi-arid climate, with a relatively low endowment of water resources, current problems related to water insecurity are unprecedented: the majority of the population (~70%) lacks basic access, and there are increasing cases of farmlands and entire villages being abandoned due to aquifer exhaustion (Lackner 2017: Ch. 8, World Bank 2021). In response to the exacerbating issues, a national water law was enacted in 2002, along with government institutions and broader policies to ensure sustainable water management. However, "[…] although institutions are in place, they are far from having a real impact on the problems" (Ward 2015: xxxiii). As Climate change is (so far) considered a rather marginal factor in the past and ongoing dwindling of (ground-)water resources and widespread deprivation of access, special attention needs to be paid to the role of human agency and the societal governance and management of water (Haidera et al. 2011). In this way, this thesis seeks to address the social, political, and economic circumstances of hydrological change in Yemen from a historical and critical perspective, focusing on rural areas and irrigated agriculture, which amounts with approximately 90% to the vast majority of total water use today (Ward 2009). Following an extensive literature review, three interrelated research interests will be centrally explored:

- the social causes and consequences of groundwater mining;
- the politics of access and distribution;
- the linkages between changing forms of water governance, political rule, and impeded groundwater use reform.

This thesis departs from the premise that the predominant technoscientific and seemingly apolitical accounts of 'water scarcity', which tend to reduce the issue to an aggregated mismatch between population growth, increased consumption, and the absolute physical availability of

water (e.g., Vörösmarty et al. 2000), are overly simplistic to grasp the actual realities through which instances of water scarcity are *hydro-socially* produced and experienced. Drawing on the critical analytical lens of political ecology, it will be argued that such accounts, while undeniably important, give short shrift to the political forces and inner workings of society, which determine, in conjunction with hydrological processes, *how*, *why*, and *for whom* water becomes scarce or abundant (Swyngedouw 2004, Budds 2008). In doing so, this work tries to contribute to the growing literature of critical interdisciplinary water research, which may gain important and much more nuanced insights into the multifaceted and deeply political nature of hydro-social change (Linton 2014, Karpouzoglou & Vij 2017).

In the second part of the thesis, the political ecology of groundwater mining in Yemen will be sketched out, analyzed, and discussed. Chapter 3 briefly introduces the study background and research area in terms of its physical hydro-geography as well as the broader historical and political landscape in which rampant groundwater exploitation has unfolded. The subsequent Chapter 4, forming the main body of this thesis, critically investigates the emerging 'groundwater-extraction-regime' in the context of rapid technological, agrarian, and political-economic change.

The first section starts by outlining traditional water-society relations in rural Yemen before the diffusion of deep well technology. Unlike today, the geographic and ethnographic literature indicates the ingenuity of these agricultural water-management-regimes, comprising sophisticated material structures (e.g., terrace farming) and specific rules of common property. Together, these techno-social systems could arguably organize a largely sustainable use and relatively fair management of Yemen's limited water resources throughout history (cf. Varisco 1983a, 1996, Harrower 2009). Starting with the 1970s, these arrangements have steadily unraveled and shifted towards rampant groundwater exploitation, with nonrenewable fossil groundwater increasingly being tapped, alongside fundamental changes within the modes of access to, control over, and distribution of, water.

Subsequently, section 4.2. explores the onset and middle stages of these comprehensive hydro-social transformations, drawing on several case studies and general literature. First, the role of deep well technology diffusion is considered in the context of existing water management institutions at the local level, the latter of which did not anticipate the issues associated with this major technological change. The next subsection deals with the agricultural policies adopted by the emerging central state (under donor support) from the 1970s on, which have

provided sustained economic pressures for the rapid commercialization and expansion of groundwater-irrigated agriculture. In the following section, the focus is set on the peculiar political economy surrounding groundwater-fed agriculture in Yemen. It outlines the power relations and hydro-social disparities that have emerged from the historically and socially uneven distribution of the costs and benefits associated with groundwater overuse, related to the rapid commercialization of agriculture, the privatization of land and associated groundwater management as well as patronage-based state formation processes. Finally, territorial conflicts between tribes and the central state are examined, and it is shown how these tensions have been reflected in mutual pressures for fostering land- and groundwater development as a means of claiming territorial power.

Section 4.3 looks at the water crisis from a more recent perspective and outlines the overall failure of the Yemeni government to efficiently curb aquifer mining, despite the introduction of formal institutions for sustainable water management. This subchapter broadly looks at the political ecology of groundwater conservation, elaborating the role of the state, the power relations among specific actors fostering or frustrating groundwater use reform as well as the constraints entailed by pervasive corruption and legal pluralism.

Taking into account the theories and findings presented in the previous chapters, Chapter 5 summarizes, discusses, and contextualizes these points. Finally, the thesis outlines important research gaps and elaborates an overall outlook towards positive socio-ecological change in terms of sustainability and equity. Thereby, burgeoning collective action and political movements at the local level are identified as crucial for initiating sustainable trajectories out of this complex and politicized *hydro-social* crisis.

2 Theoretical Frameworks

> One could describe much of political ecology work as analyses of society-environment relations, contextualized by history and place, with a particular emphasis on environmental and social justice implications of broader political-economic change (Turner 2009: 182).

2.1 Political Ecology

Political ecology studies the relationship between society and nature in the context of power and political action (cf. Bryant & Bailey 1997, Peets & Watts 2004, Robbins 2012, Perreault, et al. & 2015). It is an interdisciplinary and critical research tradition, particularly influenced by geography, anthropology, and critical development studies. Originating in the 1970s through the merging of cultural ecology with a Marxist-oriented political economy in the context of rising concerns for the effects of global market economies on local socio-environments, the field has since developed diversely and rapidly (Blaser & Escobar 2015). As it draws on a range of empirical topics, critical theories, and epistemological perspectives, it largely defies a concise definition. In an attempt to link research with action, scholars widely share a commitment to notions of social-ecological justice, with a focus on the most marginalized social groups and especially rural places of the global South (Perreault et al. 2015).

But why is political ecology important? What are its benefits for understanding environmental issues compared to other theories? Firstly, in origin and today, political ecology is against "apolitical ecologies" (Robbins 2012). It opposes the simplified and generalist narratives of environmental crises, largely informed by the natural sciences, which 'naturalize' ecological degradation (e.g., deforestation, soil erosion, water depletion) and associated resource scarcity by conceiving them as the rather self-evident outcome of a bundle of commensurable and proximate variables such as population rise, increasing consumption, and the absolute scarcity (or regeneration capacity) of natural resources (ibid.). Similarly, social responsibility for environmental harm is often attributed to either humanity as an undifferentiated whole (e.g., Rockström et al. 2009) or 'poor', 'backward', and rapidly multiplying local people, performing 'inadequate' and 'inefficient' land-use practices (e.g., Ehrlich 1968). However, fundamental (and politically tractable) issues such as the intersection of social and environmental inequalities or the serious extent of resource maldistribution at various scales are hardly addressed. These points, however, suggest a far more nuanced consideration of the social dimensions of environmental change, which may be configured by a variety of political actors, vested interests, competing discourses, and contested decisions, alongside socio-economic

struggles and interdependencies at spatial and temporal scales that extend far beyond the present and the local level at which environmental harm occurs (Budds 2008). Therefore, although rendered objective, apolitical ecologies oversimplify the 'social side' of the nature-society-nexus by drawing on various forms of neo-Malthusian thinking (Robbins 2012: 14). As a result, apolitical ecologies are actually thoroughly political since they actively 'depoliticize' environmental problems while holding 'technocratic' and therefore implicitly normative positions (Castree & Braun 2001: 3). Little effort is made to understand more accurately the specific and multiscale historical-geographic, social, and political-economic contexts in which local forms of environmental mismanagement as well as socio-ecological vulnerabilities are inextricably embedded. Therefore, as Byrant and Bailey (1997: 37) put it,

> Political Ecologists start from the premise that environmental change is not a neutral process amenable to technical management. Rather, it has political sources, conditions, and ramifications that impinge on existing socioeconomic inequalities and political processes.

In this sense, political ecology focuses on the link between environmental problems and social power, tackling issues inaccessible by merely quantitative, scientific, and 'distant' methods. Therefore, rich case studies including historical-geographic analyses and in-depth ethnographic research are required to understand socio-ecological change 'up close' (Perreault et al. 2015). Similarly, different strands of critical social theory are drawn upon (e.g., neo-Marxism, post-structuralism, post-colonialism, feminist geography), seeking to problematize the deeply political dimensions of environmental issues from an explicitly normative viewpoint (ibid).

Nonetheless, also methods and insights from the natural sciences are incorporated into the analyses of some scholars, both in an applied and critical way (Robbins 2015). However, the different strands of political ecology tend to put their emphasis either on politics *or* ecology, an issue that has been subject to contentious and ongoing debates on the academic coherence of the field (Walker 2005). This work tries to follow Zimmerer and Basset (2003: 1) when they call for "[…] engag[ing] both the ecological [hydrological] and political dimensions of environmental issues in a more balanced and integrated manner".

Bryant and Bailey (1997) have introduced the concept of the "politicized environment" as a central framework for undertaking "Third World political ecology", allowing for a critical and actor-oriented view on (socio-)environmental change in the Global South. The entry point for this concept is the assumption that human-induced changes within the natural environment cannot be merely treated as politically inert backgrounds of social affairs. Rather, political actions, socio-economic structures as well as biophysical nature coincide within a "politicized

environment" in which uneven patterns of human-environment-relations and related environmental problems are historically conditioned and contested (Bryant & Bailey 1997: 26-45).

Related to this, political ecology widely draws up on a set of interrelated assumptions: Firstly, environmental degradation is in most cases not socially or ecologically neutral, but entails benefits, burdens, and risks that are unequally distributed among different actors, places, and segments of society (Bryant & Bailey 1997: 28). Secondly, this uneven distribution reinforces or alters existing socio-economic disparities (e.g., through the commercial appropriation of natural resources and parallel debilitation of local livelihoods) (ibid.). Thirdly, the social differentiation of costs and benefits implies political changes regarding the reinforcement or alteration of power relations between actors, which is why "any change in environmental conditions must affect the political and economic status quo, and vice versa" (ibid.). Overall, unequal relations of social power are thought to play a significant role in determining "[…] *how* nature is transformed, *who* exploits resources, under *which* regimes and with *what* outcomes for both social fabrics and physical landscapes" (Budds 2008: 60, emphasis in original).

Since the late 1990s, political ecology has increasingly moved beyond its land-centrism and started to explore a variety of previously less attended socio-ecological issues, including water, the latter of which will be briefly outlined in the next section.

2.2 The Hydro-social Cycle

The hydro-social cycle framework and related ideas stem from scholars of political ecology, critical human geography, and cognate fields critically investigating the complex interrelationships between water and society (cf. Bakker 2003, Budds 2008, Swyngedouw 2004, 2009, Linton & Budds 2014). This novel research tradition may be identified as part of broader paradigm shifts around water research and management (Gleick 2000). It is based on the assumption that "the hydrological cycle […] structures an understanding that is increasingly at odds with social and hydrological experience" (Linton 2008: 630). It is overly simplistic, for example, to equate water scarcity merely with the dwindling physical availability of water in a given region, as it is not only water *per se* that is at stake: Indeed, 'water scarcities' in the sense of its 'lived experiences' always and only manifest *in relation* to particular and historically contingent social, political, economic, and cultural arrangements, which require as much scrutiny as, for instance, changing precipitation regimes or depleting aquifers. These "social circumstances that make water what it is" (Linton 2010: 45) coincide with hydrological flows

in the actual ‘waterscape’, configuring, for example, diverging water use practices, institutions, knowledge systems, and technologies, as well as contested forms of access, control, or exclusion (Villar-Navascués & Arahuetes 2020). In this vein, Johnston (2003: 74) notes,

> Water scarcity not only reflects the relative aspects of supply (the conditions and actions that affect quantity and quality) and demand (intended and projected use) but the relative aspects of how water is valued (cultural meanings as well as economic values), relative levels of access and patterns of use, and the relative degrees of control over water resource management and distribution. Thus, scarcity might reflect the economic ability to pay for water, or the customs, social conditions, and relationships that privilege access to some while withholding access to others.

Thus, in order to substantially articulate, address, and resolve the complex and interdependent water problems facing societies today, ‘water’ has to be reconceptualized to make sense of its social and political nature (cf. Linton 2010). The hydro-social cycle follows this by theorizing the circulation of ‘water’ as an inherently socio-natural process, which is in constant and dynamic flux through both physical (hydro-)geographies as well as cultural and political landscapes (Karpouzoglou & Vij 2017). While it draws in some ways on the hydrological cycle, it extends the concept in several significant ways (Linton & Budds 2014). As an entry point it can be argued that even if the ontological distinction between water and society is maintained, human activities (both intended and unintended) have left extensive imprints on hydrologic environments at virtually every scale, particularly since the 20th century (e.g., large dams, large-scale irrigation, urban pipeline networks, aquifer mining, climate change) (Linton 2014). Thus, even from a strictly material perspective, explaining water merely in hydrological terms is less and less tenable, as its material flows and properties are shaped in concert with forces that are not only physical and hydrological, but overwhelmingly and increasingly social, political, economic, and cultural (ibid., Bakker 2003).

Emerging natural sciences perspectives on this now increasingly established insight tend to abstract human societies to quantifiable, relatively homogenous, and overly apolitical entities within “coupled human-water systems" (Sivapalan et al. 2012). A political ecology of water, in contrast, may depart from the relatively obvious and somewhat overstated realization that "water flows uphill towards money [and power] [...] [and] drought is attracted by poverty [and marginality]" (Linton 2010: 97). In other words, the societal utilization, exploitation, and mobilization of water resources imply crucial socio-political effects and conflicts at different scales; it creates winners and losers; there are the ‘water-rich’ and the ‘water-poor’, and the root causes of these pronounced struggles and injustices are fundamentally social and political rather than hydrological (Linton 2014). This is particularly evident in urban waterscapes, in

which “true scarcity does not reside in the physical absence of water in most cases but in the lack of monetary resources and political and economic clout” (Swyngedouw 2009: 58).

On a more abstract level, the hydro-social cycle further recognizes that “[…] it is not just society’s relationship with water that is at stake, but the social nature of water itself” (Linton & Budds 2013: 1). Given that the need to control and manage water is literally vital to society, the societal transformation and control of hydrological flows through technology, infrastructure, as well as cultural and material practices is a continual process that requires a certain social structure and the use of social power to be carried out in the first place (e.g., the construction of a dam) (ibid.). The resultant socio-natural waterscape is not only physically produced, but in the process internalizes the relations of power (material, political, economic, and cultural) that are constitutive for the social formation which put it in place (ibid.). This simultaneously and recursively impinges on social and political processes at different scales, which in turn influences further alterations of water. In an iterative and dialectical process, “water and society make and remake each other over space and time”, with the boundaries between water and society becoming increasingly blurred (Linton & Budds 2013: 6).

In this way, the seminal work of Karl Wittfogel (1967) demonstrates the historical co-evolution of large-scale irrigation schemes and centralized, potentially despotic polities in arid environments. The "hydraulic state" and its ruling elite pursue the management and coordination of these hydro-social arrangements while consolidating and maintaining their political authority through the centralized control over indispensable water resources, thereby excluding competing instances of power (Wittfogel 1967: 49). Despite being criticized for his material determinism (cf. Hunt 1988), Wittfogel’s central interest in the articulation of social power through particular hydro-social configurations has been echoed and adapted by subsequent research culminating in the hydro-social cycle framework (e.g., Swyngedouw 1999).

In addition to questions about the cultural production of diverging discourses (or ‘ontologies’) of water (cf. Linton 2010, Boelens et. al. 2017), which will be less relevant to this work, there is a particular interest in addressing the co-constitution of water and society in the context of capital accumulation and uneven development (Swyngedouw 2004). In doing so, intensifying processes of water appropriation by powerful actors and concomitant patterns of dispossession or ‘hydrological marginalization’ of weaker social groups are being highlighted, problematized, and, contested, in order to initiate […] different, more inclusive, sustainable, and equitable forms of hydro-social organization” (Swyngedouw 2009: 60).

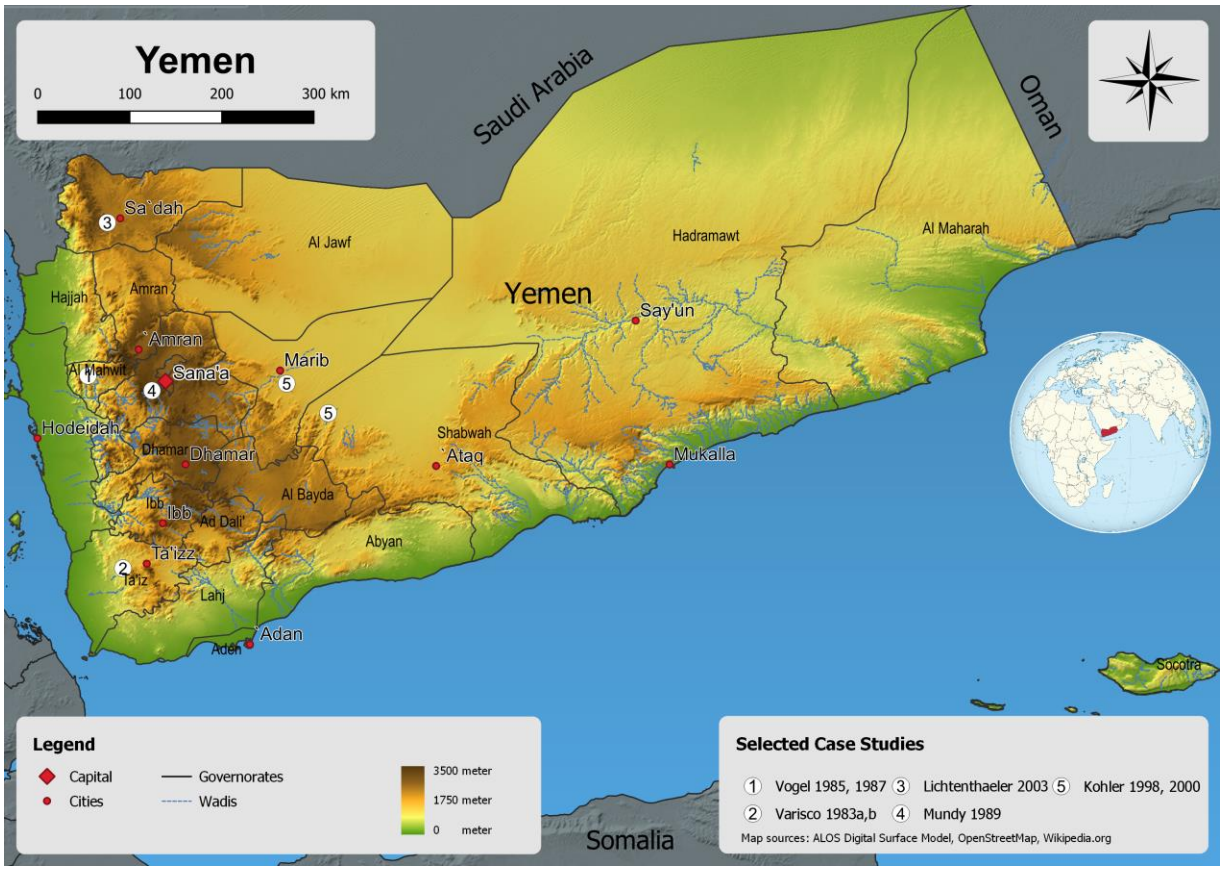
3 Geographic Context and Study Background

Hydro-social issues associated with human-induced groundwater depletion and struggles over access are common and severe in many parts of (rural) Yemen (cf. Kohler 1998, Lichtenthaeler 2003, Ward 2015, Varisco 2019). This chapter provides an introductory picture of water-society relations by roughly outlining Yemen's physical hydro-geography as well as the broader historical and political landscape in which rampant aquifer mining has unfolded.

3.1 Geography and Topography

Figure 1:

Map of Yemen and selected case studies



Source: own representation

The geographic area historically known as Yemen is located at the Southwestern corner of the Arabian Peninsula, sharing political borderlines with Saudi-Arabia in the North and Oman in the East (cf. Figure 1). Its topography is characterized by a central mountain range following the relatively slim coastal plains along the Red Sea and the Gulf of Aden, interspersed with

valleys and intermountain plateaus. Elevation maxima are found in the western highlands, with the capital Sana located at 2200 meters, surrounded by mountain ranges reaching more than 3000 meters (Hadden 2012: 8). The relief strongly declines north-eastwards to the depression of the Rub' al-Khali desert.

3.2 Climate and (Geo-)Hydrology

The Climate in Yemen is generally dry. It ranges from hyper-arid to semi-arid, with strong spatial variations due to the rugged topography. In general, the climate in the coastal areas and lowlands is very hot (mean annual temperature of 20-30 °C) with high evaporation rates and low mean annual rainfall (below 200 mm) (Ward 2015: 5-7). In the densely populated western and southern highlands, in contrast, mean temperatures are lower (13-20 °C). In these regions, mean annual precipitation can reach much higher rates due to orographic rainfall, ranging between 250-800 mm, with the absolute maximum of 1500 mm around the city of Ibb (ibid.). Rainfall patterns are subject to the strength of the Indian monsoon and thus imply a relatively high inter-annual variability. Mostly they are characterized by heavy, short-term, and spatially variable downpours, following the two distinct rain seasons: *saif* from April to May and *kharif* from July to September (Varisco 2019).

Although rainfall in Yemen is in some places relatively high compared to other regions of the Arabian Peninsula, large parts of it evaporate before ground infiltration or surface draining due to high temperatures and low humidity rates (Ward 2015: 7). Only smaller parts of the rain eventually seep into the soil and form temporary soil water, with some portions evaporating soon after as they move back to the surface through ground capillaries. In the more densely vegetated highlands and the vicinity of farmlands, parts of the soil water are further absorbed by plant roots, transpiring back into the atmosphere through the leave stomata (Ward 2015: 43). Only fractions of the rain will directly percolate into aquifer systems and only if the underlying geological structure’s permeability allows for it.

Conversely, much larger quantities of rain will turn into run-off, especially if the ground is saturated, geologically impermeable, and sparsely vegetated (Ward 2015: 44). As rainfall is highly sporadic, there are no perennial rivers in Yemen but only seasonal Wadis (although most contain baseflow regularly). After major precipitation events in the rainy seasons, run-off quickly moves downstream the drainage system and collects in the major wadi beds, forming ephemeral and often unpredictable flash floods (Ward 2015: 50). If at all, only little

amounts of these spate flows eventually enter the sea while large portions pour into aquifer systems surrounding the wadi beds, forming by far the primary recharge for groundwater reserves (Ward 2015: 55).

Groundwater is formed when water seeps beneath the Earth's surface moving through the pores and gaps of the unsaturated layer (soil water) into the saturated zone, demarcated by the water table of the concerned aquifer (Davie 2008: 60). The latter is generally considered "a layer of unconsolidated or consolidated rock that can transmit and store enough water for extraction" (Davie 2008: 61). Driven by gravity, groundwater moves mostly slowly underground downhill an impervious geological stratum within complex aquifer systems (ibid.).

Two major aquifer types can be broadly identified that are relevant for groundwater extraction in Yemen: Solid rock aquifers contain fractures and clefts that allow water to flow through them, mostly consisting of sedimentary rocks due to their high porosity and permeability (Ward 2015: 54). These aquifer types are usually extensive and may contain deep 'fossil groundwater', laid back during more pluvial times in the far past, which is replenishing, if at all, only partially throughout the year through influx from more elevated aquifer layers (ibid.). Alluvial aquifers, on the other hand, are smaller and comprise unconsolidated sediments of gravel, sand, and silt, deposited in river basins and floodplains (Ward 2015: 55). They are primarily located at the major wadi runs in the foothill and coastal regions as well as in the various scattered highland basins and intermountain plateaus. These unconfined aquifers are generally rather shallow and reach closer to the ground surface (ibid.). Drawing on seasonal spates, their water tables are subject to high inter-annual variability. Nevertheless, alluvial aquifers play an outstanding role at the local level as they recharge on a relatively regular basis and can be exploited relatively easily and cost-effectively (unlike the deep or fossil groundwater reserves) (ibid.). Due to widespread over-exploitation and exhaustion, however, emphasis has more and more shifted towards deeper and increasingly fossil groundwater reserves in recent times (Lichtenthaeler 2010).

3.3 Historical and political landscape

Yemen's political geography is historically fragmented and decentralized with the formal state government representing only one center in a broader network of power, a circumstance famously referred to as "dancing at the head of snakes" by the former president Ali Abdullah Saleh (cf. Clark 2010). A complex (post-)colonial history alongside the persistence and strug-

gles of traditional tribal social structures and allegiances have decisively compromised the creation of sovereign state institutions and unified and democratic forms of governance within Yemen's formal territory (Lackner 2017). This is reflected, among other things, in the multitude of civil wars and uprisings throughout its modern history and in particular today (ibid.).

The historical precursor of the modern Yemeni state roughly dates back to 1918, when the Northern part of today's Yemen has gained independence from the Ottoman empire and subsequently established a Zaidi Imamate (Moore 2011). Southern Yemen, in contrast, remained under British control up until 1967, when several uprisings and anti-colonial movements have culminated in its independence and subsequent conversion into a socialist state. In 1962, a burgeoning republican movement in the North, supported by Egypt, declared a revolution and overthrew the imamate (ibid.). After a raging civil war, they prevailed against the royalists, eventually proclaiming the Yemeni Arab republic, the 'modern' state entity that is still recognized internationally today (ibid.). The formal unification of the two distinct states was established in 1990, with the history of internal political tensions and conflicts, or "the politics of permanent crisis", as Sarah Phillips (2011) puts it, persisting up until today. Within this fractured societal landscape, political, economic, institutional, and military arrangements are largely bottom-up and shaped by the specific contexts of the local level, where not state but tribal authorities tend to prevail (van Steenbergen et al. 2015). This is particularly evident in the Northern and rural parts of the country (Stookey 1974). In this context, the fragile political rule of the central state has historically been largely exercised outside democratic institutions within some sort of "shadow state", whose governance capacity is dependent on the complicity and adherence of influential actors of the dispersed society (Zeitoun 2009: 18). In this vein, April Alley (2010: 386) broadly states:

> On paper, Yemen has an elected parliament and president, a multi-party system, an independent judiciary, and the framework for a democratically elected government. In reality, however, these institutions do not produce or transfer political power. Instead, power and wealth are produced and transmitted through a highly informal, yet deeply patterned web of tribally- and regionally-based patronage relationships.

Democratic institutions are therefore generally considered weak in Yemen given that the 'real' governance and power structures have proven effectively oligarchic (Zeitoun 2009: 18): Control over the decision-making-processes thus largely rests with a relatively small group of wealthy, politically connected, and influential individuals, including in particular the tribal leaders (*shaykhs*), rich traders, security and state officials, and other political-economic elites (Ward 2015: 30).

Under these historical circumstances, the emerging central state has broadly pursued the overarching interests "[…] to acquire legitimacy with citizens […], to create prosperity; and to consolidate its power by ensuring that influential groups have preferential access to wealth and prestige they desire" (Ward 2015: 118). As will be outlined later, the development of the natural capital residing in the nation's groundwater reserves was key to achieving all of these goals, with the lack and disintegrity of governance and institutions, however, significantly compromising the sustainable and fair management of this precious resource (ibid., cf. Ch. 4.3).

3.4 Groundwater mining and the deprivation of access

Since a few decades, "Yemen is facing a water crisis unprecedented in its history", with unsustainable aquifer mining representing the most visible component of the involved hydrosocial issues (Lichtenthaeler 2010: 30). Rough projections estimate that extraction exceeds recharge by 20 to 400% for different basins and aquifer complexes (with a total average of 54%), leaving many areas and large tracts of the population prone to extreme water stress (Ward 2015: 43, Varisco 2019, cf. Table 1).

Table 1:

Estimated groundwater abstraction per basin (in million m³/ year)

Region	**Total internal renewable water resources**	**Total water use**	**Deficits**
Highland Plains	100	500	-400
Tihama	741	1000	-259
Wadi Tuban, Wadi Bana and Abyan Delta	355	364	-9
Eastern Escarpment	315	540	-225
Hadramawt	161	281	-120
Al Ghaydah	77	n.a.	-
Wadis Ahwar, Mayfa'ah, Hajar	180	102	-
Rub' al-Khali	171	n.a.	-
Total	**2100**	**2787**	**-1130**

Source: Ward 2015: 43

Although urban areas contribute to groundwater over-exploitation and are entwined with a multitude of hydro-social problems (e.g., urban-rural water transfers, unequal water-supply-regimes), this thesis sets its focus on rural areas and agricultural groundwater use. With 90% of total consumption, the latter is by far considered as the main consumer of Yemen's (ground-)water resources (Ward 2009). With 11 percent of the GDP and 33% of the total workforce, the agricultural sector further represents a central pillar of Yemen's (political) economy while water resources constitute the lifeline of the largely agricultural rural economy (Ward 2015: 79).

Groundwater 'mining' (when abstraction rates exceed recharge) entails several socio-hydrological changes as it proceeds or intensifies in space and time. Although it may initially provide maximized water yields and year-round irrigation, adverse and often dormant changes are increasingly provoked. These include the plummeting of water tables that may proceed up until the practical exhaustion of the aquifer, which subsequently, can only be exploited by its annual recharge rate (Davie 2008: 62). In the Yemeni highlands, groundwater levels dropping 2-6 meters annually is not uncommon, with the areas of Sana'a, Taiz, Amran, and Sa'da being particularly affected by groundwater depletion (Varisco 2019). Deep and fossil groundwater reserves are increasingly being tapped, and there are cases of farmlands and entire villages being abandoned due to aquifer exhaustion (Lichtenthaeler 2010, Lackner 2017).

In this context, shrinking water yields forced deepening and re-equipping of existing wells, re-drilling in new locations, and the accumulation of drilling failures further contribute significantly to the sharp increase in the economic cost of groundwater extraction (Ward 2015: 57). Overall, this directly undermines the social accessibility of groundwater resources, not only in terms of its absolute physical availability but even more so, its economic affordability, with the most marginalized social groups in particular struggling (ibid.).

Likewise, quality issues related to sea water intrusion and salination in coastal areas, increased mineralization of deep groundwater in unconsolidated aquifers as well as nitrate pollution through replenishment of water losses nearby irrigated farmlands may result in reduced agricultural yields while further entailing major health and ecological implications (ibid.).

Not least, groundwater mining at one particular place considerably alters the overall hydrological regime of the affected aquifer complex and catchment area, causing adverse hydrological changes beyond the immediate locale where groundwater (over-)exploitation occurs (Ward 2015: 58). Alterations of historical groundwater recharge patterns thus not only pro-

voke regionally declining water levels but also risk the draining of springs and alterations of historical wadi runs, which renders the overexploitation of groundwater reserves as a particular driver of distributional conflicts (Weiss 2015).

A couple of decades ago, issues related to groundwater (over-)exploitation were of minor concern in Yemen, as surface water (springs and spate slows) and direct rainfall had constituted the most important water sources for the largely subsistence-based agricultural economy, which were arguably successfully and sustainably managed over centuries (Varisco 1996). The following chapter outlines the political ecology of groundwater mining in Yemen and starts with a brief overview of 'traditional waterscapes', tracing their central characteristics and conditions of change towards today's 'groundwater-extraction-regime'.

4 The Political Ecology of Groundwater Mining in Yemen

4.1 Traditional waterscapes

There is a long and arguably successful history concerning sustainable water resource management and related irrigation practices in the geographic area historically known as Yemen (cf. Varisco 1983a,b, 1996, 2009, Harrower 2009). Given the challenging physical geography described above, the 'making' of the waterscape has played an important role, with surface water and direct rainfall constituting the major input for agricultural practices over millennia (Varisco 1996). In this context, sophisticated material structures for capturing, distributing, and utilizing the limited amounts of water as well as associated forms of social collaboration can be found in 'pre-modern' Yemen.

While not representing the only example of large-scale hydraulic structures in ancient times, the 'Great Ma'rib Dam' in Wadi Adhanah is likely the most prominent one, built in the sixth century BC in the context of the rising Kingdom of Sheba (cf. Brunner & Haefner 1989). The complex hydro-social formation and the centralized management to ensure its functioning had been held in place for more than a thousand years. Its political, economic, and cultural influence has shaped the mythology of 'Felix Arabia' ('happy/fertile Arabia') during the time of the Romanian empire. Forming a central national symbol, the cultural legacy of the 'Great Ma'rib Dam' is still reverberating today, as seen for example, in Yemen's official coat of arms (ibid.).

Given the historically largely fragmented political and physical geography, however, most water-management-regimes have been traditionally engaged in localized and community-based arrangements, relatively absent from state-like influences (Ward 2015: 117). In this context, various place-based waterscapes have emerged and evolved over centuries, differently utilizing a variety of water sources, as Carapico (2007: 154, cited in Weiss 2015) eloquently notes:

> Yemen's traditional water resource management mechanisms – canals, cisterns, shallow wells, spate systems, and other devices tailored to each microenvironment – were ecologically elegant, separating every drop of water by use: drinking, cooking, livestock, bathing, irrigation. Private and community water rights, with minute provisions for drinking and irrigation, were a central feature of both Islamic and tribal law: water management was a crucial part of the agrarian order.

Two overarching forms of 'traditional' (agricultural) water-management-regimes can be identified in the geographic and ethnographic literature, roughly generalized in the following:

4.1.1 Highlands: terrace farming and water harvesting

The Yemeni highlands are characterized by pronounced terrace formations as the steep slopes do initially not allow for agriculture. To enable arable land in these difficult environments, terrace structures have been created over centuries by laboriously carrying ground material and fertile soil from the valley floor or alluvial fans nearby (Varisco 1991). According to Helmut Eger (1984), terrace farming in Yemen works even in areas with as little as 150 mm annual rainfall, using drought-resistant crops (esp. Sorghum), sophisticated water harvesting techniques, and place-specific terrace configurations. These intend to make the best use of the immediate water regime, as reflected in sound local experience and environmental knowledge (Ajl 2018: 132).

The geographer Horst Vogel (1888a, b) studied the properties of indigenous slope terracing in the Jibal Haraz massive, located at the center of the Serat mountain range in the North of Yemen, with its hydrologic conditions shaped by two rainy seasons in form of heavy and short-termed rainstorms. Therefore, as Vogel (1988a: 29) puts it, "the basic principle of arable [terrace] farming is to ensure that a maximum of direct rainfall as well as of runoff rainwater is made available for agricultural production […], [while] preventing erosive flooding". To accomplish this, the overlying slopes are modified by simple means so that either seasonal hillside streams or overland runoff find a coordinated path to the terraces. There, the water infiltrates into the soils, while excess water is drained away by complex subsurface drainage systems. At some sites, Vogel (1988b) observed cisterns that were connected to these "underground conduits", storing water for later irrigation or domestic purposes (cf. Figure 2).

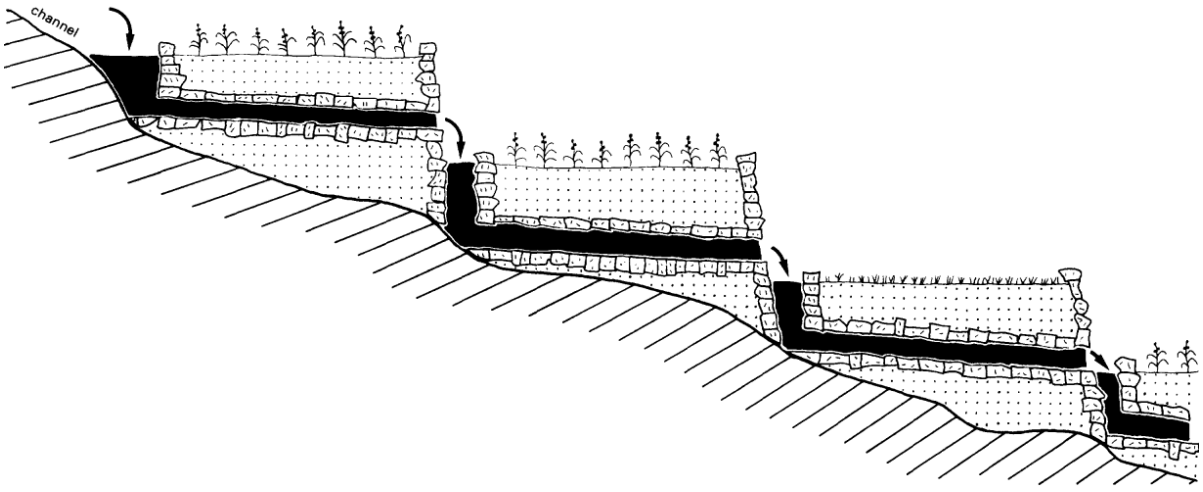
The anthropologist Daniel Varisco (1980, 1983a, b) examined local water management techniques, institutions, and practices in the highland valley of al-Ahjur. There, a series of springs run through the upper valley hills, constituting the major source of water for the adjacent communities. Cisterns collect these spring flows, facilitating an organized distribution to the villagers and the extensive terrace plots beneath. Water use is governed by specific rules of common property; a set of customary (*'urf*) and Islamic (*Shari'a)* legal provisions embedded within the tribal socio-political organization of the particular locale (Varisco 1983a).

A key principle here is the intimate linkage between land ownership and access to water. Water rights are defined according to the size of the individual landholdings and the specificities of the cultivated crops so that each irrigator is granted access to certain amounts of water within certain periods (Varisco 1983b). Most of the associated practices are carried out by the irrigator individually, such as the metering of water in the communal cistern or rerouting the earthen channel network so that water reaches the fields to be irrigated (Varisco 1983b). Disputes are considered rare in these systems because the involved smallholders work together on a face-to-face basis, usually linked by kinship and economic interdependence. When conflicts do arise, they are arbitrated by the local *shaykh*, the (exclusively male) head of the tribal local community, again drawing on customary and Islamic law (Varisco 1983a).

In 1983, approximately three-quarters of the total cultivated area in North Yemen were still shaped by these combined water-harvesting and agricultural structures, yet with a strong downward trend due to abandonment and concomitant soil erosion (Varisco 1991, Vogel 1988a).

Figure 2:

Terrace farming and underground conduits in Jibal Haraz, Yemen



Source: Vogel 1988b: 34

4.1.2 Coastal and foothill areas: spate irrigation

Over millennia, seasonal floods have served as the major source of water for agriculture in the wadi runs of the coastal and foothill regions (Ward 2015: 64, Varisco 1983a). At many sites, a series of spate harnessing- and irrigation schemes are constructed along a wadi: Provisional

diversion dams made of ground materials act as barriers to redirect the seasonal floodwaters into a gravity-driven channel network, distributing the water to the nearby set of fields under the supervision of the individual farmers (Varisco 1996). The relatively simple and temporary structures do not require extensive social intervention to convey runoff to downstream users, as they usually discharge only portions of the seasonal spate while 'naturally' breaking when the floodwaters are too great (Ward 2015: 64). Both construction, preservation, and organization of these systems were largely the matter of the local community, with state-like involvements historically considered rather marginal (Varisco 1983a).

The coordinated utilization of the often unpredictable seasonal spates is based on Islamic and customary legal provisions (cf. Mundy et al. 2007). In principle, the more elevated fields are to be irrigated first ('*al 'ala fa al 'ala*; 'the upper to the upper'), while ensuring flow rights and a fair distribution for lower fields, either in terms of the local irrigation system or communities downstream the Wadi (ibid.). These norms and provisions were further upheld by local and regional authorities: Irrigation officials, appointed by the regional sultan, monitored the flood diversion and distribution and organized labor to maintain barrages and irrigation structures (Varisco 1983a). Irrigation officials were also responsible for settling disputes between upstream and downstream users, often in cooperation with regional Islamic courts. Local conflicts, on the other hand, were adjudicated by the local *shaykh* (ibid.).

4.1.3 Groundwater use

Both in coastal and highland areas, shallow hand-dug wells have been historically used to withdraw limited amounts of groundwater from the alluvial aquifers surrounding the seasonal Wadis (Varisco 1996). However, groundwater has played a rather supplementary role among the various water sources and was particularly used for obtaining potable water for the adjacent communities, livestock watering, and small gardening works (ibid.).

Customary and Islamic law does not restrict the digging of a well on private land if it adheres to a 'protection zone' to other wells, ranging between 250 to 500 meters (*harim* well-spacing rule) (Ward 2015: 309). Besides, thirsty people from nearby communities must be granted access for drinking if needed (ibid.). However, land ownership and water rights are inextricably linked and therefore there are no provisions stipulating rules for the amount of groundwater being abstracted (Kohler 2000). Given the context in which these norms originated, this is hardly surprising, as traditional and hand-and-dug wells could only extract very limited

amounts of water due to the shallow depth and the physical constraints of man and animal power, ‘naturally’ restricting overuse, with the subsistence-based agricultural economy and its largely drought-resistant crops generally not demanding excessive quantities of water (Ward 2015: 69-70).

In the past five decades, Yemen's community-based (agricultural) waterscapes have undergone pronounced hydro-social transformations. The emerging ‘groundwater-extraction-regime’ will be outlined in the following chapter.

4.2 The emerging groundwater-extraction-regime

Since the late 1960s, and especially since the 1970s, (deep) well irrigation and unsustainable groundwater use practices have proliferated across large parts of Yemen. In just a few decades, the existing hydro-social arrangements described above, which were based primarily on surface water flows and direct rainfall, supplemented by springs and shallow wells, have largely unraveled. The rapid transition to runaway groundwater development through diesel-powered tube wells has fundamentally and increasingly undermined both the integrity of local and regional water regimes as well as the governance and management systems that have historically adapted to these (socio-)environments. The following sections seek to trace the transformation of hydro-social relations that has culminated in today's groundwater crisis in rural Yemen through a critical examination of the historical, social, political, and economic circumstances of (geo-)hydrological change.

4.2.1 Rapid technological change vis-á-vis local institutions

The diffusion of motorized deep well technology in the 1960s and 1970s constitutes the entry point for the complex set of relations that has initiated rampant groundwater overuse (Ward 2015: 260). Initially, a foreign concept in Yemen, where wells are historically hand-dug, the new technology has changed local perceptions regarding the economic opportunities of groundwater development (ibid.). The former challenges associated with the utilization of water - regarding the high risk for conflict, the need for compliant social collaboration, as well as the physical constraints evoked by the shallow well depths, limited man and animal power, and rainfall variability - could suddenly be eluded by the unprecedented technical capacity to (individually) drill as deep as never before, to maximize the water yield and to provide year-round irrigation (Lichtenthaeler 2010).

However, at the local level, existing norms and institutions regarding water management have largely been retained (cf. Kohler 1998). As described in the last chapter, both customary and Islamic law do not impose any restrictions on the amount of groundwater abstraction on private land, but only stipulate minimum distances between wells (*harim* rule). Although groundwater is originally *res nullius* (i.e., property of no one; *mubah* in Yemeni Arabic) in Islamic law (*Shari'a*), it can be virtually privatized if it is developed and mobilized in any kind of container or pipe, including well (Kohler 1998, Ward 2015: 309). Customary law (*'urf*) goes even further, prescribing an intimate connection between land and water rights that

allows private landowners to exploit the underlying groundwater reserves however intended, a cultural residue of ‘pre-modern’ waterscapes, designed to provide an impetus for the laborious development of groundwater and arid land (Kohler 2000, Weiss 2015).

These ancient institutional arrangements are quite rigid as they are entwined with local belief systems and broader religious and tribal traditions, leaving relatively little room for quick and decisive changes, despite the unprecedented opportunities and challenges provided by the advent of tube well technology (Lichtenthaeler 2003: 23). Because of these cultural barriers, institutions at the local level have been slow to adapt, if at all, to the new circumstances, and the delayed state responses in form of national legislations and formal water authorities have not demonstrated significant impacts on groundwater overuse either, as will be explained in more detail later (Weiss 2015).

Similarly, the privatization of uncultivated communal or unowned, 'dead' (*mawat*) land has not encountered major obstacles: Its 'revival’ is encouraged by S*hari’a* law and represents a highly desirable action. It is only through the process of developing *mawat* that its property rights can be acquired (e.g., preparing fields, building a house, or digging a well) and by that, also the right to extract groundwater unlimitedly (Lichtenthaeler 2003: 26). In this process, over the past decades, the previously largely communal forms of water and land management have been increasingly transformed into individualized (and increasingly capitalist) modes of production, accompanied by a decline in cooperation, the expansion and intensification of agricultural land, as well as the intrusion of external, profit-oriented irrigators into groundwater-rich areas (Moore 2011). Related to this, Stefan Kohler (1998: 138), during his field research in the Harib governorate, when he asked whether there was any communication between water users about groundwater issues, received the answer: "No, we have all switched to groundwater use, there is nothing to discuss", an observation also made by Gerhard Lichtenthaeler (2003) in the Sa'da Basin in Northern Yemen.

Furthermore, at the local level, perceptions of groundwater had for a long time been characterized by the widespread belief that it represents a limitless gift from God, similar to the vast oil reserves given to the Saudis. Up until the late 1990s, groundwater had commonly been referred to as *Bhar*, which is the Yemeni Arabic term for the sea, evoking imageries of divine abundance (Lichtenthaeler 2003: 161).

In this context, groundwater has virtually constituted a ‘free access’ resource for decades, and in this sense, some scholars state that a form of the "tragedy of the commons" (cf. Hardin

1968) seems to have occurred in Yemen (Kohler 1998, Lichtenthaeler 2003). Although, paradoxically, the quasi-privatization of formerly communally managed land and water resources has paved the way for the proliferation of groundwater overdraft (Lichtenthaeler 2003: 28). The 'tragedy', moreover, is highly uneven and simultaneously constitutes a fortune for others (Zeitoun 2012). As the access to groundwater has become a virtually fully private affair, and thus largely a matter of individual affordability and political clout, it is profoundly skewed, and the term 'commons' rendered rather inappropriate, as will be argued further below.

4.2.2 Economic incentives and market forces

These preconditional and local factors have been further catalyzed by a set of structural and more distant socio-economic forces, strongly influencing local decision-making processes regarding groundwater management and the bourgeoning development of groundwater-irrigated commercial agriculture.

During the oil boom of the 1970s and early 1980s, Yemeni migrant workers in Saudi Arabia and other Gulf states provided remittances which, along with profits from illicit cross-border trade, provided large amounts of individual capital to finance drilling equipment and diesel pumps (Kohler 1998: 188). As opportunities for foreign labor declined in the early 1980s and increasing government curbs on illegal cross-border trade reduced revenues from smuggling, economic interest in agriculture has (re-)intensified (Lichtenthaeler 2000).

These trends were decisively reinforced by the agricultural policies set up by the emerging central state, supported by international organizations and a variety of donors, who identified groundwater-fed agricultural development as an ideal way to launch a 'green revolution' and by that, tangible national economic development (Varisco 1991, Ward 2000). In this context, the operation of various macro-economic levers has both subsidized the economic costs of groundwater abstraction while providing sustained economic incentives for the transformation of the agricultural production system towards water-intensive commodity crop farming (Ward 2000, Lichtenthaeler 2010). In particular, heavily subsidized diesel prizes (fuel for the motorized deep-wells) and low-interest agricultural loans have made the operation of pump-powered deep wells and construction of large-scale well-irrigation schemes cheaper and more profitable than ever before. At the same time, no formal levies on groundwater have ever been imposed, thus it has virtually been for free (ibid.).

Additional protectionist policies, such as the import ban on vegetables and fruits in 1984 have further promoted the commercialization of agriculture: the domestic production of high-value crops such as citrus, grapes, and banana, requiring year-round irrigation, has become much more profitable on the national market (Ward 2009). Furthermore, the large-scale cultivation of *qat*, a mild drug and central part of Yemeni everyday culture, has been actively encouraged. Previously imported from Ethiopia, an import ban in 1989 and the absence of any taxes or regulations have given free rein to runaway domestic production (Ward 2000). Demand and Profitability skyrocketed in the subsequent decades, and its production has increasingly ousted that of food crops, accounting today for approximately 30-40% of total water use in agriculture as well as one-third of the agricultural GDP (Lichtenthaeler 2010, Weiss 2015).

On the other hand, the production of traditional and largely drought-resistant subsistence cereals such as sorghum (constituting the central crop of traditional farming) has been more and more supplanted by increased imports of commercial or donated wheat from the 1980s on, which were sold at heavily subsidized prices (Ward 2000). This has significantly contributed to declining revenues of domestic cereals on which the low-income farmers depended (ibid.). Generally, traditional farming practices such as terracing and associated forms of water harvesting have been actively neglected and no adequate policies were implemented to support the maintenance of these systems (ibid.).

Following these pronounced changes, the overall agricultural production system has shifted more and more towards privatization, mechanization, and commercialization through largescale groundwater irrigation and commodity crop farming, accompanied by the market-driven decline of traditional forms of community-based agricultural and related water management and associated water harvesting techniques (Moore 2011).

In the wake of these market forces, the agricultural sector has undergone extreme economic development in absolute terms, indicated, among other things, by extensive areal land-use changes, with groundwater-irrigated croplands increasing 14-fold from the early 1970s to 2015, whereas rain- and spring-fed croplands have plummeted substantially (Varisco 2019; cf. Table 2). The number of agriculturally used wells is currently estimated at 100 000, serving approximately 40% of the total farmland (Ward 2015: 91).

Although the development of groundwater-irrigated agriculture has initially brought benefits to large segments of society, these are increasingly being undone as inequality of access rises

and groundwater resources continue to degrade, running a risk to eventually undermine any benefits that the initial 'groundwater-boom' may have entailed (Ward 2015: 121).

Table 2:

Agricultural land use and water sources in Yemen

	Area of farmlands (ha)	Rainfed	Flood	Spring	Wells
2015	1,172,185	468,873	152,385	29,305	521,622
2002	1,133,480	532,736	124,683	45,339	430,722
1983	1,019,868	790,283	95,953	24,729	118,984
1974	1,515,000	1,285,000	120,000	73,000	37,000

Source: Varisco 2019

4.2.3 Political Economy and patronage

The transformation of the agricultural waterscape into a 'groundwater-extraction-regime' was neither socially nor hydrologically neutral but has resulted in increasingly uneven socio-environmental outcomes (Moore 2011). Although initially many households improved access to water and large tracts of farmers gained higher agricultural revenues, there has been a strong increase in inequality of access to, and control of (ground-)water resources and the derived agricultural benefits as the various water sources have started to dwindle. Ancient systems of community-based water management were fundamentally and increasingly alienated as the traditional rules do not provide efficient mechanisms to curb land privatization and associated groundwater mining, transforming previously communally defined water (and land) rights into virtually wholly private affairs and by that into a question of individual affordability and political clout (Ward 2009, Moore 2011). Viable alternatives have failed to materialize, as substantive policy responses from both the central state and local communities were largely absent or ineffective (Weiss 2015). The associated "politicized environment" (Byrant & Bailey 1997) is shaped by "[…] a political economy encouraging increased rather than reduced water consumption [with] the resultant over-exploitation affect[ing] groups in unequal measures" (Zeitoun et al. 2012: 54).

Following this, those groups with the means and capital to acquire large tracts of land, to drill and operate various deep wells, and to purchase sufficient amounts of fuel, have found them-

selves in the privileged position to appropriate excessive amounts of groundwater for the irrigation of their large-scale commodity-croplands (Weiss 2015). The deregulated institutional environment at the local level has further rendered this issue to be "[…] tolerated in terms of traditional customary and religious practices" (Lichtenthaeler 2003: 225). Therefore, those social actors who were already 'better off' and in a position of authority, broadly encompassing the tribal leader (*shaykhs*), large landowners, rich traders, and other rural elites, have disproportionately benefitted from the unregulated, competitive, and virtually fully privatized land and groundwater management and the state-sponsored subsidies described above (Moore 2011). Although considered the main consumers of groundwater resources in the agricultural sector, these wealthy actors are effectively much less exposed to the induced and intensifying hydrological stress, as they strongly benefit from the Status Quo while gaining the monetary resources and opportunities to essentially circumvent the problem (Zeitoun et a. 2012).

Conversely, the alteration of the basin-wide water regimes has particularly affected the shallower wells, spring flows, or spate runs used by less entitled individuals, social segments, and communities, who are struggling along with the externally induced degradation of water sources and the draining of their farmlands (Moore 2011, Weiss 2015). In this context, the burdens, costs, and risks of runaway groundwater mining and the emerging 'water crises' have largely and increasingly been borne out at the expense of disempowered downstream communities, low-income and small farmers, rural landless, poor households, and especially women and girls (Ward et al. 2007, cf. Table 3). The latter of which are responsible for fetching water daily for estimated three-quarters of Yemeni families, often from overly distant and overused wells (Ward 2015: 137). Beyond that, the increasing commodification of water, as reflected in the emergence of informal water markets and extensive systems of private water tanks, may even abundantly supply those who can afford it in areas where groundwater is nearly wholly exhausted, such as in the Taiz region (Moench 1997). Those without these financial means and entitlements, however, lack the capacity to keep up with the ever-declining groundwater levels and rising costs of water provision, enforcing water and food insecurity, land sales, or the abandonment of irrigated agriculture altogether (Lichtenthaeler 2003: 21). As shown in Table 3 further below, the deprivation of access to water affects particularly the poorest and most marginalized segments of the population, as they tend to pay the highest prices for obtaining access. Overall, this has increasingly led to major health issues, the destruction of rural livelihoods, and the ongoing impoverishment and marginalization of large tracts of the rural peasant population (ibid., Ward 2015: 260).

Qat, a mild drug and extremely popular component of Yemeni cultural, political, and economic life (cf. Gatter 2012) is an illuminating example of how the 'water crisis' is embedded within vested interests and rigid social power structures. As described earlier, following state incentives, lax regulations, and increasing demand, the profitability of this cash crop has strongly intensified from the late 1980s on (Ward 2000). Qat farming expanded tremendously, culminating in a 'multi-million-dollar business' that accounts for an estimated one-third of total water use in agriculture today (Weiss 2015). While qat, as a high-value crop, secures the livelihoods of many small farmers and increasingly represents "the crop of choice" (Ward 2015: 82), large tracts of its production, trade, and marketing are controlled by "cartel-like organizations" (Moore 2011: 45). This is illustrated by the proliferation of large-scale qat plantations in the past decades, with adjacent "*qat* palaces" and the strong political opposition to any serious restrictions on qat production, which in its most radical form includes the threat of shooting down planes importing cheaper *qat* from international markets (Ward 2015: 119, Weiss 2015).

The appropriation of common resources by private power and concomitant patterns of dispossession and marginalization are not exclusive for Yemen but represent an issue across the globe (Robbins 2012: 157-175). However, in the context of Yemen's effectively patronage-based and oligarchic political system, which historically feeds on a highly hierarchical society, the socio-ecological injustice implied in this phenomenon is hard to overestimate.

Yemen's political geography is historically fragmented and decentralized, with the central government representing only one center in a broader network of power (Phillips 2011). Political, economic, institutional, and military arrangements are largely bottom-up and shaped by the specific contexts of the local level, where not state but tribal authorities tend to prevail (Steenbergen et al. 2015). Since the creation of the republic in the 1960s, and even more, since the unification of North and South Yemen in 1990, the fragile political rule of the central state has largely been carried out within some sort of "shadow state" (Zeitoun et. al 2009). In this context, the 'real' Yemeni power structures have historically been constituted by extensive systems of patronage-relationships, seeking for, while being dependent on, the complicity and agreement of influential actors of the fractured society (Alley 2010). In this context, the co-optation of powerful (esp. tribal and military) elites into the central state-apparatus through the provision of preferential access to a variety of rights and resources is considered to have played a historically important role in the consolidation (and territorializa-

tion) of state power, drawing particularly on the capital provided by oil revenues and aid budgets (Alley 2010). Arguably, the development of groundwater-irrigated agriculture was embedded within these patronage-driven state formation processes, as there is ample evidence that state actions have amplified the uneven allocation of land and water resources and by that, the accumulation and concentration of prosperity and political power (Steenbergen et al. 2015).

For instance, Christopher Ward (2015: 119) argues that in an attempt to assert state legitimacy and authority, peripheral and largely autonomous areas, in particular, were granted the lowest interest rates for agricultural loans. These were particularly channeled to powerful constituencies such as tribal leaders, rich traders and smugglers, military elites, large-scale landowners, and others, with the ulterior motive of integrating these actors in the sphere of influence of the expansionist state (ibid.). Already entitled to appropriate large tracts of land and underlying water resources due to their grip on power and economic assets, these actors have been additionally and regularly granted diverse rewards or 'political gifts', including direct cash-transfers, privileged access to public funds and direct investments, or simply seedlings, pump-equipment, and the provision of deep wells (Steenbergen et al 2015, Lichtenthaeler 2003: 96).

In this context, a new social class of 'tribal entrepreneurs' (e.g., commercial farmer *shaykhs*, large landowners, drilling contractors) has emerged in compliance with the central government's ruling elite (Zeitoun 2009, Steenbergen et al. 2015). Following Karl Wittfogel's (1967) work described earlier, David Moore (2011: 46) refers to this circumstance as the "Yemeni state hydraulic", emphasizing the historical co-constitution of the market- and patronage-driven redistribution of land and associated (ground-)water resources and its derived benefits into the hands of a selected few on the one hand, and the reinforcement and maintenance of oligarchic state structures on the other. The interrelationships between the uneven allocation of water and land resources, unequal relations of political and economic power, as well as patronage-based state-formation processes is also noted by Christopher Ward (2009: 262) when he argues that,

> these processes of capitalism and concentration of power have been readily abetted by the state through incentives for groundwater extraction and through direct investment. The rapid development of water resources helped to legitimize the state as a 'development agent'. Meanwhile, the more discreet underlying processes of accumulation of wealth and power through growing control of water and land have consolidated the important political support of the military and capitalist elite around the central state.

Gerhard Lichtenthaeler (2000: 160) illustrates such patronage-mechanisms in the largely autonomous Sa'da basin where "main actors, shaykhs and traders had well-established links with central government […] [and] benefitted in numerous ways from the government's agricultural policy". This is exemplified by a powerful *Shaykh* establishing a 25-hectare orchard with some 10 000 citrus trees, backed by the Sana government, who provided the drilling of various deep wells (ibid.).

Historically, the fragile central state has had a strong interest in perpetuating the loose patchwork of allegiances and patronage relationships on which it depended (Clark 2010). In this context, the long-lasting lack of adequate political responses from the central government to curb rampant groundwater mining can be seen as a strategic, albeit tacit political strategy (Ward 2015: 119). By restricting and regulating abstraction, the fragile state would have lost among itself the politically vital support of the powerful constituencies profiting extraordinarily from groundwater mining; a reduction in agricultural revenues would have been accompanied by the loss of an important source of patronage (ibid.).

Table 3:

Uneven modes of access to water in rural Yemen

	Better-off	**Poor**	**Very poor**
Water sources for agriculture	Tube well; Spring; Terraces; Spate head-end	Shared tube well; Spring; Terraces; Spate tail-end; Water purchase	No access
Use of diesel	Yes	Limited	No
Time spent water fetching	-	-	Several hours every day, esp. women and girls
Cost of water per m³	Well operating costs	network supply: low vendor supply: high	Very high, if purchased

Sources: Ward et al. 2007: 4, Zeitoun 2009: 22

4.2.4 State expansion and tribal autonomy

Partly because of such patronage mechanisms, but also due to more 'tangible' attempts of the emerging central state to consolidate and territorialize its power in largely tribal areas, state presence in general and involvement in developing groundwater-fed agriculture, in particular,

has been seen with suspicion by many tribal actors and communities interested in maintaining autonomy and independence (Moore 2011). For instance, Gerhard Lichtenthaeler's (2000, 2003) fieldwork in the Sa'da basin revealed that there were growing concerns that the central government might attempt to appropriate large tracts of 'dead land' (*mawat*) for state-centered agricultural development and/or the military control over tribal territories. These fears were further fueled both by rumors from migrant workers who had observed similar events in Saudi Arabia and by the informal provisions enshrined in customary and Islamic law setting the course for the relatively simple appropriation and privatization of arid land by the mere process of developing it. Arguably, both the perceived and 'real' intrusion of state power into Sa'da's tribal territories have catalyzed the development of groundwater resources as Lichtenthaeler (2000: 150) outlines:

> Tribal perceptions vis-a-vis government politics triggered the acceleration of groundwater-irrigated agriculture. [...] Within Sa'da's 'politicized environment', notions of political autonomy and resistance to state control have remained core values and objectives of many actors and tribal communities. Attempts by the state to establish control over the Sa'da region have had direct repercussions on groundwater development.

Indications for this argument are, among others, the response of tribal communities to the government-led expansion of the Sa'da airport in 1982, who hastily privatized the surrounding communal land, developing it into irrigated farmlands (Lichtenthaeler 2003: 81). Similarly, surveys of Yemeni hydrologists near Sa'da town in the same year have been perceived as "the extended arms of the national government", either feared as a precursor of state seizure and new water legislation or seen as a sign of possible government subsidization (Lichtenthaeler 2003: 86). Both perceptions have entailed the same response, namely the drilling of new deep wells and the demarcation and preparation of agricultural fields (ibid.).

Pervasive mechanisms of patronage and corruption, however, were not absent from these territorial struggles. For instance, the increasing military presence near a government-controlled airport had initially encouraged nearby tribal communities to preempt the state and quickly privatize and cultivate the surrounding communal graze land, thereby obtaining the associated land and water rights (Lichtenthaeler 2003: 81). However, due to endless disputes over its distribution among the involved tribal communities, the government was able to seize the opportunity to appropriate the once tribal grazing land for the construction of a 'model farm' for the Ministry of Agriculture. Aggression by the tribes to stop this failed to materialize, as their political leaders received a considerable sum of money as compensation (ibid.).

4.3 The political ecology of groundwater conservation

4.3.1 Hydrological state failure

Until the mid-1990s, both formal and informal state policies had structurally encouraged the rapid (and increasingly uneven) development of Yemen's groundwater resources through economic incentives, subsidies, direct investment, patronage-relationships, and, not least, the long-lasting absence of any formal regulatory mechanisms surrounding (agricultural) groundwater consumption on private land. The excessive and individualistic use of groundwater and the economic profits derived from it has underpinned the central government's overarching goal of consolidating power in a largely tribal society by favoring key interest groups and influential constituencies alongside the promotion of national (esp. rural) economic development (Ward 2000, Moore 2011). However, as outlined by Mundy (1989) and Varisco (1980), significant degradation of water resources had already begun as early as the 1970s and 1980s, with falling water tables, drying up of springs, or the alteration of historical wadi runs provoking pervasive struggles over access and distribution.

During these decades, the environmental and socio-economic issues associated with increasing groundwater mining have received little or no political attention from the central government. This is not very surprising, given that the extraction of groundwater was of great political interest. However, the small dam program in the 1980s represents a notable exception (Alderwish et al. 2014). The controversial project, which invested heavily in the construction of permanent dams in the coastal wadis, was intended to increase groundwater recharge rates and water yields for spate irrigation (ibid.). However, some scholars indicate that the derived benefits quickly turned into distributional conflicts between upstream and disempowered downstream farmers, with the fragile central state being generally overwhelmed by the novel administrative responsibilities these structures required (Ward 2009).

It was not until the 1990s and especially the early 2000s that there were substantial shifts in thinking about water development in political, donor, and academic circles in the wake of worsening water scarcity, social inequality, and economic crises, or in other words, because of “reality kicking in” (Zeitoun et al. 2012: 63, Alderwish et al. 2014). As a result of the growing awareness of the need for groundwater conservation and more equitable distribution, parts of the fractured Yemeni state have attempted to establish a formal system of water management, supported by the expertise and funding of international donors and development

organizations (e.g., World Bank, the Dutch government, UNDP) (Alderwish et al. 2014). A variety of legal, institutional, administrative, economic, and technical instruments have been proposed to manage and regulate water top-down and by that (re-)gain control over the de facto privatized, virtually freely accessible, and rapidly depleting resource.

One of the pioneering efforts among these was the establishment of the National Water Resource Authority (NWRA) with UNDP support in 1996, which was centrally mandated to manage the national water resources sustainably (Ward 2015: 265 ff). After protracted negotiations that lasted several years, a National Water Act was finally introduced in 2002, establishing formal principles and regulations for controlling groundwater mining and reduce resource capture through the informed recognition and restriction of water rights (ibid.). In 2003, the Ministry of Water and Environment (MWE) was created, which henceforth supervised the NWRA, while being in charge of designing and implementing water reform policies. These institutional changes and initiatives were further compounded by the introduction of the National Water Resource Management Strategy and Investment Plan (NWSSIP) enshrining the proposed visions, initiatives, and regulatory measurements regarding sustainable water management into an overarching framework (ibid.).

Various measures and actions that would assumably lead to more efficient, equitable, and sustainable water use have been proposed and since been attempted to be implemented. Most notably, these include direct state control measures for the regulation of water use (e.g., well-licensing, well-spacing rules, permissions for well-deepening and new wells, designating prohibited zones in heavily overexploited areas, GPS-tracking of drilling rigs), and water resource monitoring (e.g., well census, hydrological assessments) (Alderwish et al. 2014, Weiss 2015). Moreover, there have also been more indirect regulations, such as changes in the overall economic incentive structures (e.g., rising diesel price, subsidies for sustainable irrigation methods), public awareness campaigns for the need for water conservation as well as “frail attempts at decentralized partnership approaches” (Ward 2015: xxxv, 264-269).

However, the implementation of these efforts has ever since faced strong practical challenges and opposing interests. Albeit formal institutions now do exist on paper, they are far from having substantial impacts on groundwater mining in the agricultural sector (Weiss 2015). Across the country, local realities are still being dominated by illicit deep well drilling and runaway groundwater exploitation, with resource capture and struggles over access persisting virtually unchanged (ibid.). The Taiz region is one of the few exceptions, however, where the

majority of illegal well drilling has arguably been brought under control (Abu Hatim & Mohamed 2009).

Overall, the central government's capacity to provide viable organizational arrangements for sustainable water management has been and continues to be, challenged by several issues. Some experts identify the lack of financial and human resources, and thus 'implementation capacity', as a major cause of the failure of government initiatives as a whole. The MWE and NWRA, for example, are considered understaffed and generally lack the expertise to substantially deal with the challenges at hand (Ward 2000). In addition, there are widespread problems related to the legitimacy of state institutions, which creates additional political barriers and issues surrounding the implementation and realization of state-led (ground-)water conservation policy (Kohler 1998, Weiss 2015).

In most rural areas, local communities are marked by traditional tribal structures and Islamic and customary politics, with the central state being generally perceived as either rival or thoroughly illegitimate (ibid.). Thus, any attempts of the state to impose control over local resources, be it on behalf of 'sustainability', tends to be rigorously rejected since the belief systems of local tribal cultures are often permeated by notions of autonomy and resistance to central state power (Lichtenthaeler 2010). Moreover, the long history of entrenched corruption and lack of rule of law in government agencies and institutions, as well as the experience of numerous state and military interferences in power struggles and local rivalries under Saleh's rule have additionally undermined the potential trust in, and credibility of the central state in the eyes of most tribal communities (Weiss 2015).

Related to this, essential state institutions such as the judicial apparatus have had great difficulty establishing themselves, even in many urban areas, where the influence of the state is much more present (Lackner 2017). The widespread lack of trust due to its weak capacity, missing independence, as well as the oftentimes reluctant enforcement of judgments, have decisively compromised their structural integration in the broader Yemeni society. This technically and decisively hampers the implementation of groundwater use reform (Weiss 2015). In this context, Al-Hamdi's (2000) field study in the Sanaa Basin found that the majority of respondents (96%) preferred local and Islamic-tribal courts over state courts for water disputes, due to high costs (e.g., of bribes), the accusation of bias, and the expectation of unfair trials. Indicating Yemen's weak and corruption-prone judicial and enforcement system, Abu Hatim and Mohamad (2009) have further shown how in several cases large landowners were

charged under the national Water Law (especially for illegal well drilling), but after a short time and under peculiar circumstances, the charges were dropped and the defendants released. The ineffectiveness of government regulation is also evident in a World Bank case study in the Sanaa region, which has found that despite 141 charges of illegal drilling in 2007, only two were prosecuted by state enforcement authorities (World Bank 2010: 46).

These findings strongly indicate that state enforcement of national water legislation can be considered if it is applied at all, unreliable and thoroughly uneven. This may further contribute to the ongoing stratification of Yemeni society related to the unequal access and exploitation of groundwater resources while failing to effectively curb aquifer depletion (Moore 2011). Both of which were paradoxically the basic problems that should be addressed by national water legislation in the first place.

4.3.2 Legal and institutional disintegrity

Traditional legal systems at the local level are generally reluctant to apply the provisions of the national water legislation because it is widely perceived as an instrument of state control and partly contradicts the legal provisions of customary (*urf'*) and *Shari'a* law (Weiss 2015). As noted above, these traditional legal systems generally dictate that water is nobody's property (*mubah*) yet it can be privatized once it is transferred from the commons to any type of container, including well (Kohler 1998). In addition, water rights cannot be alienated from land rights. Needless to say, both sets of regulations are ill-equipped to deal with the problems posed by commercial agriculture and the advent of deep well technology. Moreover, the *shaykh's* ability, legitimacy, and authority to settle conflicts at the local level, which used to be primarily based on their social position and knowledge of customary and Islamic law, has been increasingly undermined in the course of major social, political, and economic transformations. Considered among the main beneficiaries of state patronage and groundwater overexploitation, these actors tend to face irresolvable conflicts of interest and they are often no longer in a position to fulfill their role as neutral mediators of water disputes (Ward 2009).

In general, agricultural water rights in Yemen are poorly defined and vaguely safeguarded at both the local and national levels, and several different and sometimes contradictory legal frameworks coexist. Misiedjan & Rijswick (2015) identify 5 different sources of law that provide rules for the societal use and management of water. While all agree upon safeguarding the right of anyone to obtain sufficient amounts of safe water for drinking and domestic pur-

poses, there are pronounced divergences regarding ownership rights. As already mentioned, legal regimes at the local level are traditionally dominated by customary (*urf*') and Islamic legal provisions (S*hari'a*), which barely provide regulations on groundwater appropriation on private land (Kohler 1998). Conversely, the Constitution, the Civil Code, and the 2002 Water Law are the primary legal sources in national contexts, yet there are some pronounced contradictions.

The Yemeni Constitution designates the state as the sole owner of any type of natural resources, including water, and it is ought to use the resources for the benefit of its people (Misiedjan & Rijswick 2015). However, the Constitution renders itself subordinate to the Islamic *Shari'a*, which has its own water rules. The Civil Code, on the other hand, is consistent with *Shari'a* law and safeguards 'free access' to common water resources, while allowing private ownership if it is mobilized in some kind of container (ibid.). Similarly, the 2002 Water Law follows the principle of *Shari'a* as it states: "Water is in principle permissible for all and does not possess a private ownership except by means of conveyance or acquisition" ((Misiedjan & Rijswick 2015: 4). Nonetheless, according to the Water law, water is ought to be managed and regulated by state authorities under particular circumstances, such as the digging of wells that extend 20 meters (ibid.). Overall, there are some decisive legal ambiguities: On the one hand, water is owned by no one and is freely accessible, which is consistent with *Shari'a*. On the other hand, the state sees itself as the owner of all water resources and accordingly formulates rules to regulate them (ibid.). This sort of legal incoherence constitutes a deeply technical issue. It further complicates groundwater governance as it hampers an accountable codification of water rights (Weiss 2015).

The only viable response to the lack and disintegrity of governance and institutions, accentuated by the skewed forms of access, control, and distribution, are oftentimes pronounced conflicts between competing (ground-)water users and usages (e.g., between farmers, irrigation vs. domestic purposes) (Ward 2009). Particularly in the case of disagreements between hostile tribal communities, some scholars are indicating that such tensions provoke the use of armed force regularly, claiming many deaths every year (cf. Handley 2001, Small Arms Survey 2010). However, the much more common non-violent, and potentially productive conflicts are oftentimes strongly compromised by the social power structures opposing the assertions of disenfranchised water users. For instance, Gerhard Lichtenthaeler (2003: 187) described a case in which an influential trader built a 10-hectare farm that was operated with 8 deep wells.

After a 500-meter deep submersible pump was installed, several wells of other small farmers in the vicinity went dry, initially triggering a series of outrages. However, these quickly cooled down when the adjacent farmers realized that "[…] the big neighbor had no obligation to share these resources" (Lichtenthaeler 2003: 187).

Therefore, in many cases, powerful large landowners and commercial farmers can effectively continue to insist on the intimate linkage between land ownership and water rights enshrined in customary and Islamic law, and thus, keep on appropriating groundwater while dispossessing others. Conversely, where national law is applied, they are capable of circumventing its rules simply by taking actions such as noncompliance, threat or use of violence, or by bribing judges, authorities, and other state officials (Zeitoun et al. 2012, Weiss 2015).

4.3.3 Political economy

In more general terms, Zeitoun et. al (2009, 2012) indicates the persistence of a political economy in favor of runaway groundwater mining and the rigid power asymmetries therein as the major obstacles for the implementation of (ground-)water use reform in the agricultural sector. As outlined earlier, the burdens and benefits associated with groundwater mining in Yemen are historically and socially highly unevenly distributed. Large landowners, commercial farmers, and other political-economic elites (e.g., state officials, military leaders), have taken the leading role in the unchecked appropriation of land and groundwater resources in the context of large-scale, well-irrigated commodity crop farming, while disproportionately benefitting (Moore 2011). Weaker social actors (e.g., small farmers, rural landless, esp. women and girls), in contrast, have found themselves increasingly dispossessed and 'hydrologically marginalized' as they lack the economic wealth and political power for gaining viable access and for competing in the "race to the bottom" of the aquifer (Lichtenthaeler 2010). In other words, access to, and exploitation of the supposedly common groundwater resources have been, and continue to be, fundamentally uneven, and the status quo (i.e., rampant groundwater mining, lack of regulation, uneven enforcement) is not necessarily unfavorable for all stakeholders involved in agricultural groundwater use (Zeitoun et. al 2012).

From a political ecology perspective, the establishment of a more sustainable and just agricultural water-management-regime constitutes as a decidedly political process, mediated by the clash and negotiation of diverging interests of different actors as well as the battle of different forms of social power exerting control over the societal use and management of the biophysi-

cal environment (cf. Bryant & Bailey 1997). Zeitoun (2009: 25) roughly differentiates the notion of power into hard and soft power. The former refers to the repression and enforcement by means (or threat) of violence (e.g., arms), while the latter represents either economic power (e.g., patronage or bribe), the (perceived) legitimacy of specific actors and decisions or, related to the latter, discursive and ideational (or "bargaining") power. All forms of power are used by different actors involved in the irrigation sector to pursue their interests. Thereby, the persistence of unequal relations of power between the actors proposing and the ones opposing water use reform takes a central role in the hampered realization of effective groundwater use reform on the ground (Zeitoun et. al. 2012, Steenbergen et. al 2015).

In this context, actors interested in, and/or responsible for safeguarding equitable water rights and the implementation of water demand management principles (i.e., policy resulting in more efficient, equitable, and sustainable water use), roughly including the MWE and NWRA, multilateral development organizations and donors, as well as small farmers are considered to have very limited influence on actual decision-making processes concerning agricultural water use (Zeitoun et al. 2012). This is due to the lacking institutional ability, weak enforcement capacity, and funding shortfalls, or low legitimacy of both the actors themselves and their specific goals dedicated to the reduction of groundwater overdraft and the reallocation of groundwater resources in the eyes of the powerful (ibid.).

In Contrast, actors showing strong resistance to groundwater use reform (e.g., large landowners, commercial farmer *shaykhs*, rich trades, military elites, and the ministry of irrigation over which they exert influence) "benefit directly from current water use practices […] and are considered the most influential over actual water use" (Zeitoun et al. 2012: 58). The vested interests of this wealthy, armed, influential, and politically well-connected group of actors, whose complicity to the central government constitutes an important pillar for political rule and stability, has thus constituted one of the overarching obstacles for the implementation and realization of sustainable water management, as Helen Lackner (2017: 273) summarizes:

> Removing water management from the control of the large rural landowners, who are over-exploiting the resource for irrigation of high value and other crops, would require challenging a group of powerful individuals whose support [the former autocratic president] Saleh needed to remain in power. Hence all efforts at water conservation were deliberately undermined to ensure that this group could continue and increase its use of the scarce resource at the expense of the future of all other Yemenis.

5 Discussion

5.1 Summary

Investigating the social, political, and economic circumstances of hydrological change in rural Yemen, this thesis has sought to trace the transformation of hydro-social relations that has culminated in today's 'groundwater crisis'.

As the literature review revealed, various local forms of indigenous water management used to be well adapted to Yemen's challenging climate and hydrology. Rooted in traditional water harvesting techniques, Islamic and customary law, local customs, environmental knowledge as well as forms of tribal socio-political organization, these place-based hydro-social regimes could arguably organize a largely sustainable use and relatively fair management of Yemen's limited water resources throughout history. Since the 1970s, these arrangements, which relied primarily on surface runoff, direct precipitation, seasonal floods, and, to a much lesser extent, alluvial aquifers, have started to dismantle and shifted towards rampant groundwater exploitation. The concomitant proliferation of unsustainable groundwater use practices through diesel-powered tube wells has profoundly and increasingly undermined both the integrity of local and regional water regimes as well as the intricate systems governing the flows of water.

Against a backdrop of a lack of local regulatory mechanisms for groundwater extraction on private land, the novel opportunities provided by the diffusion of deep well technology have paved the way for rampant groundwater mining in the first instance. These trends have been structurally and systemically catalyzed by the agricultural policies adopted by the emerging Yemeni state (with donor support) from the 1970s on: pervasive economic incentives, subsidies, direct investments, as well as the long-lasting absence of formal governance and institutions for sustainable groundwater management have decisively underpinned the emerging 'groundwater-extraction-regime'. On the other hand, the looming degradation of water resources had been widely disregarded in the initial rush to unprecedented rural and national economic development, the latter of which arguably served to consolidate state power within a very fractured political geography.

In particular, the rapid expansion of agriculture following the privatization and commercialization of land and associated water management has been accompanied by an increase in unsustainable groundwater extraction rates in the agricultural sector, which now accounts for a

vast majority of total water use in Yemen. This is also reflected in extensive land-use changes, with groundwater-irrigated cropland increasing 14-fold since the early 1970s, accompanied by a sharp decline in traditional rainfed and spring-fed croplands (Varisco 2019).

The initially widespread positive effects derived from maximized water yields and year-round irrigation have been increasingly overshadowed by adverse (socio-)hydrological changes. These include, above all, the drawdown of water tables and the exhaustion of aquifers, increasing groundwater salinization, alteration of wadi runs, and the drying up of springs. The immediate social consequences, such as water and food insecurity, destruction of economic livelihoods and social decline, as well as pronounced health problems, have affected different places, actors, and social segments in increasingly uneven ways. In this context, the historical and ongoing degradation of (ground-)water resources and widespread deprivation of access are deeply and reciprocally intertwined with alterations and reinforcements in socio-economic, cultural, and political power relations within Yemeni society.

As the access to the formerly commonly used land and associated water resources has quickly become a virtually fully private affair, and thus, largely a matter of individual economic means, social status, and political clout, the benefits, burdens, and risks associated with groundwater overuse are historically and socially highly unevenly distributed. In Yemen's highly hierarchical society, large segments of the population (small farmers, rural landless, poor downstream communities, and especially women and girls) have found themselves increasingly dispossessed and 'hydrologically' marginalized as they face major socio-economic, political, cultural, and, not least, (geo-)hydrological obstacles for gaining viable access to (ground-)water. These disempowered social groups at the margin of Yemen's political economy bear the real brunt of the 'groundwater crisis'. This is particularly serious as these actors are the most vulnerable to the exacerbating situation despite being the smallest consumers.

Conversely, against a backdrop of persistent tribal structures and hierarchies, land and associated groundwater appropriation through large-scale, commercial agriculture has constituted an important source of patronage and social power in the context of the growth and expansion of the effectively oligarchic Yemeni state. Through uneven water resource allocation patterns, the formal and informal 'ruling elite' (e.g., commercial farmer *shaykhs*, state officials, rich traders, military elites) has disproportionately benefitted from rampant groundwater mining while reinforcing their grip on power through resource capture and the 'monopolization' of water (and land) rights. In this way, these actors are much less exposed to the induced hydro-

logical stress because they have the capital and opportunities to keep up with the ever-declining water levels and rising costs of access. This has decisively compromised the overarching political will for, and realization of, nascent political remedies (e.g., national water legislation) as the Status quo is not necessarily unfavorable for the most powerful actors involved in agricultural water use.

These "power geometries that choreograph access to and exclusion from water" (Swyngedouw 2009: 59) are still constitutive of the everyday (re)production of the hydro-social cycle in Yemen. Despite the introduction of national water law in 2002, state institutions, and broader policies to ensure sustainable water management (e.g., well licensing), groundwater mining and resource capture continue almost unchecked in many places. The fragile and corruption-prone central state apparatus, which is virtually nonexistent in many rural areas due to its low legitimacy and weak enforcement capacity, is generally ill-equipped at implementing its water policies in terms of curbing aquifer depletion and safeguarding equitable water rights. In this way, powerful actors can keep on appropriating this precious and depleting resource by circumventing the national water laws through actions such as non-compliance, bribery, political leverage, or simply by reference to the concurrent and in many places still prevailing Islamic and customary legal provisions.

5.2 Interpretation and contextualization

The results of the literature review support the central argument of this paper, namely that water-related phenomena and issues such as ‘water scarcity’ are generally about much more than just water per se. Rather, they imply important historical-geographic, social, political, economic, and cultural dimensions, in addition to purely hydrological ones, which a political ecology of water needs to critically make sense of. The related hydro-social cycle concept, which is still in its infancy, recognizes this holistic complexity and hybridity and examines the entanglements and reciprocities of social and hydrological processes at different scales from an explicitly normative perspective (cf. Swyngedouw 2009, Linton & Budds 2014).

Although most political-ecological studies on water focus on highly anthropogenic and thoroughly socially constituted urban waterscapes (cf. Swyngedouw 2004), this work has shown that a hydro-social perspective also appears meaningful and important on much larger scales. In this way, this thesis has attempted to reveal how the severe ‘groundwater crisis’ in (rural) Yemen does not merely represent the ‘self-evident’ and seemingly apolitical expression of its

comparatively scarce water resources, which has been steadily undermined by rising demand in the wake of rapid population growth, 'neutral' economic development, or inadequate local water use practices. Although setting the focus on such proximate demographic, socio-economic, and hydrological factors is not necessarily unimportant, such natural-science-dominated and neo-Malthusian accounts are analytically flawed and close themselves off from the 'bigger picture'. The reductionism inherent in such perspectives only allows for an overly abstract, de-historicized, and depoliticized understanding of the complex *socio-natural* phenomena that are being attempted to be described. The monolithic and teleological understanding of society and history, together with the deeply entrenched vision of nature as an object external to social and political processes, risks addressing the 'symptoms' rather than the causes of 'environmental crises', while the actual victims of phenomena such as aquifer depletion may be overlooked or lumped together with the main polluters and beneficiaries.

As it was tried to be presented in this paper, a political-ecological perspective on water scarcity intends to re-contextualize such technoscientific readings. In this way, it addresses more closely and critically the complex socio-political forces and inner workings of society at different temporal, spatial, and social scales, which determine, in conjunction with hydrological processes, *how*, *why*, *where*, and *for whom* water becomes scarce or abundant. In this way, the analytical lens shifts from 'water' to *hydro-social relations*; from absolute and volumetric terms to the historical 'becoming' and 'lived realities' through and in which instances of water scarcity are hydro-socially produced, experienced, or contested. Such history- and place-specific, heuristic, and ethnographic approaches 'narrate stories' about the "[…] *nature of society* and the *nature of its water flows*" (Swyngedouw 2009: 59, emphasis added, Linton 2010: 294). By 'denaturalizing', historicizing, and politicizing what is often seen as a given and fixed set of socio-hydrological circumstances, hydro-social analysis aims to produce critical and socially relevant knowledge and thus serves as an emancipatory lever for more sustainable, democratic, and socially inclusive forms of water governance across scales (Loftus 2009).

In this way, it can be argued that although the exacerbating water shortages in Yemen constitute a 'real' material reality and, at worst, even a matter of life and death (the per capita availability of renewable water resources is about 85 m^3 annually, less than one-tenth of the internationally recognized limit for acute water scarcity) (Lackner 207: 266), the actual underpinnings and manifestations of the 'groundwater crisis' exceed demographic concerns and the

mere fact that water is comparatively physically scarce. Such a picture ignores societal complexity and the agency of various forms of power impinging on hydro-social relations. Similarly, it implies that one can draw direct lines between the physical and human geography; between the physical availability and social accessibility of water. Both are assertions which are arguably a crude abstraction, even in Yemen: In fact, there are large-scale (fossil) groundwater reserves in the least populated Eastern desert areas, which may supply the Yemeni population for an estimated 5000 years to come but accessing and distributing them faces major technical, political, and socio-economic obstacles, exceeding even those of desalination (Ward 2015: 261). Likewise, social access to water arguably correlates not only with its absolute availability but with wealth, status, political cloud, land ownership, etc. Thus, the 'better-off' generally have control over access and may directly benefit from rampant groundwater overuse while it is, for the most part, the poorest and politically invisible social groups at the margins of Yemen's political economy bearing the real burden of the dwindling groundwater resources.

In this context, this thesis has shown how pervasive instances of 'water scarcity', as they exist in Yemen, should better be addressed and understood – in terms of its depth and relevance - as phenomena that "[…] necessarily involve the mixing of social and hydrological processes" (Linton 2010: 290). In this way, it was emphasized how severe (socio-)hydrological issues related to aquifer mining and experiences of water scarcity are always socially mediated and thoroughly politicized regarding both its absolute and volumetric hydrological properties (and especially the human-induced changes therein) as well as the various broader, less tangible, but overly crucial, social circumstances and manifestations.

While the former evidently shapes the latter, the actual hydro-social realities and problems related to water scarcity are simultaneously and perhaps more crucially conditioned by a number of historically contingent 'non-hydrological' social, political, economic, and cultural factors inherent in the hydro-social cycle as it occurs in rural Yemen: precipitation regimes, aquifer recharge rates, climate variability, ancient fossil groundwater reserves etc. come together within a broader hydro-social assemblage encompassing such diverse things like local groundwater use practices and institutions, unchecked diffusion of deep-well technology, land ownership-regimes, local environmental knowledge and imageries, tribal and Islamic politics, state-sponsored incentives for groundwater mining, the commercialization of agricultural production, (hydro-)social inequality and structures of domination, forms of nepotism and pat-

ronage, territorial struggles, state and policy failure, institutional decay, legal pluralism, pervasive corruption etc. These factors are all deeply inscribed in the actual 'waterscape', continually (re-)shaping the flows of water as a combined social and hydrological process. In this sense, it can be argued that it is not merely the relationship of society with water that is at stake in Yemen, but the social and political nature of water itself. Ultimately, the historical emergence of the 'groundwater extraction regime' and the ongoing 'groundwater crisis' are deeply and reciprocally enmeshed with the very fabric of Yemeni society and political economy, both of which are embedded in and express the particular hydro-social configurations as outlined in this thesis. To initiate hydro-*socially* sustainable pathways out of this complex and politicized crisis, there is a fundamental need for pronounced social and political change, the rearrangement of cultural, economic, and political institutions, and the establishment of governmental accountability and a polity that is informed by general rather than particular interests regarding the governance and management of (ground-)water.

5.3 Limitations, outlook, and future research

The critical analytical lens of political ecology is characterized by a strongly normative stance on environmental problems. Adopting notions of social-ecological justice, political ecology attempts to bridge the gap between research and political action. Following this position, this thesis has attempted to politicize the historical unfolding of the 'groundwater crisis' in Yemen by emphasizing its fundamentally (hydro-)socially produced character and the social power relations that surface in the actual waterscape and uneven experiences of 'water scarcity'.

However, it is important to note that the purely literature-based nature and extraordinarily large scope of this work have only allowed for a highly generalized and simplified view of the actual hydro-social realities and issues that have been attempted to be described. In this context, the mere juxtaposition of 'pre-modern' and supposedly successful and sustainable water management regimes on the one hand with the market- and patronage-driven runaway groundwater extraction regime on the other is a crude, but (for this work) necessary, generalization. Therefore, this portrayal is meant rather as an analytical and politically mobilizable simplification of the actual hydro-social conditions as they occur in Yemen. The various local hydro-social arrangements are historically and today highly specific and, in some places, traditional forms persist, while groundwater extraction is not necessarily mining aquifers in such disastrous and uneven ways as indicated in this thesis. Similarly, the strongly historical stance

is not intended to mourn or romanticize Yemen's traditional water management regimes. Instead, the historical approach is used not only to outline specifically how technological, social, and political-economic transformation processes have led to today's precarious forms of mismanagement of Yemen's limited (ground-)water resources but also to indicate concrete cases of presumably more resilient and feasible ways of managing water. In this way, it was pointed out that there are obviously "[…] better, less coercive, less exploitive, and more sustainable ways of doing things" (Robbins 2012: 20). However, a return to traditional water management regimes is by no means a panacea and the social, political, and economic arrangements in which they were embedded have largely disintegrated, alongside the capacity to sustainably cope with the challenging hydro-geography.

Given the lack of case studies and hydrological assessments across large parts of Yemen, there is an urgent need for interdisciplinary research on water-society relations that addresses both the hydrological conditions and availability, and, as importantly, the various social, political, economic, and cultural contexts and structures through and in which instances of 'water scarcity' manifest themselves in material and cultural ways. This requires close collaboration between hydrology and (critical) social sciences, although there is still some disagreement about what this collaboration should look like in concrete terms. In this context, Wesselink et al. (2017) point to the strength of critical 'hydro-social' studies in providing rich narratives and a comprehensive understanding of individual cases from which natural science-oriented 'socio-hydrology' may derive mathematical models and quantitative analyses.

In this work, the discursive circumstances affecting hydro-social relations have only been marginally explored. Related to this, Gerhard Lichtenthaeler (2003) has indicated more specifically the historically outstanding role of local tribal cultures and imageries regarding the prevailing (but changing) interpretations of Islamic law as an important shaping force of local water management practices, which merits further investigation. This also applies to the [...] potential use of poetry as a culturally accepted form of communicating [...] principles of groundwater sustainability and water demand management" (Lichtenthaeler 2003: 223).

This paper has examined the water crisis in the context of irrigated agriculture and the social circumstances of human-induced (geo)hydrological change in rural areas. However, the (socio-)hydrological impacts of global climate change should also be taken into account, as aridity has arguably increased in recent decades while rainfall is increasingly associated with extreme weather events (Mohamed et al 2017). Likewise, cities also contribute significantly to

groundwater mining and are entwined with a multitude of hydro-social issues (e.g., urban-rural water transfers, unequal water-supply regimes), which requires further scrutiny, especially in Taiz and Sanaa, the latter of which is expected to be the first capital in the world to run out of water altogether in the near future (Varisco 2019).

Further questions arise regarding the role of water in the ongoing (civil) war, which may further undermine forms of water governance through institutional decay while there are several reported cases related to the 'weaponization' of water supply infrastructure (cf. Gleick 2019).

Although the capacity of traditional water management systems related to the regulation of groundwater abstraction is arguably very low in Yemen, this does not necessarily preclude the possibility of their 'revival' through the adaptation to the challenges provided by the new hydro-social realities. At some places, rising political movements and forms of collective action at the local level have recently demonstrated their ability to curb groundwater overdraft while claiming more equitable access (cf. Taher et al. 2012, Ward 2015: 333). Still in their infancy, these 'bottom-up' efforts must be actively encouraged and expanded to initiate sustainable and emancipatory socio-ecological outcomes. As the central government is widely perceived as illegitimate and has proven too weak and fragile to have significant impacts on rampant groundwater mining, it may, according to Weiss (2015: 261),

> […] stand to play a far more effective role in groundwater management through selective transfers of knowledge, resources, technology, and capacity to locally conceived initiatives than through top-down, heavy-handed regulation.

6 Conclusion

As it has turned out, the nature of Yemen's water crisis goes well beyond simplified notions of Malthusian catastrophes in the face of limited (ground-)water resources and rapid population growth, but rather represents the outcome of complex historical interactions among social, political, economic, cultural, and hydrological factors. Specifically, this thesis has explored the reconfiguration of water-society relations associated with technological, agrarian, and political-economic change in rural Yemen. These centrally include the quasi-privatization of land and associated water rights, the rapid commercialization and mechanization of irrigated agriculture following state incentives, the unchecked proliferation of motorized deep wells, patronage relationships, territorial struggles, as well as the absence or ineffectiveness of any institutional arrangements regulating groundwater withdrawal on private land.

Yemen's waterscapes, overall, are "[…] dependent upon institutions and practices as much as on the hydrological cycle, they are not only physically produced, but also socially enacted" (Bakker 2003: 49). In just a few decades, the established hydro-social arrangements that were based primarily on surface water flows and direct rainfall, supplemented by springs and shallow wells, have largely unraveled. The rapid shift to a virtual dependence on groundwater through diesel-powered tube wells and the concomitant proliferation of unsustainable groundwater use practices has profoundly and increasingly undermined both the hydrological cycle and existing forms of water governance. Following these transformations, both the hydrological availability as well as social accessibility of (ground-)water resources has been fundamentally compromised, giving way to a system that is both unsustainable and exclusionary. While the majority lacks access, control over groundwater has shifted to fewer, politically and economically powerful people within an effectively oligarchic and patronage-based state, which is why no sustained political will to address the crisis has come up for decades.

By attending hydro-social relations and the 'water-power-nexus', this thesis has tried to elaborate a richer understanding of the socio-ecological ramifications of Yemen's groundwater issues. This might inform future interdisciplinary water research and water policies that "[…] deliberately put people at the center of water solutions" (Linton 2014: 114). Ultimately, the ongoing 'water crisis' is to an arguably large extent the expression of a deeply social and political crisis. To initiate *hydro-socially* sustainable pathways, Yemen must overcome the social and political fault lines and struggles that have shaped its modern history to date.

References

Aji, M. (2018): Yemen's Agricultural World: Crisis and Prospects. In Zurayk, R., Woertz, E., & Bahn, R. (Ed.): Crisis and Conflict in Agriculture. Boston: CABI, pp. 131–143.

Alderwish, A. M., Al-Khirbash, B., & Mushied, H.(2014): Review of Yemen's control of groundwater extraction regime: situation and options. In International Research Journal of Earth Sciences 2 (3), pp. 7–16.

Al-Hamdi, M. I. (2000): Competition for scarce groundwater in the Sana'a plain, Yemen. A study of the incentive systems for urban and agricultural water use. 1st ed. Rotterdam: A.A. Balkema.

Alley, A. L. (2010): The rules of the game: Unpacking patronage politics in Yemen. In: The Middle East Journal 64 (3), pp. 385–409.

Bakker, K. J. (2003): A Political Ecology of Water Privatization. In Studies in Political Economy 70 (1), pp. 35–58.

Blaser, M. & Escobar, A. (2016): Political Ecology. In Adamson, J., Gleason, W. A., & Pellow, D. N. (Ed.): Keywords for Environmental Studies: NYU Press, pp. 164–170.

Boelens, R., Hoogesteger, J., Swyngedouw, E., Vos, J., & Wester, P. (2016): Hydrosocial territories: a political ecology perspective. In Water International 41 (1), pp. 1–14.

Brunner, U. & Haefner, H. (1986): The successful floodwater farming system of the Sabeans, Yemen Arab Republic. In Applied Geography 6.

Bryant, R. L., Bailey, S. (1997): Third World political ecology. London: Routledge.

Budds, J. (2008): Whose scarcity? The hydrosocial cycle and the changing waterscape of La Ligua River Basin, Chile. In Boykoff, M. T., Goodman, M. K. (Ed.): Contentious geographies: Environment, meaning, scale: Ashgate.

Budds, J., Linton, J., & McDonnell, R. (2014): Geoforum special issue Editorial: The Hydrosocial Cycle. In Geoforum.

Carpaccio, S. (2007): No quick fix: Foreign aid and state performance in Yemen. In: Binder L. (Ed.): Rebuilding devastated economies in the Middle East. New York: Palgrave Macmillan

Castree, N. & Braun, B. (Ed.) (2001): Social Nature: Theory, practice and politics. Oxford: Blackwell Publishers.

Clark, V. (2012): Yemen. Dancing at the Heads of Snakes. New Haven: Yale University Press.

Davie, T. (2008): Fundamentals of Hydrology. 2nd ed. Abingdon: Routledge.

Eger, H. (1988): Runoff Agriculture. A Case Study About the Yemeni Highlands. Wiesbaden: Reichert.

Ehrlich, P. R. (1968): The population bomb. Ballantine Books.

Gatter, P. (2012): Politics of qat: The role of a drug in ruling Yemen. Wiesbaden: Reichert.

Gleick, P. H. (2000): A Look at Twenty-first Century Water Resources Development. In Water International 25 (1), pp. 127–138.

Gleick, P. H. (2019): Water as a weapon and casualty of armed conflict: A review of recent water-related violence in Iraq, Syria, and Yemen. In Wiley Interdisciplinary Reviews: Water 6(4), e1351

Hadden, R. L. (2012): The geology of Yemen: An annotated Bibliography of Yemen's geology, geography, and earth science. Virginia: Army Geospatial Center.

Handley, C. D. (2001): Water stress: Some symptoms and causes. A case study of Taiz, Yemen. Aldershot: Ashgate.

Hardin, G. (1968): The Tragedy of the Commons. In Science 131 (3859), pp. 1243–1248.

Harrower, M. J. (2009): Is the hydraulic hypothesis dead yet? Irrigation and social change in ancient Yemen. In World Archaeology 41 (1), pp. 58–72.

Hunt, R. C. (1988): Size and the structure of authority in canal irrigation systems. In Journal of anthropological research 44 (4), pp. 335–355.

Jagannathan, N. V., Mohamed, A. S. & Kremer, A. (Ed.) (2009): Water in the Arab world: management perspectives and innovations. Washington, D.C.: World Bank Group.

Johnston, B. (2001): The political ecology of water: an introduction. In Capitalism Nature Socialism 14 (3), pp. 73–79.

Karpouzoglou, T. & Vij, S. (2017): Waterscape: a perspective for understanding the contested geography of water. In WIREs Water 4 (3), e1210

Kohler, S. (1998): Institutionen in der Bewässerungs-Landwirtschaft im Jemen. Wiesbaden: Reichert.

Kohler, S. (2000): Customary Water Rights and Modern Technology: The Overuse of Groundwater Resources in Wādīḥarīb, Yemen. In Études Rurales (155/156), pp. 167–178.

Lackner, H. (2017): Yemen in Crisis. Autocracy, Neo-Liberalism and the Disintegration of a State. London: Saqi.

LeBrun, E. (2010): Under Pressure: Social Violence Over Land and Water in Yemen. Yemen Armed Violence Assessment Issue Brief No. 2. In Small Arms survey. Available online at http://www.smallarmssurvey.org/fileadmin/docs/G-Issue-briefs/SAS-Yemen-AVA-IB2-ENG.pdf.

Lichtenthaeler, G.(2000): Power, Politics, and Patronage: Adaptation of water rights among Yemen's northern highland Tribes. In Études Rurales (155/156), pp. 143–166.

Lichtenthaeler, G. (2003): Political ecology and the role of water. Environment, society, and economy in northern Yemen. 1st ed. Aldershot: Ashgate.

Lichtenthaeler, G. (2010): Water Conflict and Cooperation in Yemen. In Middle East Report (254), pp. 30–36.

Linton, J. (2008): Is the hydrologic cycle sustainable? A historical-geographical critique of a modern concept. In Annals of the Association of American Geographers 98 (3), pp. 630–649.

Linton, J. (2010): What is water? The history of a modern abstraction. Vancouver: UBC Press.

Linton, J. (2014): Modern water and its discontents: a history of hydrosocial renewal. In WIREs Water (1), pp. 111–120.

Linton, J. & Budds, J. (2014): The hydrosocial cycle: Defining and mobilizing a relational-dialectical approach to water. In Geoforum 57, pp. 170–180.

Mehari, A., van Steenbergen, F., & Schultz, B. (2007): Water rights and rules, and management in spate irrigation systems in Eritrea, Yemen, and Pakistan. In Giordano, M., Butterwort, J. (Ed.): Community-based water law and water resource management reform in developing countries. Oxford: CAB International, pp. 114–129.

Menga, F. & Swyngedouw, E. (Ed.) (2018): Water, technology and the nation-state. London: Routledge.

Misiedjan, D. & van Rijswick, H. (2015): A human right to water while the wells run dry: Analysing the legal and regulatory framework of Yemen water law. In Journal of water law 24 (5/6), pp. 199–206.

Moench, M. (1997): Local water management: options and opportunities in Yemen. Survey report of the decentralized management study. Sana'a: World Bank.

Mohamed, H., Elayah, M., & Schuplen, L. (2017): Yemen between the impact of the climate change and the ongoing Saudi-Yemen war: A real tragedy. Centre for international development issues.

Moore, S. (2011): Parchedness, politics, and power: the state hydraulic in Yemen. In Journal of Political Ecology 18 (1), pp. 37–50.

Mundy, M. (1989): Irrigation and Society in a Yemeni Valley. On the life and death of a bountiful resource. In Peuples méditerranéens (46), pp. 97–128.

Peet, R. & Watts, M. (Ed.) (2004): Liberation ecologies: environment, development and social movements. London: Routledge.

Perreault, T., Bridge, G., & McCarthy, J. (Ed.) (2015): The Routledge handbook of political ecology. New York: Routledge.

Phillips, S. (2011): Yemen and the politics of permanent crisis. New York: Routledge.

Robbins, P. (2012): Political ecology. A critical introduction. 2nd ed.: Blackwell.

Robbins, P. (2015): The Trickster science. In Perreault, T., Bridge, G., & McCarthy, J. (Ed.): The Routledge handbook of political ecology. New York: Routledge.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F., … & Foley, J. A. (2009): A safe operating space for humanity. In Nature 461, pp. 472–475.

Sivapalan, M., Savenije, H., Blöschl. G. (2012): Socio-hydrology: a new science of people and water. In Hydrological Processes 26 (8), pp. 1270–1276.

Stookey, R. (1974): Social structure and politics in the Yemen Arab republic. In Middle East Journal 28 (4), pp. 409–418.

Swyngedouw, E.: The political economy and political ecology of the hydro-social Cycle. In Journal of Contemporary Water Research & Education (142), pp. 56–60.

Swyngedouw, E. (1999): Modernity and hybridity: Nature, regeneracionismo, and the production of the Spanish waterscape, 1890–1930. In Annals of the Association of American Geographers 89 (3), pp. 443–465.

Swyngedouw, E. (2004): Social power and the urbanization of water. Flows of power. Oxford: Oxford University Press.

Turner, M. D. (2009): Ecological: natural and political. In Castree, N., Demeritt, D., Liverman, D., & Rhoads, B. (Ed.): A Companion to Environmental Geography. 1st ed.: Wiley-Blackwell, pp. 181–197.

van Steenbergen, F., Kumsa, A., & Al-Awlaki, N. (2015): Understanding Political Will in Groundwater Management: Comparing Yemen and Ethiopia. In Water alternatives 8 (1), pp. 744–799.

Varisco, D. M. (1982): The adaptive dynamics of water allocation in al-Ahjur, Yemen Arab Republic. Ph.D. dissertation, Department of Anthropology, University of Pennsylvania.

Varisco, D. M. (1983a): Sayl and ghayl: The ecology of water allocation in Yemen. In Human Ecology 11 (4), pp. 365–383.

Varisco, D. M. (1983b): Irrigation in an Arabian valley. A system of highland terraces in the Yemen Arab Republic. In Expedition, pp. 26–34.

Varisco, D. M. (1991): The future of terrace farming in Yemen: A development dilemma. In Agriculture and Human Values 8 (1-2), pp. 166–172.

Varisco, D. M. (1996): Water Sources and Traditional Irrigation in Yemen. In New Arabian studies.

Varisco, D. M. (2019): Pumping Yemen Dry: A history of Yemen’s water crisis. In Human Ecology 47 (3), pp. 317–329.

Villar-Navascués, R. A. & Arahuetes, A. (2020): The hydrosocial cycle: Understanding water as a socionatural production. In W. L. Filho (Ed.): Clean Water and Sanitation: Springer (Encyclopedia of the UN sustainable development goals), pp. 1–11.

Vogel, H. (1988a): Deterioration of a mountainous agro-ecosystem in the Third World due to emigration of rural labor. In Mountain Research and Development 8 (4).

Vogel, H. (1988b): Impoundment-type bench terracing with underground conduits in Jibal Haraz, Yemen Arab Republic. In Transactions of the Institute of British Geographers 13 (1), pp. 29–38.

Vörösmarty, C. J. & Sahagian, D. (2000): Anthropogenic disturbance of the terrestrial water cycle. In Bioscience 50 (9), pp. 753–765.

Walker, P. A. (2005): Political ecology: where is the ecology? In Progress in human geography 29 (1), pp. 73–82.

Ward, C. (2000): The political economy of irrigation water pricing in Yemen. In A. Dinar (Ed.): The political economy of water pricing reforms. New York: Oxford University Press, pp. 381–394.

Ward, C. (2009): Water Conflict in Yemen: The Case for Strengthening the Local Resolution Mechanisms. In Jagannathan, N. V., Mohamed, A. S., Kremer, A. (Ed.): Water in the Arab world: management perspectives and innovations. Washington, D.C.: World Bank Group, pp. 233–267.

Ward, C. J. (2015): The water crisis in Yemen. Managing extreme water scarcity in the Middle East. 1st ed. London: Tauris.

Ward C., Beddies S., Hariri K., Yaffiei S. O., Sahooly A., & Ger-hager B (2007): Yemen's water sector reform program – a poverty and social impact analysis. Washington, D.C.: World Bank.

Weiss, M. I. (2015): A perfect storm: the causes and consequences of severe water scarcity, institutional breakdown, and conflict in Yemen. In Water International 40 (2), pp. 251–272.

Wesselink, A., Kooy, M., & Warner, J. (2017): Socio-hydrology and hydrosocial analysis: toward dialogues across disciplines. In Wiley Interdisciplinary Reviews: Water 4(2), e1196

Wittfogel, K. (1957): Oriental Despotism. A Comparative Study of Total Power. 1st ed. New Haven: Yale University Press.

World Bank (2010): Sana'a Basin integrated water resources management: assessment of phase I. Washington, D.C.: World Bank.

World Bank (2012): Overview. Available online at https://www.worldbank.org/en/country/yemen/overview, checked on 5/15/2021.

Zeitoun, M. (2009): The political economy of water demand management in Yemen and Jordan. Cairo: IDRC.

Zeitoun, M., Allan, T., Al-Aulaqi, N., & Jabarin, A. S. (2012): Water demand management in Yemen and Jordan: Addressing power and interests. In Geographical Journal 178 (1), pp. 54–66.

Zimmerer, K. S., & Bassett, T. J. (Ed.) (2003): Political ecology: an integrative approach to geography and environment-development studies. New York: Guilford Press

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Berlin, den 30.8.2021

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