ADVANCING LIVELIHOOD WATER SECURITY IN THE RURAL GLOBAL SOUTH

by

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Abstract

Climate change and variation, and rising demand for freshwater increasingly impact water security for humans, ecosystems, and integrated social-ecological systems. In the rural global South, diverse water-related risks interact with systemic inequalities to unevenly impact the assets, capabilities, and activities underpinning resource-based livelihoods. As such, livelihood water security – whether and to what extent people can avoid unacceptable risks, meet context-specific needs, and achieve self-defined aspirations – is critical for disadvantaged groups, without which they may experience pronounced impacts to their food and income security. This challenge has revealed significant research gaps in how rural livelihood water security concerns are conceptualized, studied, and addressed in local and regional contexts, including whether and to what extent equity and sustainability objectives and outcomes are reflected and achieved in water security approaches. In response, this dissertation i) undertakes a systematic scoping review of the English-language refereed scholarship to ascertain how water security for rural livelihoods in global South contexts is conceptualized and addressed; ii) conducts an empirical and multi-village analysis of the equity and sustainability effects associated with an over $1B USD water security program ("Jalyukt Shivar Abhiyan") in Maharashtra state, India, intended to transform villages and agricultural livelihoods into "drought-free" systems; and iii) develops an integrative methodological and epistemological approach to analyze dynamics affecting the distribution of livelihood water security initiatives at larger policy-relevant scales. This dissertation was informed by an extensive review of scholarly research; ninety-four (94) interviews, including individual and focus-group meetings with key informants, and households in three drought-prone villages; and statistical analyses of secondary climate, agricultural, demographic, and water security project data in Maharashtra. It advances knowledge of how water (in)security for rural livelihoods is conceptualized, analyzed, and addressed in both scholarly and applied contexts in the global South, stresses the importance of advancing water security in holistic, widespread, and long-term ways, and identifies key considerations to support this approach.

Lay Summary

Over one billion people depend on water for livelihood activities, such as farming, in rural areas of the global South. However, systemic social and economic inequalities have meant not everyone has sufficient access to water for their livelihoods – meaning they are not water secure. In addition, hydrological stressors, such as climate change and variation, exacerbate livelihood water insecurity. In my dissertation, I critically explore how water security for rural livelihoods in the global South is conceptualized and applied in research and policy efforts, and to what extent they factor in concerns of equity and sustainability. To accomplish this, I synthesize knowledge from peer-reviewed literature and critically analyze the deficiencies associated with a large-scale water security program in Maharashtra, India. Overall, my dissertation demonstrates the need for, and importance of, advancing livelihood water security initiatives in holistic, widespread, and long-term ways, and identifies key strategies to support this approach.

Preface

This dissertation is my original and independent work. I identified the research problems, designed the methodological approaches, conducted data collection and analyzed the data (in certain cases, with the support of multiple Research Assistants), developed novel contributions to the literature, and wrote each Chapter in its entirety. My advisory committee (Drs. Leila M. Harris, Hannah Wittman, and Mark S. Johnson) provided critical and constructive feedback on the research design, analysis, and contributions of each Chapter.

Chapters 2 through 4 were written as distinct manuscripts for publication in peer-reviewed journals. This has resulted in some repetition in the research contexts and methodological design sections between Chapters. These published articles will use terms like "we" instead of "I" to reflect, where relevant, co-authorship.

Chapter 2, "How is water security conceptualized and practiced for rural livelihoods in the global South? A systematic scoping review", is submitted to a peer-reviewed journal. I identified the research problem, designed the scoping review methodology, extracted and analyzed the data, and wrote the Chapter in its entirety. The research design was supported by Sally Taylor, subject librarian for Resources, Environment & Sustainability at The University of British Columbia. Drs. Lucy Rodina and Graham McDowell provided feedback on the search term criteria, coding manual, and screening phases. My advisory committee provided incisive comments that enhanced the clarity and refined the contributions of the Chapter.

Chapter 3 is under review as a co-authored manuscript for publication in a peer-reviewed journal, as of August 2020. I designed the methodology and co-conducted the data collection with the support of two research assistants (Pooja Tanna and Nirmiti Tara Daw). Pooja Tanna, Nirmiti Tara Daw, and Sudha Shah supported the transcription process. The Society for Promoting Participative Ecosystem Management (SOPPECOM) provided logistical support in Maharashtra, and served as a local third-party contact for research subjects to raise any concerns or questions outside the "Field Team" (Tanna, Tara Daw, myself). These individuals are acknowledged in the dissertation and the Chapter. Co-authors Leila M. Harris, Mark S. Johnson, and Hannah Wittman provided critical and constructive feedback on the methodological design

and contributed to refining drafts of the Chapter. Leila M. Harris facilitated additional research funding, via the International WaTERS Research Network.

Chapter 4 is under review as a co-authored manuscript for publication in a peer-reviewed journal, as of September 2020. I identified the research problem, conceptualized the contributions, collected the secondary quantitative data, completed the analyses, and wrote the Chapter in its entirety. Co-author Leila M. Harris provided feedback on each iteration of the draft. The support provided by individuals recognized in Chapter 3 informed the mixed-methodological design. Dr. Mark S. Johnson, Gaylean Davies, and Vikas Menghwani provided statistical advice. Dr. Mark S. Johnson, Dr. Hannah Wittman, and the EDGES Research Collaborative provided invaluable comments on earlier drafts.

Chapter 5 (Conclusions) will be refined and adapted for submission to a peer-reviewed journal. I wrote the entirety of the Chapter. My advisory committee provided helpful feedback on earlier drafts. Co-authorship has not been determined at the stage of submission.

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AIC: Akaike information criterion

B: Billion, if following a number.

BIC: Bayesian information criterion

n: Sample size

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This work was supported by the Social Sciences and Humanities Research Council of Canada's (SSHRC) Canada Graduate Scholarship (#767-2016-2400) and Michael Smith Foreign Supplement (#771-2017-0100), the International WaTERS Research Network, the Nehru Humanitarian Graduate Scholarship, the Liu Scholar Bottom Billion Grant (#349), and the University of British Columbia's Four-Year Fellowship and Faculty of Science.

I am particularly grateful to my Research Assistants, Pooja Tanna and Nirmiti Tara Daw, for their incredible field support, critical minds, and their unwavering commitment to the research and causes advanced within this dissertation. I am grateful to the sarpanches of each of the three villages for allowing the research to be conducted, the households and families that generously gave us their time, and the experts from around Maharashtra who met with me.

I extend sincere appreciation to the Society for Promoting Participative Ecosystem Management (SOPPECOM) for hosting me, especially K.J. Joy and Seema Kulkarni. Further, I am thankful to the Andars for their warmth and hospitality, and to the incredibly supportive group of colleagues, past and present, from the Institute for Resources, Environment & Sustainability (IRES), the EDGES Research Collaborative, the Program on Water Governance, Green College, and the National Socio-Environmental Synthesis Center (SESYNC). I am especially thankful to Alejandra Echeverri, Lucy Rodina, Udita Sanga, Courtney Hammond Wagner, Nicole J. Wilson, Vikas Menghwani, Scott McKenzie, Megan Callahan, Vrushti Mawani, and Balsher Singh Sidhu for their brilliance and intellectual support.

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Dedication

To my parents, Sudha & Hemant, for their endless support

Chapter 1: Introduction

1.1 Introduction & problem context

The failure to guarantee clean, affordable, and sufficient water for domestic, drinking, and livelihood uses for all people is one of the world's most enduring global development challenges. Today, approximately 2.2 billion people do not have safely managed[1] drinking water services and 4.2 billion people lack safely managed sanitation (World Health Organization, 2019). Nearly 4 billion people live in areas where severe water scarcity[2] exists for at least one month per year, and 500 million inhabit areas with severe scarcity year-round (Mekonnen & Hoekstra, 2016; cf. Kummu et al., 2016; Boretti & Rosa, 2019). The majority of these people live in global South countries – with 25 and 36% of those facing severe water scarcity in at least one month and year-round, respectively, living in India alone (Mekonnen & Hoekstra, 2016).

By mid-century, climate change is expected to intensify precipitation variability (Milly et al., 2008; Hoegh-Guldberg et al., 2018) and reduce surface water reliability (Jiménez-Cisnero et al., 2014). Global climate models project that a warming of 2 °C above current conditions will present an additional 15% of the population with a severe decrease in available water (Schewe et al., 2014). Further, global freshwater consumption currently exceeds 1,700 km^3 yr^{-1} (Gerten et al., 2013) and is expected to increase to about 2,453 km^3 yr^{-1} by 2050 (Wada & Bierkens, 2014) as a result of population growth, urban-industrial demand, and changing consumption patterns (*ibid*; UN, 2019b). At the planetary-scale, this volume of freshwater consumption is nearing a critical boundary, estimated at 2,800 km^3 yr^{-1} (Gerten et al., 2013), beyond which rivers may fail to deliver key downstream ecological functions (*ibid*; Rockström et al., 2014a).[3] Excessive freshwater appropriation, combined with other global dynamics that affect water availability

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[1] "Safely managed" services refer to available, on-site, and contamination-free drinking water and hygienic sanitation services where waste is disposed of safely (World Health Organization, 2019).

[2] Mekonnen & Hoekstra (2016) indicate water scarcity as a condition where the freshwater footprint exceeds availability.

[3] Gerten et al., (2013) revise Rockström et al.'s (2009) original freshwater boundary (4,000 km^3 yr^{-1}) by developing a spatially-explicit quantification of environmental flow requirements. Gerten et al.'s (2013) boundary of 2,800 km^3 yr^{-1} reflects a midpoint of what could be appropriated by humans under "strict" and "moderate" flow requirements needed to sustain ecological functions. Gleeson et al., (2020) proposes that thresholds for different forms of water (e.g., atmospheric, frozen water, groundwater, soil moisture, and surface water) are better positioned to examine specific social-ecological impacts of water appropriation.

(e.g., climate change), increase the probability of cascading and potentially irreversible impacts, such as the collapse of freshwater ecosystems and coupled livelihood systems at a global level (Gerten et al., 2013; Rockström et al., 2014; Steffen et al., 2015; cf. Rockström et al., 2009). These combined effects of climate change and freshwater consumption will impact water availability (Flörke et al., 2018), water quality (Boretti & Rosa, 2019), and decisions over how and when water is available for humans, ecosystems, and integrated social-ecological systems at local and regional scales. Unsurprisingly, the number of people living in water-scarce regions is expected to increase by 1.2 to 2.1 billion by 2050 (UN, 2018). This dissertation is concerned with how global and regional social-ecological change dynamics will impact and exacerbate water insecurity for rural and resource-based livelihoods. Elaborated below, diverse water-related risks, including those prefaced above, will have more pronounced impacts on the livelihood assets, capabilities, and activities[4] of poor and marginalized groups (UN, 2020). In response, my research seeks to advance water security approaches in holistic, widespread, and long-term ways for livelihood activities – a backbone of food, income, health, and inter-generational security and opportunity for billions of people.

Behind these concerns of water stress exist a plethora of domestic and international strategies aimed at increasing safe, affordable, and sufficient water access. The Human Right to Water and Sanitation (HRWS) (UN, 2010) and the 2030 Agenda for Sustainable Development are amongst the most significant coordinated global efforts. The latter, through Sustainable Development Goal (SDG) 6, seeks to "[e]nsure [the] availability and sustainable management of water and sanitation for all" by 2030 (UN, 2015). This ambitious international objective aims to increase the proportion of the population with safely managed drinking water and sanitation services (Targets 6.1-6.2), improve both the proportion of wastewater safely managed and waterbodies with acceptable ambient water quality (6.3), enhance water use-efficiencies and ensure sustainable freshwater extraction (6.4), increase integrated and participatory water resources management (6.5, 6.b), and protect and restore water-dependent ecological systems (6.6) (*ibid*).[5] However, "productive" water for resource-based livelihoods, such as agriculture

[4] This description draws from Chambers & Conway (1992); a full definition is provided below.
[5] Wider criticisms on SDG 6 cite disconnects between its objectives and targets (Guppy et al., 2019), inadequate focus on improving equitable water distribution (Hoekstra et al., 2017; Lele et al., 2017), and inadequate water management, allocation, and regulation frameworks needed to meet established targets (Sadoff et al., 2020).

and livestock rearing, is not explicitly embedded in SDG 6 nor in other major international guiding strategies, such as the HRWS (e.g., Hall et al., 2013; Mehta, 2014; Goff & Crow, 2014; Biggs et al., 2015), even while it may indirectly be supported by certain Targets above (6.3-6.6) (ILO, 2019) or interrelated goals (e.g., SDG 15 on ecological sustainability). This omission is problematic because livelihood water supports multiple integrated human development goals, such as poverty reduction, food security, and gender equality (Upadhyay, 2005; van Koppen et al., 2006; Mehta, 2014; van Houweling et al., 2012; Biggs et al., 2015; Hall et al., 2017) and contributes to key water sector objectives, including cost recovery, capacity building, and integrated water resources provision (Kayaga et al., 2020).

Elaborated below, livelihoods represent the "capabilities, assets (stores, resources, claims and access) and activities required for a means of living" (Chambers & Conway, 1992, p. 6). Water underpins resource-based livelihoods in a myriad of ways. At the most basic level, irrigated agriculture requires a sufficient volume of water at regular intervals; large and small livestock need good quality water; and fisherfolk depend on environmental flow releases that mimic natural flows to support river and estuarine habitats. Simply said, different resource-based activities depend on appropriate and context-specific quantities and qualities of water. The concept of livelihoods further recognizes that people perform activities – important for income, subsistence, and social objectives (e.g., Carr, 2013) with varied capabilities in diverse biophysical contexts (Chambers & Conway, 1992; Scoones, 1998). Different biophysical (e.g., micro-climate; soil drainage) and social contexts (e.g., resource-use experience) impinge on whether a person can effectively use water for their livelihood (Mehta, 2014). Livelihoods therefore require different kinds of water based on their social-ecological contexts and capabilities (*ibid*). Last, the ability to engage in a livelihood depends on one's health, nutrition, and existing or potential co-morbidities (Olsson et al., 2014). Thus, "productive" (e.g., crop, livestock, environmental flows) and "non-productive" (e.g., drinking, hygiene) water underpin livelihood activities, and their linked role in meeting multiple integrated human security objectives (e.g., Olsson et al., 2014; Mehta, 2014; Goff & Crow, 2014).

Foreshadowed above, livelihood capabilities, assets, and activities are affected by diverse water-related risks at multiple scales. These include growing urban-industrial water demand (Molle & Berkoff, 2006), unsustainable rates of water-use (e.g., Rodell et al., 2009), land-use change (Dasgupta et al., 2014), and geographically-specific impacts of climate variation and

change (Döll, 2002; Immerzeel et al., 2010; Galvin, 2009; Dasgupta et al., 2014 for climate-related risks to crop, livestock, fishing, and other livelihoods). The Intergovernmental Panel on Climate Change's *Freshwater Resources* chapter projects, amongst other findings, that climate change will increase the frequency of meteorological (lower rainfall) and agricultural (less soil moisture) droughts in dry regions, negatively impact freshwater ecosystems, reduce raw water quality, and reduce the reliability of surface water resources (see Jiménez-Cisneros et al., 2014). These emerging changes in climate, land, and water-use *interact* and will manifest specific local and regional social-ecological impacts. For example, scholars have probed how land-use change in East Africa has contributed to drought in the Sahel (Sivapalan et al., 2012); how climatic variation interacts with increasing urban demand to affect agricultural water allocations at the water-food-energy nexus in the Philippines (Shah & Zerriffi, 2017); and how groundwater abstraction is likely to increase with more frequent and intense droughts (Taylor et al., 2012).

Importantly, and elaborated in **section 1.4.2** (Conceptual approach), water-related risks cannot be assessed or quantified outside of the socio-economic and political contexts in which they occur (Taylor, 2015). In this sense, water-related risks are better framed and assessed using a coupled "social-ecological systems" approach (Berkes et al., 2003). The social-ecological systems concept stresses that hydrological impacts, such as precipitation variability, interact with and depend on, social systems and contexts to confer livelihood risks (e.g., Olsson et al., 2014; Biggs et al., 2015). Rural and resource-based livelihoods are sensitive to water-related stressors both because of their resource-dependent nature, and because systemic poverty, policy-neglect, and weak water (and/or coupled land) rights limit the capabilities for livelihoods to safeguard their water resources and adapt to undesirable conditions (Dasgupta et al., 2014; see Wagle et al., 2012; Birkenholtz, 2016; Shah & Zerriffi, 2017; Punjabi & Johnson, 2018 for case studies). In particular, climate change and variation – and other water-related threats – present different risks based on the capacities of livelihoods to adapt (Scott et al., 2013; Lemos et al., 2016). Adaptive capacity may be facilitated both by livelihood assets (e.g., financial capital, infrastructure, social networks) and powers to affect positive personal change (e.g., the ability to participate in local decision-making and be recognized) (Scoones, 1998; Olsson et al., 2014; Ribot, 2014; cf. Sen, 1981). Overall, water management policies that fail to account for how water-related risks are unevenly shaped by biophysical, and socio-economic contexts, relations, and histories, may fail to redress water insecurities for certain groups.

I deduce three conclusions and corresponding research needs from the problem context above. First, an emerging set of water-related stressors, such as climate change, will interact with underlying inequalities to exacerbate water insecurity, in uneven ways, for certain households and their resource-based livelihoods (Field et al., 2014; Olsson et al., 2014). While water stress may be faced across broader regions (*viz*. Mekonnen & Hoekstra, 2016), the inability to meet "productive" livelihood water needs will likely be exacerbated amongst marginalized groups – the consequences of which may further undermine their capabilities to meet multiple human security objectives (Mehta, 2014). Thus, understanding how water security for rural livelihoods is conceptualized and addressed, including how and to what extent equity concerns are embedded in existing research and applied efforts, is sorely needed. This need, complemented by an action-oriented agenda to comprehensively advance livelihood water security, is critical because international efforts on "productive" water access remain underrepresented.

Second, and relatedly, adapting to water-related risks, such as climate change, is imperative for reducing threats that could worsen human insecurity. A substantial theoretical and empirical literature exists on livelihood resilience and adaptation (Paavola, 2008; Ifejika Speranza et al., 2014; Taylor, 2015; Tanner et al., 2015; Shah et al., 2019) and social-ecological system transformations (Walker et al., 2004; Folke et al., 2010; Shah et al., 2018), including the constraints, limitations, risks, and opportunities of adaptation and transformation (Adger et al., 2008; Nielsen & Reenberg, 2010; Adger et al., 2012; Cote & Nightingale, 2012; Biesbroek et al., 2013; Klein et al., 2014; Curry et al., 2015; Blythe et al., 2018). Fewer studies, however, have analyzed the extent to which government-led livelihood adaptation programs and wider system-scale transformations are equitable and sustainable in contexts of climate change and variation. This research need was emphasized in the IPCC's latest chapter on *Livelihoods and Poverty*:

> "There is a lack of in-depth research on the direct and indirect effects of mitigation and adaptation climate-related policies…on livelihoods, poverty, and inequality. More in-depth research has the potential to improve the capacity of these policies to benefit poor people" (Olsson et al., 2014, p. 819).

However, climate adaptation research commonly overlooks contexts of inequality and instead focuses predominately on whether technical interventions are effective in mitigating the impacts of external climate and weather-related stressors (Taylor, 2015; Nightingale et al., 2019; Carr, 2020). One emerging example, relevant to this dissertation (described in **section 1.3**), has

involved determining the effects of "green" (soil moisture) and "blue" (liquid) water conservation on agricultural yields in contexts of precipitation variability (e.g., Rockström et al., 2007; Wani et al., 2009). These approaches only repeat Taylor's (2015) point that:

> "[C]limate change adaptation is repeatedly represented as a case of adjusting regions and communities to climatic threats with scant attention paid to the historical roots of the vulnerability that many marginal groups face. In this respect, there emerges an unnerving sense that the literature consistently sidesteps core questions concerning the historically shaped and hierarchically ordered control over land, water, capital and labour that typically characterises rural regions and unequally distributes risks and rewards within [agrarian environments]" (Taylor, 2015, p. 7).

Taylor, like others, argues that environmental risks be de-naturalized (*ibid*). That is, the systemic inequalities that affect a person's exposure, capacity to mitigate harm, and ability to be recognized by welfare systems may be more indicative of risk than the hazard itself (*ibid*; Cutter et al., 2003; Adger, 2006; Ribot, 2014; **section 1.4.2.2.**). This ontological re-framing of climate risk – from the "sky" to the ground (Ribot, 2009, p. i) – necessitates that analyses of direct and indirect effects of climate adaptation (*viz*. Olsson et al., 2014) pivot from solely analyzing the technical effectiveness of an intervention (i.e., whether *something works*) towards interrogating *how* interventions were selected and implemented, *who* they serve, and for *what* purposes. Such approaches continue to be underrepresented (Taylor, 2015; Eriksen et al., 2015; Nightingale et al., 2019; Carr, 2019), and can support more inclusive climate adaptation programs.

Third, and implicit from the stated problem context, academics interfacing with climate change, water, and livelihoods increasingly undertake grounded, policy-driven scholarship with the objective of reforming policies and programs in ways that are pro-poor and sustainable. However, critical environmental social scientists, frequently engaged in meticulous and localized empirical research, are often unable to substantively inform or convince policy-makers, who rely on data patterns scaled to the region (e.g., Birkenholtz, 2012). Using localized research to produce careful and broadly-scaled generalizations around how, and who, climate and environmental policies support across diverse contexts and larger scales remains a vexing methodological and epistemological challenge (e.g., *ibid*; Walker, 2003; Scoones, 2009). This gap, detailed by livelihood and adaptation scholars alike (see *ibid*), requires:

> "[D]evelop[ing] livelihood[] analyses which examine networks, linkages, connections, flows and chains across scales, but remain firmly rooted in place and context" (Scoones, 2009, p. 188).

This dissertation responds to these critical research needs by: i) undertaking a systematic scoping review of evidence-based scholarship to determine how water insecurity for rural livelihoods in global South contexts is defined, driven, and redressed; ii) conducting a multi-sited empirical analysis of the equity and sustainability effects associated with a major livelihood water security program in rural Maharashtra (India); iii) developing an mixed-methodological and epistemological approach linking localized qualitative empirics to larger-scale secondary data models to discern potential inequities associated with Maharashtra's livelihood water security program; and iv) clarifying how equity concerns can be advanced in future livelihood water security research and interventions.

1.2. Key research questions

This dissertation is motivated by the overarching research question: How is water security for rural livelihoods conceptualized and advanced in both scholarly and applied contexts in the global South, what are the implications for equity and sustainability, and what considerations and approaches can advance a holistic, widespread, and long-term approach to water security? I address this overarching question by pursuing three main research questions (**RQs**):

1. How is water (in)security defined, driven, and addressed for rural livelihoods across contexts of the global South, which livelihoods and geographical areas are the focus, and whom does responsibility rest for addressing water insecurity? (**Chapter 2**);
2. How are state-driven efforts, designed to secure water for agricultural livelihoods in contexts of climatic variability, re-shaping water access and distribution patterns, and with what implications for equity and sustainability? (**Chapters 3** & **4**, using the case of Maharashtra, India); and,
3. How can critical environmental social scientists innovate their methodological and epistemological approaches to analyze broadly-scaled indicators of equity, sustainability, and justice associated with livelihood water security interventions? (**Chapter 4**).

1.3. Case context

The empirical research for **RQs** 2 & 3 was undertaken in Maharashtra, India – a state where climatic variability, namely drought, has long been a public policy concern for rural and resource-based livelihoods. In India, there is no standard or universal definition of drought. Meteorological drought indicates a significant shortfall in the total precipitation for a particular place relative to its long-term average (e.g., < 75% of the total monsoon precipitation). Hydrological drought implies low water storage, surface or subsurface, driven by meteorological and/or water governance and water-use decisions. Agricultural drought occurs when insufficient water exists for crop production. These categories are interrelated. Meteorological drought can result in hydrological and agricultural drought. However, agricultural drought – resulting from precipitation variability – may not indicate a meteorological drought. Maharashtra state has historically characterized drought using the agricultural framing. Traditionally, villages are declared "drought-hit" if a rainfall deficit reduces the crop yield by over 50% from what it averaged over the prior decade (Jamwal, 2018).[6]

In 2012, Maharashtra experienced a severe "drought" that resulted in 3,905 villages suffering crop losses over 50% of what was normally cultivated (Deshmane & Pallavi, 2015). One study in south-central Maharashtra demonstrated households' major crop production fell by 86%, water collection times doubled, and that loan repayments were delayed (Udmale et al., 2015). Tragically, nearly 3,800 farmer suicides were recorded in 2012 – almost 20% higher than the annual average (1995-2013). The 2012 event was considered, at the time, the worst drought since 1972.[7] The state's 2014 drought was even more impactful than that of 2012. Around 58% (24,000) of the state's villages lost more than 50% of their crop yield (Pallavi, 2015a; Government of Maharashtra [GoM], 2014).[8]

In December of 2014, the then newly-elected Bharatiya Janata Party (BJP, 2014-2019) implemented a flagship drought-relief campaign, called "Jalyukt Shivar Abhiyan".[9] The

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[6] This is the *paisewari* system, where yields are estimated by officials at the end of a season.
[7] Only 45% of sorghum, 30% of groundnut, 20% of pearl millet, 60% of cotton, and 50% of rice was cultivated in the 1972 wet season in Maharashtra (Ladejinsky, 1973; cf. Dréze & Sen, 1990).
[8] The Government of Maharashtra originally pinned this figure at 19,059 villages (GoM, 2014). However, an additional 5,700 villages were later found to encounter major (>50%) crop losses (Pallavi, 2015a).
[9] Jalyukt Shivar Abhiyan can be translated into *a campaign for a waterful (or water-plenty) environment.*

campaign aimed to make 5,000 additional villages each year "drought-free" (GoM, 2014) and "water secure" (GoM, 2018; Water Conservation Department, 2019) by implementing decentralized water harvesting and conservation initiatives (GoM, 2014). This included a focus on "blue" (liquid) and "green" water (soil moisture) conservation (*ibid*). The objective of Jalyukt Shivar Abhiyan was not to control nature (i.e., eliminate meteorological drought) but to implement water conservation strategies to prevent instances of agricultural drought. The program was further critical in light of future climate change projections whereby:

> "Maharashtra could face an increase in rainfall variability, including droughts and dry spells, as well as increased likelihood of flooding. … [which] have important implications for groundwater recharge, since heavy intensity rainfall is lost as runoff while low intensity rainfall, which contributes to groundwater recharge, decreases in frequency" (TERI, 2017, p. 106).

The emphasis on village-scale water harvesting as a mechanism for "freeing" villages from agricultural drought was, however, a reaction to the inequitable state-wide distribution of surface irrigation water and the enormous corruption of irrigation funds by officials and the contractor lobby. I now turn to this context in historicizing the Jalyukt Shivar Abhiyan campaign.

Since 1950, Maharashtra has completed 2,056 large dams – making the state the most prolific large dam builder in the country (Government of India [GoI], 2019).[10] The vast majority (89%) of the state's large dams were completed during or after the series of droughts from 1971-73 (*ibid*). Large dam development is correlated with the rise in water-intensive crops across the state, namely sugarcane. For example, since 1970, the harvested sugarcane area has grown from 167,000 ha (1970-71) to 1,022,000 ha (2011-12) – a 511% increase (GoM, 2013). Despite representing about 5% of the net sown area (*ibid*), sugarcane uses over 70% of the state's irrigation water (Lalvani, 2008). Moreover, a sizeable share of this irrigated land is owned by state officials and their political cronies, who critics charge with forcing land-sales from farmers and shaping water licenses[11] (Chithelen, 1985; Attwood, 1985; Lalvani, 2008; Dandekar &

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[10] A large dam has i) a maximum height of > 15 meters (m) from the foundation to the crest, or ii) a height of 10-15m and several additional size parameters related to length (> 500m), storage (> 1 million cubic meters) and discharge (>2000 m^3 per second) (GoI, 2019, p. 3).

[11] Lalvani (2008) clarifies "[i]t is an accepted fact that no other sector of the economy is as well represented in government as the sugar sector. Many of the cane growers have occupied important positions in government…" (p. 1476).

Thakkar, 2013). The use of water for sugarcane continued despite prior warnings that sugarcane had, since the 1970s, limited the distribution of water and left much of the state's drought-prone area "water-starved" (Brahme, 1983, p. 6). This had implications in 2012 and 2014 as many villages and households were unable to protect their crops from precipitation shortfalls.

But what further heightened tensions leading up to, and following, the 2012 drought was the fact that while $10B USD (70,000 INR crore) was allegedly spent on irrigation projects from 2000-2010, the proportion of irrigated area *decreased* by 0.1% from 2000-2010 (GoM, 2011, p. 3) [12]. The drought, systemic concentration of irrigation water for sugarcane, and the so-called "irrigation scam" of $10B USD forced the incumbent Congress Party to immediately explore the suitability of certain decentralized watershed initiatives to enhance water security for villages in drought-prone areas. This was only furthered by the incoming BJP party in 2014, who as stated above, institutionalized Jalyukt Shivar Abhiyan to create 20,000 "drought-free" villages in Maharashtra (2014-2019) (GoM, 2014)[13].

The scale and expenditure of the "drought-free" campaign was significant. From 2014-2019, $1.3B USD (9,634 INR crore) was spent completing around 630,000 conservation works in 22,586 villages (Khan, 2020; Bhadbhade et al., 2019). Learning from this case study, this dissertation unpacks how "drought-free" interventions were advanced in practice; explores how and to what extent the focus on water harvesting and conservation enhanced the capture, equity, and sustainability of water for agricultural livelihood risk reduction in drought-prone villages (**RQ** 2); and analyzes how social, environmental, and economic factors affected the broader distribution of its key security infrastructures across the state (**RQ** 3). The empirical and methodological contributions derived from the case will support considerations to advance livelihood water security in equitable and sustainable manners, more generally.

1.4. Research frameworks

1.4.1 Theoretical framework

Political-ecology is the theoretical framework employed in this dissertation (Robbins, 2011; Perreault et al., 2015). Although political-ecology has several varied definitions and intellectual

[12] The revised report, which I could not locate, apparently lists a 0.1% increase (not decrease) according to secondary sources. Nevertheless, the ±0.1 percentage point change is marginal.
[13] Both 20,000 and 25,000 drought-free villages were figures listed as objectives by sources.

research traditions (Perreault et al., 2015; Tetreault, 2017), Robbins (2011) argues it is best contrasted with what he calls "apolitical ecologies" (p. 14). "Apolitical ecology" (*ibid*) refers to how environmental problems such as land degradation, famine, and water scarcity were, in the 1970s and well-before, de-politicized and blamed on population growth (Ehrlich, 1968) or on insufficient knowledge, technological deficiencies, and inadequate management (Robbins, 2011; Perreault et al., 2015; Tetreault, 2017). Bryant & Bailey (1997) suggest by the mid-1970s the neo-Malthusian and eco-modernization explanations of environmental problems were criticized for ignoring how resource and power distribution precipitated "environmental" crises (Sen, 1981; Watts, 1983; Blaikie, 1985). This marked the beginnings of political-ecology. Today, political-ecology encompasses multiple epistemological and methodological approaches that foreground how political-economic contexts and entrenched inequities shape environmental impacts. This includes analysis of how capitalist exploitation and class relations ("structuralist" or "neo-Marxian") affect local environmental dynamics and risk (e.g., Blaikie, 1985; Watts & Bohle, 1993). Structuralist interpretations have, however, been criticized for their deterministic and de-contextual approach, which has often ignored agency and resistance, and sidelined intersectional experiences (Tetreault, 2017). Traditions such as feminist political-ecology, with a focus on gender and broader social power relations (Rocheleau, 2008; Elmhirst, 2015), have complemented and enriched such approaches (Tetreault, 2017). Further, political-ecologists have undertaken locally-situated research, including interrogating the discourses of environmental problems related to how narratives sustain themselves and benefit dominant interests ("post-structuralist political ecologies") (Blaikie & Brookfield, 1987; Mehta, 2001; Forsyth, 2001; 2008).[14] The structuralist (neo-Marxist) and post-structuralist (environmental discourses) research traditions have received criticism for "either too little or too much [economic] structure or politics" in explaining the uneven experiences of social-ecological harm (Forsyth, 2008, p. 760; Walker, 2005). Described below, my analysis of the "drought-free" campaign contributes to a middle-ground between these approaches for political-ecological theory (**section 1.5.2**).

Political-ecological approaches have blossomed in the water world (e.g., Swyngedouw, 1999; Bakker, 2012; Loftus, 2009; 2014; Budds & Hinjosa, 2012; Linton & Budds, 2014; Wutich & Brewis, 2014; Truelove, 2019; Sultana, 2020), making in-roads to disrupt the

[14] For lengthier reviews on the matter, see e.g., Forsyth (2008) and Tetreault (2017).

Malthusian logic that water crises are primarily caused by physical water shortages, lack of infrastructure, or climate-driven patterns (e.g., Mehta, 2014; Shah & Narain, 2019). The arguments of political-ecologists have been recognized in global development reports (UNDP, 2006) and academic declarations (Santa Cruz Declaration, 2014). For example, the landmark United Nations Human Development Report (2006) titled *Beyond Scarcity: Power, Poverty and the Global Water Crisis* explicitly argued, "[T]he roots of the crisis in water can be traced to poverty, inequality and unequal power relationships, as well as flawed water management policies that exacerbate scarcity" (UNDP, 2006, p. v). Political-ecologists have emphasized coupled relationships between hydrological dynamics and social relations using "hydro-social" (Linton & Budds, 2014) or "socio-natural" frameworks (Bakker, 2012; Loftus, 2009) "by which water and society make and remake each other over space and time" (Linton & Budds, 2014, p. 175). This includes how environmental citizenship (Anand, 2017), gender, class and caste, and social relations (e.g., Truelove, 2019; Shah & Narain, 2019), and development discourses (Mehta, 2001) affect – and are in turn affected by – decisions about water interventions, conditions under which access is possible, and the uses of water for particular gains.

In advancing the study of rural livelihood water security, this dissertation does not adhere to one single research camp from political-ecology. Rather, it argues political-ecology as an explanatory framework is most powerful when linking political interests behind policies and programs to a diverse set of lived experiences, for which an entitlements approach provides a key analytic – i.e., a middle-ground between structuralist and post-structuralist approaches (Tetreault, 2017). This dissertation understands climate risks and water insecurity are co-constituted both by discourses on *what* the perceived solutions are, *who* implements and designs such strategies, and *how* certain actors are able to claim benefits through the distribution of resources, rights, and power (e.g., Watts, 2000). To do so enables an analytical focus on the interlinkages between political, hydrological, and socio-economic dynamics – and their implications for livelihood water (in)security.

1.4.2 Conceptual approach

This dissertation employs three major concepts: livelihoods, vulnerability, and water security. Each concept is defined below, and framed in relation to the overarching theory of political-ecology described above.

1.4.2.1 Livelihoods

"Livelihood" is a primary concept employed in this dissertation's study of water (in)security. Following Scoones' (1998) adaptation of Chambers & Conway's (1992) original definition, a livelihood comprises:

> "[T]he capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base" (Scoones, 1998, p. 5).

This definition recognizes that a person or households' capitals, capabilities, limitations, and opportunities are building blocks for pursuing and sustaining a means of living (*ibid*). Livelihood decisions, including in negotiating the effects of social-ecological change, can serve multiple ends, including subsistence, income-generation, and social and cultural objectives, identities, and subjectivities (Bebbington, 1999; Nielsen & Reenberg, 2010; Marshall et al., 2012; Curry et al., 2015; Carr, 2013; 2019). Anchored to normative commitments of equity, sustainability, and capacity-building (Scoones, 2009), livelihood approaches seek transformative change in the institutions and social relations that constrain a person's assets, capabilities, and linked freedoms (Chambers & Conway 1992; Bebbington, 1999; Scoones, 1998; 2009).

These perspectives emerged from concerns that Western-led, macro-economic approaches had de-contextualized and justified the "needs" of the rural poor (Chambers & Conway, 1992; Chambers, 1995; Estrella & Gaventa, 1998) within the global expansion of capitalism that served economic and geo-political objectives of donor countries. People and livelihoods were positioned as poor because of a lack of jobs or market opportunities (i.e., "employment thinking"), malnourished because of lack of production ("production thinking") and deprived because of the former two ("poverty-line thinking") (per Chambers & Conway, 1992, p. 2-3). Economic liberalization, de-regulation, reduced trade restrictions, and export-oriented growth not only failed to systematically improve livelihoods (Ahmed & Lipton, 1997), but eroded critical financial and technical extension services depended on by the poor (Eakin, 2005), reduced profitability particularly amongst smallholders (Rigg, 2006), and accelerated de-agrarianization and de-peasantization in certain rural contexts (Bryceson, 2002; SAPRIN, 2002).

Livelihood approaches were intended to shift the positionality and objectives of interveners from "top-down to bottom-up, from centralized standardization to local diversity, and

from [a] blueprint to [a] learning process" (Chambers, 1994, p. 953). It emphasizes a political, historical, and participatory-based approach to understanding the multi-faceted social, institutional, and ecological contexts that mediate livelihood assets and capabilities (Chambers, 1994; 1995; Scoones, 1998; 2009; Morse & McNamara, 2013). The livelihood perspective is well-aligned with a political-ecological theorization because it understands the distribution of power and resources in societies as integral to the conditions and performance of a livelihood.

1.4.2.2 Vulnerability

The concept of vulnerability implies being susceptible to harm (Adger, 2006) and is characterized as a function of livelihood exposure, sensitivity, and capacity to mitigate or adapt to social-ecological stressors (e.g., *ibid*; Turner et al., 2003; Smit & Wandel, 2006). Exposure indicates the extent to which a livelihood encounters a stressor, such as precipitation variability (Adger, 2006). Sensitivity refers to the degree to which livelihood activities, including their capabilities and assets, are affected by a hazard (Gallopín, 2006). Adaptive capacity reflects the ability of individuals, households, or communities to undertake often incremental changes to mitigate the sensitivity of their production systems to stressors (Smit & Wandel, 2006; Engle, 2011). In characterizing vulnerability, different intellectual research traditions have paid particular attention to either exposure, sensitivity, or adaptive capacity in debating *what* the sources of harm are, and *how* they ought to be moderated (e.g., Eakin & Luers, 2006).

The natural hazards paradigm, one such research tradition, positioned entire regions as "vulnerable" if faced with hazards intense enough to create multiple adverse outcomes, like food and income insecurity (e.g., Ribot, 2009). Known as "outcome vulnerability" (O'Brien et al., 2007), proponents of the hazard paradigm sought to mitigate the potential impact of stressors, such as droughts and typhoons, including by building critical infrastructure (e.g., seawalls, reservoirs). By the 1970s and 1980s, efforts to integrate decision-making processes and broader institutional systems into risk assessments became widespread based on the understanding that vulnerability was not reducible to the physical impact of a stressor (McLaughlin & Deitz, 2008; Bassett & Fogelman, 2013). Early efforts, defined under the cultural ecology paradigm – another research tradition – understood social-ecological systems as self-regulating, whereby human adaptation to environmental stressors achieved a homeostatic or equilibrium state (Walker, 2005; McLaughlin & Dietz, 2008). This paradigm implicated environmental planning institutions and

individual decision-making choices for failing to achieve these stable, equilibrium states (*ibid*; see Burton et al., 1993). However, it neglected how colonial and capitalist forces eroded collective risk sharing institutions, imposed new social relations of (re)production, and concentrated the distribution of resources and power in societies (e.g., Blaikie & Brookfield, 1987; Watts, 1983; Watts & Bohle, 1993; Bassett & Fogelman, 2013; Ribot, 2014; Taylor, 2015). A third research tradition, the political-economic (or political-ecological) paradigm, excoriated individual choice, unbridled agency, and poor planning as inadequate explanations of vulnerability and instead understood that "vulnerability [is] shaped by political economic processes and the social relations of production in which constraint rather than choice limit[] adaptive capabilities" (Bassett & Fogelman, 2013, p. 45; Adger & Kelly, 1999; Blaikie et al., 1994; Cutter et al., 2003; Ribot, 2009; 2014; Carr, 2019). This historical, political, and economic framing is now an established explanation of climate change vulnerability. For example, the latest Intergovernmental Panel on Climate Change's (IPCC) *Impacts, Adaptation, & Vulnerability* Working Group stated:

> "Differences in vulnerability and exposure arise from non-climatic factors and from multidimensional inequalities often produced by uneven development processes (very high confidence). These differences shape differential risks from climate change" (Field et al., 2014, p. 6).

This dissertation rejects a natural hazards explanation of livelihood water insecurity. Taking a cue from Sen (1981), it understands a person's endowments (i.e., owned and accessed things) and their entitlement bundle (i.e., the set of resources one can attain from endowment structures) to affect their susceptibility to insecurity. After Watts & Bohle (1993), I recognize endowments and entitlements are shaped by the "structural and historical processes by which specific patterns of entitlements and property rights [came] to be distributed" (p. 48). This perspective of vulnerability is allied with a political-ecological framework and coupled livelihood perspective because it views roots of harm as "not fall[ing] from the sky" (Ribot, 2009, p. 1) but situated in the social, economic, and political systems that shape a person's capabilities and capitals (Scoones, 2009; Taylor, 2015; cf. Sen, 1981). In the context of the Maharashtrian case, this framework invites a grounded analysis of vulnerability, which extends beyond equating risk with precipitation shortfalls and instead analyzing whether and to what extent people and livelihoods can access benefits from interventions designed to "free" villages as a whole from drought.

1.4.2.3 Water (in)security

Water security is a framework used to assess whether and to what extent people, livelihoods, and ecosystems have and can acquire specific forms of water to avoid unacceptable levels of risk (Grey & Sadoff, 2007; Hall & Borgomeo, 2013), meet context-specific needs and wants, and achieve self-defined aspirations (Jepson et al., 2017a). Aligned with broader capabilities-based approaches, water security is characterized in a growing and interdisciplinary literature as a *process* reflective of the capacities to achieve *states* where current wants and needs, and long-term aspirations are met (e.g., *ibid*). Described earlier, livelihood water security enables a host of integrated human security dimensions to be met, including income, food, and mental and physical wellbeing (Zeitoun, 2011; Young et al., 2019; Brewis et al., 2020; Rosinger & Young, 2020). Following a political-ecological theorization, I understand that politics, power, and capital intersect to condition biophysical exposure (e.g., floods, dryness), infrastructure and resource access (e.g., water provision services), and broader capabilities to access safe, sufficient, and clean water (Budds & Hinojosa, 2012; Loftus, 2014; Zeitoun et al., 2016; Gimelli et al., 2018).

Clarified in **Chapter 2**'s findings, scholarly research on the subject has largely framed water extraction, conveyance, efficient-use, and (re)regulation as the predominant responses to be undertaken to reduce livelihood water insecurity in rural settings. State-sponsored projects, including what is observed in Maharashtra (**Chapters 3** & **4**), have not improved water security for all and in many cases have clarified the reality that water is only available to privileged members of society. This dissertation holds that the challenge of water insecurity is better advanced when researchers and practitioners engage with the underlying causes of insecurity's emergence and resist the uncritical adoption of universalized, short-term strategies that merely reproduce how water is planned, used, and circulated in social-ecological systems (e.g., Kirchhoff et al., 2016). The political-ecological approach I adopt links both social and biophysical factors to the (re)production of water insecurity. Although broader biophysical dynamics (e.g., precipitation variability, geology) may affect villages as a whole, I follow Sen (1981) in understanding water insecurity as linked to the inability for people to translate their own assets and relations into protections that limit conditions or experiences of water insecurity (i.e., entitlement failure) (Wutich & Brewis, 2014). My approach resists evacuating the "ecology" from political-ecology (cf. Walker, 2005; Turner, 2015) by understanding villages as internally differentiated social-ecological systems, for which environmental factors and peoples'

endowments and entitlements (Sen, 1981; Leach et al., 1999) serve roles in enabling residents, in uneven ways, to benefit from water-related interventions.

1.4.2.4 Rural global South

This dissertation has a broad geographical scope across the rural global South (**Chapter 2**), with particular emphasis on India (**Chapters 3** & **4**). This subsection briefly clarifies the use of the concepts "rural", "global South", and "rural global South". Rural areas, rarely described in explicit terms, are often oversimplified as spaces with less population density, infrastructure networks and built-up space, and more resource- and land-based livelihoods, such as agriculture (Lerner & Eakin, 2011; Dasgupta et al., 2014). A more complex juxtaposition characterizes certain rural areas and villages, including those sampled in this dissertation, as hosting industrial yards, airports, mechanic shops, and city-dwellers' vacation homes (Simon, 2008).[15] Thus, I conceptualize rural areas as having mosaic features (*ibid*) where migration, off-farm livelihoods, and new flows of resources are accreted upon land- and resource-based livelihoods (Lerner & Eakin, 2011). This is, however, a materialist definition. Described below, the rural *global South* is characterized by political-economic, social, and institutional *systems* and *relations* that have structured livelihood resources, opportunities, and activities.

The global South is a critical boundary concept with varied meanings and uses, including i) substituting for regressive concepts (e.g., "Third World", "developing" countries); ii) reflecting the limited political, economic, cultural and epistemic power of certain peoples outside of hegemonic global power structures ("subalternity") (Kloß, 2017; López, 2007), including de-territorialized understandings of subalternity within global North and South contexts (Schneider, 2017; Mahler, 2017; Gaventa, 1998)[16]; and iii) relating to historical and active processes of colonialism and global neoliberalism that have consolidated power and resource distribution and, in conjunction with exclusive social institutions, exacerbated socio-economic inequalities in

[15] Terms include "city-village" (Simon, 2008), "urbanizing rurality" (Angeles & Shah, 2019), and peri-urban.

[16] Popularized by the phrasings like, "Souths in the geographic North and Norths in the geographic South" (Mahler, 2017), or "'Souths within the 'North,' just as there may be 'Norths within the 'South'" (Gaventa, 1998, p. 51). De-territorialization rejects categorical distinctions between North and South as poverty-stricken and poverty-free (Gaventa, 1998).

countries branded as low- and middle-income (Mahler, 2017; Kloß, 2017; Schafer et al., 2017). This latter point is how the concept is applied in the dissertation.

Bringing both concepts together, I understand the *rural global South* as both material and relational sites where resource-based livelihoods and systemic inequalities interact to heighten, albeit unevenly, the exposure and sensitivity to climate and broader social-ecological stressors. This is emphasized in the latest Intergovernmental Panel on Climate Change's *Rural Areas* Report, which stated people and livelihoods here are:

> "[U]niquely vulnerable to the impacts of climate change because [their] [g]reater dependence on agriculture and natural resources makes them highly sensitive to climate variability, extreme climate events, and climate change [and because] [e]xisting vulnerabilities caused by poverty, lower levels of education, isolation, and neglect by policymakers can all aggravate climate change impacts" (Dasgupta et al., 2014, p. 618).

My focus here is not intended to re-enforce categorical differences between North-South, nor dismiss environmental injustices for marginalized communities in the global North, including around water insecurity (e.g., Ranganathan, 2016; Meehan et al., 2020). Rather, I recognize that the rural global South is a critical hotspot where water security for livelihoods serves an integral role in maintaining and advancing human security for millions of people.

1.5. Dissertation objectives and contributions

The aim of this dissertation is to advance the study of water security for rural livelihoods in the global South in scholarly and applied contexts by synthesizing the existing refereed literature, analyzing justice, equity, and sustainability dimensions of major initiatives, and developing insights informed through multi-scalar and multi-methods approaches that support robust analytics at larger spatial scales to inform policy-making and change (**Table 1**). This is advanced through four specific objectives and higher-level research contributions. Additional case-specific contributions are provided in each Chapter.

1.5.1 Clarify how water security is conceptualized and addressed for rural livelihoods in the global South

In **Chapter 2**, I systematically assess English-language peer-reviewed journal articles (2000-2019; n = 99) with the objective of clarifying how "water (in)security" is defined,

conceptualized, and addressed in the context of rural livelihoods across the global South. The Chapter contributes the most comprehensive assessment to-date of how the concept of water (in)security is applied to rural livelihoods. Precisely, I identify the definitions of water (in)security, synthesize the causes of, and responses to, water-related risk, clarify which livelihoods are represented and underrepresented, and where responsibility of action for addressing water security rests. Based on a closer synergy between the livelihood and water security concepts, I conclude with a research agenda to advance more comprehensive water-related risk reduction approaches.

1.5.2 Analyze equity and sustainability dynamics of state-sponsored livelihood water security initiatives

In **Chapters 3** and **4**, I conduct a multi-sited and multi-scalar empirical analysis of the equity and sustainability dimensions associated with the implementation of Maharashtra state's over $1B USD flagship drought-relief program designed to transform 20,000 villages into "drought-free" systems. As discussed, the state program relied on the implementation of "green" (soil moisture) and "blue" (liquid) water conservation initiatives which, when up-scaled at the village-level, were intended to eliminate instances of agricultural drought. These integrated water conservation initiatives have received significant attention in the water and food resilience literatures, and have been emphasized as key response options to protect rural resource-based livelihoods from climate change and variability (Rockström et al., 2014a; Rockström & Falkenmark, 2015; Falkenmark, 2016). This is because, in comparison to the inequitable and unsustainable impacts of large dam development, "green" and "blue" water initiatives harvest a wider spectrum of the available water (i.e., both soil moisture and liquid water) at a local-level, directly accessible to users (Rockström et al., 2014a,b). **Chapter 3** analyzes the equity and sustainability effects of an integrative green-blue water conservation program intended to advance rural livelihood water security in contexts of climate change and variability – an important knowledge gap. This effort further contributes an analysis of the direct and indirect equity effects of a major state-sponsored climate adaptation-transformation program for rural livelihoods (*viz*. Olsson et al., 2014). Last, the empirical analysis contributes to a middle-ground between structuralist and post-structural approaches in political-ecology by linking the "political" – scientific rationales and interests governing certain adaptation interventions (e.g., Eriksen et al., 2015) – with situated socio-

economic inequalities within villages to understand the equity and sustainability outcomes of the "drought-free" campaign.

1.5.3 Advance a multi-scalar and mixed-methods approach in political-ecology to analyze distributional patterns of livelihood-water adaptations

Chapter 4 advances a mixed-methods and multi-scalar approach to explore factors that affect the distribution of livelihood water security initiatives at larger spatial scales. These broader-scaled efforts are increasingly advocated by political-ecologists as crucial for assessing and challenging government policies that could deepen inequities in and across regions (e.g., Birkenholtz, 2012). However, "scaling-up" (Galt, 2010) local qualitative research remains a key methodological limitation of political-ecological research on climate adaptation (*ibid*; Birkenholtz, 2012). **Chapter 4** demonstrates how local fieldwork findings can structure secondary data collection and specify meso-scale regression models that re-analyze, at larger spatial scales, potentially meaningful relationships between social, economic, and environmental factors and the distribution of water security initiatives. The local and meso-scale findings advance a more holistic understanding of resource distribution patterns at multiple scales – in ways that are more amenable to informing and advancing policy-making. Where political-ecologists (Galt, 2010; Birkenholtz, 2012) have advanced related methodological approaches, none have demonstrated how political-ecology's strengths in inductive field-based research can be integrated with the power of meso-scale statistical modelling to understand resource distribution patterns and corresponding equity and justice concerns. I advance this novel methodological contribution with an explicit awareness of criticisms levied by political-ecologists against certain quantitative approaches, namely statistical analyses. Attentive to such critiques, I reject the notion that statistical results are objective, definitive, and reflective of an external reality "out there" (Amrhein et al., 2019a,b; Wasserstein et al., 2019). I instead compare local, qualitative results with meso-scale quantitative results using the coefficient direction, effect size, and confidence intervals (Amrhein et al., 2019a). This enriches the ways in which quantitative and qualitative results can gel or diverge from each other, which extends beyond "agreeing" or "conflicting". My interpretation yields an epistemological contribution, demonstrating qualitative (e.g., household/village-level) and quantitative results (e.g., meso-scale) at multiple social-ecological scales can cohere, remain exploratory, or be entirely

inconsistent with one another. The degree of compatibility between qualitative-quantitative and local-meso-scale offers different pathways for policy research, including advancing assertions where findings gel, or outlining targeted research areas that could serve as a pathway for future policy interrogation. In sum, my approach contributes to how mixed-methodological research can engage in "holistic triangulation" (Turner et al., 2017), where multiple datasets, analyses, and novel interpretational strategies (*viz.* Amrhein et al., 2019a) can reveal different angles of social-ecological phenomena to develop richer analyses (Nightingale, 2003; 2009; Turner et al., 2017; Uprichard & Dawney, 2019). I extend qualitative and local applications of holistic triangulation (Nightingale, 2003) by demonstrating how qualitative and quantitative approaches can be interlinked to advance a more comprehensive, yet partial, understanding of the distribution of water security infrastructures at larger, policy-relevant scales. I demonstrate political-ecology as a critical theoretical framework in informing and interpreting resource distribution patterns at larger social-ecological levels.

1.5.4 Identify pathways to advance widespread and long-term livelihood water security

Chapters 2 and **3** develop contributions to advance widespread and long-term livelihood water security for the broader peer-reviewed scholarship and for water conservation programs similar to those implemented in Maharashtra, respectively. **Chapter 5** (Conclusions) builds on these specific propositions by offering a broader approach for re-imagining livelihood water security, interlinked with the contemporary agrarian crisis in India.

1.6. Methodological approach

1.6.1 Critical realism

A critical realist philosophy informed the methodological approach in this dissertation. Critical realism is an integrative research philosophy that emerged from the polarity between positivist (value-neutral observers capable of deriving objective laws from a real and independent world) and interpretivist approaches (value-laden observers unable to observe a real world outside of their experiences) (Archer et al., 2013; Maxwell & Mittapalli, 2010). Critical realism instead:

> "[Combines] a realist ontology (the belief that there is a real world that exists independently of our beliefs and constructions) with a constructivist epistemology (the belief that our *knowledge* of this world is inevitably our own construction, created from a

> specific vantage point, and that there is no possibility of our achieving a purely 'objective' account that is independent of all particular perspectives)" (Maxwell, 2012, p. vii, italics in original).

Critical realists are concerned about how partial observations, shaped by our histories, knowledges, and modes of inquiry, become reduced to objective characterizations about the world (Forsyth, 2001). This is most apparent when partial explanations behind biophysical processes, like soil erosion (Blaikie & Brookfield, 1987) or water scarcity (Mehta, 2001), masquerade as universal laws, ultimately giving rise to specific solutions that may reflect only a particular set of interests (Forsyth, 2001; 2008). In the case of Maharashtra, I acknowledge externally "real" biophysical processes generate events, like groundwater change or moisture preservation, but remain "skeptical" of how such observable events are used to communicate an environmental reality (Forsyth, 2001, citing Hannah, 1999). Namely, I am critical of how "drought-free" systems become characterized and the ways in which people experience this reality (**Chapter 3**). In line with my **RQs**, I understand measuring physical objects and events – such as groundwater levels and crop growth in "drought-free" villages – as insufficient to explore how residents differently experienced both the outcomes of the implemented initiatives and the nature of a "drought-free" village. Further, a critical realist approach has supported the mixed-methodological research design, detailed below (Maxwell & Mittapalli, 2010; Maxwell, 2012). The use of different methodologies is not intended to converge upon or demonstrate singular experiences of an "objective" reality (Nightingale, 2003) but to explore how varied datasets, methodologies, and scalar analyses can reveal different elements of observable outcomes (Uprichard & Dawney, 2019). Ultimately, I am committed to interrogation, reflection, and reflexivity in advancing a richer, though partial, understanding of livelihood water security.

1.6.2 Methodology & data sources

1.6.2.1. Systematic scoping review

To answer **RQ** 1, I conducted a "systematic scoping review" of peer-reviewed journal articles focused on the study of water (in)security as applied to rural livelihoods in global South contexts (2000-2019; n = 99). A systematic review is a transparent and reproducible methodology that systematically analyzes a bounded set of literature against pre-defined research questions (Peters et al., 2020; Petticrew & Roberts, 2006). Systematic reviews aim to provide precise answers

around well-bounded, often disciplinary, research questions and are widely used in medicine, psychology, and cognate disciplines (Peters et al., 2020). Systematic *scoping* reviews follow the same methodological approach, but adopt broader knowledge synthesis objectives related to "map[ping] the key concepts that underpin a field of research…[and] clarify[ing] working definitions, and/or the conceptual boundaries of a topic" (Peters et al., 2020, p. 409 citing Arksey & O'Malley, 2005). My review recognizes peer-reviewed articles as a major evidentiary basis shaping policy.[17] While directly evaluating the grey literature (e.g., policy documents, websites, reports) remains important, peer-reviewed articles represent a major reference set to understand and establish *who* and *what* is studied, *where*, and *how* – potentially lending key insights for future research and policy development. I further relied on insights developed from a previously conducted and distinct literature review on water security and agricultural livelihoods (n = 131) in order to inform the development of the coding manual.

1.6.2.2 Multi-village qualitative inquiries

To answer **RQs** 2 and 3, I conducted combined surveys and semi-structured interviews with households (n = 63) in three heterogenous villages served by the campaign, with the support of two local field assistants. We collected data on household demographics, water uses, conditions of water access, knowledge of the campaign (including its implementation process), who and what benefits from the now completed interventions, and perspectives on how water could be better managed in each village. Government officials (n = 7), and key informants (n = 18) – including watershed experts, journalists and historians – were further interviewed on matters of drought, rural and watershed development, and the Jalyukt Shivar Abhiyan campaign.

The primary data collection occurred in Pune District from January until end-April 2018 (dry season). Pune District was selected because of its varied climatic and social-ecological village and livelihood contexts, and access to a large number of non-governmental organizations and informants familiar with the campaign. To select villages, I used the state's publicly available Jalyukt Shivar database (GoM, 2015a), which lists the approved initiatives and maps the completed works for villages selected in each intervention year. I used the database to identify projects that were completed and mapped in villages within Pune District for the

[17] Described in **Chapter 2**, most of the included publications were conducted with the objective, explicit or implicit, of informing evidence-based decision-making and policy.

intervention years prior to fieldwork (i.e., 2015-2016 and 2016-2017). Villages in these cohorts (n = 241), particularly those in 2015-2016, were prioritized by the government for creating drought-free plans based on their level of water scarcity and its effects on agricultural production. Once the database was downloaded and translated from Marathi to English, a three-tiered selection strategy was used to identify the three villages suitable for sampling. First, I selected villages considered to be "well served" under the campaign. I defined a "well served" village as one where the diversity of completed and mapped initiatives (e.g., canal digging, cement dams, contour trenching, sediment removal, etc.) listed within a village was higher than nearly 90% of the served villages in 2015-17. Villages with a higher number of different water conservation initiatives were likely to have a higher number of absolute interventions. Second, within this subset of "well served" villages (n = 45), I selected three sub-districts (Purandar, Mawal, and Indapur) surrounding Pune City on the basis of different climate and agricultural features identified using secondary data sources (e.g., agricultural and population census records; long-term precipitation data). Third, one village was selected from each sub-district based on demographic representativeness and travel cost considerations. To reduce participant risk, I anonymized each of the three sampled villages. Village 1 (in Purandar sub-district), Village 2 (in Mawal sub-district), and Village 3 (in Indapur sub-district) are described in detail in **Chapter 3**.

After receiving the permission of the sarpanches (elected head) of each village to conduct research, we sampled households in different areas or *vastis* (sub-communities tied in kinship), within which households were selected at random or at convenience. This included households near verified and mapped works (using publicly available geo-coded data from original secondary databases, GoM, 2015b), within and outside village centres, and near older, similar interventions to provide a sense of how such initiatives functioned in practice. Occasionally, village leaders and interviewed households would introduce us to participants (i.e., snowball design). The multi-sited design was not intended for cross-comparative analysis but to determine whether specific observations surrounding the campaign's implementation and effects cohered in different social-ecological contexts. This, coupled with key informant experiences, provided confidence that the observations were not an artifact of a single village.

1.6.2.3. Mixed-methods regression modelling

I aimed to "scale-up" (Galt, 2010) the local-level insights from **RQ** 2 to understand the extent to which certain factors, informed by qualitative village-scale fieldwork, shaped the distribution of farm ponds approved between 2015-16 (n = 16,036) across 352 sub-districts – a key water security initiative under the campaign. Village fieldwork was used to inform secondary data collection and specify meso-scale regression models that re-analyzed, at larger spatial scales, key relationships between social, economic, and environmental factors and the distribution of ponds. I relied on several secondary databases, including the Jalyukt Shivar Abhiyan repository hosted by the Maharashtra Remote Sensing Application Centre (GoM 2015a), Agricultural Census (GoI, 2011a), Population Enumeration Census (GoI, 2011b), Socio-Economic and Caste Census (GoI, 2011c), sub-district groundwater reports, and the Climate Hazards Group InfraRed Precipitation (CHIRPS v.2) dataset (Climate Hazard Group 2017; Funk et al., 2015). This methodology is described extensively in **Chapter 4**.

Table 1: Substantive Chapter structure, methodology, objectives and contributions.

Title	Methodology	Objectives & Contributions
Chapter 2: How is water security conceptualized and practiced for rural livelihoods in the global South? A systematic scoping review	• Systematic scoping methodology of peer-reviewed journal articles (2000-2019, n = 99). • Distinct targeted literature review from the comprehensive exam process (n = 131).	• Objective: Clarifies how the water security concept is applied to rural livelihoods in the global South by identifying water (in)security definitions, synthesizing causes of, and responses to, water-related risk, and documenting which livelihoods and geographical areas are (under)represented. • Major contribution: Conducts the most comprehensive assessment to-date of how the concept of water (in)security is applied to rural livelihoods in the global South, and develops a research agenda to advance more comprehensive efforts to study and advance water security for rural livelihoods.

Chapter 3: A "drought-free" Maharashtra? Politicizing the conditional, inequitable, and extractive outcomes of state-sponsored livelihood adaptation for rain-dependent agriculture	• Multi-sited village analysis (n = 3). • Combined surveys-semi-structured interviews with households (n = 63). • Focus group discussions (FGD) (n = 6). • Government officials (n = 7) and key informants (n = 18) interviews. • Field observation, including field visits with government officials.	• Objective: Conducts a multi-sited empirical analysis of the equity and sustainability effects associated with the implementation of Maharashtra state's over $1B USD flagship drought-relief program and determines how the distribution and longevity of benefits can be improved for similar water security interventions. • Major contribution: Develops an understanding of the equity and sustainability effects of integrative green-blue water conservation programs and contributes an analysis of the direct and indirect equity effects associated with a major state-sponsored climate adaptation-transformation program.
Chapter 4: Beyond local case studies in political-ecology: Spatializing agricultural water infrastructure in Maharashtra using a critical, multi-methods, and multi-scalar approach	• Integrative mixed-methods approach using primary (household, government and informant interviews) and secondary data. • Secondary records of farm pond data (n = 16,036; 2015-2016) approved under Jalyukt Shivar, and sub-district scale agricultural, demographic, and hydrological data reflecting key variables observed at the local level in shaping farm pond distribution and acquisition.	• Objective: Develops an integrative methodological and epistemological approach to explore resource distribution patterns of water security initiatives at multiple scales to advance considerations of equity, justice, and sustainability in policy-making. • Major contribution: Demonstrates how political-ecology's strengths in inductive field-based research can be integrated with the power of meso-scale statistical modelling to understand broader social-ecological patterns and corresponding equity and justice concerns, and indicates how varying compatibility between qualitative-quantitative results at the local and meso-scale can offer different pathways for policy research.

1.7. Positionality

I conduct this research as a Western educated, English-speaking male of Indian and inter-caste origin whose identity facilitated significant research opportunities that may not have been afforded for historically and actively marginalized sects of Indian society. I understand my identity afforded me privileges in forming research partnerships with villages, accessing

knowledge spaces, and conducting research on an everyday basis in patriarchal and casteist environments. I often reflected – had I been a domestic student from a Scheduled Caste or Tribal background, or a lower caste woman, would I have been granted access to work with villages in the way I was? Would I have been able to secure meetings with the upper caste male government officials and interrogate the very policies they were responsible for implementing? Would upper caste households allow me to enter their home and eat from their plates and cutlery in conducting interviews, as I did? The answers are clear and resounding.

These privileges were further afforded to me as a foreigner and temporary visitor from Canada – especially as it related to accessing and interacting regularly with local (e.g., sarpanches, unelected 'big' people, revenue officers), sub-district (e.g., agricultural officers, tax officers), and state government officials. Such institutions have marginalized particular groups, especially lower caste and lower caste women, by denying them recognition and social citizenship and by positioning their identities as exploitable and less-than-human. I recognize that the process of collecting data for producing knowledge would have been far riskier and far more limiting for researchers less privileged than myself. Thus, while this dissertation would not have been feasible without my committee, research assistants, and the research participants – it is equally true that it may not have been possible without the privileges I have been afforded through my identity. Last, in understanding that all analyses are partial, I recognize important barriers, including being a temporary visitor in village contexts, language and cultural barriers, and my identity, shaped the knowledge produced in this dissertation.

Overall, this dissertation advances knowledge of how water security for rural livelihoods is conceptualized, analyzed, and addressed in both scholarly and applied contexts in the rural global South, with specific focus on equity and sustainability considerations and outcomes. It accomplishes this by i) clarifying how the water security concept is framed and advanced for rural livelihoods in the peer-reviewed scholarship, ii) examining the equity and sustainability dynamics of a major livelihood water security intervention in Maharashtra state (India), and iii) developing a multi-method and multi-scalar research approach to study factors potentially affecting the distribution and access of water security-based interventions at a regional-scale. The dissertation demonstrates the need for, and importance of, advancing livelihood water security initiatives in holistic, widespread, and long-term ways, and concludes by identifying key considerations to support this approach.

Chapter 2: How is water security conceptualized and practiced for rural livelihoods in the global South? A systematic scoping review

2.1. Introduction

Indicated in **Chapter 1**, approximately two-thirds of the world's population inhabit areas where severe water scarcity exists for at least one month per year (Mekonnen & Hoekstra, 2016). By 2030, intense water insecurity could displace up to 700 million people, globally (UN, 2019a). The concept of "water security" is increasingly valued as a framework to advance integrated human-nature needs associated with safe, sufficient, and sustainable water access (Cook & Bakker, 2012; Bakker, 2012; Pahl-Wostl & Knüppe, 2015; Gerlak et al., 2018).

The discourse of "security" and "securitization" emerged from international relations (Brauch et al., 2008) as a set of actions designed to neutralize an existential threat to state interests (Buzan et al., 1998). Early applications of the concept emphasized the need to secure water for intensifying land-use for food and materials production (e.g., Geersten, 1969; Bromley et al., 1980), expanding regional settlement (Strong, 1956), and maintaining national security (Ohlsson, 1995; Shermer, 2005; Bogardi et al., 2015).[18] After the 1994 Human Development Report, water security was recognized as integral to advancing human security – lives free from fear, vulnerability, shame, conflict, and unmet wants (Cook & Bakker, 2012; Bogardi et al., 2015). Thereafter, the Ministerial Declaration of The Hague (2000, unpag.) at the 2nd World Water Forum widened the concept to a set of conditions where:

> "[F]reshwater, coastal and related ecosystems are protected and improved; that sustainable development and political stability are promoted, that every person has access to enough safe water at an affordable cost to lead a healthy and productive life and that the vulnerable are protected from the risks of water-related hazards."

This definition further recognized water's multiple contributions to coupled human and ecological needs using an integrated social-ecological systems perspective (Falkenmark & Rockström, 2005; Vörösmarty et al., 2010; Pahl-Wostl & Knüppe, 2015). However, meeting these coupled human-nature needs is readily exacerbated by the inability of water management

[18] For reviews, see Oswald-Spring et al., (2009), Cook & Bakker (2012), and Bogardi et al., (2015).

frameworks, predicated on stabilizing and optimizing centralized water resources, to reconcile shifting water availability and use contexts resulting from climate change and variation, and water demand growth (e.g., Folke, 2003; Lankford & Beale, 2007; Pahl-Wostl et al., 2011).

Since the 2nd World Water Forum, the water security concept has increased exponentially in journal publications (**Figure 1**). Bakker (2012) argues the increase reflects emerging risks to drinking water supplies, economic growth and livelihoods, water-related ecosystem services, and from hydrological variability (p. 914). Recent efforts have synthesized the definitions, metrics, and applications of water security (e.g., Cook & Bakker, 2012; Garrick & Hall, 2014; Zeitoun et al., 2016; Jepson et al., 2017b; Wutich et al., 2017; Gerlak et al., 2018; Hoekstra et al., 2018; Grasham et al., 2018), with specific contributions to water and social-ecological systems governance (Bakker & Morinville, 2013; Medeiros et al., 2017), household water insecurity (Meehan et al., 2020; Venkataramanan et al., 2020), and human health (e.g., Rosinger & Young, 2020; Wutich et al., 2020). Systematic review efforts concerning how water security is conceptualized and applied to rural livelihoods are, however, virtually non-existent. To my best knowledge, one existing study has systematically assessed the water security concept for rural livelihoods, but did so only in the context of agriculture (Malekian et al., 2017). The focus of Malekian et al., (2017) was on identifying and comparing different ontological and epistemological paradigms of agricultural water security – not on synthesizing drivers of and solution strategies to water insecurity in the extant literature. While interested in concepts and definitions, I advance a wider understanding of how water security is applied to support rural livelihoods in the global South. Systematically analyzing refereed journal articles between 2000-2019 (n = 99), I ask: How is water security defined for rural livelihoods in the global South? What factors undermine livelihood water security? What solution pathways are described and prescribed for improving it? Where does responsibility rest for redressing water insecurity, and which livelihoods and geographical areas are explored and underexplored?

As framed in **Chapter 1**, rural livelihoods in the global South are characterized by resource-dependence, high incidences of poverty, socially exclusive institutions, and insufficient policy support (Dasgupta et al., 2014) – all of which amplify water-related risks and necessitate interventions to address them. Rural livelihood precarity emerges from historical and contemporary contexts of failed land reform, capitalist exploitation (Angeles & Shah, 2019), entrenched neoliberalism (Bryceson, 2002; Eakin, 2005), and unsustainable resource use (Rigg,

2006). Further, major livelihoods, such as agriculture, pastoralism, and aquaculture, encounter cumulative water-related risks associated with climate change and variability, water quality degradation, and coupled land- and water "grabbing" from state and transnational actors (Mehta et al., 2012; Dasgupta et al., 2014; Biggs et al., 2015). Clarified in **section 1.4.2.**, water insecurity is both a function of hydrological *risks*, including competing water demands, water variability, and deficient physical infrastructure (Falkenmark, 2013a; Grey & Sadoff, 2007), and the livelihood *capabilities*, mediated by the distribution of resources, rights, and power, to resist and adapt to such risks (Scott et al., 2013; Garrick & Hall, 2014; cf. Sen, 1981).

This review was motivated by the understanding that water security approaches mark major steps beyond conventional scarcity-based frameworks in identifying, evaluating, and addressing water-related risk. For one, security approaches measure varied indicators of hydrological risk (e.g., availability, quality, sustainability) in relation to diverse water-related needs (Cook & Bakker, 2012; Hall & Borgomeo, 2013; Jepson, 2014; Wutich et al., 2017; Gerlak et al., 2018; Young et al., 2019), instead of focusing on the volume of water available and standard prescriptions over what constitutes need. Second, security approaches are open to the multiple and diverse drivers of water insecurity whereas scarcity-focused efforts often privilege biophysical and economic drivers affecting water availability. Third, security approaches increasingly recognize risk is a function of exposure and sensitivity to a water-related hazard (Garrick & Hall, 2014), meaning solution pathways at multiple scales to reduce water-related risk exist. These include mitigation (e.g., Grey & Sadoff, 2007), multi-scalar adaptations (Scott et al., 2013; Varady et al., 2016; Venkataramanan et al., 2020), and systemic transformations in how water is governed, circulated, and used (Loftus, 2014; Zeitoun et al., 2016; Jepson et al., 2017a; Wutich, 2019). This contrasts with scarcity approaches, where the solution space is more limited, owing to the often-narrower conceptualization of factors driving water unavailability.

Overall, this Chapter investigates where major water-related risks to rural livelihoods are located, identifies responses to address insecurity, and proposes future areas of research in pursuit of developing more comprehensive approaches to ensure water-related risk reduction for rural livelihoods in the global South.

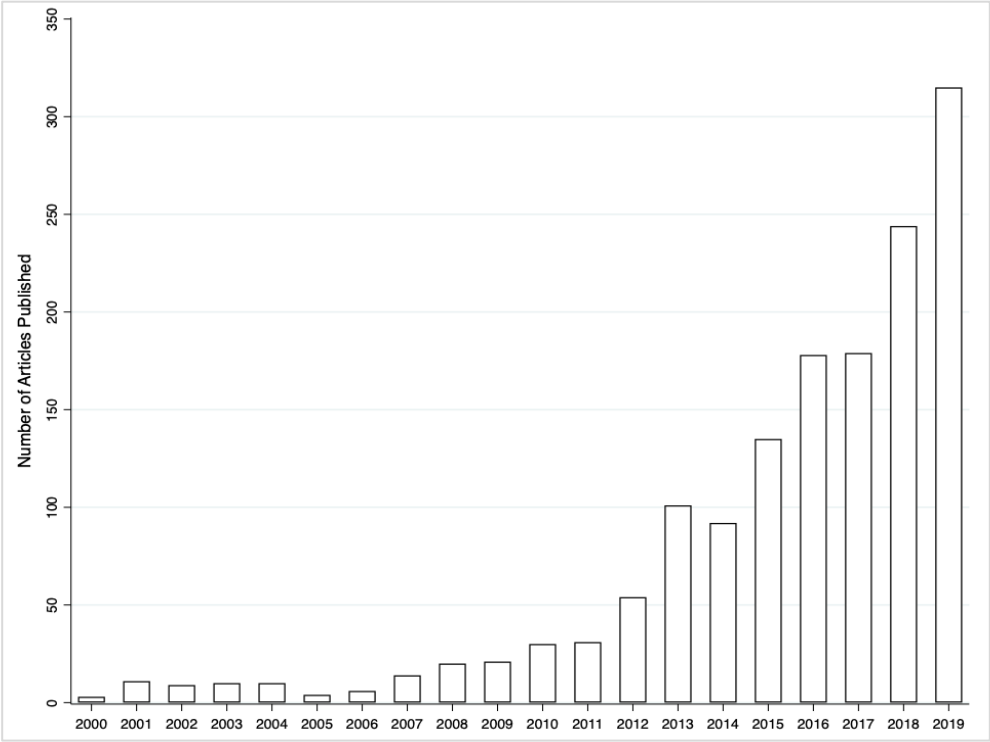

Figure 1: Number of articles published per year with "water security" or "water insecurity" in the title, abstract, keywords, and Keywords Plus® from the Web of Science (2000-2019; n = 1,467). This is a conservative estimate that excludes mentions in the main text and references.

2.2. Methodology

This section describes the reproducible methodology. Systematic reviews synthesize evidence pertaining to specific, often disciplinary, research questions (Aromataris & Munn, 2020), whereas scoping reviews commonly seek to "explore the breadth or extent of the literature, map and summarize the evidence, and inform future research" (Peters et al., 2020, p. 409).

2.2.1 Search criteria

The search criteria were specified in relation to the question: "How is water security conceptualized and practiced to support rural livelihoods in the global South?". The underlined terms represent integral components of the search criteria (listed in **Table 2**). Water security refers both to hydrological characteristics (e.g., amount, quality) and processes through which water is allocated, distributed, and made available (e.g., governance, rights). Described below, I operationalized both components in the search criteria (**Table 2**). Livelihoods are defined as "the capabilities, assets (stores, resources, claims and access) and activities required for a means of

living" (Chambers & Conway, 1992, p. 6). I operationalized this concept using search terms that reflect diverse occupations and activities in global South areas (**Table 2**). Rural areas are rarely described in explicit terms in discussing resource-based livelihoods, such as agriculture, as compared to their urban counterpart (Lerner & Eakin, 2011; Dasgupta et al., 2014). Thus, the concept of "rural" was excluded from the search criteria because it was deemed to potentially exclude relevant articles.[19] The rural criterion was evaluated by the author for each article. Articles with an explicit focus on urban livelihoods were excluded. The critical concept of the global South "incorporate[s] the centrality of historical and contemporary patterns of wealth and power into a loosely geographically defined concept" (Schafer et al., 2017, p. 8). Per section **1.4.2.4.**, global South areas are sites where historical and active processes of colonialism and global capitalism have consolidated and sustained uneven distributions of power, resources, and inequality (Mahler, 2017; Kloß, 2017). This context was operationalized by including search terms reflective of predecessor concepts (e.g., "developing" / "third world") and by including 124 low- and middle-income countries, as identified by the World Bank.

Importantly, search criteria in the social sciences must be "more exhaustive to identify all the relevant studies, than is the case for other types of review[s]" due to the relative absence of structured abstracts, standardized keywords, and detailed methodologies (Petticrew & Roberts, 2006, p. 84). This applies to the water security scholarship, which spans physical, natural, and social sciences, and does not use standardized language or metrics (Grey et al., 2013). To meet this challenge, I first determined numerous search terms related to the main concepts in the research question. Second, to minimize selection bias and expand the search range (Berrang-Ford et al., 2015), I identified multiple "Related Search Terms" (RSTs) associated with the concepts of "water" and "livelihoods" using the thesauri available in each of the databases searched (**section 2.2.2**). For example, search criteria listing "water security" (or some variant, e.g., "security of water") is incomplete because authors may use language such as, "secure water rights", "secure flow of water", etc. **Table 2** lists the self-identified terms (black) and the RSTs from the database thesauri (red). Third, I incorporated the Boolean operators, "AND", "OR", "*", and "NEAR", into the syntax of the search criteria in order to structure how databases

[19] Consider, as a hypothetical example, an article evaluating water security for agriculturalists but makes no mention of the specific concept of "rural". Had "rural" been incorporated as a mandatory inclusion criterion, this article would have been excluded.

searched for articles. The "AND" operator requires a given database to retrieve articles where multiple components of the search criteria are present (e.g., water security AND farmer AND Asia) instead of merely one of these components. The "OR" requires one or more terms to be returned within a single component category (e.g., farmer OR pastoralist; Egypt OR India). The "*" truncator enabled different prefixes and suffixes for specific terms and reduced the length of the search string (e.g., "secur*" captures security, securitization, secured, secures, securing, etc.). The "NEAR" operator was used in reference to how databases identified relevant articles focused on some variant of water (in)security. For example, "secur* NEAR/5 water" captured the word "security" (and its variations above per the "*" operator) within five words of the term "water" (e.g., water secure; security of water; securitization of water, etc.). This code was replicated for each RST (e.g., "secur* NEAR/5 suppl* of water", "secur* NEAR/5 flow of water", etc.) in order to maximize the retrieval of relevant articles. This entire process was completed for the concept of "insecurity", as well. Overall, my search strategy is comprehensive because it includes i) a broad range of non-standardized terms related to "livelihoods" and the security of "water" and ii) variations in how these terms are structured in the authors' text through the use of Boolean operators. The reproducible search criteria are listed in **Appendix A**.

2.2.2 Databases searched

I searched the Agricultural and Environmental Science Database (AESD), Aquatic Sciences & Fisheries Abstracts (ASFA), Public Affairs Information Service (PAIS), and the Web of Science Core Collection (WoS). Each database, with the exception of the generalist WoS, specialize in thematic areas relevant to the research question (**Table 3**). Google Scholar was not used because of several limitations, including a 256-character limit (my criteria is > 500 words), difficulties in bulk export of citations, and the inability to specify truncation ("*") operators (Boeker et al., 2013). I searched the title, abstract, author, keywords, and KeyWords Plus® ("TOPIC" operator) in the Web of Science Core Collection database[20] and everything but the full text ("NOFT" operator) in the other three databases (**Table 3**). Retrieving results from the title, abstract, and keywords is considered established practice because not all of the databases have the capability to search the full text, and because articles central to the study are assumed to have these search

[20] In the Web of Science Core Collection, KeyWords Plus® are indexed terms generated from the title of the cited article whereas keywords are author-included terms.

words in these locations. I limited the scope of the analysis to English-language peer-reviewed journal articles published between January 2000 and mid-September 2019. Grey literature, such as policy documents, websites, and scientific reports, were not included in the scoping review. This is the case for several reasons. First, I sought to understand how the multi- and interdisciplinary peer-reviewed research – an important repository of knowledge for shaping policy[21] – defined and conceptualized water security approaches in service of rural livelihoods. By doing so, I aimed to identify major shortcomings and establish a research agenda for future peer-reviewed studies. While grey literature is important in this domain as well, the peer reviewed literature is nonetheless a key reference set to understand and establish *who* and *what* is studied, *where*, and *how* – potentially lending key insights for future research and policy. Second, I understand that the peer-reviewed literature is not disconnected from key questions, concerns, and interests of non-academics. Indeed, NGO, (inter)governmental, and private sector authors contributed to the included set of publications. Re-stated below, lead authors had a non-academic affiliation in at least 18.2% of examined articles[22], and another 10.1% of publications had lead authors with dual academic and non-academic affiliations. Third, including the grey literature added considerable complexity, necessitating a different inclusion strategy (e.g., no abstracts or keywords) and posing complications to the replicability of the review (i.e., websites and policies are not components of a permanent record). Even as I find the focus on the peer-reviewed literature meaningful, I recognize the exclusion of the grey literature nonetheless represents a limitation in understanding how these concepts are applied more fully by other stakeholders (e.g., governments). This is an area I designate for future research (**section 5.2.**).

[21] Most of the publications included in the study were heavily empirical and conducted with the objective, explicit or implicit, of informing decision-making and policy. For example, publications ranged from detailed empirical cases and policy recommendations to agenda setting in broader forums.

[22] Another 7.1% of the publications had an indeterminable lead author affiliation.

Table 2: Search terms. The search string for each of the four databases is available in **Appendix A**. The searches were conducted on September 16 and 17, 2019. Please note: South Korea was excluded because it was not a global South country.

Concept in research question	Search criteria with Boolean truncation (*) and "NEAR" operators. Red text symbolizes additional concepts identified in the bibliometric thesauri.
Water in/security (secur* and insecure* NEAR 5 words of)	water, "water access", "access to water", "water management", "management of water", "water resource* management", "water governance", "governance of water", "water allocation*", "allocation of water*", "water efficien*", "water provision*", "provision* of water", "water distribution*", "distribution* of water", "water connection*, "connection* to water", "water suppl*", "suppl* of water", "water amount*", "amount of water*", "water qualit*", "qualit* of water", "water right*", "water storage", "water conservation", "conservation of water", "water availabilit*", "availabilit* of water", "water demand", "water level*", "level* of water", "water flow*", "flow* of water", "water quantit*", "quantit* of water"
Livelihoods	Livelihood*, farmer*, irrigator*, farming, agricultur*, horticultur*, livestock, "fish pond", "fish farm*", fisher*, aquacultur*, herder*, herding, pastoral*, farmwork*, "farm worker*", labourer*, laborer*, "agricultural worker*", "animal husbandry"
Global South	"global south", "third world", "underdevelop*", country NEAR/3 "developing", Asia, Africa, Caribbean, Pacific, "Middle East", "Latin America", "South America", Afghanistan, Algeria, "American Samoa", Angola, Argentina, Azerbaijan, Bangladesh, Belize, Benin, Bhutan, Bolivia, Botswana, Brazil, Brasil, "Burkina Faso", Burundi, "Cabo Verde", Cambodia, Cameroon, "Central African Republic", Chad, China, Colombia, Comoros, Congo, "Costa Rica", "Côte d'Ivoire", Cuba, Djibouti, Dominica, "Dominican Republic", Ecuador, Egypt, "El Salvador", Guinea, Eritrea, Ethiopia, Fiji, Gabon, Gambia, Ghana, Grenada, Guatemala, "Guinea-Bissau", Guyana, Haiti, Honduras, India, Indonesia, Iran, Iraq, Jamaica, Jordan, Kazakhstan, Kenya, Kiribati, Korea, Kyrgyz*, Lao*, Lebanon, Lesotho, Liberia, Libya, Madagascar, Malawi, Malaysia, Maldives, Mali, "Marshall Islands", Mauritania, Mauritius, Mexico, Micronesia, Mongolia, Morocco, Mozambique, Myanmar, Namibia, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Palau, Panama, "Papua New Guinea", Paraguay, Peru, Philippines, Rwanda, Samoa, "São Tomé and Principe", Senegal, "Sierra Leone", "Solomon Islands", Somalia, "South Africa", "South Sudan", "Sri Lanka", "St. Lucia", "St. Vincent and the Grenadines", Sudan, Suriname, Swaziland, Syrian, Tajikistan, Tanzania, Thailand, "Timor-Leste", Togo, Tonga, Tunisia, Turkey, Turkmenistan, Tuvalu, Uganda, Uzbekistan, Vanuatu, Venezuela, Vietnam, "West Bank and Gaza", Yemen, Zambia, Zimbabwe

Table 3: Databases searched. Source: Databases, with support from S. Taylor (pers. comm.).

	Agricultural & Environmental Science Database	Aquatic Sciences & Fisheries Abstracts	PAIS	Web of Science Core Collection
Relevant topics	Agriculture; aquaculture; animal science; forestry	Marine and freshwater resources; resource conservation	Agriculture; fishing; forest resources; resource policy	Generalist database
Operators used	AND, OR, NEAR/n			
Fields searched	NOFT (anywhere except full text)	NOFT	NOFT	Title, abstract, author, keywords, Keywords Plus®

2.2.3 Processing and de-duplication

The publications retrieved from each database were exported into RefWorks Legacy Reference Management Software (n = 2,359). These records were subsequently exported as RefWorks Tagged Format files into EndNote X9 (Clarivate, Philadelphia, PA) and de-duplicated using a seven-step methodology outlined by Bramer et al., (2016). The de-duplicated set of records (n = 1,080) were exported as a BibTex file into Rayyan-QCRI (http://rayyan.qcri.org) – an open-source web-based application for systematic reviews (Ouzzani et al., 2016). These records were examined against a set of novel multi-stage inclusion-exclusion criteria I developed.

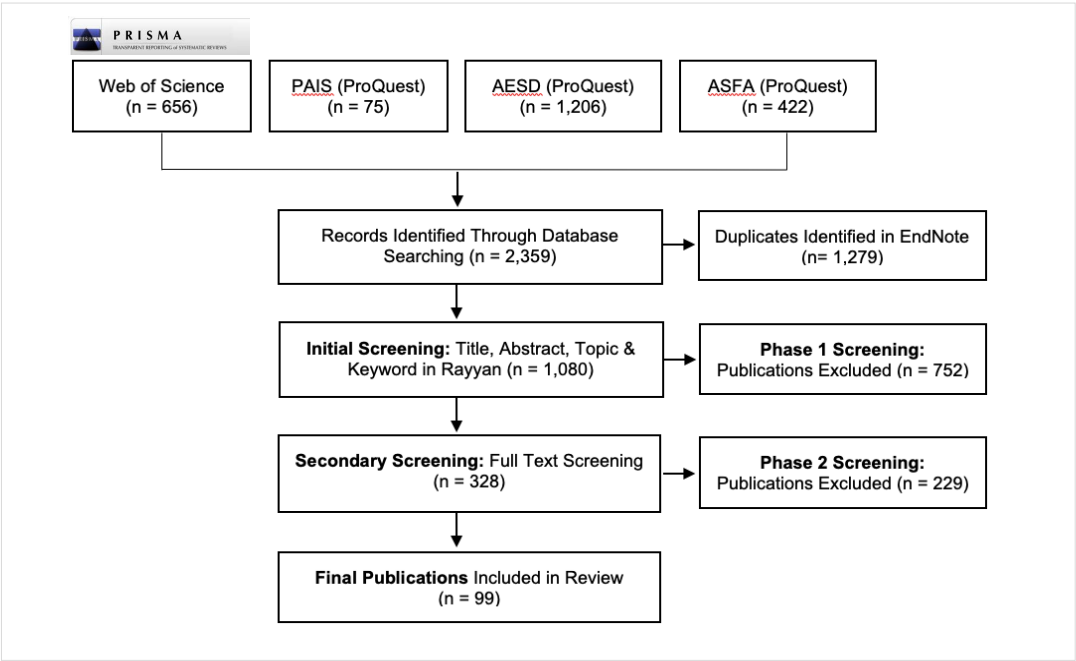

Figure 2: Process for identifying and excluding retrieved publications. PRISMA diagram adapted from Moher et al., (2009).

2.2.4 Inclusion/exclusion criteria

An initial screening process ("Phase 1 screening") excluded articles that did not meet the defined criteria for the review (**Table 4**). The articles' title, abstract, and keywords (n = 1,080) were screened and included for full-text review if the publication i) was a peer-reviewed journal article, ii) written in English, iii) published during or after January 2000, iv) had the concept of "in/security" occur in direct relation to a water-related subject term, v) used the concept of water in/security (or security of an RST) to assess, evaluate, or improve a rural livelihood, and vi) had a focus in at least one area defined to be the global South. The concept of in/security must have been explicitly related to a water-related RST and referenced in the context of a rural livelihood.

Table 4: Phase 1 screening criteria. The title, abstract, and keywords of the de-duplicated set of records (n = 1,080) were examined against the six criteria below. If all were met, the paper was designated for full-text review and screened against Phase 2 criteria.

Phase 1 inclusion criteria
1. A peer-reviewed journal article. • Where unclear, the peer-review policy for the journal in-question was consulted. If still unclear, Ulrichsweb's bibliographic information was consulted. 2. Published in English. 3. Published in or after the year 2000. 4. The concept of "in/security" occurs in direct relation to a water-related subject term in the title, abstract, or keywords. 5. Water security (or security of an RST) is assessed, evaluated, or improved for a rural livelihood. 6. Geographical focus must be in at least one area defined to be the "global South".

Shown in **Figure 2**, 752 publications were excluded through the initial screening and 328 peer-reviewed articles were designated for second stage screening where the full-text was appraised. The purpose of the second-stage was to determine the extent to which articles deemed relevant *meaningfully engaged* with water in/security as a concept. Rather than subjectively evaluating what a "meaningful" or "substantial" focus entailed, I developed an explicit set of criteria, which was reviewed by a subject librarian at The University of British Columbia (Taylor, pers. comms., Sept. 24, 2019; Jan. 23, 2020). **Table 5** provides guidance on how a "meaningful" engagement was determined.

First, an article had a substantial focus if water in/security (or security of an RST) was explicitly defined and consistently used in the context of rural livelihoods ("Category 1", **Table 5**). 30.3% of the final included articles were coded as Category 1. Second, a substantial focus was present if in/security was explicitly defined but later rarely referred to as "in/security" and instead as its constitutive elements (e.g., timing, amount, duration) (i.e., "Category 2"). No included articles were coded as Category 2. Third, a meaningful focus occurred if the concept was undefined but used consistently (≥ 5 times) in the context of rural livelihoods in the publication (i.e., "Category 3"). 69.7% of included articles were coded as Category 3. Articles were excluded (Category 4) if water in/security was inconsistent (e.g., a buzzword in the abstract; mentioned a mere handful of times). This indicated that the concept was not a component of the publication's analytical framework. Articles were further excluded outside of this framework if it was determined other criteria in the initial phase were not met upon full-text examination or if deemed out-of-scope, more generally.[23]

Table 5: Phase 2 screening criteria for evaluating a "meaningful" engagement with in/security.

	Widespread use of the concept of water security	**Limited use of the concept of water security**
Concept detailed	**Category 1:** Water in/security (or security of an RST) is explicitly defined and consistently used in the context of rural livelihoods. ✓	**Category 2:** Water in/security (or security of an RST) is explicitly defined but is later not referred to as "in/security" and instead referred to in its constitutive elements (e.g., timing, amount, duration). ✓
Concept ambiguous	**Category 3:** Water in/security is not defined but is consistently used (≥ 5 times for the standard article) in the context of rural livelihoods. ✓	**Category 4:** Water in/security is inconsistently used and not defined in the publication (e.g., appears as a buzzword in the abstract; mentioned a handful of times in the text). ✗

[23] E.g.: Other studies were excluded if it was focused solely on farmers' decisions whether to invest in a technology. I excluded several papers focused on the Livelihood Vulnerability Index, which use the original work of Hahn et al., (2009), for which water security as a concept appears tangential to the Index. Methodological papers, "Data Descriptors", and Special Issue introductory articles were excluded. One study was excluded because it was difficult to interpret.

2.2.5 Article coding

Articles designated for full inclusion (n = 99) were thematically coded using a self-designed manual (**Appendix B**). Coding themes included attribute data about the publication, its geographical focus, definition of the water in/security concept (or water-related RST), stakeholder(s) responsible for addressing water security, causes of and solutions to advance water security, the focused-on livelihoods, and the scale at which interventions existed. All articles were read and coded by the author (see **Appendix D** for the included articles).

2.3. Results

2.3.1 Metadata

The peer-reviewed scholarship on water security for rural livelihoods in global South contexts has increased considerably since 2000 (**Figure 3**). However, the majority of this growth occurred in the last decade. Notably, 85.9% of the articles included in the review were published after 2010. The decade (2000-2010) following the formalization of the water security concept at the 2nd World Water Forum saw comparatively less growth. This pattern may be attributed to the recent focus on the water-energy-food (WEF) nexus, urban-industrial demands, and the continued proliferation of climate change studies in the context of water and food systems.

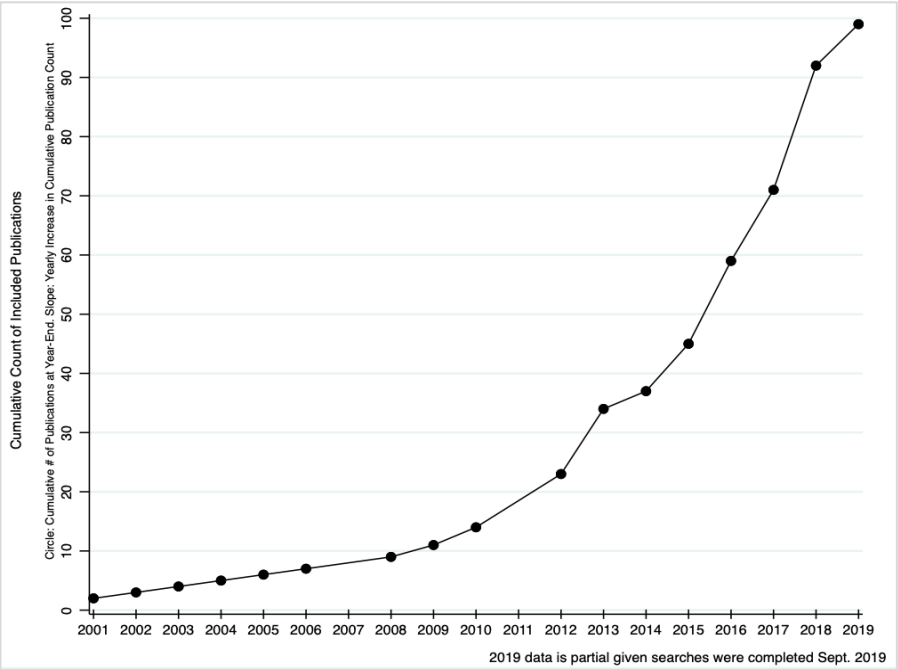

Figure 3: Cumulative count of included articles by online publication date. Note: Data for 2019 is partial because searches were conducted Sept. 2019.

The lead author affiliation was examined under the assumption that the first-author conducted the majority of the work for the publication. In about half (50.5%, n = 50) of the publications, the lead author held only a global North affiliation, in at least one of 14 countries.[24] In comparison, 40.4% (n = 40) of the publications had a lead author who was exclusively associated with an institution based in the global South, with South African affiliations accounting for nearly one-third of these publications (n = 13). In approximately 8.1% of publications, the lead author had a mixed South/North affiliation and in one the affiliation's location was indeterminable. Nearly 40% of the publications examined had authors exclusively associated with organizations in South Africa, United States, and/or England – representing key hotspots of knowledge production.

The majority of the research was produced by lead authors at academic institutions. For example, lead authors were exclusively affiliated with an academic institution in 64.7% (n = 64) of publications. In another 10.1% (n = 10), the lead author had multiple affiliations of which one was an academic organization. The lead author was exclusively associated with non-governmental (9.1%), inter-governmental (3%), private (3%) and government (2%) organizations [25] in fewer publications.

The methodological and analytical approaches were multi-disciplinary in nature. Quantitative (35.4% of publications, e.g., regression, scenario-based models), qualitative (27.3%, e.g., survey-interview analysis, ethnography), mixed-methodological approaches (14.1%), and policy or concept notes based on secondary sources and available literature (23.2%) were each well represented. The diversity of approaches is further reflected in the 56 different journals that articles were published in, ranging from critical social sciences, interdisciplinary social and natural sciences, review-based journals, to practitioner-based outlets. Five journals accounted for 26.3% of the publications and included the Journal of Cleaner Production[26], International Journal of Water Resources Development, Natural Resources Forum, Water, and Water Resources Management. Even amongst these five journals, a strong diversity exists in the scope, objectives,

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[24] Australia, Canada, Denmark, England, Finland, France, Germany, Israel, Italy, Japan, Netherlands, Spain, Sweden, and the United States. England and the United States account for over 50% of the publications where the lead author is solely affiliated with an institution in the global North.

[25] Stated above, the lead author affiliation was indeterminable in an additional 7.1% of publications. In 1%, the lead author had multiple non-academic affiliations.

[26] The Journal of Cleaner Production is well-represented likely because of its broad focus on increasing efficiencies in energy, water, and natural resource use.

and content, reflective of the multiple disciplines, research approaches, and substantive content of the publications surveyed. **Appendix C** lists these journals. **Figure 4** indicates the primary disciplines for the included articles. The disciplines reflect the Web of Science's Core Collection bibliometric metadata for the journals in which each article was published. Articles published in a particular journal were assigned disciplinary classifications, the sum of which are reflected in **Figure 4**. The most common disciplines were water resources, environmental sciences and ecology, and engineering. Environmental sciences and ecology reflect a broad category reflective of environmental governance, natural resource management, and global and regional environmental change.

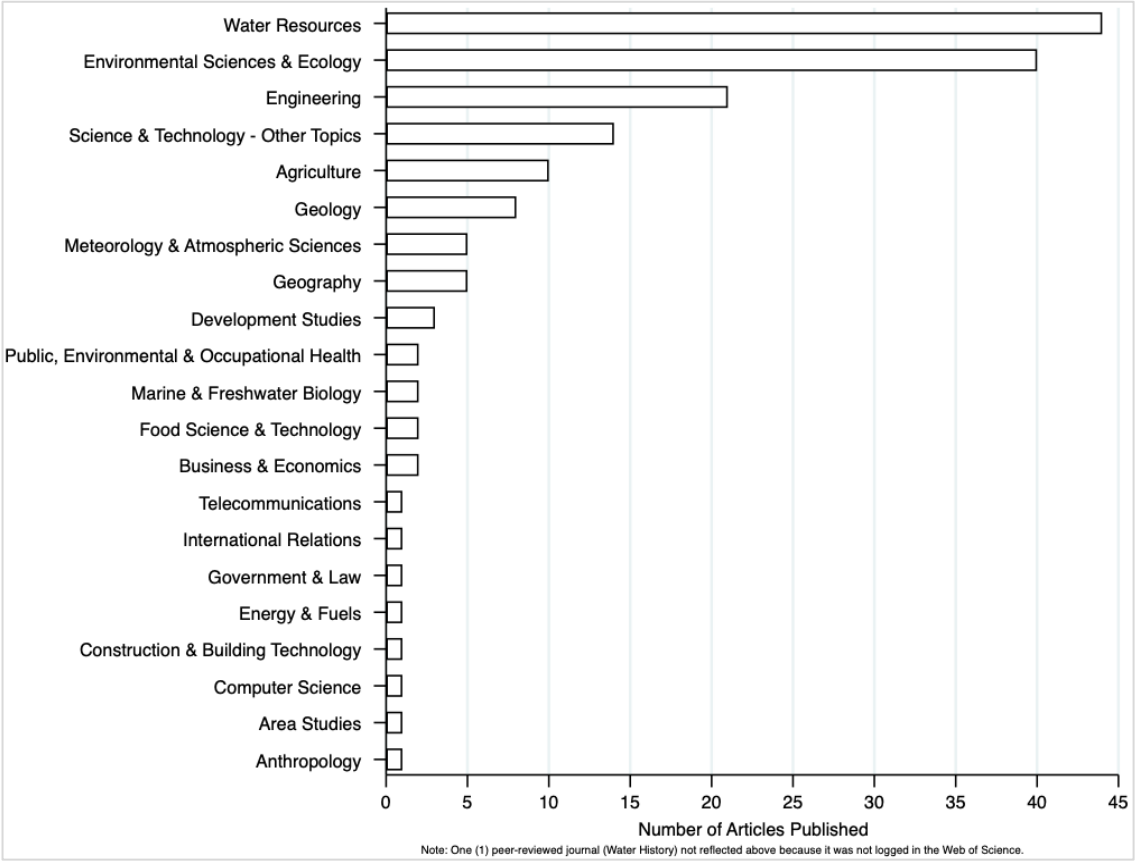

Figure 4: Articles published by discipline. Articles do not total to n = 99 because articles have more than one discipline. Disciplines based on the Web of Science Core Collection's Research Domain for each journal.

2.3.2. How is water security defined?

Only 30.3% of the publications explicitly defined water security or insecurity (or the in/security of a water-RST). Coding revealed definitions had procedural and/or outcome-oriented dimensions (**Table 6** provides illustrative examples). Procedural implies water security as a

process (e.g., involving legal, managerial, and economic means to secure water) and outcome-oriented implies a set of hydrological characteristics relative to specific water-related requirements or risk thresholds.

Table 6: Illustrative definitions exemplifying procedural and substantive definitions.

Orientation*	Example definitions from included publications
Procedural (n = 2; 6.7%)	• "Security of access to water refers to the possibility of materializing water-use rights now and in the future, and to avoiding, or controlling the risks of, unsustainable water management" (Cremers et al., 2005, p. 40).
Outcome-oriented (n = 13; 43.3%)	• "The reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water-related risks" (Agholor, 2013, p. 78, citing Grey & Sadoff, 2007). • "[The] availability of, and access to, water sufficient in quantity and quality to meet the livelihood needs of all households throughout the year, without prejudicing the needs of other users" (Calow et al., 2010, p. 248). • Secure surface irrigation service is "adequate in the amount, duration and timing of water supply that together satisfy agricultural needs… protect[s] against water-related hazards… and [is] predictable in [its] delivery" (Shah & Zerriffi, 2017, p. 3, citing Cook & Bakker, 2012; Grey & Sadoff, 2007).
Procedural & Outcome-oriented (n = 15; 50%)	• "[A]ccess by the irrigating households to sufficient and reliable water to meet their agricultural needs and their ability to assert their water rights against other parties. The key aspects of this definition are: access to reliable and adequate water supply, the ability of the household to pay for the water, and their rights or entitlements to the water which they are able to assert against other parties" (Sinyolo et al., 2014, p. 485). • "[I]nsufficient accessibility and capability of water sources and services to satisfy the household needs for health, livelihood, ecosystem, and production, coupled with inadequate acceptability and adaptive capacity of households to deal with the ecohydrological changes that impact liveability and sustainability" (Danielaini et al., 2018, p. 2). • "[D]etermined not just by absolute availabilities of water in their territories; most of all it is a function of historical and contemporary distribution patterns of resources and services (quantities and qualities), in a context of threats and encroachment practices. ... water insecurity is therefore a socio-political relationship that is felt hardest by socio-economically and politically less powerful societal groups" (Hidalgo et al., 2017, p. 68).

* Not all definitions (n = 30) shown in this table.

Definitions that were entirely outcome-oriented were reflected in 43.3% (n = 13) of the publications that provided a definition. This is not to suggest that these publications do not discuss actions needed to redress water insecurity – but that the definition on its own appears as a state or condition (e.g., Calow et al., 2010; Agholor, 2013; Shah & Zerriffi, 2017). Most of the

water security outcomes focused on an acceptable level of risk and sufficient hydrological characteristics (e.g., reliability, quantity, quality, timing, affordability), relative to particular water-related needs. This framing follows the seminal definition provided by Grey & Sadoff (2007), who defined water security as "the availability of an *acceptable quantity and quality of water* for health, livelihoods, ecosystems and production, coupled with an *acceptable level of water-related risks* to people, environments and economies" (p. 545, my italics). Only five definitions (16.7%) framed water security in relation to productivity, wellbeing, and prosperity. Even here, it remained unclear whether wellbeing was associated with maintaining existing needs, or whether such progressive objectives were intended to re-orient water security initiatives towards building capabilities and meeting aspirations.

Procedural and outcome-oriented elements of water security were present in 50% (n = 15) of the publications with a definition. These publications explicitly defined linkages between procedural (i.e., the means) and the outcomes of water security. Procedural elements enrolled different actors in mitigating and adapting to water-related risks. Mitigation strategies reduce the likelihood of experiencing water-related risks or inadequacies and included, within the definitions, broad language around environmental protection, sustainable water use, and coordinated management across scales (e.g., Wang et al., 2012; Khalid, 2018; Maleksaeidi et al., 2015; Nhamo et al., 2018). Mitigation efforts further involved resisting changes in existing water rights in the context of policies that re-allocate water (Cremers et al., 2005; Sinyolo et al., 2014). Adaptation strategies reduce the impact or degree of an existing or impending risk. Definitions emphasized building livelihood capacities to deal with ecohydrological change (Danielaini et al., 2018), and embedding resilience into water systems through monitoring, redundant water sources, and water rights to manage and cope with water variability (Wegerich et al., 2015). The water security definitions were conservative – focused on processes and linked hydrological outcomes to reduce water-related risk or gaps in sufficiency. No definitions explicitly focused on transforming existing social-ecological and institutional arrangements in water distribution and access to build human capabilities.[27]

[27] Hidalgo et al., (2017) provided a definition of water insecurity as a socio-political relationship characterized by historical and structural processes of Indigenous marginalization, water resources appropriation, and exclusion from acquiring and managing water through customary frameworks. While not explicit in the definition, the authors implicitly suggest the importance of dismantling processes of marginalization in water rights and access.

2.3.3. Drivers & solution pathways associated with water insecurity and water security

I used a combined deductive and inductive coding strategy to identify and synthesize drivers and solution pathways associated with water insecurity and water security. Each publication was assessed using the self-developed coding manual, which established via an earlier comprehensive literature review on agricultural water insecurity, five generic drivers associated with water insecurity and four solution pathways related to water security.[28] An "indeterminate" and "other" category existed for both as well to allow flexibility in the coding. In addition, I listed each driver and solution from the author(s) text. To develop the inductive codes, each cause and solution was re-coded in multiple cycles to define specific themes. I discuss both the deductive and inductive coding results below. The inductive results are represented as the percentage of "causes" listed (vs. percentage of publications) because re-coded categories are a function of individual attributed causes, not the number of unique publications. Multiple drivers and solution pathways (ranging from 2-10 per publication) were present in 73.7% and 61.6% of publications, respectively. Thus, the references in the following two sections may cite one driver or solution strategy even where several were identified by the author(s).

2.3.3.1 Drivers of water insecurity

First, the deductive and inductive coding results revealed environmental change was a prevalent driver related to water insecurity. Weather- and climate-related change and variation, discussed in 64.7% of publications (26.3% of listed causes), was the most prominent driver associated with livelihood water insecurity. The examples included uneven spatial distribution of precipitation (e.g., Chegwin & Kumara, 2018), precipitation variability (e.g., Sinha et al., 2018), extreme events, such as flooding (e.g., Borgomeo et al., 2017) and drought (Danielaini et al., 2018), and climate-related changes associated with precipitation patterns, temperature, and aridity (e.g., Falkenmark, 2013a; Al-Bakri et al., 2013). A second environmental driver associated with water insecurity was land-use processes and land-use change (4.9% of the listed causes). Land-use processes and characteristics associated with water insecurity included sedimentation and hydro-geological factors, invasive species (e.g., Bitterman et al., 2016; Everard et al., 2018), wetland

[28] This review focused on "agricultural" livelihoods instead of rural livelihoods as a broader collective; however, I did not find reason to incorporate additional deductive coding categories.

drainage (Dixon & Wood, 2003), and land conversion (e.g., Qiu et al., 2012; van Noordwijk et al., 2016).

Second, the deductive results indicated mismanagement and inadequate governance systems were associated with water insecurity in 48.5% of publications (23.9% of listed causes). The inductive coding process revealed clearer sub-themes within this broad category related to i) water governance – the organizational and administrative structures and functions around decision-making, distribution, and use (Bakker, 2003); and ii) water management – the capacity to regulate and monitor water under particular governance arrangements (*ibid*). The structure, function and capacity of water governance – including sectoral management arrangements, ineffective transboundary and cross-scalar planning within social-ecological systems – was associated with water insecurity (**Table 7**). Discussed in greater depth in relation to the solution pathways (**section 2.3.3.2**), these included the inability to manage across boundaries and competing uses (e.g., Everard et al., 2017; Sithirith et al., 2016; Rasul, 2014; Bekchanov & Lamers, 2016), gaps in key planning frameworks, strategies, and mechanisms that may alleviate such risks (e.g., Sen & Kansal, 2019; Cremers et al., 2005; Bichai et al., 2016), and inadequate economic and organizational resource support (e.g., decision-support, financial resources, extension) (e.g., Foster et al., 2012; Williams, 2015; Braune & Xu, 2009; Nazari et al., 2018). Inadequate water management included absent or the selective application of laws or regulations (e.g., Ravnborg, 2016; Baleta & Winter, 2016), perverse subsidies (e.g., Bitterman et al., 2016; Rasul, 2016), and deficiencies related to water-use and water-use rules (e.g., Komakech & de Bont, 2018; Sharaunga & Mudhara, 2016; McCord et al., 2018).

Third, I found inter-sectoral water competition – namely urban-industrial and environmental flows allocation (e.g., Rasul, 2014; Baleta & Winter, 2016; Shah & Zerriffi, 2017; Cetinkaya & Gunacti, 2018) – were associated with water insecurity in 36.4% of publications (14.6% of listed causes). Water extraction and depletion – a category related to inter-sectoral competition but here coded as livelihood water demand appeared in 32.3% of the publications (12.6% of listed causes), and included increasing irrigation demand associated with water-intensive cultivation systems, such as rubber plantations (Chiarelli et al., 2017), groundwater extraction for transnational agri-businesses (e.g., Hidalgo et al., 2017), and the potential for extensive water-use to contribute to linked socio-hydrological challenges, such as groundwater salinization (Wurl et al., 2018).

Fourth, socio-economic factors (e.g., poverty, exclusion) clearly drove water insecurity in 20.2% of publications (8.5% of listed causes) (e.g., Calow et al., 2010; Komakech et al., 2012; Bitterman et al., 2016; Mollinga, 2016). Examples include neoliberal policy shifts and the prioritization of foreign entities (e.g., Kattelus et al., 2013), exclusion from water services (Verzijl & Dominguez, 2015), and the marginalization of rights and management systems (e.g., Cremers et al., 2005; Hidalgo et al., 2017; Klümper et al., 2017). Further, few studies conceptualized, yet did not report sufficient empirical evidence to support their hypotheses that factors such as gender, education, wealth, and access to institutional credit or extension drove water insecurity (Sinyolo et al., 2014; Sharaunga et al., 2016). Many publications, not reflected in the coding above, recognized socio-economic poverty not as a *driver* but as an *outcome* of water insecurity, for which techno-managerial strategies were often discussed as key solutions.

Table 7: Inductive coding results for drivers associated with rural livelihood water insecurity.

Drivers*	Count	% Drivers
Biophysical		
• Land-related: Sedimentation, land-use change, geological	12	4.9%
• Weather and climatic-related change and variation	65	26.3%
Inadequate infrastructure (e.g., availability of infrastructure, deterioration, lack of maintenance)	13	5.3%
Inter-sectoral water competition	36	14.6%
Water extraction and depletion	31	12.6%
Other (e.g., adaptation barriers, violent conflict)	10	4.1%
Socio-economic		
• Inability to acquire water, limited participation of underrepresented groups in decision-making, marginalization of water rights and management systems	21	8.5%
Water governance		
• Structure and function: Sectoral management, lack of integrative planning, ineffective transboundary co-operation and cross-scalar planning	17	6.9%
• Mechanisms: Inadequate planning frameworks, vision, transparency, accountability	10	4.1%
Water management		
• Laws, regulations, monitoring, enforcement, regressive incentives and inefficient use	14	5.7%
Water governance & management		
• Economic and organizational resource scarcity for infrastructure and conservation promotion (e.g., decision-support, financial, extension resources)	11	4.5%

• Poorly functioning institutions (e.g., unviable markets, lack of cooperation)	7	2.8%

*Thirteen codes were removed because they were not drivers of water insecurity.

2.3.3.2 Solution pathways to water security

The deductive and inductive coding revealed multiple diverse solutions (**Table 8**) – which are descriptive (i.e., describing how certain actors responded to insecurity) or normative (i.e., arguing for a particular course of action based on viewpoints or empirical results).

First, strategies associated with increasing water supply or availability were represented in 45.5% of the publications and constituted nearly 20% of the listed strategies. Supply-oriented efforts existed at multiple geographical scales, and included regional large dams (e.g., Gohar et al., 2013), inter-basin water transfer, such as China's South-North Water Transfer Project or the Red Sea-Dead Sea desalination project (e.g., Xia et al., 2006; Rajsekhar & Gorelick, 2017), and decentralized village and household-scale water harvesting (e.g., Meyer & Solms, 2018; Liu et al., 2008; George et al., 2010). In the vast majority of publications (95.6%) where increasing water supply or availability was deductively coded as a solution, it was one of several strategies discussed. For example, Rajsekhar & Gorelick (2017) estimate the recovery of Syrian irrigated agriculture to its pre-conflict social-ecological state will produce twice the decline in transboundary inflow available for Jordanian agriculture as compared to that due to climate change. The authors recommend improved transboundary water sharing agreements between Jordan and Syria as well as additional freshwater supplied through the multi-billion-dollar Red Sea-Dead Sea desalination project (*ibid*). Liu et al., (2008) found "no-flow" events in the Yellow River (China) resulted in emergent livelihood adaptation strategies over time, where farmers consistently used selective irrigation using any available water source (1991-), increased water supply (e.g., reservoir building, well drilling, and canal dredging) and reduced demand (e.g., decreasing wheat area, drought-resistant crops, plot clustering) (1994-), and increased irrigative efficiency and diversified livelihood sources to hedge risks. A more indirect approach comes from George et al., (2010), who estimated significant improvements in agricultural water security can be made by increasing urban water distribution efficiency, re-using urban runoff (90 million cubic meters [MCM]), recycling 120 MCM of wastewater, and implementing 500,000 household rainwater harvesting units in the city of Hyderabad (India). Overall, supply improvements were diverse and co-existed at multiple scales with other solution strategies.

Second, enhancing water efficiency and productivity were also prominent responses (38.4% of publications; 17.1% of listed strategies). They encompassed efficient irrigation technology (e.g., canal lining, drip irrigation), different crop variants, and land management practices (e.g., Falkenmark 2013b; Chinnasamy & Agoramoorthy, 2015; Seeliger et al., 2018; Xu et al., 2019). A handful of articles elaborated behavioural changes (e.g., reducing water-intensive diets) (Perrone & Hornberger, 2013) and reducing demand in other competing sectors (George et al., 2010).[29] For example, Alcon et al., (2018) found farmers in the Litani River Basin (Lebanon) were willing to pay higher water prices to support the installation of plot-level water saving measures (e.g., irrigation scheduling, drip irrigation) and farm-scale water metering systems for the irrigation district to increase water security and reduce irrigation uncertainty.

Third, solutions associated with water management and governance strategies featured prominently (75.8% of publications). The inductively coded strategies revealed four major sub-themes, including a focus on i) water management, and knowledge production and information dissemination (16.3% of coded solutions); ii) new organizational structures and functions, particularly across social-ecological and jurisdictional scales (18.9% of coded solutions); iii) new mechanisms for water security (e.g., conflict resolution, ecosystem-based management, market-based schemes) (4.8% of coded solutions); and iv) strategic and sustainable planning of water and livelihoods (4.8% of coded solutions) (see **Table 8**). Water management approaches (16.3% of coded solutions) indicate regulatory, enforcement, data management, decision-making support, and monitoring processes without substantial shifts in governance frameworks. In Western Bahia (Brazil), one of the most active agricultural frontiers globally, Pousa et al., (2019) found multi-decadal regional precipitation and streamflow had decreased in both seasons while irrigated area had increased 150-fold over a similar time period. The authors recommend avoiding irrigation during low-flow periods, halting the installation of new irrigation systems, and investing in hydro-climatic monitoring systems for regulating water licensing and use (*ibid*).

A prominent focus on water governance structure and function included managing water across multiple social-ecological scales (18.9% of solutions) and, relatedly, on novel mechanisms (4.8% of solutions) for improving livelihood water security. Changes to the structure and function of water governance centred on developing cross-scalar arrangements

[29] Virtual water trading, or importing water-intensive crops was associated with studies outside the scope of this study, and often focused on national levels of food security.

between countries, and across and within basins (e.g., Duan et al., 2019; Sithirith et al., 2016); on integrative and multi-sectoral representation in water decision-making, particularly at the agriculture-water-energy nexus (e.g., Conway et al., 2015; Rasul, 2016; Nhamo et al., 2018; Mabhaudhi et al., 2019); and on organizational characteristics (e.g., transparency, participation, communication). Governance mechanisms or instruments included tradeable water rights (e.g., Bekchanov & Lamers, 2016; Matchaya et al., 2019), conflict resolution mechanisms (Shah & Zerriffi, 2017), and ecosystem service conservation (e.g., Rasul, 2014; Bremer et al., 2016; van Noordwijk et al., 2016). For example, Rasul (2014) argues for cross-sectoral coordination between agriculture, energy, drinking water and environmental sectors, and regional integration between upstream and downstream areas for advancing food, water, and energy security in the Hindu Kush Himalayas. This includes both re-structuring governance to synchronize policies across different sectors and integrate water, energy, and land into basin planning, which can be advanced by incentives including ecosystem services and cost-benefit sharing arrangements (*ibid*; Rasul, 2016). Sithirith et al., (2016) finds the Mekong River Commission (MRC) Agreement, which focuses on the Mekong mainstream river flow, poorly regulates hydrological development on shared transboundary tributaries. The inability for the international agreement to regulate for dams on shared tributaries has affected the diverse relationships with water around the production and maintenance of livelihoods (e.g., rice farming, fishing) in linked social-ecological systems (*ibid*). The authors argue co-operative regulations and mechanisms must be strengthened (*ibid*). Last, Nhamo et al., (2018) argues the Southern African Development Community (SADC) – a regional economic partnership between sixteen southern African countries – operates in national silos instead of coordinating across the larger, regional water-energy-food nexus for reducing country-specific vulnerabilities and water-related risks. These articles disassociate with management paradigms that assumed water to be predictable, static, and controllable over time and instead view risk to emerge from rigid, sectoral, and uncoordinated institutions.[30]

Another subset of the solution codes focused on formalizing sustainable water planning frameworks, and on re-examining national planning in the context of water insecurity (4.8% of

[30] This is in line with a broader scholarship on the study not included in the review: e.g., Folke, (2003), Lankford & Beale (2007), Pahl-Wostl et al., (2011) and Bakker & Morinville (2013).

coded solutions). This included, for example, re-considering the role of agriculture, or certain agricultural products, within national planning (Nazari et al., 2018; Bekchanov & Lamers, 2015).

Finally, reducing socio-economic barriers or systems preventing water access was clear in around 14.1% of the publications (e.g., Cremers et al., 2005; Hidalgo et al., 2017; Klümper et al., 2017; Danielaini et al., 2018). Themes included asserting rights or claims to water (e.g., institutional pressure, forming alliances, or asserting management frameworks), building entitlements (e.g., poverty reduction, political representation of marginalized peoples), and improving the distribution of water for historically disadvantaged groups. The focus on these systemic structures and processes is an area for significantly greater focus. The complete set of inductively-developed codes is listed in **Table 8**.

Table 8: Inductive coding results for strategies associated with rural livelihood water security.

Solutions	Count	% Solutions
Water supply		
• Improve water supply or availability	44	19.4%
• Improve water supply or availability (urban areas)	1	0.4%
Water demand, productivity & efficiency		
• Increase water productivity or efficiency	38	16.7%
• Reducing demand of other sectors	1	0.4%
Socio-economic standing		
• Build water-related entitlements (e.g., reduce poverty, enhance participation, and representation of marginalized peoples)	7	3.1%
• Asserting rights or claims to water	4	1.8%
• Distribute water for marginalized residents or communities	4	1.8%
Water governance & management		
• Transboundary, cross-scalar planning, and multi-sectoral planning (e.g., institutional structures, mechanisms)	30	13.2%
• Water management (e.g., monitoring, regulation, enforcement)	20	8.8%
• New governance mechanisms for water security (e.g., markets, willingness to pay schemes, ecosystem-based management)	9	4.0%
• Data acquisition and decision-support systems	9	4.0%
• Formalizing strategic water management planning systems	7	3.1%
• Water governance characteristics (e.g., transparency, inclusion and public participation, openness, communication)	7	3.1%
• New organizational structures (e.g., decentralized management, local participative institutions)	4	1.8%
• Strategic national planning (e.g., de-linking livelihoods from water; re-considering the role of agriculture)	4	1.8%
• Extension and training	3	1.3%
• Mitigation of hazards (e.g., early warning)	3	1.3%

• Improve water distribution and equitability	3	1.3%
• Collective action and local co-operation	2	0.9%
• Conflict resolutions mechanisms	2	0.9%
• Disseminate and raise awareness	2	0.9%
• Institutional structure change to recognize water rights	2	0.9%
• Integrate land-use planning into water management	2	0.9%
• General (improved governance and management)	2	0.9%
Other		
• Infrastructure rehabilitation and maintenance	7	3.1%
• Indeterminate or N/A	3	1.3%
• Context specificity in design and solution response	2	0.9%
• Land management (e.g., agro-forestry, invasive plant control)	2	0.9%
• Behavioural changes	1	0.4%
• Livelihood diversification to manage water-related risks	1	0.4%
• Stabilize conflict	1	0.4%

The coding manual deductively set multiple non-mutually exclusive scales at which the strategies described or argued for could exist at. The different solutions were well-distributed across scales. Individual or household scale (24.2% of publications) could include strategies, such as farmers' coping responses to inadequate irrigation (e.g., Liu et al., 2008; Ferchichi et al., 2017) or agreement to pay higher fees for improved water security (e.g., Alcon et al., 2018). The community level (21.2%) could include strategies, such as local rules around water sharing (McCord et al., 2018), communal management of groundwater resources (Foster et al., 2012), or improved reliability and maintenance of water infrastructure (Borgomeo et al., 2017). The watershed or river basin scale (37.4%) included strategies to revitalize irrigation systems (Lankford et al., 2016) and manage water at the water-energy-food nexus (e.g., Wegerich et al., 2015; Shah & Zerriffi, 2017; Colloff et al., 2018). State or province (21.2%) and country (35.4%) scales could include many of these aforementioned strategies, or broader legal and regulatory changes. The international scale (23.2%) often referenced transboundary water governance (e.g., Kibler et al., 2014; Sithirith et al., 2016; Rajsekhar & Gorelick, 2017; Mpandeli et al., 2018). Last, a small handful of publications provided a general indication of multiple scales with unspecified units (6.1%). The scale of the solutions was indeterminate in two publications.

2.3.4 Livelihood focus

Households in the rural global South often engage in diverse resource-based livelihoods (Ellis, 2000), with agricultural production remaining critical to the food and economic security of over one billion people (FAO, 2012). However, the diversity of resource-based livelihoods in the global South was not well-reflected in the studies examined. Nearly every article focused to some degree on agriculture, ranging from subsistence food production to commercial export-oriented commodities (e.g., flowers, rubber). Explicit focus on agricultural labour was not featured. Approximately 24.2% (n = 24) of publications had some focus on livestock, animal husbandry, or pastoralism – but were most commonly studied as a secondary livelihood nested under agriculture. Global figures on pastoralism are unclear but it is estimated to support around 200 million households (Dong et al., 2011; IUCN, 2020) with key regions experiencing growth (e.g., South America and Central Asia) and many areas experiencing decline from expanding agriculture (FAO, 2001). A clear absence of transhumance pastoralism, in particular, is concerning. A small subset of the articles focused on aquaculture and fishing (8.1%) and agro- or other industrial activities (7.1%). Aquaculture can constitute an important risk-reduction strategy for livelihoods facing hydrological variability and soil salinization and deserves considerably greater focus in future scholarship. Last, an insignificant share of publications focused on other resource-based livelihoods (e.g., hunting, artisanal work).

2.3.5. Geographic focus

The geographical focus was wide-ranging. 86 global South countries were studied across the 99 analyzed publications (**Figure 5**). Despite this diversity, three major country-specific clusters included India (n = 21 publications), South Africa (n = 15), and China (n = 13). Together, 42.4% of the publications examined contained at least one of these three countries.[31] Around one-third of the countries (n = 29) examined were studied once (i.e., in one publication) with most in west and central Africa, and the greater Middle East. Key absences included northern Africa and central areas of South America. Future research is warranted in these areas given the limited set of existing scholarship.

[31] This figure represents distinct publications, given in some > 1 of the countries were examined.

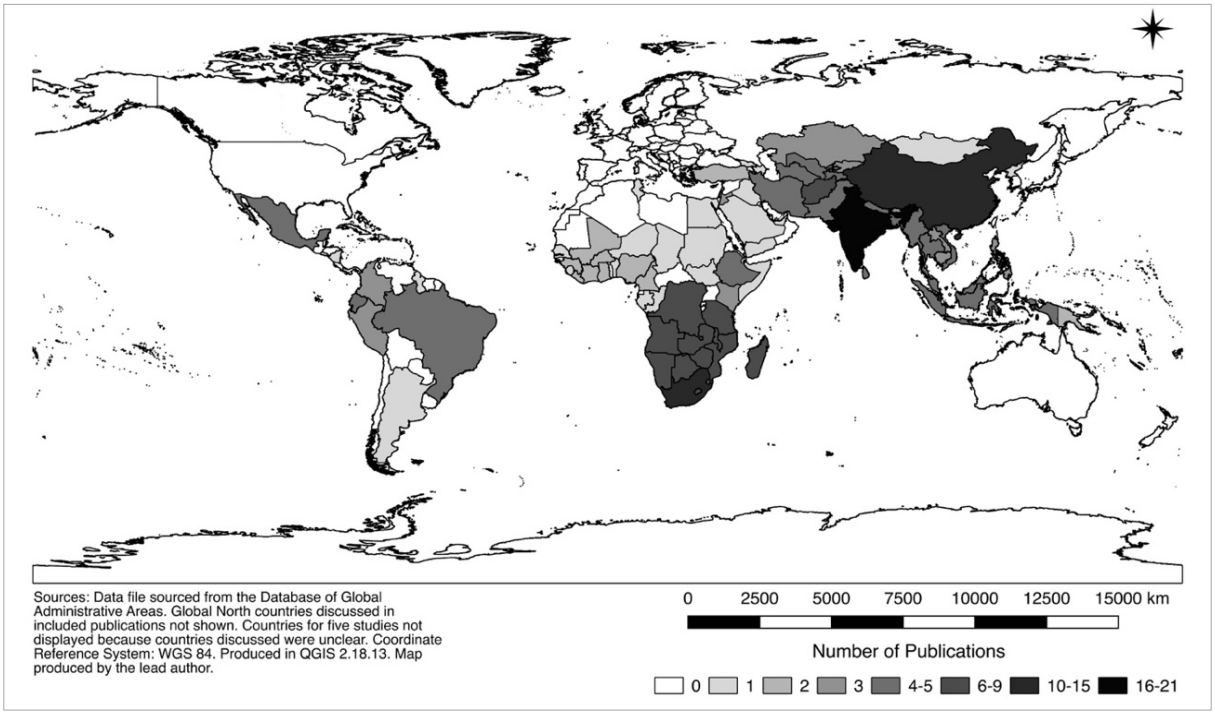

Figure 5: Articles' geographic focus. A publication can examine > 1 country. Map produced by the author.

2.3.6 Responsibility

Most articles (90.0%) were sufficiently clear in attributing some degree of responsibility to a stakeholder. A wide range of actors, including government bodies, river basin organizations, individual farmers, local communities, co-operative associations / agricultural associations, industrial water users, donors, non-governmental organizations, and consumers were represented. Government bodies or officials were at least one entity responsible for contributing to livelihood water security in 81.8% of the publications. Examples included creating national, state, or regional planning frameworks, regulations, enforcement, or coordinating water across boundaries. Individuals and local communities were coded as at least one party responsible for improving water security in 21.2% and 20.2% of the publications, respectively. Examples here included adoption of new technology, partaking in management decision-making, or developing community-based plans. Other actors, such as NGOs and donors, did not frequently appear as responsible entities.

2.4. Discussion

This section derives four insights from the results. They reflect shortcomings related to the objectives of security interventions, *who* and *what* is subject to intervention, *how* and *why* risks manifest, and *which* solutions are proposed. For each, I present areas for future research, reflecting on the wider water security and livelihoods scholarship, and their potential synergies.

Insight #1: *Water security focuses on conditions of adequacy – not on advancing prosperity.* The analyzed definitions of water security focused heavily on preventing unacceptable levels of risk or on ensuring "acceptable" and "sufficient" water – not explicitly on building capabilities or meeting self-determined aspirations (**section 2.3.2**). This is an incomplete framing if the concept is to serve livelihoods. For instance, Scoones' (1998) adaptation of Chambers & Conway's (1992) sustainable livelihood definition posits, "[a] livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base" (p. 5). Here, a "sustainable" livelihood is not just one that maintains biophysical life-support systems, but achieves "adequacy, security, well-being and capability" (Scoones, 1998, p. 5). Capabilities represent what a person can be or do, which is linked to their freedoms to pursue self-determined aspirations and notions of wellbeing (*ibid*; Sen, 1999). A preoccupation with adequacy or unacceptable water-related risk is insufficient to build livelihood capabilities for wellbeing and prosperity. Future efforts, in the livelihood context, can take cue from recent work in the broader water security literature, which has emphasized the importance of building human capabilities (Jepson et al., 2017a; Wutich et al., 2017). For example, Jepson et al., (2017a) state that water security efforts should focus on securing relations and water such that "individuals and communities…can live their lives as they choose, achieve freedoms in line with their own vision, and achieve their fullest potential" (p. 48). Pivoting from a short-term risk-reduction focus to an effort that builds capabilities – or, what people can be, do, and achieve (Sen, 1999) – should be a focus of future research and practice, particularly in the context of social-ecological and hydrological change that may increase livelihood water insecurity in the rural global South.

Insight #2: *"Who" and "what" is made secure is narrow and limits livelihood support.* Key livelihood groups were disproportionately underrepresented in the included publications –

namely agricultural labour, transhumance pastoralism, and aquaculture (**section 2.3.4**). Neglecting one livelihood is not necessarily limited to neglecting one distinct group of people; many resource-dependent households depend, either simultaneously or seasonally, on multiple livelihoods (Ellis, 2000). Indeed, a narrow focus on agriculture will neglect the "complex bricolage or portfolio of [livelihood] activities" (Scoones, 2009, p. 172) integral to rural household needs. Future research should explore water insecurity dynamics for multiple diverse livelihoods. Further, existing approaches to secure water for physical entities, such as crops or livestock, do not account for human needs to perform such livelihoods. Here, I challenge the separation of water for human consumption and livelihood generation (Cleaver & Elson, 1995; van Koppen & Hussain, 2007; Mehta, 2014). This distinction neglects how water for "domestic use" is used for livelihood activities (Cleaver & Elson, 1995) and how water for irrigation ("productive use") is used in non-farm livelihoods, subsistence, and domestic use (e.g., van Koppen & Hussain, 2007; Meinzen-Dick & Bakker, 1999). Simply said, livelihoods are not independent of an individual's physical health, thirst, and nutrition. Future research should further examine how water insecurity in "non-productive" domains can affect the ability to perform and undertake a livelihood activity.

Insight #3: *The identification and transformation of systemic processes that create and sustain water insecurity is limited.* This review found a limited focus on the relationship between water insecurity and socio-economic standing, power, and poverty. Mitigation and adaptation strategies related to proximate drivers of water-related risk exceeded efforts to identify and transform the underlying socio-economic dynamics sustaining water insecurity (**sections 2.3.3.1** & **2.3.3.2**). This concern is reflected in the wider water security scholarship (Wutich & Brewis, 2014; Loftus, 2014; Jepson et al., 2017a; Zeitoun et al., 2016). For example, Wutich and Brewis (2014) asserted, "To date, only a few scholars have explicitly taken an entitlement approach to examining how complex, interlocking institutional arrangements shape water access and insecurity" (p. 448). This is problematic because any understanding of risk related to the dominant drivers of change examined (e.g., climate change, water re-allocation, and increased water demand) cannot be understood, measured, or analyzed independently of the systems of power and marginalization. Livelihood frameworks have, in *theory*, centred structural and systemic interventions for building entitlement and endowment structures (Chambers & Conway,

1992; Scoones, 1998; 2009). Indeed, a critical component of the livelihood framework is the political-economic, class, and gender structures that mediate entitlement and endowment distribution, livelihood opportunities, and the social-ecological risks that accompany differentiated livelihood activities (Watts & Bohle, 1993; Blaikie et al., 1994; Leach et al., 1999; Scoones, 1998; Birkenholtz, 2012; Ribot, 2014; Watts, 2016). In my study, endowment and entitlement relations did not sufficiently factor into the causal structure of risk, nor in the solutions for reducing water insecurity, despite being foundational to the theoretical understanding of rural livelihoods. A stronger focus here will contribute back to the livelihoods scholarship – which despite integrating social and institutional systems into situated analyses of livelihoods (Chambers & Conway, 1992; Scoones, 1998; Cannon et al., 2003) – has received criticism for ceding ground to technical, advisory, and extension-based efforts intended to mitigate "external" hydrological risks that impact livelihood production systems (Scoones, 2009; Taylor, 2015; Nightingale et al., 2019; Carr, 2020; see **section 1.1**). Given livelihoods exist at the interface of institutions and ecological change, I advocate for the use of coupled social-ecological (e.g., Blaikie et al., 1994; Turner et al., 2003; Adger, 2006), "environmental livelihood security" (Biggs et al., 2015), or "hydro-social" risk frameworks (Linton & Budds, 2014). Such frameworks recognize that the impacts of water-related stressors interact with, and depend on, social, economic and political inequalities (Olsson et al., 2014). For example, the effects of climate-related stressors, inter-sectoral water allocation, and demand-driven extraction could be analyzed using an equity-based approach to ascertain why certain households and their livelihood activities experience differentiated water insecurity. These efforts will further support a focus on the underlying causes of water insecurity – and are well-positioned to improve human prosperity beyond the scope of technical and management-based adaptations.

Insight #4: *Global dynamics and interactions are underrepresented.* The scale at which solutions were posited were well-distributed from household to international levels. However, where the international-scale was emphasized, it was often limited to transboundary water sharing agreements or integration at the water-energy-food nexus. Following Scoones (2009), livelihood approaches have not adequately examined how "big shifts" associated with globalization, politics, and ecological change impinge on livelihood activities (p. 181). These "big shifts" (*ibid*) can emerge from social-ecological dynamics at smaller levels, which can, in an interconnected

world, reverberate across larger spatial scales (Young et al., 2006; Adger et al., 2009). Relatedly, water managers have not adequately understood "the interdependencies and dynamics of the global water system" (Hoff, 2009, p. 142; Bakker & Morinville, 2013). A socio-hydrological approach can support scholarship in this direction with a focus on understanding social and hydrological systems as coupled and generative of feedbacks across multiple scales (Sivapalan et al., 2012). This will widen the scalar analysis of water security studies, advance the understanding of feedbacks between large-scale changes and local livelihood dynamics, and support interventions at multiple levels designed to protect and enhance livelihood water security (*viz.* Scoones, 2009).

2.5. Limitations

There are limitations to this scoping review that must be recognized. First, while every effort was made to ensure the review was as comprehensive as possible (**section 2.2.1**), I do not claim that I captured the entirety of the literature on the subject – especially given the aforementioned challenges in retrieving articles from an interdisciplinary literature without standardized language and frameworks (Grey et al., 2013). Second, despite the broad search criteria around water security – both in diverse related search terms around "water", and in the phrasing of the concept through the inclusion of operators – I excluded a broader scholarship that *implicitly* assumes water security as synonymous with improved water governance and water access (i.e., articles with no mention of "security"). The scope for such an analysis is larger and includes >11,000 de-duplicated records.[32] Third, the inability to include non-English refereed scholarship is an unfortunate limitation that reinforces the English-language synthesis of knowledge. A more diverse set of scholarship could have yielded new or complementary insights, or be used to compare and interrogate the water security concept as derived in the English-language literature. This is an important area for future research in order to de-stabilize and further inform the discourse and ontology around water governance, more broadly. Fourth, I excluded grey literature for reasons detailed in **section 2.2.2**. Even where 28.2% of the publications featured lead authors with at least one affiliation as intergovernmental, governmental, NGO, or private sector (i.e., non-academic), I recognize the exclusion of the grey literature as a limitation in

[32] As determined through applying similar search criteria without the bounding of "security".

better understanding how water (in)security is applied more fully by these stakeholders. Fifth, I was the sole individual responsible for reading and coding each included article. The systematic review methodology recommends more than one-person review how the articles were coded to reduce or eliminate coding bias. To reduce concerns, I instituted a self-developed quality-control protocol during and after the coding process. The drivers of water insecurity and strategies for addressing water security were both deductively and inductively coded for each article. These deductive and inductive codes were cross-checked for each article. This enabled redundancy to be built into the analysis for key questions related to the causes and solution strategies for water (in)security. Further, attribute data for each article was double-checked after the initial coding process. Last, the same process was completed for other substantive questions.

2.6. Conclusions

The use of the concept water security has increased since its introduction at the 2nd World Water Forum in 2000. However, the conceptualization and application of the concept in relation to rural livelihoods has not been reviewed. To address this, I conducted a systematic scoping review of peer-reviewed journal articles (2000-2019, n = 99) to investigate how water (in)security is defined, driven, and addressed for rural livelihoods in the global South – a context where livelihood precarity is shaped by historical and structural inequities and emerging water risks.

I found refereed articles related to water security and rural livelihoods in global South contexts have increased since 2000. However, 86% of the articles included in the review were published after 2010, indicating much of the scholarly growth is relatively recent. A core strength of the literature rests in the multiple disciplines and diversity of methodological strategies employed. This is exemplified upon considering the 99 included publications were published in 56 different journals, ranging from critical social sciences, interdisciplinary sciences, to practitioner-based outlets. Further, the geographic focus spanned an impressive 86 countries. The majority of articles recognize multiple drivers of water insecurity (73.7%) and solution pathways for advancing water security (61.6%). This is another important strength of the literature as it demonstrates a departure from single causes or solutions towards a complexity science approach where multiple simultaneous drivers and solution strategies are identified for understanding and advancing water security.

I found four major shortcomings in this emerging literature. First, under one-third (30.3%) of the included publications defined water security or insecurity. These definitions conservatively centred on outcomes of "adequate" water supplies or "acceptable" water-related risks. Future research must re-orient water security interventions from a conservative focus on risk-mitigation, towards an approach that recognizes the role of water access and sustainability in building livelihood capabilities and human prosperity. This is especially critical in the context of emerging water-related risks that threaten to further increase livelihood precarity. Second, common rural livelihoods, such as agricultural labour, transhumance pastoralism, and aquaculture, were heavily underrepresented in the examined publications. This is problematic because agricultural livelihoods (the dominant focus of publications) often co-exist with these aforementioned resource-based livelihoods (Ellis, 2000). Further, the included articles upheld a long-standing dualism between "productive" (livelihood) and "unproductive" (domestic / drinking) water. The ability to perform livelihood activities is not independent of an individual's physical health and nutrition – which water plays a central role in (e.g., Mehta, 2014; Goff & Crow, 2014). Future water security research that supports households and coupled livelihoods should focus on the diversity of livelihoods given their interconnected natures as well as on how domestic water insecurity can affect the ability to perform and undertake a livelihood activity. Third, mitigation and adaptation strategies related to proximate drivers of water-related risk outnumbered efforts to understand and transform the underlying dynamics that create and sustain water insecurity. For instance, weather- and climate-related change and variation (64.7% of publications), water mismanagement and poor governance (48.5%), inter-sectoral water competition (36.4%), and water extraction and depletion (32.3%) were more prominent than how inequality and power affected water insecurity (20.2%). Increasing water supply or availability (45.5% of publications), water efficiency and productivity (38.4%), and varied dimensions of water management and governance (75.8%) – including regulations, planning frameworks, new organizational structures and functions, and mechanisms for water security – were more common than strategies explicitly reducing socio-economic barriers or systems preventing water access (14.1%). The examined publications, on the whole, have not adequately reflected how entrenched inequalities affect the ability of the key water security responses described above to address risk for all people, nor sufficiently explored how equity concerns can enable interventions to be re-visited in pro-poor ways (e.g., Biggs et al., 2015) – both major

contributions advanced in **Chapter 3**. Last, a considerable focus rested on cross-scale and transboundary water management; however, future research should examine how coupled land-water interactions at multiple spatial scales impact local and regional livelihood systems (Hoff, 2009). Addressing these shortcomings will advance the water security and livelihoods scholarship in ways that support human prosperity, diverse and interconnected livelihoods, and concerns related to equity and justice.

Chapter 3: A "drought-free" Maharashtra? Politicizing the conditional, inequitable, and extractive outcomes of state-sponsored livelihood adaptation for rain-dependent agriculture

3.1. Introduction

One of the most prominent risks to water security for rural livelihoods in the global South, as evidenced in the refereed scholarship (**Chapter 2**), is climate change and variation. Climate change and variation is expected to impact crop production and livelihood generation in rural areas (Dasgupta et al*.,* 2014), and is of particular concern for agricultural systems with limited irrigation to mitigate potential production risks (Jiménez-Cisneros et al*.*, 2014). As such, improving water security for rain-dependent agriculture in contexts of heightened precipitation variability is a public policy imperative (Falkenmark, 2016). This policy need gains further importance upon considering water's multiple contributions to human development (UN, 1994), including for food security, poverty alleviation, and well-being (per **Chapter 1**).

Despite projections of increased precipitation variability in certain rain-dependent agricultural areas (Jiménez-Cisneros et al*.*, 2014), water security scholars often explain crop – and linked food and economic – risks as driven by "management induced" scarcity (Rockström et al*.,* 2010, p. 545). That is, production risks from variable rainfall patterns are more problematic in contexts where management practices have not adapted land and crop systems to capture, and use more efficiently, the dynamic availabilities of water (*ibid*; Agarwal, 1999; Lundqvist & Falkenmark, 2010). The potential for social-ecological adaptations to mitigate the effects of precipitation variability has increased calls to i) improve water availability (e.g., moisture conservation, supplemental irrigation) and ii) enhance water productivity (e.g., drip irrigation, drought-tolerant variants, shifted planting dates) (Wani et al., 2009; Rockström et al., 2010; Agarwal, 1999). These are prominent strategies to enhance water security, as clarified in **Chapter 2**. Increasing the amount of water available to agriculturists can involve enhancing rainfall infiltration and conserving soil moisture ("green water") for the crop root zone, as well as capturing runoff and baseflow ("blue water") for supplemental irrigation (Rockström et al., 2007; 2010; 2014a,b). Soil moisture can be enhanced through in-situ (on-farm) interventions, such as farm bunding, terracing, and mulching (Kahlon & Lal, 2011) – important given a large

percentage of precipitation (≥ 70% in semi-arid contexts) is often lost from farmers' fields via evaporation and runoff (Rockström et al., 2007, p. 326). Further, land management activities across the watershed can slow runoff, increasing percolation and baseflow. Last, water can be captured in small dams or ponds on farmers' fields, communal land, or in drainage courses. As one example, Sreedevi and Wani (2009) found in-situ adaptations for rainfall infiltration and runoff collection contributed to average increases in maize (72%), castor (60%), and groundnut yield (28%) in drought-prone areas of Andhra Pradesh (India). Such successful field experiments underpin current calls from the scientific community urging governments to fund and up-scale integrative green-blue water conservation to protect and even enhance crop production in contexts of precipitation variability (Rockström & Falkenmark, 2015).

In India, government-led water security interventions in rainfed areas since the 1970s have included the Drought Prone Area Program (DPAP) and the Desert Development Programme (DDP) (Kerr, 2002; Kumar et al., 2018). These high-profile central government programs – spending over US $253 million[33] (mid 1970s-1993) (MoRD, 1994) – focused on "soil and moisture conservation, water resources development, afforestation and pasture development" to restore the ecological balance, reduce desertification, and enhance crop yields (*ibid*, p. 10).

In 2014, the government of Maharashtra launched a decentralized green-blue water conservation campaign, Jalyukt Shivar Abhiyan, to make 5,000 new villages "drought-free" each year (2015-19) (GoM, 2014). While the campaign aspired to reduce the impacts of intra- and inter-annual precipitation variability on crop production and drinking water, I focus here on the agricultural dimension. In this context, "drought-free" refers to eliminating agricultural drought – seasons where village crop yield is < 50% of what it averaged over the last decade, due to shortfalls or variabilities in precipitation.[34] Described below, Jalyukt Shivar was an umbrella campaign wherein several nested government schemes as well as corporate donations were coordinated to fund drought-relief initiatives in villages.[35] With support from local officials,

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[33] Valued at the current exchange rate.
[34] 19,059 villages (48.3% of Maharashtrian villages) were declared drought-hit based on < 50% crop yield in December 2014 (GoM, 2014, p. 18). This formed a key basis for the campaign.
[35] As a clarification, I use the word "drought-relief" interchangeably with the drought-freeness program (Jalyukt Shivar Abhiyan). Unless explicitly stated, drought-relief does not refer to financial relief from the state or central government in the aftermath of the drought.

selected villages prepared implementation plans using fourteen general types of conservation initiatives funded by schemes under the campaign with the objective of becoming "water neutral" – a state where overall village water availability met demand to reduce or eliminate instances of agricultural drought (GoM, 2014).

Earlier programs (e.g., DPAP, DDP) failed to reduce water scarcity in part because water conservation initiatives were implemented in piecemeal ways without strategic concern for how they could mitigate drought impacts (MoRD, 1994, p. 11). In contrast, Jalyukt Shivar touted a "ridge-to-valley" planning approach (Water Conservation Department, 2018), widely considered a scientific method for watershed development in India. The approach, prioritizing systematic land-management interventions across the micro-watershed ahead of drainage-line works "in the valley", intends to: i) reduce the velocity of runoff and thus increase the proportion percolated and conserved as baseflow, available for wells; ii) increase soil moisture captured on agricultural land through in-situ activities (e.g., farm bunding); and iii) increase water harvested in drainage-lines or waterbodies through new or restored physical structures (WOTR, 2016). A ridge-to-valley approach positions land-management interventions across the entire catchment area as vital to both "blue" (runoff, baseflow, groundwater) and "green" (moisture) water conservation.

From 2015 until mid-2019, the campaign spent almost US$1.3B in 16,500 villages, implementing around 254,000 water conservation interventions (Bhadbhade et al., 2019; Khan, 2020), both to protect wet season agriculture (Jun-Oct) from "uneven, unpredictable, and intermittent rainfall" (GoM, 2014, p. 1) and to support dry season cultivation using water conserved in the wet season. As clarified in **Chapter 1**, Jalyukt Shivar was further important because climate change is expected to increase precipitation variability across the state (TERI, 2017, p. 101). Overall, the campaign resembled an integrative green-blue water conservation approach called for by agricultural water security scholars to mitigate crop losses from precipitation variability (Rockström & Falkenmark, 2015).

Analyzing interview data from key informants, government officials, and households in three villages, I explore whether and to what extent Jalyukt Shivar enhanced the *capture* (the availability of multiple forms of water), *equity* (distribution of water conservation benefits, including for socio-economically disadvantaged residents), and *sustainability* (non-depletion) of water for agricultural risk reduction in drought-prone villages. Although experimental field studies, such as those cited earlier, can evaluate the technical efficacy of infrastructure (e.g.,

contributions to groundwater recharge), a broader focus on the equity and sustainability considerations lends greater clarity to understanding *who* is in a position to derive benefits for agricultural production and under *what* conditions (e.g., Prathapar et al., 2015; Taylor, 2015).

While motivated by the need to critically evaluate the state drought-relief program, the case-context, objective, and analytical focus contributes a critical analysis at the intersections of water conservation, agriculture, and environmental change. First, I examine how environmental governance systems conceptualize and aim to transform villages into "drought-free" spaces. Where "drought-proofing" or "drought-resistance" are used to guide agricultural livelihood resilience in semi-arid and arid regions with high absolute water scarcity, I focus on interventions intended to mitigate impacts of precipitation variability on crops (i.e., agricultural drought) across diverse social-ecological and climatic contexts, including but not limited to semi-arid environments. Second, the promotion of integrative green-blue water initiatives must be complemented with studies evaluating their social-ecological outcomes as they increasingly become part of government programs (Kerr, 2002; Samuel et al., 2007; Bharucha et al., 2014). I examine the framing, implementation, and linked equity and sustainability effects of the Jalyukt Shivar campaign, as scaled out by the state government. Last, I analyze how water conservation initiatives are re-configuring water access and use patterns in the making of "drought-free" spaces. I find water inequities and extraction are increasing and argue that "drought-freeness" cannot be considered a reality unless the benefits of water conservation are widespread, accessible, and long-term. Below, I outline the methodology (**section 3.2**) before describing the drought-relief campaign (**section 3.3**). **Sections 3.4** & **3.5** present the results and the implications for risk-reduction initiatives at the interface of agriculture and environmental change.

3.2. Methodology

This study is primarily based on combined surveys and semi-structured interviews with households (n = 63) in three heterogenous villages served by the campaign. Complementing household data collection, government officials (n = 7), and key informants (n = 18) were interviewed – including watershed experts, journalists and historians – on subjects of drought, rural and watershed development, and the drought-relief campaign. Of these 25 key informants, 19 were knowledgeable about the campaign's objectives and outcomes in different areas of the state, including in some cases through first-hand observation.

Of the 36 districts in Maharashtra, primary data collection occurred in Pune district because of its varied climatic and social-ecological contexts, and access to a large number of non-governmental organizations and informants familiar with the program. Primary data collection occurred with the support of two local field assistants from January until end-April 2018 (dry season) in three villages in Pune district, each with unique climatological, livelihood, and agro-ecological characteristics. The multi-sited design was not intended for cross-comparative analysis but to determine whether specific observations surrounding the campaign's implementation and effects cohered in different social-ecological contexts. This, coupled with key informant experiences, provided greater confidence that the observations were not an artifact of a single village. To select villages, I used the state's publicly available Jalyukt Shivar database (GoM, 2015a), which lists the approved initiatives and maps the completed works for villages selected in each intervention year. I used the database to identify projects that were completed and mapped in villages within Pune district for the intervention years prior to fieldwork (i.e., 2015-2016 and 2016-2017). Villages in these cohorts (n = 241 in Pune district), particularly those in 2015-2016, were prioritized by the government for creating drought-relief plans based on their level of water scarcity[36] and its effects on agricultural production.

Once the database was downloaded and translated from Marathi to English, a three-tiered selection strategy was used to identify the three villages suitable for sampling. First, I selected villages considered to be "well served" under the campaign. I defined a "well served" village as one where the diversity of completed and mapped initiatives (e.g., canal digging, cement dams, contour trenching, sediment removal, etc.) listed within a village was higher than nearly 90% of the served villages in 2015-17. Villages with a higher number of different water conservation initiatives were likely to have a higher number of absolute interventions (corr: 0.76). Second, within this subset of "well served" villages (n = 45), I selected three sub-districts (Purandar, Mawal, and Indapur) surrounding Pune city on the basis of different climate and agricultural

[36] Villages were selected for the campaign by district-level committees if they: i) were included in prior or on-going watershed programs; ii) continuously declared scarcity (crop yield < 50%) for the last five years; iii) were continuously "tanker-fed" for the last five years; iv) exist in a watershed where groundwater is semi-critical/critical/over-exploited; and v) were part of watershed sanctioned programs but experienced drought for the last five years (Government official interview #2, January 2018; Government of Purandar, 2014; CTARA, 2018). The criteria, which overlap, are broader than the crop yield statistic for declaring drought (< 50% production) because the campaign also focused on redressing drinking water scarcity.

features identified using secondary data sources (e.g., agricultural and population census records; long-term precipitation data). Third, one village was selected from each sub-district based on demographic representativeness and travel cost considerations of the research team. To re-iterate, I have anonymized each of the three sampled villages to reduce participant risk. Village 1 (in Purandar sub-district), Village 2 (in Mawal sub-district), and Village 3 (in Indapur sub-district) are shown in **Figure 6**. **Table 9** summarizes the agro-ecological, climatic, and livelihood characteristics of each village. **Tables 10** & **11** report the interventions in Pune district and in each village. An "intervention" reflects the government's classification of a single project, which can include i) a singular activity in a focused area (e.g., concrete dam) or a wider area (e.g., deepening of a stream-course); or ii) clustered components (e.g., handful of contour trenches) in a focused area that are recorded, by the government, as one intervention. The number of land- and drainage-course interventions are indicative of the weight given to them in producing drought-relief plans. I draw on these tables in the results.

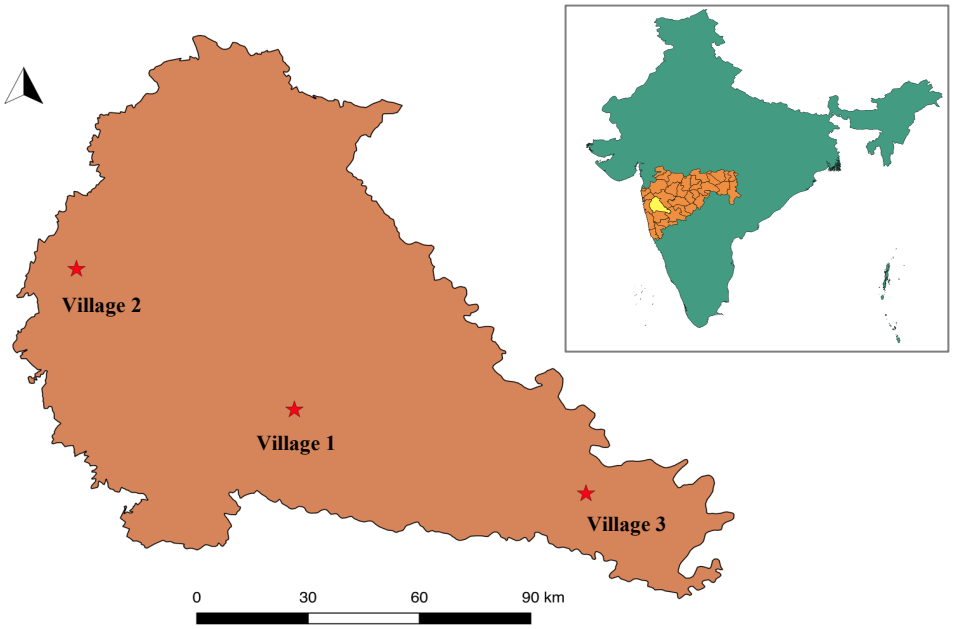

Figure 6: Study villages in Pune District. Map produced by the author.

Table 9: Sub-district and village characteristics. Sources: Author's interview data, Climate Hazards Group InfraRed Precipitation (Funk et al., 2015; Climate Hazards Group, 2017), Agricultural census (GoI, 2011a) and Population Enumeration census (GoI, 2011b).

Sub-district	Village characteristics
Purandar • 731 mm of rainfall	Village 1 • 461 households (2,409 residents)

• Cereal/pulse/vegetable cultivation dominant	• Fig, custard apple, cereal and vegetable cultivation, and livestock. • Multiple sources of water available for irrigation but differentiated access based on physical location and economic standing.
Mawal • 1,547 mm of rainfall • Cereal/sugar cultivation dominant	Village 2 • 330 households (1,880 residents) • Hillside and rural/peri-urban context • Rice, cereal cultivation, and livestock. Off-farm livelihoods common (e.g., water park, restaurants, school). • Most of the area under cultivation is unirrigated. Few wells in village.
Indapur • 582 mm of rainfall • Cereal/sugar/fruit cultivation dominant	Village 3 • 855 households (4,141 residents) • Sugarcane, pomegranate, maize, and cereal, including large-scale export-oriented agriculture (horticulture). Livestock prevalent but grazing declining from land enclosure and agricultural intensification. • Borewells and wells; served by Khadakwasla canal (Pune) but irrigation is intermittent. Capital-intensive pipelines from Ujani Dam.

After receiving verbal permission from the sarpanch (elected head) of each village to conduct research, two research assistants and I sampled households in different *vastis* (sub-communities tied in kinship) who could have benefited from the interventions. This included sampling households near verified and mapped works (using publicly available geo-coded data from secondary databases, GoM, 2015b), within and outside village centres, and near older, similar interventions to provide a sense of how such initiatives functioned in practice.[37] Occasionally, village leaders and interviewed households would introduce us to additional participants. In total, across the three villages, we conducted household survey-interviews (n = 63) and focus groups (n = 6) collecting data on demographics, water uses, conditions of water access, knowledge of the campaign (including its implementation process), who and what benefits from the now completed interventions, and perspectives on how water could be better managed in the village. At least 60% of the combined household survey-interviews had female respondents. The six focus groups (ranging from 4 participants to > 10, and including participants that were sampled in household survey-interviews) were convened as a means of exploring similar questions contained within the household data collection forms. We ensured, where possible, focus group discussions were composed of participants from similar socio-economic groups to reduce participant risk. Interviews were conducted in Marathi, Hindi or a mix and often audio-recorded with voluntary informed consent (see **Appendix E** for Data Collection Instrument).

[37] Sampling near older similar structures is important where new initiatives were not accessible.

Interview transcriptions and notes were coded for each village and for the collective set of key informants. I used a multi-cycle coding analysis as described by Saldaña (2009, p. 67-70) using NVivo 12.0. I coded large proportions of the text using "structural coding" – content-based codes representing broad areas of inquiry that establish a foundation for more in-depth coding (*ibid*). Structural categories (e.g., "concerns of Jalyukt Shivar", "water access") were re-coded into more refined content-based codes. For instance, "concerns of Jalyukt Shivar" was further re-coded to reflect refined statements and indications, including inequalities (e.g., upland/lowland), concentration of benefits, lack of water conserved, appropriation of water, and so on. The coding of household and key informant interviews indicated, in addition to the campaign's material outcomes, the broader political architecture and interests that mediated these effects. The results below reflect the multi-sited synthesis across villages, key informants, and official interviews.

Table 10: Number of approved interventions in Pune district (2015-2016). Source: GoM (2015a). Work types regrouped and coded based on the GoM (2019). Asterisk (*) indicates green water initiatives that could contribute to blue water (baseflow) conservation.

Green water / Blue water / Unknown	Projects Approved in Pune District (2015-2016)
Afforestation	28 (0.45%)
Land Bunding or Terracing	653 (10.45%)
Deep Continuous Contour Trenching (CCT)*	849 (13.59%)
Deepening, Widening, De-Silting or Linking Streams or Nallahs	325 (5.20%)
Diversion Structure	30 (0.48%)
Concrete / Cement Dam	534 (8.55%)
Stone Checkdam	42 (0.67%)
Loose Boulder Structure / Blockage	324 (5.18%)
Earthen Dam	669 (10.71%)
Desilting Tanks and Lakes	81 (1.30%)
Desilting Cement and Earthen Dams	453 (7.25%)
Farm or Forest Ponds	380 (6.08%)
Repair of Weir, Dam Structure, or Water Retention Areas	162 (2.59%)
Repair and Strengthening of Percolation Tank	57 (0.91%)
Bore and Well Recharge	23 (0.37%)
Recharge Shaft	1203 (19.25%)
Efficient Irrigation (e.g., Sprinkler, Drip Irrigation)	66 (1.06%)
Hydro-Fracturing	52 (0.83%)
Unknown or Not Available	318 (5.09%)
Number of Approved Projects in Pune District (2015-16)	6249
Green water	1530 (24.48%)
Blue water	4401 (70.43%)
Unknown or Not Available	318 (5.09%)

Table 11: Planned, and completed and mapped projects in each sampled village. Source: GoM (2015a). Work types re-grouped using the original data and coded as green or blue based on GoM (2019). Asterisk (*) indicates green water initiatives that could contribute to blue water (baseflow) conservation.

Green water / Blue water	Village 1		Village 2		Village 3	
	Planned	Completed & mapped	Planned	Completed & mapped	Planned	Completed & mapped
Concrete Dam or Storage Weir	13 (21.7%)	10 (21.3%)	0 (0%)	0 (0%)	8 (13.8%)	5 (12.8%)
Loose Boulder or Earthen Dam	9 (15%)	2 (4.3%)	10 (27%)	10 (38.5%)	0 (0%)	0 (0%)
Diversion Structure for Irrigation	0 (0%)	0 (0%)	1 (2.7%)	1 (3.8%)	0 (0%)	0 (0%)
Repair of Water Storage or Dam	0 (0%)	0 (0%)	1 (2.7%)	1 (3.8%)	7 (12.1%)	4 (10.3%)
De-silting and Deepening Nallahs	1 (1.7%)	0 (0%)	0 (0%)	0 (0%)	11 (19%)	6 (15.4%)
Deepening of Dams, Ponds, or Tanks	7 (11.7)	7 (14.9%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Well Recharge	0 (0%)	0 (0%)	2 (5.4%)	2 (7.7%)	0 (0%)	0 (0%)
Recharge Shaft	20 (33.3%)	20 (42.6%)	0 (0%)	0 (0%)	11 (19%)	11 (28.2%)
Continuous Contour Trenching*	10 (16.7%)	8 (17%)	13 (35.1%)	10 (38.5%)	21 (36.2%)	13 (33.3%)
Agricultural Terrace	0 (0%)	0 (0%)	2 (5.4%)	1 (3.8%)	0 (0%)	0 (0%)
Agricultural Field Improvement (Farm Bunding)	0 (0%)	0 (0%)	8 (21.6%)	1 (3.8%)	0 (0%)	0 (0%)
Total	60	47	37	26	58	39

Note: There were a handful of completed but unmapped initiatives. These were not included in the "completed and mapped" column because they were unverifiable. In Village 1: one (1) stream-course deepening, one (1) contour trench, and four (4) additional boulder / earthen dams were built. In Village 3: one (1) additional deepening project of a stream-course was completed.

3.3. Jalyukt Shivar Abhiyan: The making of "drought-free" villages

As prefaced in **Chapter 1**, Jalyukt Shivar Abhiyan was formalized in 2014 but has its origins in the 2012 state drought – popularly referenced as the worst drought since 1972 (Dandekar & Thakkar, 2013). While the 1972 drought is understood as a natural calamity, the effects felt in 2012 were blamed on a systemic "disaster [in] water management" (*ibid*, n.p.). In fact, the amount of rainfall in 2012 for certain districts exceeded the long-term annual average (1901-2002) (**Figure 7**). Sugarcane cultivation (4% of the net sown area in Maharashtra), using over 70% of the irrigation water in the state (GoM, 2011), received significant blame. But what intensified public mistrust was the revelation of the "irrigation scam" where nearly $US10B of public money spent on state irrigation projects from 2000-2010 was not reflected in the services constructed. During this period (2000-2010), the state's gross irrigated area increased by only 3% (GoM, 2011).[38] The political fallout was enormous, and forced the still in-power Congress-NCP government (2010-2014) to promote decentralized interventions as a form of water governance distinct from large dams (Jitendra, 2019). This focus was later formalized under Jalyukt Shivar by the new Bharatiya Janata Party (BJP) government in 2014. This section describes the evolution of Jalyukt Shivar and traces how the types, spatiality, and extent of drought-relief interventions were shaped by government interests to demonstrate a "drought-free" Maharashtra under the prevailing context of drought, irrigation sector corruption, and public resentment.

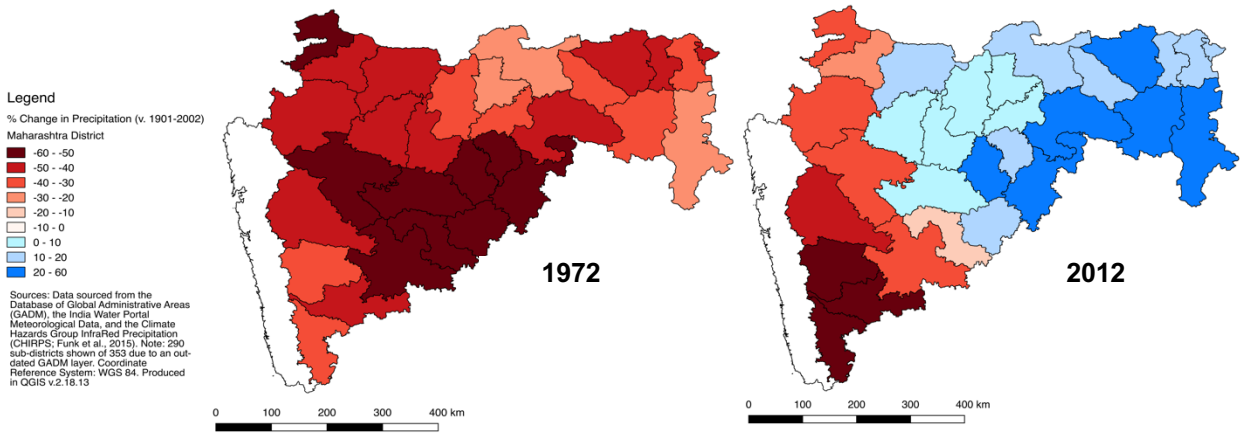

Figure 7: District-wise annual precipitation anomaly for 1972 (left) and 2012 (right) relative to the long-term annual average (1901-2002). White shading indicates no data. Map produced by the author.

[38] The average decadal increase in gross irrigated area was 34% from 1960-2000 (GoM, 2011).

In the immediate aftermath of the 2012 drought and the irrigation scam, a retired groundwater scientist in northern Maharashtra named Suresh Khanapurkar gained celebrity-status for a proposed fix to water scarcity in drought-prone areas (Jitendra, 2019; Key informant interview #11, 23 March, 2018). The deposition of sediment in streams, Khanapurkar proffered, reduced their ability to retain runoff and recharge local aquifers – a problem that widening and deepening could solve if replicated across the entire state (Key informant interview #9, 03 March, 2018). He pointed to the water-filled streams in Shirpur sub-district as an encouraging sign of the impacts of deepening, widening, and damming. A government committee was later appointed by the state to review the scientific merits of deepening and widening and found, according to Joy (2015), environmental impacts, cost ambiguities, and replicability issues, concluding that Khanapurkar's claims over recharge were "rather exaggerated" (*ibid*). A second government report justified its replication, albeit with certain limitations, across the state (*ibid*). Despite the tenuous scientific and environmental basis of stream modification, the easily visible nature of water in restored streams and canals explained the political attention Khanapurkar's idea received.[39] This was clarified by a leading expert on watershed development in Maharashtra:

> "I don't think any serious effort to understand its [stream deepening and widening] sustainability, what is the type of interchangeability with the surface and groundwater which takes place, and type of like interaction that you have and things [was made]. …[T]he other context was, there was already a drought [for] a continuous, two-three years. So, when people saw, physically, water stored [they said], 'okay this is the answer to long-term drought'" (Key informant interview #16, 05 April, 2018).

Khanapurkar's proposal received considerable state patronage as a "miracle cure" (Joy, 2015, n.p.) for drought by the incumbent Congress-NCP party in what some critics saw as an effort to divert attention from the "irrigation scam" (Jitendra, 2019). What followed, in the lead-up to the 2014 state election, were similar initiatives led by notable "watermen" of various political parties at local levels (Pallavi, 2015b). Further, the Divisional Commissioner of Pune led Jalyukt Gaav Abhiyan ("waterful village") (Jitendra, 2019) – a pilot program removing sediment from stream-courses, constructing small dams, repairing weirs, and interlinking canals – claimed, by the state

[39] Water storage has long been positioned by government as the solution for overcoming water scarcity in drought-prone areas – in Maharashtra and elsewhere in India (Mehta, 2001; Bharucha, 2016; 2018).

government, to have created both 8.40 TMC (thousand million cubic feet) of storage and raised groundwater levels between one and three metres (GoM, 2014, p. 2).

The capacity of drainage-course initiatives to render water visible and available for transforming villages into "drought-free" spaces enabled these interventions to form an integral and well-funded component of the state's flagship drought-relief program. More specifically the "main sources of the fund[ing]" came from the District Planning Development Committee funds, and Central and State Government funds (Department of Land Resources, n.d.). District level funds alone, available for cement concrete dams, canal deepening, and old water structure repair (GoM, 2014, p. 7-8), comprised over 40% ($5.3M USD) of the anticipated expenditure in Pune District in the initial year of the campaign (Indian Express, 2015). Central and State funds, even while distributed for a broader set of interventions, allocated substantial funding[40] for drainage-course and waterbody interventions (GoM, 2014). Last, corporate social responsibility donations emerged as a major source of drainage-course funding (Key informant #16, 22 June, 2020). By March of 2016, only one and one-half years after the campaign's initiation, 90 INR crores (*ca.* $12M USD) had been donated by public and corporate social responsibility actors (Press Trust of India, 2016), made available for funding concrete dams, canal deepening, and water structure repair (GoM, 2014, p. 7).

3.3.1 Drainage-course and waterbody bias

In practice, drainage-line and waterbody infrastructure ("blue water") became overrepresented in relation to the wider set of interventions expected under the state's purported ridge-to-valley approach, wherein systematic land-area treatments occur across the micro-watershed to conserve moisture and increase the contribution of runoff as baseflow. Four established watershed development experts I interviewed confirmed this, with one stating:

> "[The campaign and its implementers] don't follow [a] ridge-to-valley approach. ... The bulk of expenditures is happening on river-courses or stream-courses. ... [W]hen we do watershed development, we take [a] ridge-to-valley [approach]. *We emphasize area treatments as opposed to drainage line treatments.* Area treatments are largely soil and

[40] For example, the Mahatma Phule Scheme – one of several schemes – allocated 25 crores ($3.3M USD) for water structure repair, de-silting, recharge, and awareness initiatives in 2015-2016 (GoM, 2014).

> water conservation -- *in situ* -- and then last, we go to the drainage line treatments" (Key informant interview #8, 02 March, 2018; my italics).

Another leading watershed development expert asserted that a focus on comprehensive area treatment could have increased the impact and scale of water conservation under the campaign:

> "If they [implementers of the campaign] had done a ridge-to-valley approach… the overall water velocity [from upper lands to the lower areas] would have been much less… and much more would have been converted into baseflow. …[T]he benefit of interventions would have been much more widespread from an equity point of view. When you have much more of a ridge-to-valley or area treatment-based [approach] then the water gets percolated and access to water would have been much better for people in the entire watershed to some extent. [The water will] finally [drain] to the valley, but at least people who have wells would have got recharge a little more. Now, what has happened is the benefit has been for people who are close to the riverbeds" (Key informant #16, 22 June, 2020).

The narrow focus on drainage-course and waterbodies was so apparent it was challenged as "unscientific" in a public interest litigation (PIL) filed in the Bombay High Court (Desarda vs. The State of Maharashtra, 2016) – but was later upheld by the same court (Benwal, 2019).

In Pune district (2015-16), at least 48% of the total approved projects were situated on waterbodies and drainage-courses (**Table 10**). This percentage is likely substantially higher given "recharge shafts" constitute a large proportion of the interventions (19.25%) and can be located on stream-courses and waterbodies. In Village 1, Village 2, and Village 3, 40.5%, 46.1% and 38.5% of completed and mapped interventions, respectively, involved constructing or repairing small dams (earthen and cement) and de-silting watercourses or waterbodies (**Table 11**). Apart from these structures, "recharge shafts" were implanted into the ground to increase recharge in Village 1 and Village 3 (**Table 11**). The geo-coded secondary data revealed most shafts were located on stream-courses and waterbodies. Thus, the collective drainage-course and waterbody works is closer to 83% (Village 1), 46% (Village 2), and 59% (Village 3) of the completed and mapped interventions. Land area treatments (non-drainage) accounted for under one-third of the completed and mapped interventions in the three villages – and were largely

comprised of scattered deep-contour trenches, much of them now re-filled with sediment.[41] Soil moisture conservation ("green water") on farmers' fields – critical for mitigating potential impacts of precipitation variability – was virtually absent across the three villages (1.78% of completed and mapped projects) (10.45% in Pune District in 2015-16) (Bhadbhade et al., 2019).

Last, the drainage-course and waterbody emphasis was reinforced through large private farm ponds (commonly *ca.* 30 x 30 x 3m, 2,196 m^3), built in many villages by farmers as a drought-relief initiative (Kale, 2017). Ponds further proliferated after 2016 following the introduction of the Magel Tyala Shettale (MTS) or "Farm Pond on Demand" subsidy – and are hence conspicuously absent in village-level initiatives in **Table 11**. After village plans were implemented, individual farmers continued building ponds subsidized under MTS and other schemes. Public media and even government officers in their interviews erroneously characterized MTS as entirely unrelated to Jalyukt Shivar, when in fact, the campaign is a convergence of MTS and other schemes used to finance drought-relief initiatives [42] (Key informant #7, pers. comm., 15 March, 2018; GoM, 2014). Although new pond storage is not retroactively counted in Village 1, Village 2, and Village 3's Jalyukt Shivar plans (approved before May 2015), their proliferation constitutes an important drought-relief intervention made possible through schemes nested under the campaign. One agricultural officer stated Village 1 had a "record" 225 farm ponds at the time of fieldwork (January 2018) (Government official interview #2, January 2018). In Village 3, a local agricultural officer estimated that from 2016-2017, an additional 400 farm ponds had been built (Government official interview #5, March 2018).[43] Across the state, 161,000 ponds were completed as of June 2019 under Jalyukt Shivar – reinforcing the emphasis on waterbody storage ("blue water") for drought-relief.

While not explored in-depth, it is worth noting that the water storage bias was further reinforced at the village-scale – even as villages were explicitly selected on the diversity of water

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[41] Geo-coded data from the campaign revealed deep contour trenches were scattered, not systematically developed in sampled villages, and sometimes not located on sloped areas where runoff rate is highest.

[42] This was further confirmed through identifying the funding source listed on the public Jalyukt Shivar database (GoM, 2015a).

[43] I verified nearly 90% of the 225 ponds stated by the officer in Village #1 using satellite imagery. However, the statistic of the total ponds constructed before and after 2016 provided by the officer in Village #3 appeared hyperbolic. I use the 2016-17 statistic of the additional ponds to indicate that farm pond numbers have risen more recently, in a broad sense, across the state.

conservation interventions. Villages selected by district-level committees were required to hold a *shivar pheri* or a transect walk where relevant officials (e.g., Talathi, Agricultural Supervisor, Agricultural Assistant at the sub-district level) and residents interactively planned drought-relief initiatives for the village (Government official interview #1, January, 2018; GoM, 2014, p. 9). However, participation was gendered, and limited to "big" people and members within core institutions of the village (e.g., sarpanch, gram panchayat members, *pani samiti* [water committee]). Nevertheless, well-constructed "blue water" storage projects and more efficient use of existing water were perceived by interview respondents as most effective for redressing local water crises. Taken together, the government's promotion of drainage-level and waterbody work as the needed interventions for drought-relief, combined with respondents' perceptions of these as the most effective water security strategies, contributed to the disproportionate focus on such initiatives, relative to what is otherwise expected under the state's touted ridge-to-valley focus. These dynamics crowded-out the potential value and impact of a catchment-wide focus, including the role of "green water" conservation in mitigating precipitation variability.

3.3.2 Planning and implementation

The ambitious objective of freeing 5,000 additional villages from drought each year imposed rapid village planning and associated metrics that allowed villages to be documented as "drought-free". The selection of villages by district-level committees, development of local irrigation plans, subsequent approvals for funding, and expenditure for construction activities had to be completed within the fiscal year, and ideally within a span of months before the first rains arrived in June (GoM, 2014). After that, the campaign selected and allocated budget for a new round of villages. In contrast, one leading watershed development expert said effective watershed development requires between 24 and 36 months (Key informant interview #8, 02 March, 2018). Rapid implementation, in part, limited interventions to public land areas, such as drainage courses, grazing areas or Forest Department land. This was confirmed by an NGO researcher familiar with the campaign's effects in western Maharashtra:

> "This government wants to say we are doing something for the farmers, something for water conservation. They came up with the flagship program and they have to show you the results. They [don't have] that much time to discuss with the farmers [about] the whole thing so, they use the common land. The whole [of the] common land, like rivers, lakes,

> and ponds – and they dredge it like anything… very unscientific works they were doing" (Key informant interview #6, 19 February, 2018).

This informant is suggesting that private land development – and required processes, particularly landowner consent and planning – were traded-off given the limited time period to plan, build, and advance a "drought-free" status. This further limited the potential focus on in-situ (on-farm) initiatives, namely soil moisture conservation on farmers' fields, discussed above.

Last, the interventions were intended for villages to become "water neutral" – a state where overall village water availability met demand to reduce agricultural drought. In Village 1, for example, the drinking and crop water requirement was estimated at 538.72 TCM (thousand cubic meters), of which existing watershed works store 360.79 TCM of water (Government of Purandar, 2014). The initiatives proposed under the campaign were estimated to store 118.66 TCM, thus closing the annual supply-demand gap (*ibid*). In theory, runoff otherwise lost from villages in a normal year, is captured during the monsoon and protects farmers from rainfall variability (Government official interview #7, 12 April, 2018). This storage further supports dry season cultivation, which may either not be possible for some or be risky for others if water was unavailable (*ibid*). By raising the aggregated volume of water, the government was able to formally count thousands of villages as water neutral and allege their "drought-freeness" despite questions of improved access being unresolved for village residents. The inadequacy of existing metrics for evaluating the campaign were made clear by one frustrated expert:

> "So, two metres in groundwater level was increased. ... [But] two metres where? In which well? So, a well near your bandhara [check dam], so how many farmers are getting benefited by that 2 metres of increase?…[Y]ou have to bring metrics -- good metrics: How much of new land was brought under *rabi* [dry season] crop? How many farmers who were initially doing only kharif [wet season crop] are now able to do *rabi* also?" (Key informant interview #7, 24 February, 2018).

The pace and limited scope of implementation enabled the government to tout, last year, that over 16,000 villages were made water neutral. These figures convey success but, as the interviewee suggested above, are disconnected from the everyday lived experiences of how that water comes to be distributed and accessed within villages. Demonstrated below, where villages are made "water neutral" and may resist, on an aggregate scale, significant yield declines to be classified in a formal sense as "drought-free", such a reality may not be lived or experienced by

all residents. In sum, the types, locations, and scope of the campaign were shaped by government interests to demonstrate a "drought-free" Maharashtra – particularly under the wider context of irrigation sector corruption, repeated drought, and public resentment towards the state. This had implications for the capture, equity, and sustainability of water, which I now turn to.

3.4. How effective, equitable, and sustainable were Jalyukt Shivar interventions?

The findings below examine the effects of water security initiatives in drought-prone villages and emerge from the coded interview data. They hold across the majority of sampled villages and are described in informants' experiences in other areas of Maharashtra; however, in limited cases, individual villages break from these general patterns. Where this occurs, it is noted.

3.4.1 Capture and regeneration

Participants stated that key blue water initiatives were sometimes unable to consistently capture water due to local variations in precipitation, topography, and geology. Although the purpose of the campaign was to reduce the effects of precipitation variability, participants in Village 1 stated changes over the last seven or eight years in rainfall intensity affected the capacity of drainage course works and farm ponds to capture water. One agricultural officer problematized changing rainfall dynamics as the reason why check-dams – a core intervention in the village – were unable to store water:

> "In [Village 1], also there are CNB [cement nallah bunds] works, but the problem in [Village 1] is that ever since the work has been done, there has been no rain for 2 years now" (Government official interview #2, January 2018).

This reference to "no rain" was echoed by respondents and is a referral to shortcomings in the amount, duration, and intensity of precipitation. Reflective of other sampled respondents, one indicated similar parallels to the officer above:

> "Earlier there was more rain because all these streams would fill up a lot. The bandharas[44] would be full. Now it doesn't even fill up to half. … Not even half. There is only a light drizzle and then the rains are over" (Village 1 interview #20, 26 March, 2018).

[44] Some check-dams were built earlier in the village by the Rotary Club.

These drainage-course works exist alongside large private farm ponds, which store water from precipitation, canals, and most commonly, groundwater pumped from wells, for high-value crops like figs, grapes and pomegranate. While ponds function to reduce farmers' dependence on capital-intensive water access, such as private tanker trucks, farmers rely on these sources if shortcomings in precipitation – and consequently, groundwater – occur. This was clarified in one focus group with Village 1 farmers, some of whom owned ponds:

> Respondent (#6): "Some people have made farm ponds, but there has been less rain… That is the condition now. There is lots of land, but such less rain. That's why the tanker water is used to fill them."
>
> Respondent (#2): "…The water is not enough. So, when that finishes, we can buy water [from a private water tanker]. With that you can store it in the farm pond and then later, it can be used. Or, we can even release the water directly in the farm. Otherwise, now there is the Purandar upsa[45] [project], from there we can buy the water and store in the farm pond" (Focus Group #1, Village 1, January 2018).

In Village 1, and in the context of fig farming, water costs vary depending on the amount needed and the size of the fig farm; however, at least one water tanker (1,200/- [$17.00 US]) may be needed every twelve days for a relatively smaller-sized cultivation (e.g., 20 fig trees) during the mid-late dry season if water runs out. For those that use the Purandar upsa – a lift irrigation scheme transporting polluted water from Pune's Mula Mutha river to the surrounding area – a contribution of 5,000/- (~$70.00 US) is needed. In absolute terms, these are sizeable, given the average income for rural households in Maharashtra is 8,938/- per month ($117.00 US) (NABARD, 2018). Noted earlier, a ridge-to-valley focus could have increased the proportion of surface runoff conserved as baseflow and available for agricultural water use.

A second example comes from Village 2 – an area that can receive high rainfall during the monsoon (**Table 9**). Aside from two farm bunding initiatives, several land contour interventions (10) and small dam projects (12) were intended to reduce erosion, store water for animal use, and increase groundwater recharge. Unfortunately, the land contours were not systematically constructed across the sloped valley and the small dams were located far from the

[45] A pipeline transporting polluted water from Pune is released into a stream where pond owners can appropriate a portion of it.

main village. Further, any potential benefits were not easily accessible because the sloped and impervious geology was not conducive to recharge. This was illustrated by one resident:

> "[T]he forest officials had dug them [bandhara structures] for the jungle animals to drink water, and for the cattle from the village to drink from. But that was not a success. It all flowed away. We get tremendous amount of rainfall for four months but every bit of the water flows off and does not get stored. Because of the rocky terrain it all washes away. It doesn't stay much. Even if we put in bore wells, it doesn't go into the bore and the bore wells stay dry" (Village 2 interview #19, 07 March, 2018).

Made clear by respondents, the poor quality of works and the geological conditions result in sub-optimal outcomes. A final example comes from Village 3. The benefits from stream-course development were not uniform, as captured in a conversation with one household:

> "[W]ater seeps inside [the ground because of the bandhara or checkdam] and this allows groundwater levels to improve. And the seepage doesn't happen as per our wish. It is a natural process, so it can happen wherever it is possible in whatever quantity depending on the geography and landscape" (Village 3 interview #20, 22 March, 2018).

This respondent is highlighting that increasing the storage volume through stream-course development, and where and when that seepage occurs, are different matters that affect the distribution of benefits. The central point is that the narrow focus on drainage-course and waterbodies was insufficient to match local biophysical and hydrological variability. A focus on conserving multiple dimensions of the water spectrum could have increased the impact and distribution of water conservation benefits. Missed opportunities included a systematic focus on contour trenching to enhance the proportion of surface runoff conserved as baseflow for wells in Village 1; or in-situ efforts to maximize rainfall infiltration and conserve soil moisture for rainfed rice cultivation in Village 2 where sub-surface drainage was not capturable.

3.4.2 Equity

The implementation of drainage-course works and farm ponds concentrated benefits for subsets of the population within villages and excluded residents, including historically disadvantaged groups, who did not possess endowments (e.g., capital, land size, land location) needed to access the potential benefits of drainage-course works or to construct farm ponds. I attend to these considerations for stream-course development, before returning to the case of farm ponds.

3.4.2.1. Land location

Drainage-related works (i.e., weirs, dams, irrigation structures, deepening, recharge pipes) constituted a substantial share of the completed and mapped interventions in Village 1 (83%), Village 2 (46%), and Village 3 (59%). Numerous respondents and informants made clear that such projects concentrated the distribution of benefits to those farming, often in low-lying areas, near the installation. This can be illustrated by one higher-earning (> 10,000/- [$130 US] per month) household who farmed a medium-sized plot (5 acres) near a small dam:

> "I feel there should be some improvements in terms of water supply to the villagers. … Right now, those who live close to the bandharas, they get water supply but the ones living on the higher plains, they suffer from lack of water supply. This should change. And every year post-Diwali, that is, November and months after that until the next rain, our village starts facing dropping water levels. This should change" (Village 3 interview #11, 20 March, 2018).

What this respondent makes clear is how the benefits of lowland stream-course work are not reachable for those who live in upland spaces because water, conserved at lower spatial points, cannot travel up the hydraulic gradient. This has meant that certain households, without direct access to water storage initiatives, undertake enormous costs to acquire water for agriculture – such as farm ponds or water pipelines. One household interviewed, who reported giving up half an acre of their land without compensation for the construction of a new bandhara, said:

> "Our well is far from the bandharas. Hence, we didn't see any change happening in the water levels in our well. … It doesn't help us. It is maybe helping some, but not us". Later continuing, "We gave some land to them too [0.5 acre]. … [W]e gave [it] away thinking we might also benefit from [the bandhara]. We thought it will help us solve water problems. And nothing really happened in our favour" (Village 3 interview #10, 20 March, 2018).

Due to the inaccessibility of water, the same household, albeit in a relatively privileged position financially, spent a substantial amount[46] to construct a pipeline for agriculture to secure water:

> "We need to grow seasonal vegetables along with other bi-monthly and yearly crops, and if [we] don't farm other vegetables [and other produce], how can we survive? None of us

[46] Some spend around US $39,200-$52,300 (30-40 /- INR lakh) to connect water pipelines to nearby reservoirs.

> have ever been to school. We are not educated [such that] we could think of finding a job or something elsewhere" (Village 3 interview #10, 20 March, 2018).

The consequences of water inaccessibility are much more severe for poorer households, who may be unable to invest in pipelines, farm ponds or other water-related adaptations. This was made evident by one household in the same village farming a smaller parcel (2.5-3 acres) on a hillside, who when asked if the small dams helped them, said:

> "No, unfortunately not. It depends where do you have your well. ... [T]hese projects are not for upper level lands. It is useless for upper reaches. … [The people farming the hillside] depend upon [the] rainy season. Whatever water becomes available naturally. Those few months. ... [B]ecause we face water scarcity, we plough [our] maize early and feed our cattle with it. We can't really do much on our land. If we were well-off then we would have arranged water. With that extra water we could have done many things in our farm – grown better crops too. Not like now, we plough them early" (Village 3 interview #6, 19 March, 2018).

In recognizing the varied capacities of households to adapt to water shortage, and the potential consequences of water inaccessibility, it is essential to recognize the distribution of stream-course benefits are not random. Villages are socio-spatial assemblages where land acquisition, settlement, and capital accumulation have often occurred in fertile and lowland areas. It is not uncommon, as I observed, to see lower castes (i.e., Scheduled Castes, Scheduled Tribes) living "outside" the village or be landless, and for these castes and households within lower strata of upper castes to farm drier and marginal upland areas. This understanding is well-reflected in how key informants characterized the distribution of benefits in villages, exemplified by one watershed expert who referred to himself as a "close observer" of the campaign:

> "[E]verywhere you find that the better off lands are owned by the rich farmer and… are always located along the nallah courses [or] the stream courses. And the poor farmers' land, the Scheduled Caste and Scheduled Tribe farmers' land, are always located away from the nallah courses. You can say, the upper reaches land. … [T]he focus of the program is on nallah deepening and widening, [and] creating waterbodies along the nallah courses. The immediate results and beneficiaries are the better off farmer[s]. … Also, for the small farmers and poor farmers, they do not have a major say in the planning process in terms of identifying the structures [and] location [of] the structures.

> … [The program] is not really addressing the needs of the small and marginal farmers, needs of the landless people, [and] needs of the upland farmers" (Key informant interview #5, 19 February, 2018).

This quotation should not be interpreted as implying a deterministic pattern of settlement in each village but an acknowledgement that the location of farmland is historically produced through social exclusion. While the central point of this section relates to the narrow distribution of benefits associated with the implemented initiatives of the drought-relief program, empirics from Village 1 provide a clear indication of how stream-course works indirectly excluded historically disadvantaged groups and deepened entrenched inequities in water access.

In the mid-1900s, the state Tenancy Act provided the foundation for agricultural tenants and tillers to purchase land from the landowners at a price set by the government (Focus Group #1, Village 1, January 2018). In Village 1, the Marathas were historically agricultural workers whereas Scheduled Tribes groups, such as Naik, and Scheduled Caste groups, such as Mahar and Matang castes, were involved in non-agricultural occupations (*ibid*). This legislation enabled Maratha tenants to purchase land from the landowning Brahmin community (*ibid*). Over time, lower caste groups either purchased smaller pieces of land, were recipients of parcels from the government, or remained landless (*ibid*). Today, while the Maratha caste is internally stratified on socio-economic axes – as a broader collective, they hold larger and geographically favourable farming areas. For example, of the Maratha households interviewed in Village 1, 58% of them held medium or large landholdings (> 4 acres)[47], with the Kale clan (a strata of the Maratha caste) holding the largest sized plots. In comparison, 85% of the lower castes (Scheduled Caste or Tribe) interviewed were either landless or held marginal or smaller plots (< 4 acres). I return to the benefits of larger land sizes, immediately below (**section 3.4.2.2**). I identified in interviews and through field observation that Scheduled Tribe and Scheduled Caste (Dalit) households often had their farmland far from nine of the ten cement bandharas under the campaign, which were constructed on two streams near to the village – one of which was an outlet for imported wastewater irrigation that could be stored, appropriated and used by farmers nearby. One lower caste (Ramoshi) household said, of water inaccessibility:

[47] The average landholding size in the sub-district is 1.43 ha (3.53 acres) (GoI, 2011a). Approximately one-quarter of all landholdings in Maharashtra are < 0.5 ha (1.25 acres).

> "Not everyone [gets water for farming]. There are 'big people' belonging to the Maratha caste. … They bring water from the Purandar Upsa [a lift irrigation system on a stream near the village with new bandharas]. … They have their borewells for drinking. [They] also have wells. What does our lower community have? … [N]obody thinks about our people. Now, our people have land there [upland at the foothills of the Fort]. But because there is no water, there are no crops. If it rains, then the crops grow" (Village 1 interview #20, 26 March, 2018).

Where the examples above for Village 3 demonstrated the central point – that is, the distribution of benefits were limited with consequences for households without access – the empirics in Village 1 extend this finding, concretizing how a narrow drainage-course bias indirectly concentrated the benefits not *spatially* but *socio-spatially* in ways that deepened entrenched inequities in water access. I carry forward this point below in relation to land size.

3.4.2.2. Capital and land size

The second point concerning the distribution of benefits relates to who constructs private farm ponds, which range from a minimum of about 15 x 15 x 3m to the standard 30 x 30 x 3m (Government official interview #2, January 2018). Consistent with others' field research (e.g., Kale, 2017; Yadav, 2019), we rarely observed minimum-sized ponds. Ponds often met, and sometimes even exceeded, the standard-size and were developed almost exclusively by medium- and large farmers. Two reasons underlie this pattern. First, we were told by government officials and household respondents that farmers ought to hold at least 1.5 acres to consider constructing a farm pond, given the high opportunity cost of losing land in the pond's construction (Focus Group #1, Village 1, January 2018).[48] The cultivatable land lost in the construction of smaller-sized ponds is sizeable for small and marginal farmers, and likely accounts for the bias observed

[48] Farm ponds under Jalyukt Shivar were funded by multiple schemes. The Magel Tyala Shettale ("farm pond on demand") program came only after 2016 and subsidized farm ponds under the campaign. MTS explicitly set a 1.5-acre eligibility requirement. However, given the set of different funding sources for pond development under the wider campaign, it is incorrect to assume that marginal farmers with under 1.5 acres were inherently excluded from constructing ponds. Nevertheless, the standard sized pond (900 m^2) does result in a substantial portion of land being lost in construction for marginal farmers (e.g., Phadke et al., 2018).

in pond ownership (Phadke et al., 2018). Of the household respondents who owned a pond, only two farmed small plots (1-4 acres); the other nine pond-owners held between 4 and 20 acres.[49]

Even where farmers may hold ≥ 1.5 acres, the cost of a pond further exacerbates the ownership bias against small and marginal farmers (Phadke et al., 2018). A standard sized pond (30 x 30 x 3m) can cost 75,000-150,000/- ($1060 to $2111 USD) for the excavation and another 150,000-200,000/- ($2111-$2646 USD) for an optional plastic lining used to prevent water percolation (Prasad, 2018). Schemes converging under Jalyukt Shivar offer farmers a maximum subsidy of 50,000/- ($704 USD) for excavation and a 50% subsidy for the cost of plastic lining, limited to 75,000/- ($1056 USD) (Government official interview #2, January 2018; Prasad, 2018). The capital costs depend on the size, geological profile, lining material, and service providers (SANDRP, 2017; Prasad, 2018). Notably, the rockier terrain in Village 2 prevented the proliferation of farm ponds because excavation cost can be over double (200,000/-) the normal cost (Government official interview #3, February 2018) – emphasizing how problematic standardized solutions for drought-relief can be. In sum, financial capital is needed for building farm ponds, even after subsidies have been accounted for.

Overall, farm ponds are largely inaccessible to village residents who own smaller land sizes and who cannot afford the capital and operating costs. This was made clear in one memorable conversation with a smallholder farmer (< 1 acre), who cut down their 100 fig trees because of water scarcity and the high cost of purchasing tanker water, and instead planted 50 less water-intensive *sitafal* trees (custard apple):

> "[The sarpanch has] plenty of water. … They are towards the hilly side. So, when it rains, [the water] immediately goes into their well. They also built a big farm pond. … That's why they're able to manage, and because they have such a large farm, they didn't mind building a farm pond. Now, what can we make on 1 acre of land?... [I]f we make a farm pond on half the land, what can be done on our other half?" (Interview #23, Village 1, 27 March, 2018).

This respondent makes a clear linkage not merely between land-size and pond acquisition – but, as described in **section 3.4.2.1**, between biophysically favourable farming locations and the ability to benefit from drought-relief initiatives. In sum, the empirical evidence surrounding

[49] One farmer did not report their land-size but it was estimated around 100 acres.

drainage-course works and farm ponds demonstrates how privileged groups – some of which have access to hydrologically advantageous spaces (e.g., in lowlands; by streams and irrigation outlets which the bandharas serve; at the base of hillsides where water drains) and larger land-sizes – have benefited from the drought-relief campaign where others, including but not limited to historically disadvantaged groups, have not.

3.4.3 Groundwater extraction

Widespread farm pond development has heightened groundwater extraction in drought-prone villages, particularly in the absence of enforced regulations over their size, number, and function (Kale, 2017). A standard-sized farm pond (30 x 30 x 3m) can hold a volume of 2,196 m^3, nearing that of an Olympic-sized swimming pool (2,500 m^3)[50] (Prasad, 2018; cf. GoI, 2016). Despite different experiences in Village 2 (absence of ponds limited by cost), Village 3 (filled with groundwater / canal water), and Village 1 (largely groundwater-fed), key informants familiar with farm pond use across Maharashtra, as well as household respondents in the sampled villages, indicated that large volumes of groundwater are pumped out during the wet season (Sept-Oct) to fill farm ponds, which support existing, new, or expanded cultivation of water-intensive crops in the dry season (Key informant interviews #7 [24 February, 2018], #11 [23 March, 2018], #18 [20 April, 2018]). Their proliferation has been found to accelerate groundwater depletion across the state (Key informant interview #18, 20 April, 2018; Kale, 2017; SANDRP, 2017). This is because farm ponds improve the certainty in the volume of water that a now pond-owner can access by converting a common pool resource into a private good (Prasad & Sohoni, 2018). This encourages a shift from traditional crops to water-intensive fruits or vegetables, "increas[ing] the monthly irrigation requirement which is fulfilled by increased groundwater extraction" (*ibid*, p. 5-6). Using secondary data from Village 1 – a typical semi-arid village – my estimates indicate ponds undermine water conservation for drought-relief.

Village 1 (1,283 hectares) receives about 679 mm of rainfall each year contributing to an estimated runoff of 538.94 TCM (thousand cubic meters) (Government of Purandar, 2014). At

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[50] Farm ponds are trapezoidal in shape. The volume can be estimated as: $Volume = \left(\frac{a+4B+C}{6}\right) * d$, where a is surface area, b is mid-range surface area, c is pond bottom surface area and d is depth. For a standard-sized pond, a is 900m^2 (30 x 30m), b is 729m^2 (27 x 27m), c is 576m^2 (24 x 24m), and d is 3m.

the time of the campaign (2014-2015), the estimated village water requirement inclusive of human, agricultural, and livestock uses, was estimated at 538.72 TCM (*ibid*). Notwithstanding farm ponds, which I understand are sites of water extraction for intensifying or expanding water-intensive cultivation instead of mechanisms for enhancing water conservation, the pre-existing conservation works and proposed initiatives under Jalyukt Shivar were estimated to capture 421.5 TCM of water during a normal year – 78% of the runoff (*ibid*). [51] Thus, the proposed soil and water conservation initiatives reduced the supply-demand gap, but did not capture enough water to meet the aggregated village needs. From 2014-2018, Village 1 saw a 400% increase in the number of farm ponds, from 45 to 225 (*ibid*; Government official interview #2, January 2018). One official confirmed the horticultural area increased dramatically as a result (Government official #6, March 2018). Some ponds are smaller (e.g., 20 x 20 x 3m) and others are significantly larger than the standard sized pond. Assuming each pond had the standard dimensions and only 50% of their capacity (1,098 m^3) was filled using groundwater, about 247 TCM would be extracted (equivalent to 59% of runoff captured by the other existing and proposed initiatives).[52] This figure (247 TCM) does not include other agricultural water uses for non-pond owners or drinking water needs of the village, which were already substantial.[53] Therefore, in normal rainfall years, village water demand – with the additional farm ponds and corresponding increases in water use – should exacerbate the existing water deficit. Farm ponds, which continue to be developed, are a major threat to long-term groundwater sustainability.

Large appropriations of groundwater, used for cultivating and expanding existing horticultural crops, undermine drought-relief efforts to conserve water for villages as a whole (**Figure 8**). This was indicated by an official, who viewed appropriation as a positive outcome:

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[51] This estimate excludes the contribution of farm ponds to water conservation. If ponds functioned as sites of recharge (i.e., versus sites of water extraction), the water conserved by existing and proposed works amounts to 90% of the total village water requirement, approximating a "water neutral" state (Government of Purandar, 2014).

[52] The exact village crop water requirement with the current 225 farm ponds is not available; however, the volume pumped into the ponds is considerable, and likely more than was used before given intensified or expanded cultivation of water-intensive crops, like figs.

[53] According to the Government of Purandar (2014), the crop water requirement with only 45 farm ponds was estimated at 415.6 TCM and the livestock and human drinking needs were 123.16 TCM. Given the significant increase in farm ponds for horticultural intensification and expansion (Government official interview #2, January 2018), the existing agricultural water requirement (415.6 TCM) has likely only increased.

> "Because of the farm ponds, lots of land has come into cultivation. … And when was [a] farm pond possible? When water is possible, only then. The farm ponds, the water conservation work that have happened, through that the farm ponds are filled. And from that, even the small areas, even up to half acre, that also can be cultivated" (Government official interview #6, March 2018).

The central point is that the proliferation of farm ponds has increased the pressure on groundwater resources and undermined the objective of the drought-relief campaign. Further, as ponds are invariably owned by larger-landed farmers, their role in extraction re-distributes the benefits associated with water conservation within a narrow subset of the village population (Key informant interviews #11 [23 March, 2018], #18 [20 April, 2018]).

Figure 8: Extractive farm ponds. Left: A pond with a plastic lining to prevent seepage. Right: A farm pond, built in 2017, next to a stream-course where multiple recharge pipes and one concrete dam were implemented under the campaign in 2015 (Village 1). Source: Author's photographs.

3.5. Discussion

The case of Jalyukt Shivar provides three key insights at the intersection of water, agriculture, and climate-related risk reduction. First, the case linked the disproportionate focus on drainage-course and waterbody initiatives to widened inequities in water access. Initiatives excluded certain residents, including historically disadvantaged people, who did not hold key endowments – such as capital, land size or beneficial land location – that may otherwise enable them to acquire benefits associated with the narrow character of the program. Moreover, farm ponds –

promoted as a *drought-relief* intervention – have increased the pressure on groundwater, and further skewed the distribution of benefits through appropriating water intended for villages as a whole. The nature of drought-relief is inadequate because it does not explicitly ensure that benefits are widely distributed and that water-use is safeguarded in the long-term. Future integrative water conservation programs should avoid a narrow focus on a subset of water conservation initiatives, which are unlikely to yield broadly-distributed gains. Discussed earlier, a ridge-to-valley approach could have resulted in a wider distribution of benefits in part through conserving multiple dimensions of the water spectrum at multiple spatial locations. Further, increasing aggregated village-scale water availability is not synonymous with increasing household-scale water access. A targeted, farmer-centric approach to public-private land interventions could have improved access and benefit from different forms of water conservation. My case demonstrates the need for local governance institutions to manage the collective interests of residents for *how* water is distributed and used because the initiatives benefited only some, often privileged residents, and constituted absences and risks to others. **Chapter 5** (**section 5.3.3.**) builds on these recommendations, re-imagining livelihood water security approaches for drought-preparedness.

Second, proponents of integrative blue-green water management may suggest the undesirable outcomes in sampled villages arose because of unscientific, standardized, and biased planning and implementation of interventions. I do not refute these claims but re-frame them. Rather than placing the burden of responsibility on local actors and tail-end concerns over whether infrastructure was "correctly" planned and constructed within villages (e.g., Rockström et al., 2014b; cf. Kale et al., 2019; Bhadbhade et al., 2019), the Maharashtrian case suggests we understand these uneven social-ecological dynamics as unfortunate *outcomes* of broader governance structures and political contexts through which the purposes and objectives of drought-relief infrastructure were established and later implemented. That is, the outcomes of green- and blue-water programs are intrinsically linked to broader governance structures and contexts that shape these outcomes – not solely to a single officer or powerful elite.

Third, researchers ought to be less concerned with particular interventions (Meinzen-Dick, 2007) and more devoted to understanding and promoting particular design and implementation principles. In calls for up-scaling and intensifying water conservation programs, scholars have sometimes assumed that these solutions will be used, adopted, and planned in

rational and scientific ways coherent with the researchers' intention or expectation. This Chapter confronts this slippage, inviting careful attention to how water security risks can remain tangential amongst a wider set of other government interests that affect how infrastructure becomes planned and implemented. If water scarcity and insecurity are, as Zwarteveen et al., (2017, p. 2) remind us, crises of how water is governed, who is served and underserved, and how flows of water actively become re-configured, it is sensible that governance systems and implementation dynamics receive much greater attention in the context of drought-relief and agricultural risk reduction.

3.6. Conclusions

Improving water security for food production and livelihood generation in drought-prone areas is a public policy imperative in many countries, including those in the global South. Considerable research on water resilience, often based on field experiments, has shown interventions to control erosion, conserve soil moisture ("green water"), and capture runoff ("blue water") can protect rain-dependent agriculture from precipitation variability. I explored how such an integrative water conservation program in Maharashtra functioned in practice, and whether and to what extent it enhanced the *capture*, *equity*, and *sustainability* of water and water use for agricultural risk reduction in drought-prone villages. While promoted as a scientific program, I found popularized solutions and political impulsions to demonstrate "drought-freeness" limited the nature and scope of drought-relief interventions, consequently animating a conditional, unequal and highly extractive set of outcomes around water availability and use. These outcomes, I argued, cannot be understood in isolation from the broader institutional contexts through which the campaign evolved and was implemented.

There are some important limitations to recognize, which serve as bases for future research. I limited the scope of this Chapter to synthesizing the broader conceptualization, implementation, and effects of the campaign. Of particular importance is detailed ethnographic work on how drought-relief plans were developed and implemented through village bodies, grassroots officials, and the contractor-lobby. These micro-level processes are likely to impinge on who was made water secure, and who was not, and will complement the broader focus here on government interests that shaped the natures and outcomes of the campaign. Further, I acknowledge the importance of understanding and managing potential cross-scalar impacts of

hydrological change resulting from the up-scaling of water conservation initiatives (**section 5.3.1.**). Overall, the Maharashtrian case demonstrates that without an overlapping focus on social difference and entitlement structure, policy programs designed to protect communities from the risks associated with environmental variation can deepen existing inequities. In conclusion, the likelihood of agricultural drought will not be reduced for all people, and villages as a whole, if water access and use is not widespread and safeguarded for the long-term.

Chapter 4: Beyond local case studies in political-ecology: Spatializing agricultural water infrastructure in Maharashtra using a critical, multi-methods, and multi-scalar approach

4.1. Introduction

Understanding the causes behind the uneven distribution of environmental risk in society, and using evidence-based research to challenge governance systems that fail to ameliorate such risks, is a hallmark of critical geography. The intellectual research tradition of political-ecology constitutes a key subset of such inquiries through its analytical focus on the relationships between the distribution of resources and power, and the (re)production of environmental harm in society (Perreault et al., 2015). Demonstrated in **Chapter 3**, political-ecology approaches can evaluate whether climate adaptation beneficiaries include those facing disproportionate risks to environmental change, and identify the socio-economic and political dynamics shaping the nature and allocation of risk response initiatives. Political-ecology thus serves a key analytical role for research intent on advancing equity and justice in the context of a changing planet.

However, political-ecological scholarship has received criticism for its local and case-based nature, which is poorly positioned to influence policy-makers who rely on data patterns scaled to the larger region for decision-making (Walker, 2003; Birkenholtz, 2012). This criticism is in fact borne out of a major strength of political-ecology – its locally situated focus on eliciting individuals' specific experiences of environmental change (an "idiographic" approach) (Birkenholtz, 2012). As Birkenholtz (2012) explains, idiographic approaches use qualitative methodologies to connect individual and group-level experiences of risk to institutional structures and relations of power, registering the causal mechanisms that produce and distribute harm. However, even where the causal structures of risk are identified as multi-scalar (Blaikie & Brookfield, 1987; Mustafa, 1998), the empirical focus often remains linked to single or multiple communities (e.g., recall **Chapter 3**). The localized nature of political-ecology research, compared with its potential to affect social and environmental policy, has led to calls for novel approaches that "[offer] reasonable generalizability, while maintaining explanations of local social processes that affect differential vulnerability and adaptive potential" (Birkenholtz, 2012, p. 301; Galt, 2010). Parallel arguments have been made by political-economists, notably Castree

(2010, p. 37), who argues the focus on individual case studies risks leaving the environmental governance literature impoverished in "cross-case comparison and the identification of commonalities between different sets of cases". While synthesis of empirical and theoretical research to discern the causes and effects of social-ecological change at larger scales may not automatically affect policy decisions, such efforts – complementing situated and place-based research – are increasingly viewed by human geographers as important to assess and challenge government policies that could otherwise deepen inequities in varied contexts (e.g., Castree, 2008a,b; Birkenholtz, 2012).

This Chapter argues research design and analyses that learn from mixed methodological approaches can enable political-ecology to pivot in ways that use knowledge of local dynamics around resource acquisition to investigate corresponding patterns of regional resource distribution and risk. Complementing the efforts made by the authors above, I offer a linked inductive (qualitative) and deductive (quantitative) research approach to explore, at multiple social-ecological scales, specific factors that affect the distribution of climate adaptation initiatives. The inductive-deductive approach develops several meso-scale quantitative models to re-scale and re-analyze particular relationships revealed by local fieldwork and document synthesis – thus *integrating* qualitative data into quantitative analyses (Fetters et al., 2013).

Following a critical realist research philosophy (Maxwell & Mittapalli, 2010, **section 1.6.1.**), the meso-scale models should not be interpreted as producing "law-like generalizations" (Kwan & Schwanen, 2009), or objectively "confirming" qualitative findings (Nightingale, 2003; Harris et al., 2017). To do so risks (re)creating methodological hierarchies (Rocheleau, 1995), and conflating modelled results with an external reality "out there" when in fact such results reflect ranges of uncertainty associated with particular effects under the data collected, assumptions made, and modelling strategies used (Amrhein et al., 2019a, p. 262; Wasserstein et al., 2019; Gelman & Greenland, 2019; cf. Maxwell, 2012). Taking these concerns seriously, my coupled qualitative-quantitative approach constitutes multiple partial bodies of knowledge – informed through particular datasets, methodologies, and analytical techniques – intended to advance a more comprehensive (yet, incomplete) understanding of factors affecting the distribution of water security initiatives at multiple scales. Owing heavily to criticisms of quantitative research as a positivist science (Kwan & Schwanen, 2009), few critical geographers have explored how local fieldwork and regional-scale quantitative analysis can be harnessed to

"scale up political ecology" (Galt, 2010) and inform policy-making in a careful manner – methodological and epistemological contributions made here.

The integrative methodological approach analyzes, through the available secondary data, how socio-spatial and biophysical characteristics (identified through document and field research in three heterogenous drought-prone villages) affect the distribution of over 16,000 farm ponds approved for construction across Maharashtra (India). Described in **Chapter 3**, farm ponds are subsidized by the state government to reduce agricultural livelihood risks from precipitation variability (Kale, 2017). To re-iterate, ponds function as large water storages where, most commonly, groundwater is extracted in enormous volumes for private use (*ibid*). Empirically, the Chapter complements qualitative village- and household-scale research documenting the uneven development and social-ecological impacts of ponds in Maharashtra (see Kale, 2017; Phadke et al., 2018; **Chapter 3**) by contributing an analysis of how their broader distribution articulates with spatial indicators of environmental stress and socio-economic wellbeing. Of the several noteworthy results, my coupled approach finds evidence for a policy bias against both i) households with marginal-size landholdings as it relates to acquiring farm ponds, and ii) sub-districts with more marginal-sized landholdings when it comes to the spatial distribution of ponds. This specific finding raises concerns about the extent to which farm ponds, an emerging state-sponsored livelihood adaptation, are just and equitable. Other findings are accompanied with wider ranges of uncertainty or run counter to my qualitative results – and therefore require further scrutinization. Herein, farm pond count is positively associated both with the number of Scheduled Caste households, and rural marginal cultivators in a sub-district. These associations require deeper investigation to understand potential contributions to equity.

The Chapter's major epistemological contribution demonstrates that qualitative (e.g., household/village-level) and quantitative results (e.g., sub-district) at multiple social-ecological scales can cohere, remain exploratory, or be entirely inconsistent with one another (Nightingale, 2003; 2009; Morgan, 2019; Uprichard & Dawney, 2019). This contribution emerges from my refusal to dichotomously analyze quantitative results as "significant" and "non-significant" (Wasserstein et al., 2019). Assessing compatibility using the coefficient direction, effect size, and confidence (or "compatibility") intervals (Amrhein et al., 2019a), as I do, enriches the ways in which quantitative and qualitative results can gel or diverge from each other, which extends beyond "agreeing" or "conflicting". The degree of compatibility between qualitative-quantitative

and local-meso-scale offers different pathways for research and activism – a key interest that has motivated efforts to "upscale" (Galt, 2010), "extensify" (Birkenholtz, 2012) or regionalize political-ecology in the first place (Walker, 2003).

Finally, I reject the dualism between the "critical" and the "quantitative" (e.g., Wyly, 2009). I maintain that a mixed-methodological approach can contribute to political-ecology's critical "community of practice" (Robbins, 2011, p. 86), particularly when quantitative analyses examine contextualized and grounded relationships, illuminate wider socio-economic structures of marginalization (e.g., Carter, 2009), value statistical uncertainty and variability (Amrhein et al., 2019; Wasserstein et al., 2019), and recognize the limitations and partial contributions of statistical analyses to knowledge production (Kwan & Schwanen, 2009; Harris et al., 2017). Below, I outline how a linked inductive-deductive approach builds on existing methodological efforts in political-ecology (**section 4.2**). **Sections 4.3**-**4.5** describe the case study, methodology, and results. **Section 4.6** concludes with an epistemic framework for working through the complementarities and differences between qualitative and quantitative results at multiple scales to drive actionable research in ways consistent with geography as a critical practice.

4.2. Towards methodological integration in political-ecology

"Idiographic" research approaches are dominant in political-ecology research, and are used to describe different experiences of risk (or other phenomena) that individuals or groups face in particular contexts (Birkenholtz, 2012). The analytical focus is on particularity and difference (*ibid*), often studied using inductive research designs where researchers develop explanations of context-specific phenomena from the ground-up using ethnography, observation and interviewing (Rocheleau, 1995; Castree, 2008b).

On the other hand, "nomothetic" research approaches – from the Greek, *nomos*, or law – develop generalizable patterns shared between certain sub-groups or entire populations, often outside single case contexts (Birkenholtz, 2012; Magliocca et al., 2018). A focus on generalizable patterns has often, but not always, relied on deductive research approaches where theories or hypotheses about a set of experiences are tested through quantitative analyses, especially inferential statistics (Galt, 2010). Other approaches for developing generalizable knowledge rely on inductive approaches where case-based research is synthesized to develop globally-scaled theories (see Sen, 1981; Ostrom, 1990; Wutich & Brewis, 2014). For example,

Magliocca et al., (2018) offer a typology for advancing "generalizable knowledge claims" where empirical case-based research can be synthesized to identify the causes, magnitude, and effects of social-ecological change in ways that accounts for and makes explicit the robustness of a claim, and the conditions under which it holds.

Despite the recognized value associated with generalizable knowledge, nomothetic approaches – and more precisely, the use of quantitative analyses – have often been characterized as conflicting with the analytical foundations of political-ecology. For one, and following Birkenholtz (2012), nomothetic approaches cannot easily elicit the underlying nuance and causes of social vulnerability in social-ecological systems and thus are not easily able to support policy action targeting *the roots of differentiated harm* – a cornerstone of political-ecological research (*ibid*, p. 300). Second, inferential – and even descriptive statistics – are often criticized for (re)producing categorical generalizations, which risks obscuring the lived experiences of particular groups (Rocheleau, 1995; Liverman, 2018). Further, interpretations can reproduce dangerous essentializations (e.g., Carter, 2009). For example, Carter (2009) argues that failures to de-construct associations between African Americans and urban residential crime in past studies have perpetuated racist linkages between criminality and people of colour. The author suggests alternative quantitative approaches (e.g., path analysis) coupled with structural interpretations of such associations could have revealed that such an effect is mediated by racial exclusion, limited opportunities, and government neglect (Carter, 2009, p. 472). Last, quantitative analysis has struggled to account for how knowledge is partial and constructed through social histories, experiences, and positions of power (Wyly, 2009; Haraway, 1988). For instance, the post-structural turn in political-ecology demonstrated how seemingly objective facts about the world, such as biophysical processes like water scarcity and soil erosion, reflect or are entirely consistent with problem-framings by politically powerful institutions and groups (Blaikie & Brookfield, 1987; Mehta, 2001; Forsyth, 2001). For these reasons, many political-ecologists – and critical human geographers – have often held nomothetic approaches, and their associated deductive and quantitative designs and methodologies, with skepticism.

Yet, while political-ecologists (and political-economists) have recognized the value of producing more generalizable knowledge for policy action and change (e.g., Walker, 2003; Castree 2008a,b; Galt, 2010, 2016; Birkenholtz, 2012), few outside the "critical quantitative" community (e.g., Kwan & Schwanen, 2009) have endorsed, let alone applied, deductive and

quantitative approaches in regionalizing political-ecology research. For example, Castree (2008a,b) suggests comprehensive literature reviews can support the synthesis of "fairly widespread" mechanisms and effects of environmental neoliberalism in different places (qtd. 2008a, p. 138). Birkenholtz (2012) does not engage with quantitative approaches, instead calling for extending local human vulnerability research by i) understanding subjective experiences of environmental risk across heterogenous social-ecological sites; ii) identifying the underlying factors that mediate vulnerability using ethnographic, interviewing, and observational techniques with resource-users, state planners, and development workers; and iii) mapping dynamics, relations, and effects to develop a richer account of differentiated environmental risks within a bounded resource system (p. 304). Galt's (2010) work, closer to my approach, integrates local and case-based inductive knowledge into hypothesis development for explaining large-scale data patterns. Galt (2010) develops a political-ecological framework about farmer pesticide overuse in different country contexts using primary and secondary data, which is used as a basis for hypothesizing why certain countries' (Guatemala, Spain, Jamaica, China) vegetable exports violate pesticide thresholds in the United States (*ibid*). However, Galt (2010) stops short of testing or evaluating these hypotheses. My contribution identifies potentially meaningful factors that affect the acquisition and distribution of climate adaptation initiatives, hypothesizes their dynamics and effects at wider spatial scales, and coming full circle, *tests* these hypothesized associations through secondary data regression models to build a broader understanding of social-ecological patterns at local and policy-relevant scales.

My integrative methodological and epistemological approach involves "the linking of qualitative and quantitative approaches and dimensions together to create a new whole or a more holistic understanding than achieved by either [method] alone" (Fetters & Molina-Azorin, 2017, p. 293). Following Fetters et al., (2013), I use a "building approach" where inductively developed insights about farm pond distribution informed secondary data collection to re-analyze, at a larger-scale, relationships found to be meaningful at the local level. When qualitative insights inform the quantitative analyses and interpretation, we can avoid testing relationships without sufficient theoretical or empirical support, and reduce the likelihood of interpreting associations in de-contextualized ways. Further, the integrative approach enables a "holistic [method of] triangulation" where quantitative and qualitative results can be compared

and contrasted, creating an innovative space to identify potential synergies and areas for future targeted research (Turner et al., 2017, p. 250; Uprichard & Dawney, 2019).

4.3. Case study

As now elaborated in **Chapters 1** & **3**, the state of Maharashtra experienced recurrent agricultural droughts, which led in 2014, to the formulation of the decentralized water harvesting campaign – Jalyukt Shivar Abhiyan – in a bid to make the state "drought-free" by 2019 (GoM, 2014). Villages, selected for drought-relief each year by district-level committees, designed water conservation plans in conjunction with sub-district level revenue, engineering and agricultural officers (GoM, 2014; Key informant interview #7, February 24, 2018). As an umbrella program, Jalyukt Shivar coordinated financing from several government programs to fund fourteen different water conservation initiatives related to "green" (soil-moisture) and "blue" (drainage) water harvesting (GoM, 2014). The construction of farm ponds on farmers' plots was one popular initiative under the campaign (see **Chapter 3**).

The field research used to inform model development relied heavily on interview data collected from three social-ecologically diverse and drought-prone villages. At the time of fieldwork (January, 2018) the three villages sampled had, between them, over 1,000 farm ponds (Government official interview #2, January 2018; Government official interview #5, March 2018). These ponds, subsidized through varied schemes, were built before, during, and after 2015. The data I use, described below, is listed under the initial campaign intervention year of 2015-2016. Farm ponds proliferated even further after 2016 with the introduction of the Magel Tyala Shettale ("Farm Pond on Demand") subsidy – another state-level program financing pond development nested underneath Jalyukt Shivar Abhiyan (Key informant interview #7, pers. comm., March 15, 2018). I did not observe major differences in the structure and function of farm ponds built during different periods, in diverse social-ecological contexts, and subsidized through varied government programs. Across these contexts, I observed ponds to function as private storage units often for larger-landed farmers, who line them with a thick plastic sheet and commonly extract and fill them with groundwater for their use during the dry season (**Chapter 3**). This has enabled expanded cultivation or intensification of water-intensive crops, such as figs, grapes, and pomegranate. The only observed differences between ponds were in their size – a choice left to the farmer, with the standard size nearing the volume of an Olympic-sized pool

(30 x 30 x 3m; 2,196 m^3) – and occasionally in the sources of water used to fill them (**Figure 9**). While canal irrigation, private tankers, or other sources could be used in particular contexts, the pumping of wells for filling ponds for dry-season use is an experience observed across Maharashtra (see Kale, 2017; Phadke et al., 2018). As of July 2019, 161,000 ponds had been completed under the campaign. The sample examined here (n = 16,036) provides an emerging indication of their distribution and association with areal characteristics of water scarcity and social vulnerability across the state.

Figure 9: Typical farm ponds in Maharashtra. Source: Author's photographs.

4.4. Methodological approach

I identified social, biophysical, and economic characteristics likely to affect drought-relief investment under Jalyukt Shivar Abhiyan. This included a focus on factors affecting farm pond distribution and those shaping the campaign as a whole under which ponds are nested. From January-April of 2018, I conducted, with support from two local field assistants: i) document analysis (e.g., government, popular media), ii) semi-structured interviews with key informants (n = 25), including state officials and development practitioners, and iii) combined survey-interviews (n = 63) and focus groups (n = 6) with households in three heterogenous villages served by the campaign. These inquiries were focused on topics including but not limited to households' water access challenges, their understood purpose of the drought-relief program, the within- and between- village distribution of drought-relief interventions, and the hydrological and agricultural effects of implemented infrastructures. Documents were analyzed, and the interview data was structurally coded using NVivo 12.0 into categories that reflected its content

(for methodological details, see **Chapter 3**). The fieldwork insights informed the selection of independent variables within the meso-scale models.

To be clear, the model results draw associations between the expected count of farm ponds and particular characteristics at the sub-district scale. They do not draw conclusions about the individual-level or village-scale relationships that were used to build it (i.e., an "ecological fallacy", Robinson, 1950). But that does not mean individual-level associations do not underlie the aggregated relationships – only that one cannot know or conclude this without individual-level data. This is because "ecological inference" – drawing conclusions about individuals using aggregated data – is vulnerable to unidentified spatial biases, information loss, and confounding (Openshaw, 1985). Without making explicit statistical linkages between meso-scale associations and individual behaviour, the integrative models – interpreted in conjunction with local qualitative research – should be read as a different yet complementary body of evidence designed to better understand the distribution of important water security strategies across the state in the context of climate variability.

4.4.1 Dependent variable: Farm pond count

The dependent variable is the sub-district level count of farm ponds approved in Maharashtra for the reporting year 2015-2016. This publicly available farm pond data was downloaded, translated, and cleaned from the Jalyukt Shivar Abhiyan repository hosted by the Maharashtra Remote Sensing Application Centre (GoM, 2015a). The public database was filtered by "work type" (e.g., silt removal, earthen dams, farm ponds) in order to identify the listed farm ponds. The de-duplicated records indicated 16,036 farm ponds were approved for construction (2015-2016). Farm ponds and support schemes existed well before 2015, and after 2016. However, data prior to 2015 is not publicly available, and data after 2016 contains serial duplication and was deemed inadequate for quantitative analysis. **Figure 10** shows the number of approved farm ponds (2015-16) for 290 of the 358 sub-districts (talukas) in Maharashtra.

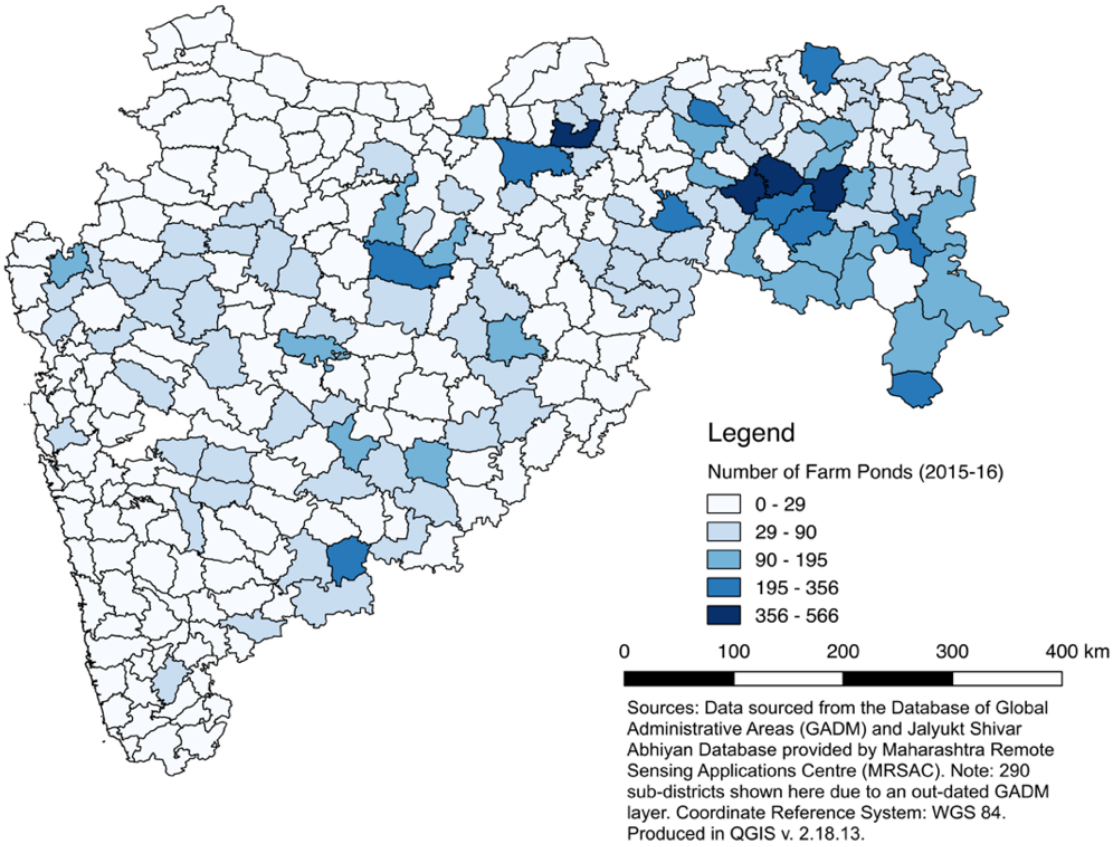

Figure 10: Distribution of approved farm ponds (reporting year 2015-16). 290 of the 358 sub-districts are shown due to an outdated jurisdictional boundary layer. Map produced by the author.

4.4.2 Independent variables: From inductive observations to deductive testing

This section describes the independent variables and the data sources used in the quantitative analysis (**Table 12**), which were informed by field-work and document synthesis. These include: annual average precipitation; the rate of groundwater exploitation; number of "wholly unirrigated" holdings; number of rural marginal cultivators (< 6 months of cultivation work/year); number of marginal landholdings (< 0.5 ha); number of rural Scheduled Caste households; number of rural households where the highest earner makes ≥ 10,000 /- INR. per month ($132 USD/month); and control variables related to the sub-district geographic and population size. These variables reflect my understanding of: i) how villages were selected under the campaign (2015-16) and thus broader factors affecting the drought-relief investments, inclusive of farm ponds; and ii) household-scale characteristics identified as important for owning a pond (e.g., wealth, land-size). I justify each variable below using interview and field observation data.

First, document research and semi-structured interviews with key informants revealed physical water scarcity in villages was a major consideration for the implementation of Jalyukt Shivar Abhiyan. The government criteria for water scarcity informed the selection of villages for drought-relief funding. These criteria included whether, in the last five years, a village i) has been "declared as a scarcity village"[54], ii) required external tanker trucks to provide drinking water, and iii) whether it existed in a semi-critical, critical, or over-exploited watershed despite having over 50% of prior watershed interventions completed in efforts to reduce water scarcity (Government of Purandar, 2014; Government official interview #2, January 2018). In prioritizing villages at the beginning of the campaign (2015), one agricultural officer stated:

> "[T]anker-fed villages are given top priority. The villages that are tanker-fed for up to 5 years, tanker-fed villages, where the total rainfall yearly is less than 500 mm and where there is supply of tankers for drinking purpose – those have been selected as top priority" (Government official interview #2, January 2018).

The formal Jalyukt Shivar Abhiyan Government Resolution (GoM, 2014) further indicates a set of hydrological criteria upon which areas were prioritized:

> "Almost 82% area in the state is dryland while 52% area is drought-prone. There are 188 Talukas (2234 villages) where [the] groundwater level dropped for more than 2 [m]etre[s] and drought situation were declared in 19059 villages from 22 districts in the year 2014-15. *This 'Jalyukta Shivar' campaign needs to be implemented in these locations on priority*" (GoM, 2014, p. 3; my emphasis).

These quotations indicate several hydrological variables important in prioritizing campaign-served areas. Three relevant indicators include whether villages i) received drinking water from tankers, ii) had low (< 500 mm) annual average precipitation levels, and iii) experienced groundwater decline. The latter two indicators were integrated into the models. Government data on the number of villages declared drought-hit (< 50% crop production) was inaccessible. Further, government water tanker data on the frequency of village visits was unreliable.

To integrate precipitation levels into my meso-scale models, the long-term annual average precipitation (1986-2016) at the sub-district scale was calculated using the Climate Hazards Group InfraRed Precipitation (CHIRPS v.2) dataset (Climate Hazard Group, 2017; Funk et al.,

[54] This means a village experienced agricultural drought for the last five years (< 50% of production) (CTARA, 2018).

2015). The CHIRPS dataset combines satellite imagery with data from 50-160 rainfall stations in India to interpolate gridded precipitation data at a 5-kilometre resolution for annual temporal bands (Funk et al., 2015). To calculate annual average precipitation for each sub-district, the gridded raster data was imported into QGIS 2.18.13 along with jurisdictional sub-district boundaries from the Global Administrative Areas dataset (GADM, 2017). The annual mean precipitation for each sub-district was then calculated for each year using the zonal statistics function. These annual values (1986-2016) were averaged for each sub-district to generate a single long-term mean value. The sub-district boundaries defined by the GADM dataset did not reflect the most current legal boundaries. In cases where sub-districts were absent from the GADM file, a value could not be estimated using spatial statistics. To avoid dropping 63 sub-districts, a statistic representative of the neighbouring spatial area was estimated using simple averaging techniques.

The stage (%) of sub-district groundwater development (existing gross groundwater annual draft [hectare meters (ham)/year] divided by the net annual groundwater availability [ham/year]) was used as a proxy variable for groundwater depletion and sourced from the most current district groundwater reports (2008-2010). This variable was transformed into a binary variable to reflect "safe" (< 70%) and "unsafe" (>70%) rates of groundwater development. The transformation was completed because the "unsafe" value reflects groundwater development that is either semi-critical (70-90%), critical (90-100%), or over-exploited (>100%) – key selection criteria outlined by the government (*viz*. Government of Purandar, 2014).

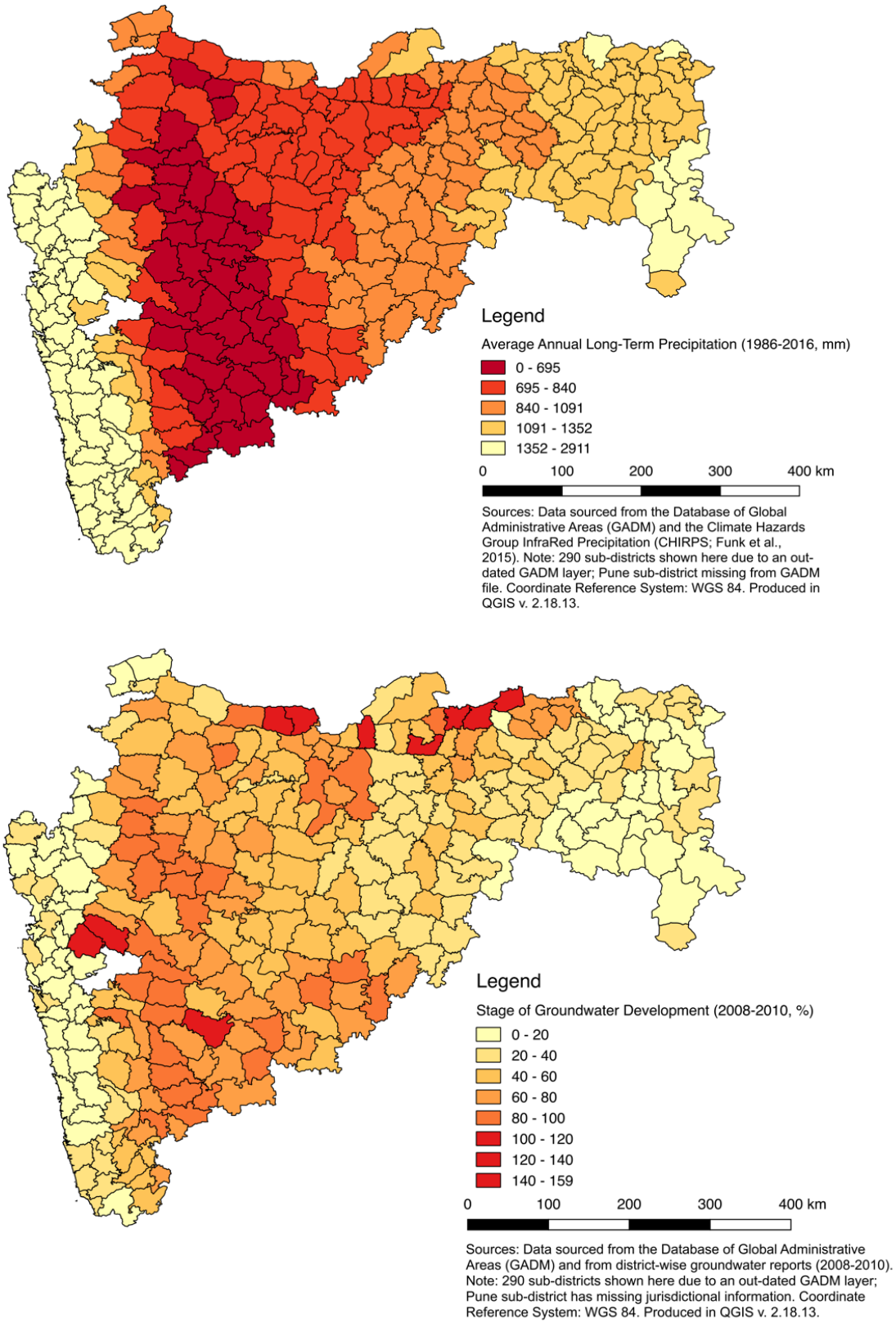

Figure 11: Annual average long-term precipitation (mm, top) and stage of groundwater development (%) in 290 sub-districts (bottom). White shading indicates absence of boundary data. Maps produced by the author.

Second, government documents and semi-structured interviews with government officials and development practitioners revealed the program was intended to support the wet (*kharif*) crop, but also provide irrigation for the cultivation of a second, or third annual crop for farmers during the dry (*rabi*) season. For example, one objective of the Jalyukt Shivar campaign involves a "[r]eduction in area under dry land crops and increase in area under irrigated crops" (GoM, 2014, p. 12). Connected to this, one state-level government official stated in an interview:

> "Jalyukt Shivar is essentially giving us the storativity of the water, the storativity of water by the farmer during the monsoon is helping him to take one more crop" (Government official interview #7, April 12, 2018).

This official illustrates the relationship between lack of irrigation and the inability of farmers to engage in a second or third crop. The number of agricultural holdings that are "wholly unirrigated" and the total number of rural marginal cultivators in a sub-district (i.e., cultivators working less than six-months per year) was extracted from the most recent Agricultural Census (GoI, 2011a) and the Population Enumeration Census (GoI, 2011b), respectively. I control for the effect of sub-district size through including a variable on the total number of agricultural holdings and the total number of households in a sub-district.

Third, field observation, and interviews with households and informants affirmed that land size and financial capital were important indicators of farm pond development (per **Chapter 3**). Interviews revealed farmers ought to hold at least 1.5 acres to own a farm pond because of the trade-off associated with transforming a significant share of the parcel for the pond (Focus Group #1 Village 1, January 2018; Phadke et al., 2018). This insight was shared by key informants familiar with the proliferation of ponds across the state:

> "[W]ho gets the chance for these farm ponds?...These are mostly the medium farmer, horticulture owners, big farmers, which have some influence at the different levels. Basically, these are the farmers. The people who actually needed them [the farm ponds] are marginal farmers, who don't have the irrigation source. They don't get these farm ponds" (Key informant interview #18, April 20, 2018).

This informant also underscores how potential social and political relations of larger farmers can affect their ability to acquire a pond. Pond development – whether pre-2015 or after – has a sizeable capital cost. Ponds constructed *before* 2015, and not under the campaign (2015-2019), could be subsidized by different schemes (e.g., National Horticulture Mission) (GoI, 2014). Farm

ponds funded through various government schemes nested under Jalyukt Shivar receive a maximum of 50,000/- for the construction of the pond (Government official interview #2, January 2018; Prasad, 2018). Other schemes associated with the campaign can provide up to 75,000/- for the cost of the lining (Government official interview #2, January 2018). Notwithstanding future operational costs, subsidies cover a portion of the standard farm pond (30 x 30 x 3m) costs, which can range between 75,000/- and 350,000/- ($1,060-$5,655 USD) depending on geography, soil conditions, and lining (Prasad, 2018). Thus, and clarified in **Chapter 3**, farmers require both larger land sizes and financial capital to construct a pond. I included variables at the sub-district scale indicative of wealth (number of households where the highest earner makes ≥ 10,000/- INR per month) and land size (number of agricultural holdings that are < 0.5 ha [< 1.25 acres]) into the models. The wealth indicator is the highest income bracket in the Socio-Economic and Caste Census (GoI, 2011c) and was included with the assumption that a relatively higher level of income to invest in plastic sheets, borewells, and other operational costs is an important indicator of adoption. The land size variable (< 0.5 ha) is the lowest landholding category in the Agricultural Census (GoI, 2011a) and is a proxy for households who face land and financial barriers – given their interrelationships – to pond adoption. I control for the effect of sub-district size as a potential confounder.

Fourth, historically marginalized castes are amongst the most disadvantaged groups in India with respect to land ownership, which "largely accounts for their perpetual poverty" and the everyday forms of social and economic exploitation faced (Mohanty, 2001, p. 3857). In my fieldwork, Scheduled Castes (a lower caste denomination) often held smaller plots of land or were entirely landless. This point can be further illustrated across the entirety of Maharashtra using the latest data from the Agricultural Census (GoI, 2011a), where, in virtually all districts, Scheduled Caste households hold a substantially larger percentage of the total marginal (< 1 ha) and small (1 ≤ 2 ha) landholdings, as compared to medium (4 ≤ 10 ha) and large (>10 ha) landholdings (**Figure 12**). I included a variable for disadvantaged caste (number of households in a sub-district that are designated Scheduled Caste) from the Socio-Economic and Caste Census (GoI, 2011c) and included the total households in a sub-district to control for this effect. Other factors equal – including the number of marginal landholdings – more Scheduled Caste households in a sub-district could reflect unaccounted factors (e.g., relative poverty, small landholdings) associated with structural marginalization.

The expected relationships between each predictor and the dependent variable, after accounting for the set of other control variables, is presented in **Table 12**. These independent variables are limited by the availability and the accuracy of input data, and their different temporal periods of collection. Further, I examine the distribution of farm ponds listed under the 2015-16 intervention year; it is possible that certain expected relationships discussed below (**section 4.5**), such as sub-district level rainfall and groundwater extraction rate, may even weaken if future analyses examined data post-2016. This is because Jalyukt Shivar prioritizes the most impacted drought-prone villages first. Nevertheless, my work is a critical entry point in exploring the distribution of a key climate adaptation and water security support across the state.

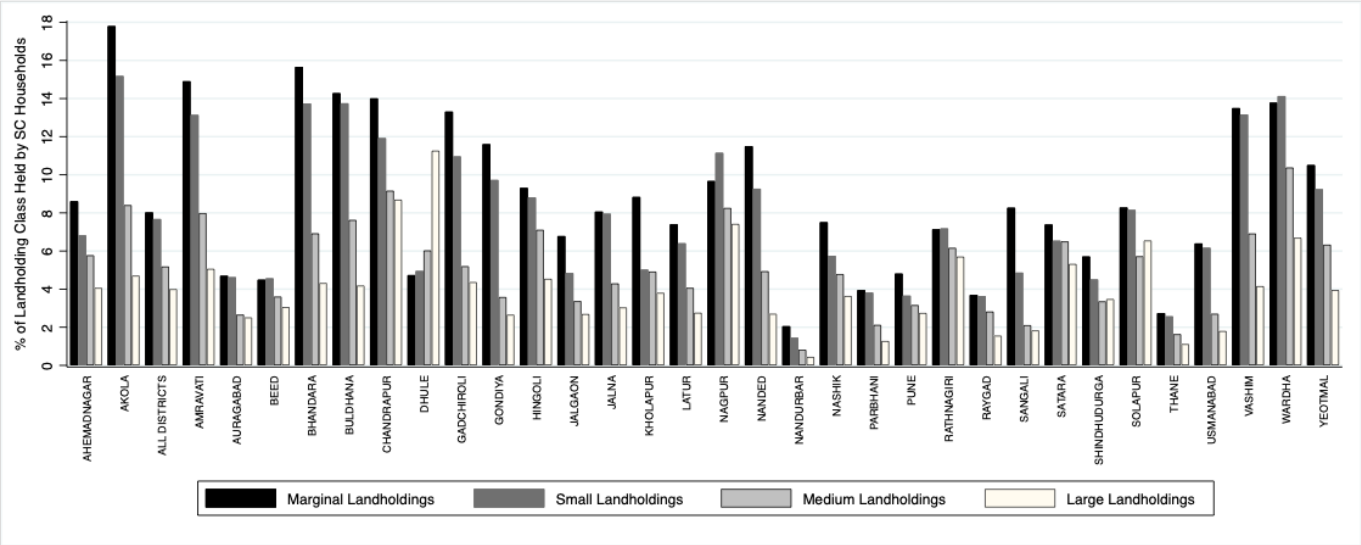

Figure 12: Percentage of landholding classes held by Scheduled Caste households across Maharashtra. Secondary data sourced from the Agricultural Census of India (GoI, 2011a).

Table 12: Independent variables and the expected relationships with the number of approved farm ponds at the sub-district scale (2015-16) after controlling for confounding variables.

Predictor variable (unit, date) *	Expected relationship
Annual average precipitation (mm, 1986-2016)	Negative (-)
Stage of groundwater development (0= "safe"; 1=semi-critical, critical, over-exploited) (2008-2010)	Positive (+) (reference group =0)
Number of "wholly unirrigated" holdings (2011)	Positive (+)
Number of rural marginal cultivators (2011)	Positive (+)
Number of marginal landholdings (< 0.5 ha, 2011)	Negative (-)
Number of rural Scheduled Caste households (2011)	Negative (-)
Number of rural households where the highest earner makes ≥ 10,000 /- INR per month (2011)	Positive (+)

Control: Number of landholdings (2011)	Positive (+)
Control: Number of rural households (2011)	Positive (+)

*All variables scaled to the sub-district level. A one-unit increase for the person, holdings, and household indicators corresponds as a 1,000 unit increase. A one-unit increase in annual average precipitation corresponds as a 100mm unit increase.

4.4.3 Model selection

A negative binominal regression model was selected because the dependent variable was an over-dispersed count variable (O'Hara & Kotze, 2010). Four similar models were run (M1-M4). Model 1 (M1) is the baseline model (n = 352 sub-districts) with the nine independent variables identified in **section 4.4.2**. Model 2 (M2, n = 344) drops eight observations (i.e., sub-districts) deemed to exert a strong influence on single or multiple parameter estimates calculated in M1. These observations were visually identified using a Cook's D test. Model 3 (M3) dropped 63 sub-districts where the annual average long-term precipitation could not be quantified using zonal statistics due to the outdated sub-district boundaries vector file (n = 290) (**section 4.4.1**). Model 4 (n = 282) dropped eight additional observations deemed as influential – of which several were shared with M2. Both M2 and M4 can be broadly understood as an *ad-hoc* sensitivity analysis on M1. Variance inflation factor scores were computed to assess and resolve multi-collinearity. Each model passed an omitted variable bias test, indicating no major misspecification errors. To evaluate the extent regression residuals were independent, I used Moran's *I* statistic to assess spatial autocorrelation. Moran's *I* score ranges between 1 (perfect clustering) and -1 (perfect dispersion), with scores near zero indicating randomness. I first indicated which sub-districts could be considered neighbours in order to assess whether neighbouring sub-districts had correlated values. I created a spatial weights matrix, where a lower and upper distance band between centroid coordinates of each sub-district was established for which located pairs were considered neighbours (Chakraborty, 2009; Chakraborty et al., 2014). Residual values represented a subset of the regression model used because the vector layer used for Maharashtra contained only coordinates for 290 sub-districts. The maximum distance between centroid values in districts, and the average maximum distance between centroids for each region were used to define the radius for each sub-district within which neighbours would be classified. The magnitude of spatial auto-correlation was weak (Moran's *I*

= 0.06—0.1; $p < 0.01$), and rivaled levels which have been deemed acceptable in other environmental justice studies (e.g., Landry & Chakraborty, 2009).

Table 13 reports the raw unstandardized regression coefficients, which correspond to the change in the natural log of the expected count for the dependent variable given a one-unit change in the predictor variable, holding constant the other variables (Long & Freese, 2006). For ease, I report the percent change in the expected count of the dependent variable for a unit increase in the associated predictor (*ibid*). Both estimates are reported in **Table 13**. The analysis was completed in Stata 16 (StataCorp, College Station, TX).

4.5. Results

This section reports results for the four models, organized by the level of coherence between my qualitative findings and the modelled results. Following recent science reform movements, the degree of compatibility between quantitative and qualitative results is not based on whether the effects are "statistically significant ($p < 0.05$)" (Wasserstein et al., 2019). This is because statistically significant *p*-values do not inherently mean an effect exists "out-there"; similarly, "statistically insignificant" results do not mean an association does not exist (Amrhein et al., 2019a). Compatibility is instead based on broader statistical parameters, including the coefficient's point estimate (direction and modelled effect size) and values within the 95% confidence intervals, reported below (*ibid*). I interpret these interval estimates, following Amrhein et al., (2019a, p. 307), as "compatibility intervals" – various possible effect sizes *compatible* with the secondary data on-hand, the modelling strategy, and the assumptions made (Gelman & Greenland, 2019). The reported intervals do not imply complete certainty because such values are "nothing more than an exhibit of relations between the data and various possibilities under the analysis assumptions" (Gelman & Greenland, 2019, p. 2). In refusing to dichotomize the results as "significant" / "not significant", the broader method of reporting adopted reveals multiple ways in which qualitative and quantitative results can gel or diverge. This helps articulate different research and policy activities for "scaling-up" political-ecology (Galt, 2010) (elaborated in **section 4.6**).

First, one relationship had a consistent direction, effect size, and interval range across M1-M4 – with these parameters registering consistency with the qualitative insights. This was a negative association between the number of marginal landholdings and the expected count of

farm ponds at the sub-district scale. Holding other variables constant – including proxies for the geographic size of the sub-district – I find the expected count of farm ponds decreases 5.6% (M1, $p = 0.001$), 6.7% (M2, $p < 0.001$), 5.1% (M3, $p = 0.003$) and 5.7% (M4, $p = 0.001$) for each one unit increase in the number of marginal landholdings (i.e., every additional 1,000 marginal landholdings). While the point estimates are the most compatible with the data, the change in the expected farm pond count ranges from a sizeable 9.7% decline (M2) to a minor 1.8% decline (M3) for each additional 1,000 marginal landholdings. Estimates outside the reported intervals are plausible (e.g., if additional years of farm pond data are used). However, the current estimates are consistent with the qualitative knowledge.

Second, multiple instances exist where the coefficient direction was entirely consistent with the qualitative findings, but the range of modelled effect sizes yielded greater uncertainty. That is, while the point estimates are the most compatible estimates under the data modelled (Amrhein et al., 2019a), the interval values indicate the range of compatible effect sizes are wider and could reasonably be positive or negative. All models estimate a negative association between annual average precipitation and the expected number of farm ponds at the sub-district level. A 4.7% (M1, $p = 0.09$), 3.5% (M2, $p = 0.22$), 4.9% (M3, $p = 0.09$), and 5.8% (M4, $p = 0.05$) decrease in the expected number of sub-district farm ponds given each additional 100mm in annual mean precipitation is estimated. While the direction of the point estimates is consistent and aligned with the qualitatively-developed expectations, the modelled data indicates the expected number of farm ponds could range from a considerable 11.1% decline (M4) to a very minor increase of 2.1% (M2) for each additional 100mm of average annual precipitation. Had I acceded to the hierarchy of the p-value and regarded three of the four estimates (M1-M3) as "insignificant" or having "no effect", I may have erroneously written-off the potential compatibilities with the qualitative data, instead of recognizing their consistencies are accompanied with a greater level of modelled uncertainty (Amrhein et al., 2019b). Moving on, I observe a positive association between the number of marginal cultivators and the expected count of sub-district farm ponds. The results suggest a 9.7% (M1, $p = 0.12$), 11.8% (M2, $p = 0.049$), 7.8% (M3, $p = 0.22$), and 12.1% (M4, $p = 0.053$) increase in the expected count of farm ponds for each additional 1,000 marginal cultivators, holding constant the other included predictor variables. The modelled effect size across all models is similar; however, the models indicate a difference in the expected count of farm ponds could range between a modest 4.4%

decrease (M3), to a substantial 25.8% increase (M4), for each additional 1,000 marginal cultivators. Last, all models indicate a positive association between the number of households where the highest earner makes or exceeds 10,000/- per month, and the expected number of farm ponds at the sub-district level (M1: 6.0%, $p = 0.16$; M2: 6.1%, $p = 0.09$; M3: 5.6%, $p = 0.27$; M4: 5.7%, $p = 0.18$). Nonetheless, and as with the cases above, a difference in the expected count of ponds ranged from a modest 4.1% decline to a large 16.3% increase (both M3). This subsection recognizes the point estimates – all consistent with the qualitative findings – are the most compatible values with the data (Amrhein et al., 2019a) but also, that a relatively wider range in the breadth and nature of the modelled effects associated with each relationship exists. Where potential exists for these effects to run counter to the qualitative knowledge, the size of the effects, reflective of the data and modelling strategy, are minor, as indicated above.

Third, multiple relationships ran counter to my qualitative understandings. For one, I anticipated a positive relationship between the stage of groundwater development and the expected sub-district count of farm ponds. All four models, however, suggest negative effects. Accounting for the other predictor variables, sub-districts registering an "unsafe" (i.e., semi-critical, critical, or over-exploited) groundwater development rate were predicted to have 38.3% (M1, $p = 0.03$), 44.3% (M2, $p = 0.01$), 30.1% (M3, $p = 0.15$), and 42.1% (M4, $p = 0.03$) fewer expected ponds, as compared to sub-districts with "safe" groundwater development rates. The baseline model suggests a 38.3% decline in the expected count, with a difference in the estimate ranging between a 60.3% and 4.0% decline (M1). In M3, the effect associated with sub-districts with an unsafe groundwater development rate decreases (M3: -30.1%) and has a considerably larger range of compatible effect sizes (-57.0% to +13.5%). M2 and M4 used diagnostic tests (i.e., Cook's D test) to identify and exclude several observations, including three sub-districts that strongly affected the regression coefficient. By removing these influential observations (M2 and M4), the already large point estimate *increases* (M2: -44.3%; M4: -42.1%). Moving on, I anticipated a negative association between the number of Scheduled Caste households and the expected count of farm ponds at the sub-district scale. Interestingly, all four models indicate a positive association. The models estimate the expected number of farm ponds increase by 10.1% (M1, $p = 0.01$; CI: 2.7%–17.9%), 7.4% (M2, $p = 0.04$; CI: 0.4%–15.0%), 8.8% (M3, $p = 0.02$; CI: 1.4%–16.7%), and 7.7% (M4, $p = 0.03$; CI: 0.6%–15.3%) for a one-unit increase in the number of Scheduled Caste households (i.e., for every additional 1,000 of such households),

holding constant the other variables in the model. The point estimates and interval ranges for both the number of Scheduled Caste households and groundwater development rate (namely, when removing influential observations) appear inconsistent with my qualitative expectations. Further, the large modelled effect sizes for groundwater development warrant more research.

Finally, one relationship – with a negligible and inconsistent effect size – stands in contrast to the qualitative results. The number of wholly unirrigated holdings have a minor effect on the expected count of farm ponds at the sub-district level (M1: -0.12%, $p = 0.88$; M2: -1.1%, $p = 0.22$; M3: 0.1%, $p = 0.92$; M4: -0.7%, $p = 0.42$). The point estimates and interval ranges include positive and negative values. While a source of consistency is the near-zero effect size (M1-M4), the estimates are internally inconsistent and conflict with my inductive observations.

The results can be summarized as such. First, a negative association between the number of marginal landholdings (< 0.5 ha) and the expected number of farm ponds exists (M1: -5.6%, $p = 0.001$; M2: -6.7%, $p < 0.001$; M3: -5.1%, $p = 0.003$; M4: -5.7%, $p = 0.001$). The modelled data indicates a bias against sub-districts with more marginal-sized landholdings. Relatedly, the models estimate a positive association between the number of households with the highest earner making ≥ 10,000/- ($132 USD/month) and the expected count of farm ponds (M1: 6.0%, $p = 0.16$; M2: 6.1%, $p = 0.09$; M3: 5.6%, $p = 0.27$; M4: 5.7%, $p = 0.18$). Despite these point estimates being consistent with my qualitative insights, I recognize the compatible effect sizes range between a modest 4.1% decline to a substantial 16.3% increase (both M3) in the expected count of ponds. A positive association between the number of marginal cultivators (M1: 9.7%, $p = 0.12$; M2: 11.8%, $p = 0.05$; M3: 7.8%, $p = 0.22$; M4: 12.1%, $p = 0.053$) and the anticipated number of ponds is the most compatible estimate given the data and model strategy used. Nonetheless, small negative (-0.14% [M4] to -4.4% [M3]) and large positive effects are also compatible with the data (21.6% [M3] to 25.8% [M4]). Annual average precipitation is negatively associated with the expected sub-district farm pond count (M1: -4.7%, $p = 0.09$; M2: -3.5%, $p = 0.22$; M3: -4.9%, $p = 0.09$; M4: -5.8%, $p = 0.05$). The difference in the breadth and nature of the effect under the model ranges from a sizeable 11.1% decline (M4) to a minor increase of 2.1% (M2) for each additional 100mm of average annual precipitation. Interestingly, sub-districts with an "unsafe" (semi-critical, critical, over-exploited) groundwater development rate are associated with fewer expected farm ponds (M1: -38.3%, $p = 0.03$; M2: -44.3%, $p = 0.01$; M3: -30.1%, $p = 0.15$; M4: -42.1%, $p = 0.03$) as compared to sub-districts with "safe" rates

of groundwater development. Even more surprising, the models indicate the number of Scheduled Caste households (M1: 10.1%, $p = 0.01$; M2: 7.4%, $p = 0.04$; M3: 8.8%, $p = 0.02$; M4: 7.7%, $p = 0.03$) is positively associated with the expected farm pond count at the sub-district scale. **Section 4.6** provides an epistemic framework for categorizing these varied and complex effects for advancing a research and policy action agenda.

4.6. Discussion

The results indicate varying degrees of consistency and divergence from my inductive observations. Given this, how can we reconcile the differences between inductive and deductive results and leverage this cross-scale complexity to advance scholarship and policy-making? Adapting insights from the mixed methods scholarship, I outline four heuristic categories for interpreting the multi-method and multi-scalar set of results above: *Complementary, exploratory, divergent,* and *indeterminate* (Nightingale, 2009; Turner et al., 2017; Morgan, 2019; Fetters & Molina-Azorin, 2018; Uprichard & Dawney, 2019). These categories reflect the empirical data above and, more broadly, the understanding that generalizable results that cohere across methodologies and scales are not always possible. As such, the epistemic framework (**Table 14**) provides guidance on navigating this complexity for advancing research and policy action.

4.6.1 Complementary results

Complementary outcomes register consistent patterns between inductive/qualitative research, and deductive/meso-scale quantitative models. I use Fetters & Molina-Azorin's (2018, p. 12) notion of "complementary" results, which the authors define as "different, nonconflicting interpretations" of broader social-ecological phenomena (also Nightingale, 2009). Complementary results can further be seen as derived from Turner et al.'s (2017, p. 250) concept of "holistic triangulation", wherein the "the objective is to obtain fuller understanding [of the phenomena] through unique insights/perspectives gained from the different research strategies being utilized" – rather than a convergent design, where the employed methodologies are directly interchangeable, analyze the same facet of a research problem, and provide substitutable results (*ibid*; Morgan, 2019, p. 7 on the "original meaning of triangulation"). A complementary result is best exemplified by the effect of land-size on the distribution of farm ponds at local- (household) and meso-scales (sub-district). As discussed, the semi-structured interviews and document

research revealed household land size (≥ 1.5 acres) was an important factor affecting farm pond acquisition. The meso-scale models – integrating this data-driven understanding – found the number of marginal landholdings (≤ 1.25 acres) in a sub-district is negatively related to the expected count of farm ponds. The evidence suggests state support, in the context of farm pond distribution and acquisition, is biased both against marginal landholders *and* marginal landholding regions. I argue complementary results can be used to initiate formal policy challenges on justice-based grounds. The evidence behind this land bias could be used to advocate for the importance of smaller sized ponds available for a wider set of farmers (Kale, 2017), or for structures – and institutional arrangements – on public land that de-link state support from landholding size (Kumar & Saleth, 2018). Importantly, complementary results do not close-the-book on this finding. The results exist in relation to the data collected, the models used, and the limitations associated with both of these facets (Amrhein et al., 2019b). An important limitation in my case is the coarser scale at which land-size and farm pond counts exist; village-scale data could improve these estimates at a more refined scale. These limitations provide impetus for future investigation. Nonetheless, complementary outcomes, when not overburdened by the limitations of the data and modelling approach, represent qualitatively rigorous and statistically powerful results that cohere across social-ecological scales, indicators, and analytical techniques with applications for progressively informing policy.

4.6.2 Exploratory results

Exploratory results have point estimates consistent with qualitative observations, but also have a wider range in the breadth and nature of modelled effect sizes, as compared to complementary outcomes. Specifically, while the point estimates are the most compatible estimates under the data (Amrhein et al., 2019a), the interval values indicate that the modelled range of effect sizes are wider and could reasonably be positive or negative. An exploratory result was best illustrated by the negative effect of annual average precipitation on the expected sub-district farm pond count (M1: -4.7%, $p = 0.09$; M2: -3.5%, $p = 0.22$; M3: -4.9%, $p = 0.09$; M4: -5.8%, $p = 0.05$). While a higher degree of uncertainty exists, the point estimates are consistent with my expectations learned through fieldwork. Exploratory results provide impetus to conduct further analyses to potentially obtain more information about the nature of particular effects. This could include identifying influential observations that affect estimates, or even downscaling the

analyses to re-evaluate the effects of precipitation on the number of approved farm ponds by re-processing secondary data (e.g., overlaying rainfall data [0.05° resolution] with village geo-boundaries, processing village-scale farm pond approval data). In line with Wasserstein et al., (2019), and Amrhein et al., (2019b), exploratory results reject the idea that insignificant *p*-values (commonly, $p > 0.05$) correspond to "no effect" or an effect "unworthy" of reporting. The empirical examples demonstrate concordance with qualitative results while simultaneously attending to the uncertainties identified in the data and modelling strategy that surround these estimates.

Table 13: Regression output from M1-M4. All models report raw coefficient and confidence interval values with percent change figures in parentheses.

	Model 1		**Model 2**		**Model 3**		**Model 4**	
	Coef. (%)	95% CI & *p*-value	Coef. (%)	95% CI & *p*-value	Coef. (%)	95% CI & *p*-value	Coef. (%)	95% CI & *p*-value
Annual average precipitation ('100mm, n = 353)	-0.048 (-4.7%)	-0.103, 0.008 (-9.8%, 0.77%) $p = 0.091$	-0.036 (-3.5%)	-0.092, 0.021 (-8.8%, 2.1%) $p = 0.215$	--	--	--	--
Stage of groundwater development (0= "safe"; 1= "unsafe"; 0 = reference group)	-0.483 (-38.3%)	-0.925, -0.041 (-60.3%, -4.0%) $p = 0.032$	-0.586 (-44.3%)	-1.021, -0.150 (-64.0%, -14.0%) $p = 0.008$	-0.358 (-30.1%)	-0.843, 0.127 (-57.0%, 13.5%) $p = 0.148$	-0.547 (-42.1%)	-1.037, -0.056 (-64.6%, -5.4%) $p = 0.029$
Number of "wholly unirrigated" holdings ('1000 holdings)	-0.001 (-0.12%)	-0.016, 0.014 (-1.61%, 1.4%) $p = 0.877$	-0.011 (-1.1%)	-0.028, 0.006 (-2.8%, 0.7%) $p = 0.22$	0.001 (0.1%)	-0.014, 0.016 (-1.4%, 1.6%) $p = 0.917$	-0.007 (-0.7%)	-0.024, 0.010 (-2.4%, 1.0%) $p = 0.420$
Number of marginal cultivators ('1000 people)	0.0930 (9.7%)	-0.024, 0.210 (-2.4%, 23.4%) $p = 0.12$	0.112 (11.8%)	0.001, 0.223 (0.1%, 25.0%) $p = 0.049$	0.076 (7.8%)	-0.045, 0.196 (-4.4%, 21.6%) $p = 0.219$	0.114 (12.1%)	-0.001, 0.230 (-0.14%, 25.8%) $p = 0.053$
Number of marginal landholdings (< 0.5 ha) ('1000 holdings)	-0.057 (-5.6%)	-0.090, -0.024 (-8.6%, -2.4%) $p = 0.001$	-0.069 (-6.7%)	-0.102, -0.036 (-9.7%, -3.5%) $p < 0.001$	-0.052 (-5.1%)	-0.086, -0.018 (-8.2%, -1.8%) $p = 0.003$	-0.059 (-5.7%)	-0.093, -0.025 (-8.8%, -2.5%) $p = 0.001$
Number of rural Scheduled Caste households ('1000 households)	0.096 (10.1%)	0.027, 0.165 (2.7%, 17.9%) $p = 0.007$	0.072 (7.4%)	0.004, 0.140 (0.4%, 15.0%) $p = 0.039$	0.084 (8.8%)	0.014, 0.154 (1.4%, 16.7%) $p = 0.019$	0.074 (7.7%)	0.006, 0.142 (0.57%, 15.3%) $p = 0.034$
Number of rural households with highest earner ≥ 10,000 Rs./month ('1000 households)	0.058 (6.0%)	-0.022, 0.138 (-2.2%, 14.8%) $p = 0.155$	0.059 (6.1%)	-0.009, 0.128 (-0.9%, 13.6%) $p = 0.087$	0.054 (5.6%)	-0.042, 0.151 (-4.1%, 16.3%) $p = 0.269$	0.056 (5.7%)	-0.025, 0.137 (-2.5%, 14.6%) $p = 0.175$
Number of landholdings ('1000 holdings)	0.012 (1.2%)	-0.013, 0.037 (-1.3%, 3.8%) $p = 0.355$	0.025 (2.5%)	-0.003, 0.053 (-0.3%, 5.4%) $p = 0.079$	0.008 (0.8%)	-0.017, 0.034 (-1.7%, 3.4%) $p = 0.531$	0.020 (2.0%)	-0.008, 0.047 (-0.8%, 4.84%) $p = 0.165$
Number of rural households ('1000 households)	-0.025 (-2.5%)	-0.047, -0.003 (-4.6%, -0.31%) $p = 0.025$	-0.027 (-2.7%)	-0.048, -0.007 (-4.7%, -0.7%) $p = 0.009$	-0.026 (-2.5%)	-0.049, -0.002 (-4.8%, -0.22%) $p = 0.032$	-0.035 (-3.5%)	-0.058, -0.013 (-5.6%, -1.3%) $p = 0.002$
Annual average precipitation ('100 mm, n = 290)	--	--	--	--	-0.051 (-4.9%)	-0.109, 0.008 (-10.3%, 0.8%) $p = 0.09$	-0.059 (-5.8%)	-0.117, -0.001 (-11.1%, -0.14%) $p = 0.045$
N	352		344		290		282	
AIC; BIC	3209.2; 3251.7		3062.2; 3104.4		2650.4; 2690.8		2517.3; 2557.3	

% = percent change in expected count for unit increase in *x* ((e^*b*]-1). A one-unit increase for the person, holdings, and household indicators corresponds as a 1,000 unit increase. A one-unit increase in annual average precipitation corresponds as a 100mm increase.

4.6.3 Divergent results

Divergent outcomes (Nightingale, 2003; 2009) are those where modelling results are inconsistent with field and document research. Other terms include "discordance" (Fetters & Molina-Azorin, 2018) and "diffractive" results (Uprichard & Dawney, 2019). An advantage of divergent results, according to Morgan (2019, p. 9) is "not the differences that [divergence] generates but the opportunities that it provides for investigating those differences" (Nightingale, 2003; 2009; Harris et al., 2017). One example that illustrates divergence is the relationship between the stage of groundwater development and the distribution of farm ponds at the sub-district scale. The campaign explicitly targeted areas with declining groundwater levels; however, the quantitative results consistently indicated sub-districts with "unsafe" (semi-critical, critical, or over-exploited) groundwater extraction rates detract from the expected pond count. Said differently, farm ponds, often functioning as storage sites for extracted groundwater, are positively related to areas with "safe" groundwater development rates – and could constitute an emerging risk to groundwater drawdown in these areas. Divergence does not inherently mean something is wrong with the qualitative or quantitative approaches, but does require the processes responsible for producing these partial knowledges be re-evaluated and re-examined (Uprichard & Dawney, 2019). One immediate step involves examining other proxies of the same variable, or downscaling the experimental unit to determine whether particular relationships hold at more refined scales. Another approach could involve critically re-evaluating inductive processes of knowledge production, such as who was sampled and how particular truth claims may be de-linked from the institutional practices of pond allocation. This could provide justification for specific research questions and methodological approaches, such as institutional ethnography to examine the processes of farm pond distribution. In sum, divergent outcomes provide another opportunity to advance highly specific research questions around particular relationships.

4.6.4 Indeterminate results

Indeterminate outcomes occur when the meso-scale model results remain internally inconsistent and simultaneously conflict with inductive insights developed through qualitative research. Indeterminate refers to the fact that multiple unclear pathways exist in which to better understand the effect of a particular socio-spatial characteristic. In contrast, exploratory and divergent results have clear pathways for advancing knowledge about a given effect. Indeterminate results are

different because their statistical outcomes are unstable across models, indicating potential diagnostic problems that preclude a firmer characterization of the set of results.

Table 14: Epistemological heuristic linking inductive research with deductive regional-scale models.

	Less uncertainty in the modelled effects	**More uncertainty in the modelled effects**
Consistent with inductive results	**Complementary**: Qualitative and quantitative results are entirely consistent with each other. Complementary results should be subject to further interrogation and scrutinization, but also provide a basis for challenging policy on key grounds.	**Exploratory**: Estimates (i.e., coefficient values) are consistent with qualitative observations, but the range of modelled effect sizes are wider in their breadth and nature as compared to complementary outcomes. Exploratory results provide impetus for identifying potentially influential observations or downscaling analytics to re-evaluate associations.
Inconsistent with inductive results	**Divergent**: Results are consistent across the regional-scale models but directly conflict with inductive insights. Divergent results provide impetus for developing hyper-targeted research that could serve as a pathway for policy interrogation.	**Indeterminate**: Indeterminate outcomes are those in which the model results are internally inconsistent while simultaneously conflicting with inductive observations. This may indicate diagnostic problematics, including the possibility for confounding variables and influential observations, or even faults in inductive generalizations caused by inadequate sampling across otherwise diverse villages and regions.

Sources: Nightingale (2003; 2009), Turner et al. (2017), Morgan (2019), Fetters & Molina-Azorin (2018), Uprichard & Dawney (2019).

4.7. Conclusions

This Chapter contributed an integrative methodological and epistemological approach for "scaling-up" political-ecology (Galt, 2010), complementing existing qualitative and descriptive statistics-based approaches (*ibid*; Birkenholtz, 2012). Few have explored how political-ecology's strengths in inductive field-based research can be integrated with the power of meso-scale regression modelling to understand social-ecological patterns and corresponding equity and justice concerns at larger scales. Ironically, what has become apparent is the need for more

careful generalizability in *critical geography* (Castree 2008a,b; Birkenholtz, 2012), and greater attention to nuance in *statistical applications* (Wasserstein et al., 2019). I probed a middle-ground between these calls by using a mixed-methods approach to regionalize political-ecology.

My approach relied on local fieldwork findings to structure secondary data collection and specify meso-scale models which re-analyzed, at larger spatial scales, potentially meaningful relationships between social, economic, and environmental factors and the distribution of water security initiatives. This integrative approach analyzed, through the available secondary data and selected models, how socio-spatial and biophysical characteristics (identified in village-scale and document research) affected the distribution of over 16,000 farm ponds in sub-districts across Maharashtra. By combining and analyzing the qualitative-quantitative data together as multiple partial bodies of knowledge – informed through particular datasets, methodologies and analytical techniques – I intended to advance a more comprehensive (yet, incomplete) understanding of factors affecting the distribution of farm ponds at multiple scales.

Keeping with recent science reform movements, I abandoned the use of *p*-values as the *single* metric for reporting (Wasserstein et al., 2019). My different interpretation of the statistics demonstrates the role of modelling in scaling-up political-ecology is not merely to confirm or deny particular relationships seen "on the ground". Rather, in refusing to dichotomize my results as "significant" / "not significant", different ways in which the quantitative and qualitative results track against each other were revealed beyond a coarse "agree" / "disagree" comparative. The level of compatibility between local- and regional-scale results, outlined through the epistemological framework in **section 4.6**, offered multiple and different research and policy opportunities for advancing knowledge in specific areas.

Of the several notable results, I find evidence for a policy bias against marginal landholding areas (sub-districts) concerning the spatial distribution of ponds, which complements my field-based insights as well as other published studies (Kale, 2017; Phadke et al., 2018). While this raises important concerns about the extent to which this key state-sponsored livelihood adaptation is just and equitable, a broader evaluation of equity should further explore the positive associations identified between the expected farm pond count, and the number of Scheduled Caste households and rural marginal cultivators. Last, a lower number of ponds is associated with sub-districts having "unsafe" groundwater extraction rates, and sub-districts receiving a higher annual mean rainfall. Such associations could contribute to

undermining “safe” extraction rates or be an emerging source of water conflict in drier areas – but need further interrogation. While aggregated analyses have received their fair share of criticism (Liverman, 2018), novel approaches that are more careful – both in how models are constructed and interpreted – can be an important ally of critical geography in advancing a progressive social, economic, and environmental research agenda (Kwan & Schwanen, 2009).

Chapter 5: Conclusions and re-imagining livelihood water security

This dissertation was motivated by the need for problem-driven, solutions-focused, and policy-relevant scholarship on water security for rural livelihoods in the global South. The use of the water security concept has increased exponentially since the 2nd World Water Forum in 2000 (**Figure 1**), as has its application to rural livelihood contexts in the global South (**Figure 3**). In these areas, existing and uneven water insecurities for livelihood activities, undergirded by systemic inequalities, will likely be exacerbated by hydrological stressors. Most of the existing scholarship, however, observes or argues for technical and managerial interventions to modulate either external (e.g., precipitation variability; conflicts at the water-energy-food nexus) or internal risks (e.g., unsustainable water use) that could de-stabilize livelihood activities (**Chapter 2**). **Chapters 3** & **4** empirically demonstrated that advancing technical projects without interrogating *who* and *for what* such interventions serve, can reinforce water insecurities and contribute to maladaptive outcomes. My dissertation has both stressed, and demonstrated the need for, advancing water security in holistic, widespread, and long-term ways. This concluding Chapter summarizes the major conceptual, empirical, and methodological findings and scholarly contributions of each preceding Chapter. It offers three areas for future research, including a set of ambitious avenues for re-imagining livelihood water security, including in the context of the agrarian crisis in India.

5.1 Key findings and contributions

Chapter 2 synthesized how the concept of water security and insecurity is applied to rural livelihoods in the global South – which had remained a significant gap in our understanding. To accomplish this, I analyzed nearly two-decades of English-language peer-reviewed journal articles on the subject (2000-2019; n = 99) using a systematic review methodology. For each publication, I clarified the definition behind water security and insecurity, synthesized the causes and approaches to water-related risks, identified the rural livelihood(s) studied, and distilled where responsibility for addressing water security rested amongst different actors and scales. The Chapter contributes the most comprehensive synthesis to-date of how the water (in)security concept is applied to rural livelihoods in the global South.

The findings first revealed that most publications (69.7%) did not explicitly define water security or insecurity. The absence of a definition is problematic because it precludes an in-depth understanding of what water insecurity is and the extent to which described or prescribed efforts achieve it. In the limited publications that defined the concept (30.3%), water security or insecurity was often framed around outcomes of "adequate" water supplies or "acceptable" water-related risks. I argued for a stronger alliance between the water security concept and pro-poor livelihood perspectives, which will require water security objectives to advance human capabilities for building prosperity (Scoones, 2009) – and not merely mitigating unacceptable risk outcomes (Jepson et al., 2017a). Second, my review revealed that non-agricultural livelihoods, such as labour, aquaculture, and livestock rearing were underrepresented in the included publications. This is problematic because households in the rural global South engage in multiple and diverse livelihood activities (e.g., Ellis, 2000). Neglecting non-agricultural livelihoods excludes particular groups (e.g., landless people) and fails to comprehensively support many more millions who depend on multiple livelihood activities for their food and income security. Last, the review revealed that the majority of publications discussed multiple simultaneous drivers of water insecurity, and solution strategies for water security. This reflects the emerging understanding that water security is shaped by diverse interacting social-ecological dynamics, for which multiple intervention pathways exist. However, technical and managerial responses to proximate drivers of water-related risk outnumbered publications that linked entrenched inequalities to water insecurity. More studies focused on weather- and climate-related stressors (64.7% of publications), water mismanagement and ineffective governance (48.5%), inter-sectoral water competition (36.4%), and water extraction and depletion (32.3%) than on how inequality and power affected water security (20.2%). Only a small subset of articles indicated the need to reduce socio-economic barriers (14.1%), compared to publications focused on increasing water supply or availability (45.5%), efficiency and productivity (38.4%), and varied dimensions of water management and governance (75.8%) – e.g., regulations, planning frameworks, organizational structures, functions, and mechanisms. The literature has, on the whole, not appreciated how entrenched inequities may affect the ability of key advocated water security responses to address risk for all people, nor understood how equity concerns can enable interventions to be re-visited in pro-poor ways – major contributions advanced in **Chapter 3**. Overall, the review recommends future research examine a wider set of rural livelihood systems

in the global South, reflect whether and to what extent interventions are accessible and inclusive, and advance water security initiatives with the objective of improving human prosperity.

Chapter 3 analyzed the equity and sustainability outcomes of Jalyukt Shivar Abhiyan, the $1.3B USD state-sponsored water security program in Maharashtra (India), intended to make 20,000 villages "drought-free" (GoM, 2014) and "water secure" by 2019 (GoM, 2018; Water Conservation Department, 2019). To re-iterate, the objective of Jalyukt Shivar Abhiyan was not to control nature and eliminate significant shortfalls in precipitation (i.e., meteorological drought) but to secure water through harvesting and conservation strategies to prevent agricultural drought – instances where < 50% of a village's crop yield is produced because of precipitation deficiencies.[55] **Chapter 3** contributes to a broad knowledge gap concerning whether and to what extent government-led livelihood adaptation and transformation programs create equitable and sustainable impacts in climate variable systems (*viz.* Olsson et al., 2014). Nested within this broader knowledge gap, few have critically evaluated the equity and sustainability impacts from integrative land and water interventions as an adaptation and transformation mechanism, even as they increasingly become part of government programs (e.g., Taylor & Bhasme, 2020) – a second contribution made. Understanding why and how these interventions failed to resolve critical security challenges in Maharashtra, especially for the poor, can inform the design and planning of related interventions elsewhere and potentially reduce the likelihood of repeating deficiencies.

To accomplish this, I conducted a multi-sited empirical analysis to understand who, what, and how implemented water conservation initiatives benefited residents in three villages well-served by Jalyukt Shivar. I found state interests to demonstrate villages as "drought-free" affected the character and implementation of the campaign. Namely, the objective of raising aggregated village water availability was largely advanced through drainage-line and waterbody initiatives instead of a more balanced watershed development approach. Through 94 interviews,

[55] In recent years, the state government has blamed agricultural drought on significant departures in rainfall (i.e., meteorological drought), effectively suggesting it is not possible to protect villages from drought if there is *no rain*. Critics, like Bhadbhade et al., (2019) have questioned the logic behind drought-relief interventions that *depend* on water. The government's position is Jalyukt Shivar is designed to protect villages from certain instances of agricultural drought, namely, moderate shortfalls in precipitation or variability – not significant meteorological droughts. This directly illustrates the tensions in how environmental hazards are categorized and the role of the state in directly mediating them.

inclusive of individual and focus-group meetings, with key informants and households in three drought-prone villages, I found the campaign's implementation: i) limited the potential impact of water conservation; ii) excluded residents, including historically disadvantaged groups, who did not possess key endowments and entitlements needed to acquire benefits associated with drought-relief initiatives; and iii) fueled additional groundwater extraction, undermining water conservation efforts. The Chapter examined the framing, implementation, and linked equity and sustainability effects of the Jalyukt Shivar campaign, as scaled-out by the state government, and concluded villages as a whole cannot be considered "drought-free" or drought-resilient unless water conservation benefits are widespread, accessible, and long-term. That is, the reality of resisting agricultural drought may not be experienced by many residents even where villages may have prevented, on an aggregate scale, significant yield declines and been formally classified as "free" from drought in a given season. The general indication, however, is that even with these considerable investments, drought remains a recurrent seasonal risk for thousands of villages across the state (Bhadbhade et al., 2019). In the 2017 wet season alone, 37% (14,679) of the state's villages produced < 50% of their standard crop yield meeting the formal definition of "drought-affected" (Jamwal, 2018). The next wet season, 2018, saw nearly one-third of the state's sub-districts experience severe drought where > 60% of crops were damaged (Malik, 2018). A critical reason why many villages served by the campaign steadfastly continue to report significant seasonal crop declines, and were thus formally considered drought-affected, is because the conditional, inequitable, and extractive nature of water conservation and use did not benefit all agricultural livelihoods.[56] Where the limited scholarship on Jalyukt Shivar has emphasized deficiencies related to poor quality of work, the contractor-driven nature of the program, and the supply-oriented nature of initiatives (Bhadbhade et al., 2019; Kale et al., 2019), I connected the uneven social-ecological outcomes to the broader governance structures and political contexts through which the purposes and objectives of drought-relief infrastructure were established and implemented.

[56] The scheme was ridiculed as a "Jholyukt Shivar Abhiyan" ("scam-ridden campaign" instead of Jalyukt Shivar Abhiyan ["waterful or water-plentiful campaign"]) by opposing political parties because it primarily served the contractor-lobby while failing to increase and conserve water to eliminate drought for vulnerable villages (HT, 2020; Chari & Sharma, 2016).

Chapter 2 argued a focus on technical and institutional interventions may not reflect whether and to what extent water security interventions are accessible. **Chapter 3** empirically demonstrated this conclusion, revealing how the single focus of increasing water availability occludes how potential benefits are distributed, whether or not water use is sustainable in the long-term, and whether households facing disproportionate risks – including to the foundations of their food and basic income security from a single inadequate monsoon – are able to become "drought-free". The case affirms that normative visions, such as advancing "drought-freeness", can reproduce unequal and potentially maladaptive outcomes based on who decides how the objectives are defined and met (e.g., Shah et al., 2018). The Chapter highlights the need to integrate access and sustainability considerations into the design and planning of adaptation and transformation programs.

Chapter 4 explicitly recognized the challenge of using situated and locally-based research as an evidentiary basis for informing and reforming state level programs, such as Jalyukt Shivar. Critical environmental social scientists, who frequently engage in meticulous and place-based empirical research, are often unable to substantively inform policy-makers, who rely on data patterns scaled to the region (e.g., Walker, 2003; Castree, 2008a,b; Birkenholtz, 2012). **Chapter 4** contributed a transferable methodological and epistemological approach for "scaling-up" (Galt, 2010) place-based empirical research to explain distributive patterns, including concerns of inequity, behind water security initiatives at larger policy-relevant scales.

To do so, I used the context-specific and multi-sited fieldwork findings to structure secondary data regression models that re-analyzed, at larger spatial scales, potentially meaningful relationships between social, economic, and environmental factors and the distribution of one major initiative under Jalyukt Shivar discussed in **Chapter 3** – farm ponds. As part of this, I obtained relevant secondary data available at the sub-district level, including groundwater reports; long-term annual average precipitation; demographic and income data; land and agricultural data; and data on the number of approved farm ponds (2015-16). Where political-ecologists (e.g., Galt, 2010; Birkenholtz 2012) have advanced related methodological approaches, none have demonstrated how political-ecology's strengths in inductive field-based research can be integrated with meso-scale statistical modelling to understand broader resource distribution patterns, and corresponding equity and justice concerns associated with specific

programs.[57] This is partly because of the criticisms levied by political-ecologists against quantitative, namely statistical analyses. **Chapter 4** not only integrates statistical analyses into the set of analytical approaches but does so in a way that explicitly rejects the notion that statistical results supersede qualitative findings as objective relationships reflective of an external reality "out there" (Amrhein et al., 2019; Wasserstein et al., 2019). Instead, I compared – on equal footing – the modelled coefficient direction, effect size, and confidence intervals with the local, qualitative research findings. This enriched the ways in which quantitative and qualitative results gelled or diverged from each other, which extends beyond "agreeing" or "conflicting". The novel interpretation of multiple datasets yielded an epistemic contribution, in that qualitative (e.g., household/village-level) and quantitative results (e.g., meso-scale) at multiple social-ecological scales can cohere, remain exploratory, or be inconsistent with one another. The degree of compatibility between results offers different pathways for policy research, including advancing claims where findings cohere, or outlining targeted research areas that could serve as a pathway for future policy interrogation. Thus, the Chapter contributes a methodologically and epistemologically plural approach to "scaling-up" (Galt, 2010) research rooted to the local level, ultimately deriving a more comprehensive, yet nuanced, understanding of water security initiatives and indicators of equity, justice, and sustainability at multiple scales.

5.2 Limitations

There are some important limitations of this work, which are discussed within each Chapter, and summarized here. In **Chapter 2**, I analyzed English-language peer-reviewed journal articles published between January 2000 and mid-September 2019. There are several limitations associated with this scope of analysis. First, the inability to include non-English refereed scholarship is an unfortunate limitation that reinforces the English-language production and synthesis of knowledge. A more diverse subset of relevant scholarship could have yielded new or complementary insights, or be used to compare and interrogate concepts, namely water security,

[57] Statistical analyses concerned with equity and indicators of water security (e.g., Deitz & Meehan, 2020), the gendered nature of natural disasters (Neumayer & Plümper, 2008), and agricultural adaptation (Shah et al., 2019), all of which can be classified as political-ecological *approaches*, explore specific associations of interest informed by secondary empirical research. These studies do not conduct their own primary empirical research on a specific policy or program and attempt to scale-up that knowledge byway of statistical approaches.

derived and implemented in the English-language literature. This is an important area for future research in order to de-stabilize and further inform the discourse and ontology around water governance, more broadly. Second, the grey literature (e.g., working papers, policies, reports) was not examined. The enlarged scope of work (e.g., different inclusion strategy) and methodological challenges (e.g., replicability) were important but not the primary concerns for excluding the grey literature. Instead, the Chapter recognized the scholarly literature assessed was largely conducted with the objective of informing evidence-based decision-making and policy. The purpose of the review was to understand how this peer-reviewed scholarship – which is multi-disciplinary, empirical, and often linked to normative claims around policy-making – was defining and advancing water security. Future research could examine how the concept is defined and applied by government and non-governmental bodies – adding significant depth and nuance to the results presented in **Chapter 2**. Further, additional research could explore the extent to which implemented policies in practice reflect current and evolving trends in the water security and livelihoods scholarship. Last, I was the sole individual responsible for reading and coding each included article. The systematic review methodology recommends more than one-person review how the articles were coded to reduce coding bias. However, without additional funding or a larger study team, this became a limitation. To reduce concerns, I instituted a self-developed quality-control protocol during and after the coding process. First, the drivers of water insecurity and strategies for addressing water security were both deductively and inductively coded for each article. This enabled redundancy to be built into the analysis for key questions related to the causes and solution strategies for water (in)security. Second, key attribute data and substantive codes for each article were double-checked after the initial coding process.

The research in **Chapters 3** & **4** was focused on water security in the context of precipitation variability and shortage. Future efforts should examine how livelihoods are impacted by, and can be protected from, floods and extreme weather events, such as hail storms. This will provide different insights for enhancing livelihood water security, more broadly. Next, household-level research was limited to three villages. I recognize the possibility that villages in other areas of the state could reveal different outcomes about the effects of the program, or enrich those described. That said, I maintain that my findings are not an artifact of a single village context because villages were selected with different climatic and agro-ecological contexts. Further, I contend that these findings are not limited within one district because key

informant interviews revealed experiences with the campaign in Eastern and Western Maharashtra that corroborated key findings in the three villages sampled. Finally, I limited the discussion around the impacts of the campaign to "productive" (livelihood) water uses and did not thoroughly engage with the drinking water component of Jalyukt Shivar Abhiyan. I suggest, however, many findings around the harvesting and conservation of water similarly apply to the drinking water context based on where groundwater was conserved and who it was made available to. Indeed, each village sampled was heavily reliant on importing drinking water after around February (i.e., the mid-point in the dry season) despite the set of drought-relief interventions completed. Nevertheless, I accept that a more explicit focus on the drinking water component could have yielded additional insights, including how decisions over a limited amount of water may result in trade-offs between livelihood and domestic/drinking water uses.

In **Chapter 4**, the different temporal periods of collection between the dependent (farm pond count per sub-district) and the multiple agricultural, demographic, and hydrological independent variables remains an unmitigated limitation. Recent data, such as on sub-district groundwater reports or agricultural landholding patterns, that align with the data for the farm pond variable would render a more temporally accurate analysis. However, this remains a known challenge in collating and using multiple sources of secondary data. Further, the dependent variable data was associated with the initial year of the campaign (2015-16). It is possible that certain relationships, such as sub-district level rainfall, may weaken if future analyses examined data post-2016. This is because Jalyukt Shivar prioritized the most impacted drought-prone villages first. Nevertheless, my work provided a critical introduction into exploring the distribution of a key water security and climate adaptation intervention across Maharashtra.

5.3 Post-script & future research

In December 2019, Maharashtra state's flagship "drought-free" program, Jalyukt Shivar Abhiyan, concluded. The newly in-power Maha Vikas Aghadi (MVA) alliance – a coalition between the National Congress Party, Indian National Congress, and the Shiv Sena – chose not to expand or continue the program (Deshpande, 2020; Khan, 2020). Looking ahead, the impacts of climate change (TERI, 2017) and new central[58] and state government guidelines curtailing

[58] The central government will only support "severe" droughts, determined using a set of indices (GoI, 2016). These are considered to occur once every 10-15 years (Jamwal, 2018).

financial relief for drought-affected villages will exacerbate water insecurity impacts for livelihoods across the state (Jamwal, 2018; GoI, 2016; GoM, 2017). Notably, the government of Maharashtra recently replaced the traditional agricultural drought framing (< 50% village crop yield produced) with a complex set of indices measuring rainfall deficit, area sown, vegetation loss, soil moisture, and groundwater levels (summarized in GoM, 2017; Jamwal, 2018). The most significant change was that drought can only be classified, and assessed for villages, if significant shortfalls [59] in the total monsoon precipitation occur (*ibid*). This is problematic because wet season agriculture in Maharashtra is especially susceptible to precipitation *variability* – a core problem Jalyukt Shivar aimed to, but failed, in effectively addressing. Under the new guidance (GoM, 2017), villages not experiencing a major departure in total precipitation amount[60] during the monsoon will not be declared drought-affected even if that precipitation falls in an uneven manner (e.g., within a matter of weeks) resulting in crop loss (Jamwal, 2018). This was the case in 2017's wet season, when just 4% (or 300) of the villages that reported < 50% crop yield (i.e., "drought-affected") received financial support from the state government (see TNN, 2018). The implications are that thousands of villages will be left unrecognized as drought-hit and financially unsupported by both state and central governments in the future (*ibid*; Jamwal, 2018). The inequitable outcomes of the campaign coupled with these anti-welfare policy decisions demonstrate a major need for a more inclusive and sustainable models of water security in order to protect livelihoods and villages from precipitation variability. Below, I outline three areas of future research to advance livelihood water security. These areas, specific to but relevant beyond the Maharashtra case, will deepen our understanding of the equity and sustainability effects at multiple scales associated with similar water security interventions; clarify how such water conservation initiatives, intended largely for consumptive agricultural use, affect linked resource-based livelihoods; and theorize and advance action-oriented initiatives to advance water security in ways that extend localized technical interventions.

[59] < 50% of the total average rainfall (June and July) or if the average rainfall during the monsoon period from June to September is < 75% (GoM, 2017).
[60] Inverse of *ibid*.: >50% of total average rainfall (June and July) and > 75% (June-September).

5.3.1 Impacts of water conservation on "drought-freeness" in linked villages

First, I analyzed how Maharashtra's integrative water conservation campaign advanced equity and sustainability in livelihood water access and use *within* three villages. Key informants expressed, in their own assessment of the campaign, that the scaling-up of water conservation impacts water availability in villages sharing surface and subsurface flows. For example, the emphasis on drainage-course and waterbody structures created the potential for upstream-downstream conflicts (e.g., Government official #4, Feb. 27, 2018; Key informant #11, Mar. 23, 2018). One watershed development expert emphasized that farm ponds in a particular village they studied were appropriating significant portions of baseflow resulting in downstream reductions in water availability (Key informant interview #18, Apr. 20, 2018). These observations indicate how the intensification of water conservation and use at one scale can reverberate to undermine water availability elsewhere. My sampling strategy was not designed to explore these potential cross-scalar impacts and would have required villages to be selected based on their dependency on shared surface and subsurface flows. Assessing the potential for adverse impacts that exacerbate livelihood vulnerability ("maladaptation", Barnett & O'Neill, 2010), including how these impacts are distributed and felt in linked systems, and identifying suitable mechanisms to reduce these externalities, will be needed to advance livelihood water security at multiple scales if such conservation efforts continue to be characterized as needed (Rockström & Falkenmark, 2015).

5.3.2 Impacts of water harvesting and conservation on non-agricultural livelihoods

Second, the empirical research was conducted largely, but not exclusively, with households engaged in agricultural production. This was because a key objective of the drought-relief campaign was to reduce or eliminate agricultural drought resulting from precipitation variability and shortfalls. As such, I was interested in determining who was served and under what conditions benefits were accessible in villages that had been ostensibly advanced or transformed into "drought-free" systems. Further, certain interventions such as farm ponds were used exclusively for agriculture – not for other livelihood uses. Nevertheless, we also interviewed households, including landless peoples, who engaged in agricultural labour, animal husbandry, and/or off-farm activities to develop an understanding of water access concerns and how, and to what extent, the campaign served their needs. These households either depended on the water

security of others (i.e., in the case of landless agricultural labourers), had relatively lower intense water needs (e.g., livestock, stone-work), or engaged in livelihoods disconnected from a reliance on groundwater (e.g., restaurant workers). Future research should explicitly investigate, in detail, how other resource-based livelihoods are directly or indirectly affected through these water security interventions. For example, one key informant stated the excavation, damming, and abstraction of water from streams affected environmental flow requirements for fisherfolk in linked hydrological systems (i.e., a direct effect of the village initiatives) (Key informant interview #15, Apr. 07, 2018). Another concern is how agricultural labour demands may have shifted as a result of increased cultivation of water-intensive crops in drought-prone villages (i.e., an indirect effect). A broader livelihood analyses will clarify how other resource-based livelihoods, especially held by landless peoples (fisherfolk, labour, herders), are affected by the water security initiatives intended to support landed peoples and crop production. As such, it will contribute a deeper equity analysis with a focus on under-studied livelihoods (*viz.* **Chapter 2**).

5.3.3 Re-imagining livelihood water security approaches for drought-preparedness

Advancing a comprehensive, widespread, and long-term approach to livelihood water security is imperative in the context of climate change and regressive drought-relief policies that curtail government support for drought-affected areas. Using the livelihoods framework, I propose three interlocking strategies to advance livelihood water security – accompanied by areas for future research. They expand on the recommendations provided in **Chapter 3** for Jalyukt Shivar, which emphasized the need for a targeted livelihood approach instead of raising the aggregated water volume in a village, and on understanding the objectives and design principles of policies – including what is being implemented and who can access such initiatives – rather than relying on the technical merits for informing water security strategies. Further, my propositions engage directly with the institutional structures productive of the agrarian crisis – a context that has not sufficiently informed water security approaches to-date in Maharashtra.

Briefly, it is important to distinguish between what Reddy & Mishra (2010) have called the "agricultural crisis" and the "agrarian crisis" – while recognizing their simultaneous and reinforcing natures (*ibid*). The "agricultural crisis" is concerned with how the (in)accessibility of inputs (e.g., irrigation, credit, technology) and emerging social-ecological threats (e.g., peri-urbanization, land productivity, climate change) affect crop production (*ibid*). The "agrarian

crisis" is characterized by the systemic social and economic structures of neoliberalism, which have accreted onto historical institutional failures of land reform, to exacerbate social and economic distress (*ibid*). The shift from the state to the market has increased agricultural costs, reduced profitability – including through the de-regulation of commodity prices – shrunk public expenditure in agriculture, and intensified informal and high-interest rural credit markets (e.g., *ibid*; Vasavi, 2009; Ramcharandran & Swaminathan, 2004; National Commission of Farmers Report, 2006). The recent Farm Laws passed by the central government threaten to expand the de-regulation of agricultural produce pricing across India.[61] Mohanty (2005; 2013) and Vasavi (2009) argue neoliberalism entrenched "individualism". State withdrawal combined with the high-cost and profit-oriented livelihood approach has resulted in social disintegration and increased the pressure on individuals and their sense of ownership and responsibility over their own agricultural crises (Mohanty, 2005). Although crop failure ("agricultural crisis") is widely cited as the cause behind the thousands of farmer suicides each year in Maharashtra [62], it is the "agrarian crisis" (Reddy & Mishra, 2010) and its entrenchment of economic despair and social individualism that underlie these tragedies (Mohanty, 2005; 2013).

Water security approaches have focused on addressing the "agricultural crisis" through supply-oriented strategies, demand-reduction, and mechanisms and regulation around water use (**Chapters 2** & **3**). The same holds for Jalyukt Shivar, whereby water conservation strategies aimed to secure water in villages to reduce agricultural drought (**Chapters 3** & **4**). Scholars have had considerably less to say about the relationship between the agrarian crisis and livelihood water security, and the potential for efforts that scale-back neoliberalism to support water security. In this concluding section, I argue water security can be made more widespread and longer-lasting if situated within both the agricultural and the agrarian crisis. To this end, I outline a broader water security approach and indicate corresponding areas for future research.

Defined in the preceding Chapters, peoples' assets (capitals) and capabilities underpin their livelihood activities (Chambers & Conway, 1992; Bebbington, 1999). Capital indicates a multi-dimensional and reinforcing set of human (e.g., labour, skills, knowledge), social

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[61] Farmers are concerned the 2020 Farm Laws will enable the Central government to de-regulate agricultural prices and potentially disband the Minimum Support Price in APMCs (government sponsored markets) for certain staple crops.
[62] From 1995-2016, 69,406 farmers in Maharashtra committed suicide.

(networks and relationships), biophysical (e.g., natural resources), physical (e.g., infrastructure), and financial assets (i.e., monetary, liquidity) (Scoones, 1998). It reflects what Sen (1981) called "endowments" – the assets and resources one possesses (Leach et al., 1999). The extent to which farmers can combine their endowments (capitals) to acquire water, or another good, depends on the rights and opportunities they have – what Sen (1981) referred to as "entitlements". Both endowments (e.g., land size, land location, financial capital) and entitlements (e.g., rights, opportunities) are socially differentiated and reflect the legal, customary, and economic structures through which property, relations, and social citizenship have been shaped (e.g., Watts & Bohle, 1993; Ribot, 2014). Ultimately, people have different entitlement sets, which shape livelihood *capabilities* (Leach et al., 1999) – defining what they can be, do, and achieve for and through their livelihood (*ibid*; Chambers & Conway, 1992; Bebbington, 1999). In the context of social-ecological stress, capabilities could include being "able to respond to adverse changes in conditions [and]… also [being] proactive and dynamically adaptable" (Chambers & Conway, 1992, p. 4). The most important empirical insight from the Jalyukt Shivar case was that certain people, including historically disadvantaged residents, did not possess critical endowments (e.g., financial capital, land size, land location) or entitlements (e.g., decision-making influence, water access rights) to affect the planning or design of the campaign or directly benefit from water availability initiatives for their livelihoods. In other words, many people did not possess the *capabilities* – a reflection of their endowment and entitlement structure – to be "drought-free" within the political design and architecture of the campaign.

Learning from my case and the ideas above (Sen, 1981; Chambers & Conway, 1992; Scoones, 1998), livelihoods can become **capable** of being water secure in drought contexts when they hold the necessary **endowments** (e.g., natural, hydrological, physical, financial, social capital), and **entitlements** (e.g., rights and opportunities) to acquire and use specific forms of water to avoid unacceptable risks, meet context-specific needs, and achieve self-defined aspirations associated with their activities now and in the future. **Figure 13**, an adaptation of Chambers & Conway's (1992, p. 7) schematic of livelihood components and flows, summarizes the approach for broadening initiatives like Jalyukt Shivar to enhance water security.

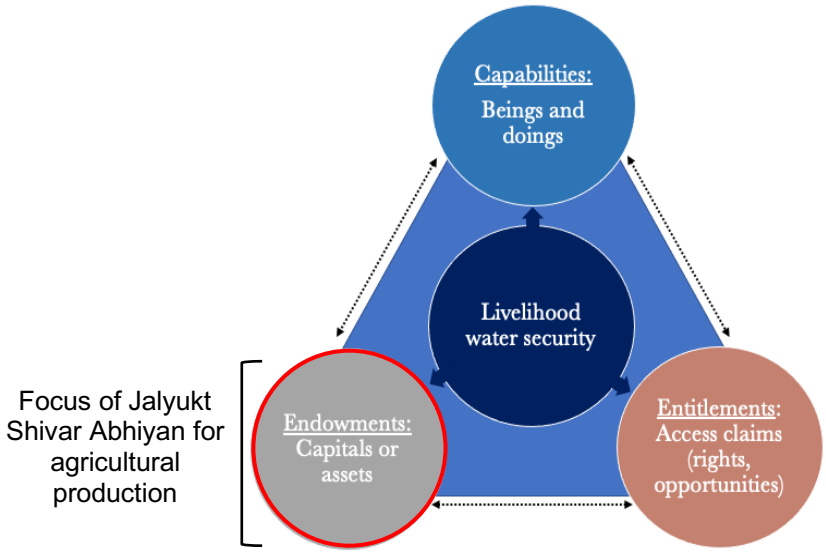

Figure 13: Advancing livelihood water security. Source: Adapted from Chambers & Conway (1992, p. 7) using concepts from Sen (1981, 1999). The red circle represents the only focus of the Jalyukt Shivar Abhiyan campaign.

A more focused set of interventions at the village-scale can improve livelihood water security. The most immediate involves re-framing, not abandoning, technical water harvesting initiatives. To be clear, the case of Jalyukt Shivar should not be read as one where technical initiatives are inherently flawed. Instead, the uneven social-ecological outcomes observed in Maharashtra reflect design and implementation concerns of who was included in decision-making processes, how infrastructures were planned and where they were sited, and whether and to what extent people could and could not access them to serve their agricultural livelihood activities. I argue technical interventions should seek to build individual water endowments explicitly linked to livelihood activities – and not merely raise the aggregated water storage. These efforts should prioritize disadvantaged households who may be excluded from efforts that build aggregated water endowments and consequently face disproportionately [63] larger impacts from precipitation shortfalls or variability (e.g., food insecurity, debt bondage, dangerous work). Here, in-situ interventions (i.e., soil moisture conservation, small-size ponds, evaporation management) that raise hydrological endowments, even by marginal absolute levels, can reduce instances of crop failure in the wet season for many farmers without a reliable irrigation source (e.g., for other

[63] A disproportionate risk can be defined as the probability of experiencing adverse human insecurity outcomes – such as food insecurity, unsafe livelihood activities, and economic bondage (UNDP, 1994) – that are not proportional (i.e., linear) to the social-ecological stressor.

recommendations, see Kale, 2017; Bhadbhade et al., 2019). This re-framing will necessitate significant re-distributions in power from small groups of powerful individuals within villages towards communities as a whole to shape intervention planning and objectives. Thus, entitlement-building (rights and opportunities) will be imperative for improving individual water endowments (**Figure 13**).

A second approach to advance widespread and sustained water security will involve village-scale agreements around water-use and water sharing. These institutional agreements have a rich history in Maharashtra and especially in Pune District with the advent of *pani panchayats* (water villages) – a community-established set of rules for re-distributing and sustainably using the common-pool resource of groundwater (Thakur & Pattnaik, 2002; cf. Ostrom, 1990). While technical interventions that incrementally raise green and blue water endowments can reduce the potential for unacceptable outcomes (i.e., crop failure), local institutions that regulate water use and enact sharing arrangements can preserve and re-distribute large stocks of water to further protect livelihoods from precipitation variability, meet basic needs, and support livelihood aspirations for a large number of people. It can also support beneficiaries who do not benefit directly from water conservation interventions (e.g., landless people). Local institutions, when forged between communities, can further support efforts to mitigate potential cross-scalar hydrological risks, which may otherwise undermine livelihood and domestic water security in neighbouring and distant places (**section 5.3.1.**).

Third, agricultural institutions that characterize the neoliberal political-economy must be re-imagined for livelihood participants to pursue widespread and long-term water security. This is an emerging space for advancing water security, given technical efforts have remained disconnected from institutions productive of the agrarian crisis. Major actions argued by the National Commission on Farmers (2006) report for addressing the agrarian crisis involve inclusive agricultural extension services, affordable access to institutional credit, enhancing remuneration for crops that are of a lower water intensity, and improving off-farm livelihood opportunities. Policies in India have advanced water security for agriculture by developing large-scale and micro-irrigation schemes for efficient use (Shah & Narain, 2019). They rarely recognize how extension, credit, commodity pricing, and off-farm economic opportunities can not only directly and indirectly build water entitlements but as Bebbington (1999) argued, challenge the fundamental structures under which water is circulated and distributed in

communities. For example, including small and marginal farmers into extension services and subsidy programs that often privilege upper caste and big farmers can enhance their technical knowledge. Low-interest formal credit can enable households to pursue, in a safer manner without considerable risks (Mohanty, 2005), opportunities for raising water endowments. Providing higher prices for lower water-intensive crops (e.g., food staples) or creating a floor price for a broader set of agricultural products (e.g., vegetables) can provide livelihood pathways for households that are remunerative and less-water intensive. Building off-farm or non-farm livelihood activities can help livelihoods de-link from water-related risks, or build their capabilities for acquiring the water they need and want to support their livelihood aspirations. Where current efforts secure water *for* agriculture (i.e., "agricultural crisis"), a focus on the agrarian crisis can shift the dial from technical approaches that alleviate impacts of climate variability, to those that foreground how institutional structures at multiple scales detract from the ability for people to acquire and access water.

All three areas of water security are underexplored and require, as a whole, considerable research. For one, while Maharashtra has a rich history of decentralized water institutions that decide how water is collectively managed and used, a richer understanding of how collective resource management bodies can be advanced, situated within a political-economic context of water use, is needed. Part of this challenge will involve shifting the dominant public perception of groundwater from a *de facto* private right linked to land to a publicly shared common-pool resource (e.g., Kumar & Saleth, 2018). Considerably more research that determines how perceptions around groundwater ownership can change will be helpful – for without this, institutional arrangements will likely encounter significant resistance from the most powerful sects of village society. Further, and relatedly, the strategies above will involve a fundamental re-distribution of resources and power at the village-scale concerning how resources are regulated, used, and shared. Advancing representation and power in decision-making will not be possible without sustained anti-caste movements, education, and activism from researchers, NGOs, and government. Interveners must commit to identifying and unequivocally safeguarding the interests and wellbeing of disadvantaged groups, especially lower caste women, in any and all adaptation and transformation efforts. Last, applied research must explore linkages between broader institutional reforms in inclusive extension, formal credit, and remunerative prices and water and human security. Overall, academics concerned with historically-framed "resource-

based" problems, e.g., water security, must consider how they can learn from, and advance in their own work, broader anti-caste, anti-oppression, and anti-neoliberal movements.

5.4 Summary and conclusion

This dissertation contributed to a growing body of water security research, which has largely focused on domestic and drinking water, and neglected productive water needs – a critical concern in global South regions. It critically analyzed scholarly and state-driven efforts to advance livelihood water security in rural global South contexts, with a specific focus on water security adaptations to drought in rural Maharashtra. More precisely, it a) undertook a systematic scoping review of the English-language refereed scholarship to ascertain how water insecurity for rural livelihoods in global South contexts is conceptualized and addressed; b) conducted an empirical and multi-village analysis of the equity and sustainability effects associated with an over $1B USD water security program (Jalyukt Shivar Abhiyan) in Maharashtra state, India, intended to transform villages and agricultural livelihoods into "drought-free" systems; and c) developed an integrative methodological and epistemological approach to analyze dynamics affecting the distribution of livelihood water security initiatives at larger, policy-relevant scales. This research was informed by an extensive review of scholarly research; field observations and ninety-four (94) interviews, including individual and focus-group meetings with key informants and households in three drought-prone villages; and statistical analyses of secondary climate, agricultural, demographic, and water security data in Maharashtra.

In Maharashtra, and certainly elsewhere, the assets, capabilities, and livelihood activities of historically disadvantaged groups – including lower caste households, women, marginal farmers, and landless peoples – are and will continue to be disproportionately impacted by climate and related social-ecological change. As I demonstrated, particularly in **Chapter 3**, historical and active social and economic marginalization has affected where people live, to what extent they can participate in decision-making forums, and whether such groups could reasonably benefit from water security initiatives relative to more privileged sects. In response to these growing concerns at the interface of environment and inequity, my dissertation has advanced knowledge of how water (in)security for rural livelihoods is conceptualized, analyzed, and promoted in both scholarly and applied contexts in the rural global South, stressed the importance of advancing water security in holistic, widespread, and long-term ways, and

identified key considerations to support this approach. Outside of the objectives and context-specific contributions made in each Chapter, I empirically demonstrated that efforts to improve water security in contexts of climate variation will not result in widespread, accessible, and long-term benefits – and can even work against these objectives – if entrenched social, economic, and political inequalities are sidelined. I hope that the contributions made here will be used as a basis for reconsidering the overtly technical and de-politicized approaches to water security in India (Shah & Narain, 2019) and elsewhere. To do so would translate into significant improvements for the lives of marginalized peoples, who stand to face the most pronounced impacts from climate-related change dynamics. Finally, I explicitly recognized, from the outset, that the role of academics has shifted from independent observers to active political partners, participants, and co-contributors of change. I hoped to have lived up to this role through my critical examination of refereed scholarship, explicit problem-oriented and policy-focused objectives, and methodological innovation in support of an equity-oriented and sustainable approach to water security for rural livelihoods.

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Appendices

APPENDIX A: Search string criteria used for each database.

Database	Search string
Web of Science	TOPIC: (((secur* NEAR/5 water) OR (secur* NEAR/5 “water access”) OR (secur* NEAR/5 “access to water”) OR (secur* NEAR/5 “water management”) OR (secur* NEAR/5 “management of water”) OR (secur* NEAR/5 “water resource* management”) OR (secur* NEAR/5 “water governance”) OR (secur* NEAR/5 "governance of water") OR (secur* NEAR/5 "water allocation*") OR (secur* NEAR/5 "allocation of water*") OR (secur* NEAR/5 "water efficien*") OR (secur* NEAR/5 "water provision*") OR (secur* NEAR/5 "provision* of water") OR (secur* NEAR/5 "water distribution*") OR (secur* NEAR/5 "distribution* of water") OR (secur* NEAR/5 "water connection*") OR (secur* NEAR/5 "connection* to water") OR (secur* NEAR/5 "water suppl*") OR (secur* NEAR/5 "suppl* of water") OR (secur* NEAR/5 "water amount*") OR (secur* NEAR/5 "amount of water*") OR (secur* NEAR/5 "water qualit*") OR (secur* NEAR/5 "qualit* of water") OR (secur* NEAR/5 “water right*”) OR (secur* NEAR/5 “water storage”) OR (secur* NEAR/5 “water conservation”) OR (secur* NEAR/5 “conservation of water”) OR (secur* NEAR/5 “water availabilit*”) OR (secur* NEAR/5 “availabilit* of water”) OR (secur* NEAR/5 “water demand”) OR (secur* NEAR/5 “water level*”) OR (secur* NEAR/5 “level* of water”) OR (secur* NEAR/5 “water flow*”) OR (secur* NEAR/5 “flow* of water”) OR (secur* NEAR/5 “water quantit*”) OR (secur* NEAR/5 “quantit* of water”) OR (insecur* NEAR/5 water) OR (insecur* NEAR/5 "water access") OR (insecur* NEAR/5 "access to water") OR (insecur* NEAR/5 "water management") OR (insecur* NEAR/5 "management of water") OR (insecur* NEAR/5 "water resource* management") OR (insecur* NEAR/5 "water governance") OR (insecur* NEAR/5 "governance of water") OR (insecur* NEAR/5 "water allocation*") OR (insecur* NEAR/5 "allocation of water*") OR (insecur* NEAR/5 "water efficien*") OR (insecur* NEAR/5 "water provision*") OR (insecur* NEAR/5 "provision* of water") OR (insecur* NEAR/5 "water distribution*") OR (insecur* NEAR/5 "distribution* of water") OR (insecur* NEAR/5 "water connection*") OR (insecur* NEAR/5 "connection* to water") OR (insecur* NEAR/5 "water suppl*") OR (insecur* NEAR/5 "suppl* of water") OR (insecur* NEAR/5 "water amount*") OR (insecur* NEAR/5 "amount of water*") OR (insecur* NEAR/5 "water qualit*”) OR (insecur* NEAR/5 "qualit* of water”) OR (insecur* NEAR/5 “water right*”) OR (insecur* NEAR/5 “water storage”) OR (insecur* NEAR/5 “water conservation”) OR (insecur* NEAR/5 “conservation of water”) OR (insecur* NEAR/5 “water availabilit*”) OR (insecur* NEAR/5 “availabilit* of water”) OR (insecur* NEAR/5 “water demand”) OR (insecur* NEAR/5 “water level*”) OR (insecur* NEAR/5 “level* of water”) OR (insecur* NEAR/5 “water flow*”) OR (insecur* NEAR/5 “flow* of water”) OR (insecur* NEAR/5 “water quantit*”) OR (insecur* NEAR/5 “quantit* of water”)) AND ((livelihood* OR farmer* OR irrigator* OR farming OR agricultur* OR horticultur* OR livestock OR "fish pond" OR "fish farm*" OR fisher* OR aquacultur* OR herder* OR herding OR pastoral* OR “farmwork*” OR “farm worker*” OR labourer* OR laborer* OR “agricultural worker*” OR “animal husbandry”)) AND (("global south") OR ("third world") OR ("underdevelop*") OR (country NEAR/3 "developing") OR (Asia) OR (Africa) OR (Caribbean) OR (Pacific) OR ("Middle East") OR ("Latin America") OR ("South America") OR (Afghanistan) OR (Algeria) OR ("American Samoa") OR (Angola) OR (Argentina) OR (Azerbaijan) OR (Bangladesh) OR (Belize) OR (Benin) OR (Bhutan) OR (Bolivia) OR (Botswana) OR (Brazil) OR (Brasil) OR ("Burkina Faso") OR (Burundi) OR ("Cabo Verde") OR (Cambodia) OR (Cameroon) OR ("Central African Republic") OR (Chad) OR (China) OR (Colombia) OR (Comoros) OR (Congo) OR ("Costa Rica") OR ("Côte d'Ivoire") OR (Cuba) OR (Djibouti) OR (Dominica) OR ("Dominican Republic") OR (Ecuador) OR (Egypt) OR ("El Salvador") OR (Guinea) OR (Eritrea) OR (Ethiopia) OR (Fiji) OR (Gabon) OR (Gambia) OR (Ghana) OR (Grenada) OR (Guatemala) OR ("Guinea-Bissau") OR (Guyana) OR (Haiti) OR (Honduras) OR (India) OR (Indonesia) OR (Iran) OR (Iraq) OR (Jamaica) OR (Jordan) OR (Kazakhstan) OR (Kenya) OR (Kiribati) OR (Korea) OR (Kyrgyz*) OR (Lao*) OR (Lebanon) OR (Lesotho) OR (Liberia) OR (Libya) OR (Madagascar) OR (Malawi) OR (Malaysia) OR (Maldives) OR (Mali) OR ("Marshall Islands") OR (Mauritania) OR (Mauritius) OR (Mexico) OR (Micronesia) OR (Mongolia) OR (Morocco) OR (Mozambique) OR (Myanmar)

	OR (Namibia) OR (Nepal) OR (Nicaragua) OR (Niger) OR (Nigeria) OR (Pakistan) OR (Palau) OR (Panama) OR ("Papua New Guinea") OR (Paraguay) OR (Peru) OR (Philippines) OR (Rwanda) OR (Samoa) OR ("São Tomé and Principe") OR (Senegal) OR ("Sierra Leone") OR ("Solomon Islands") OR (Somalia) OR ("South Africa") OR ("South Sudan") OR ("Sri Lanka") OR ("St. Lucia") OR ("St. Vincent and the Grenadines") OR (Sudan) OR (Suriname) OR (Swaziland) OR (Syria*) OR (Tajikistan) OR (Tanzania) OR (Thailand) OR ("Timor-Leste") OR (Togo) OR (Tonga) OR (Tunisia) OR (Turkey) OR (Turkmenistan) OR (Tuvalu) OR (Uganda) OR (Uzbekistan) OR (Vanuatu) OR (Venezuela) OR (Vietnam) OR ("West Bank and Gaza") OR (Yemen) OR (Zambia) OR (Zimbabwe))) Refined by: DOCUMENT TYPES: (ARTICLE OR REVIEW OR EDITORIAL MATERIAL) Timespan: 2000-2019. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI.
Aquatic Sciences & Fisheries Abstracts (ASFA) – ProQuest (Search 1 of 2)	(noft(secur* NEAR/5 water) OR noft(secur* NEAR/5 “water access”) OR noft(secur* NEAR/5 “access to water”) OR noft(secur* NEAR/5 “water management”) OR noft(secur* NEAR/5 “management of water”) OR noft(secur* NEAR/5 “water resource* management”) OR noft(secur* NEAR/5 “water governance”) OR noft(secur* NEAR/5 "governance of water") OR noft(secur* NEAR/5 "water allocation*") OR noft(secur* NEAR/5 "allocation of water*") OR noft(secur* NEAR/5 "water efficien*") OR noft(secur* NEAR/5 "water provision*") OR noft(secur* NEAR/5 "provision* of water") OR noft(secur* NEAR/5 "water distribution*") OR noft(secur* NEAR/5 "distribution* of water") OR noft(secur* NEAR/5 "water connection*") OR noft(secur* NEAR/5 "connection* to water") OR noft(secur* NEAR/5 "water suppl*") OR noft(secur* NEAR/5 "suppl* of water") OR noft(secur* NEAR/5 "water amount*") OR noft(secur* NEAR/5 "amount of water*") OR noft(secur* NEAR/5 "water qualit*") OR noft(secur* NEAR/5 "qualit* of water") OR noft(secur* NEAR/5 “water right*”) OR noft(secur* NEAR/5 “water storage”) OR noft(secur* NEAR/5 “water conservation”) OR noft(secur* NEAR/5 “conservation of water”) OR noft(secur* NEAR/5 “water availabilit*”) OR noft(secur* NEAR/5 “availabilit* of water”) OR noft(secur* NEAR/5 “water demand”) OR noft(secur* NEAR/5 “water level*”) OR noft(secur* NEAR/5 “level* of water”) OR noft(secur* NEAR/5 “water flow*”) OR noft(secur* NEAR/5 “flow* of water”) OR noft(secur* NEAR/5 “water quantit*”) OR noft(secur* NEAR/5 “quantit* of water”)) AND (noft(livelihood*) OR noft(farmer*) OR noft(irrigator*) OR noft(farming) OR noft(agricultur*) OR noft(horticultur*) OR noft(livestock) OR noft("fish pond") OR noft("fish farm*") OR noft(fisher*) OR noft(aquacultur*) OR noft(herder*) OR noft(herding) OR noft(pastoral*) OR noft(“farmwork*”) OR noft(“farm worker*”) OR noft(labourer*) OR noft(laborer*) OR noft(“agricultural worker*”) OR noft(“animal husbandry”)) AND (noft("global south") OR noft("third world") OR noft("underdevelop*") OR noft(country NEAR/3 "developing") OR noft(Asia) OR noft(Africa) OR noft(Caribbean) OR noft(Pacific) OR noft("Middle East") OR noft("Latin America") OR noft("South America") OR noft(Afghanistan) OR noft(Algeria) OR noft("American Samoa") OR noft(Angola) OR noft(Argentina) OR noft(Azerbaijan) OR noft(Bangladesh) OR noft(Belize) OR noft(Benin) OR noft(Bhutan) OR noft(Bolivia) OR noft(Botswana) OR noft(Brazil) OR noft(Brasil) OR noft("Burkina Faso") OR noft(Burundi) OR noft("Cabo Verde") OR noft(Cambodia) OR noft(Cameroon) OR noft("Central African Republic") OR noft(Chad) OR noft(China) OR noft(Colombia) OR noft(Comoros) OR noft(Congo) OR noft("Costa Rica") OR noft("Côte d'Ivoire") OR noft(Cuba) OR noft(Djibouti) OR noft(Dominica) OR noft("Dominican Republic") OR noft(Ecuador) OR noft(Egypt) OR noft("El Salvador") OR noft(Guinea) OR noft(Eritrea) OR noft(Ethiopia) OR noft(Fiji) OR noft(Gabon) OR noft(Gambia) OR noft(Ghana) OR noft(Grenada) OR noft(Guatemala) OR noft("Guinea-Bissau") OR noft(Guyana) OR noft(Haiti) OR noft(Honduras) OR noft(India) OR noft(Indonesia) OR noft(Iran) OR noft(Iraq) OR noft(Jamaica) OR noft(Jordan) OR noft(Kazakhstan) OR noft(Kenya) OR noft(Kiribati) OR noft(Korea) OR noft(Kyrgyz*) OR noft(Lao*) OR noft(Lebanon) OR noft(Lesotho) OR noft(Liberia) OR noft(Libya) OR noft(Madagascar) OR noft(Malawi) OR noft(Malaysia) OR noft(Maldives) OR noft(Mali) OR noft("Marshall Islands") OR noft(Mauritania) OR noft(Mauritius) OR noft(Mexico) OR noft(Micronesia) OR noft(Mongolia) OR noft(Morocco) OR noft(Mozambique) OR noft(Myanmar) OR noft(Namibia) OR noft(Nepal) OR noft(Nicaragua) OR noft(Niger) OR noft(Nigeria) OR noft(Pakistan) OR noft(Palau) OR noft(Panama) OR noft("Papua New Guinea") OR noft(Paraguay) OR noft(Peru) OR

	noft(Philippines) OR noft(Rwanda) OR noft(Samoa) OR noft("São Tomé and Principe") OR noft(Senegal) OR noft("Sierra Leone") OR noft("Solomon Islands") OR noft(Somalia) OR noft("South Africa") OR noft("South Sudan") OR noft("Sri Lanka") OR noft("St. Lucia") OR noft("St. Vincent and the Grenadines") OR noft(Sudan) OR noft(Suriname) OR noft(Swaziland) OR noft(Syria*) OR noft(Tajikistan) OR noft(Tanzania) OR noft(Thailand) OR noft("Timor-Leste") OR noft(Togo) OR noft(Tonga) OR noft(Tunisia) OR noft(Turkey) OR noft(Turkmenistan) OR noft(Tuvalu) OR noft(Uganda) OR noft(Uzbekistan) OR noft(Vanuatu) OR noft(Venezuela) OR noft(Vietnam) OR noft("West Bank and Gaza") OR noft(Yemen) OR noft(Zambia) OR noft(Zimbabwe)) Limits: DATE: After January 01, 2000; Article OR Feature OR Case Study OR Commentary OR Editorial OR General Information OR Literature Review OR Review
Aquatic Sciences & Fisheries Abstracts (ASFA) – ProQuest (Search 2 of 2)	(noft(insecur* NEAR/5 water) OR noft(insecur* NEAR/5 "water access") OR noft(insecur* NEAR/5 "access to water") OR noft(insecur* NEAR/5 "water management") OR noft(insecur* NEAR/5 "management of water") OR noft(insecur* NEAR/5 "water resource* management") OR noft(insecur* NEAR/5 "water governance") OR noft(insecur* NEAR/5 "governance of water") OR noft(insecur* NEAR/5 "water allocation*") OR noft(insecur* NEAR/5 "allocation of water*") OR noft(insecur* NEAR/5 "water efficien*") OR noft(insecur* NEAR/5 "water provision*") OR noft(insecur* NEAR/5 "provision* of water") OR noft(insecur* NEAR/5 "water distribution*") OR noft(insecur* NEAR/5 "distribution* of water") OR noft(insecur* NEAR/5 "water connection*") OR noft(insecur* NEAR/5 "connection* to water") OR noft(insecur* NEAR/5 "water suppl*") OR noft(insecur* NEAR/5 "suppl* of water") OR noft(insecur* NEAR/5 "water amount*") OR noft(insecur* NEAR/5 "amount of water*") OR noft(insecur* NEAR/5 "water qualit*") OR noft(insecur* NEAR/5 "qualit* of water") OR noft(insecur* NEAR/5 "water right*") OR noft(insecur* NEAR/5 "water storage") OR noft(insecur* NEAR/5 "water conservation") OR noft(insecur* NEAR/5 "conservation of water") OR noft(insecur* NEAR/5 "water availabilit*") OR noft(insecur* NEAR/5 "availabilit* of water") OR noft(insecur* NEAR/5 "water demand") OR noft(insecur* NEAR/5 "water level*") OR noft(insecur* NEAR/5 "level* of water") OR noft(insecur* NEAR/5 "water flow*") OR noft(insecur* NEAR/5 "flow* of water") OR noft(insecur* NEAR/5 "water quantit*") OR noft(insecur* NEAR/5 "quantit* of water")) AND (noft(livelihood*) OR noft(farmer*) OR noft(irrigator*) OR noft(farming) OR noft(agricultur*) OR noft(horticultur*) OR noft(livestock) OR noft("fish pond") OR noft("fish farm*") OR noft(fisher*) OR noft(aquacultur*) OR noft(herder*) OR noft(herding) OR noft(pastoral*) OR noft("farmwork*") OR noft("farm worker*") OR noft(labourer*) OR noft(laborer*) OR noft("agricultural worker*") OR noft("animal husbandry")) AND (noft("global south") OR noft("third world") OR noft("underdevelop*") OR noft(country NEAR/3 "developing") OR noft(Asia) OR noft(Africa) OR noft(Caribbean) OR noft(Pacific) OR noft("Middle East") OR noft("Latin America") OR noft("South America") OR noft(Afghanistan) OR noft(Algeria) OR noft("American Samoa") OR noft(Angola) OR noft(Argentina) OR noft(Azerbaijan) OR noft(Bangladesh) OR noft(Belize) OR noft(Benin) OR noft(Bhutan) OR noft(Bolivia) OR noft(Botswana) OR noft(Brazil) OR noft(Brasil) OR noft("Burkina Faso") OR noft(Burundi) OR noft("Cabo Verde") OR noft(Cambodia) OR noft(Cameroon) OR noft("Central African Republic") OR noft(Chad) OR noft(China) OR noft(Colombia) OR noft(Comoros) OR noft(Congo) OR noft("Costa Rica") OR noft("Côte d'Ivoire") OR noft(Cuba) OR noft(Djibouti) OR noft(Dominica) OR noft("Dominican Republic") OR noft(Ecuador) OR noft(Egypt) OR noft("El Salvador") OR noft(Guinea) OR noft(Eritrea) OR noft(Ethiopia) OR noft(Fiji) OR noft(Gabon) OR noft(Gambia) OR noft(Ghana) OR noft(Grenada) OR noft(Guatemala) OR noft("Guinea-Bissau") OR noft(Guyana) OR noft(Haiti) OR noft(Honduras) OR noft(India) OR noft(Indonesia) OR noft(Iran) OR noft(Iraq) OR noft(Jamaica) OR noft(Jordan) OR noft(Kazakhstan) OR noft(Kenya) OR noft(Kiribati) OR noft(Korea) OR noft(Kyrgyz*) OR noft(Lao*) OR noft(Lebanon) OR noft(Lesotho) OR noft(Liberia) OR noft(Libya) OR noft(Madagascar) OR noft(Malawi) OR noft(Malaysia) OR noft(Maldives) OR noft(Mali) OR noft("Marshall Islands") OR noft(Mauritania) OR noft(Mauritius) OR noft(Mexico) OR noft(Micronesia) OR noft(Mongolia) OR noft(Morocco) OR noft(Mozambique) OR noft(Myanmar) OR noft(Namibia) OR noft(Nepal) OR

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APPENDIX B: Systematic scoping review questionnaire

This manual was developed, in part, from the insights provided from Ford et al. (2014), Singh et al. (2017), McDowell (2017, pers. comm.), and Rodina (2018, pers. comm.).

1. Article number

2. Who was the article coded by?

3. What is the title of the article?

4. What was the year of publication?

5. What are the authors' names, in order from first to last? (Last name, initials)

6. What is the affiliation of the lead author? Check all that apply.

- Academic
- Government
- Intergovernmental Organization
- Non-Governmental Organization
- Private Organization
- Indeterminate

7. What is the name of the organization for which the lead author is affiliated with?

8. Lead author's location (country name). In case of multiple countries, list "Multiple: Country 1; Country 2...".

9. What is the name of the journal?

10. Is water in/security explicitly defined? Mark only one.

- Yes
- No
- Maybe

11. If water in/security is explicitly defined, please enter the definition.

12. What is the central cause(s) of water insecurity listed?
Purpose: This information will allow a clear identification of where the central sources of risk rest. These codes have been informed by a wider literature review on water security in rural and agricultural contexts. Check all causes outlined by the author(s).

- Hydro-Climatic Hazards (E.g., Climate Change/Variability; Aridity; Extreme Events)
- Demand-Driven (E.g., Local Depletion; Changes in Crops to Meet Dietary Preferences)
- Inter-Sectoral Competition (E.g., Water Transfers; Urban or Industrial Competition, Environmental Allocations)

- Water Mismanagement or Poor Governance (E.g., Inadequate Regulations; Lack of Monitoring; Fragmented and Reactionary)
- Socio-Economic Standing (E.g., Poverty, Social Exclusion)
- Indeterminate or Not Specified
- Other:

13. What is the specific cause(s) of water insecurity? Describe. Purpose: A richer evaluation of the code #12.

14. What is the action argued for, or implemented in response to the cause of water insecurity?
Purpose: This question provides important information on the nature of the response for improving water security. Each of these response types comes from a broader literature review in the water security and agriculture. Check all that apply.

- Increase Water Supply (E.g., Green/Blue Water; Wastewater; New Infrastructure)
- Use Existing Water Availability More Efficiently (E.g., Virtual Water Trade; Drought-Tolerant Crops)
- Improved Water Governance and Management Practices (E.g., Allocation Decisions; Coordinated Management; Participatory-Based)
- Reducing Social or Economic Barriers or Systems Preventing Water Access
- Indeterminate (No Option Provided)
- Other:

15. What are the specific solutions(s) for water insecurity? Describe. Purpose: A richer evaluation of the code #14.

16. Describe the methodology employed. Check all that apply.

- Quantitative (e.g., Inferential, Spatial). Exclude: Descriptive Statistics
- Qualitative
- Mixed Methodology. Exclude: Descriptive Statistics
- Policy or Concept-Based (No Primary or Secondary Empirical Data)
- Other:

17. Who is primarily responsible for improving water security? Check all that apply.

- Local Communities
- Non-Government Organizations
- Government
- Unknown (Not Explicitly Listed)
- Other:

18. Which rural livelihood(s) are primarily targeted? Check all that apply.

- Agriculturalists
- Livestock Breeding or Pastoralism
- Aquaculturalist
- Industrial Activities

- Indeterminate
- Other:

19. At what scale are the solutions designed and implemented? Check all that apply.

- Individual or Household
- Community, Village, Hamlet, Town
- Watershed or River Basin
- State or Province
- Country
- International (i.e., multiple countries, e.g., transboundary treaties)
- Multiple scales with Unspecified Units (e.g., general indication).
- Indeterminate

20. Primary geographical place of focus of study (Full country name). If multiple, list as "Multiple: "Country 1; Country 2".

21. What are the primary future research needs articulated in the paper for improving water security? Describe.

22. Notes

APPENDIX C: List of journals included articles were published in.

Journal Name	# Publications	Percentage
Agricultural Systems	1	1.01%
Agricultural Water Management	2	2.02%
Agronomy Journal	1	1.01%
Annals of the Association of American Geographers	1	1.01%
Applied Geography	1	1.01%
Climate	1	1.01%
Current Opinion in Environmental Sustainability	1	1.01%
Ecosystem Services	2	2.02%
Environment, Development & Sustainability	1	1.01%
Environmental Development	1	1.01%
Environmental Science & Policy	1	1.01%
Food Security	2	2.02%
Global Environmental Change	3	3.03%
Groundwater	2	2.02%
IDS Bulletin	1	1.01%
IEEE Access	1	1.01%
International Journal of Business and Society	1	1.01%
International Journal of Climate Change Strategies and Management	1	1.01%
International Journal of Disaster Risk Reduction	1	1.01%
International Journal of Environmental Research and Public Health	2	2.02%
International Journal of the Commons	1	1.01%
International Journal of Water Resources Development	5	5.05%
Irrigation & Drainage	4	4.04%
Journal of Agricultural Science	1	1.01%
Journal of Cleaner Production	6	6.06%
Journal of Contemporary Water Research & Education	1	1.01%
Journal of Environmental Management	1	1.01%
Journal of Hydrology	3	3.03%
Journal of Integrative Agriculture	1	1.01%
Journal of Peace Research	1	1.01%
Journal of Peasant Studies	1	1.01%
Natural Hazards	1	1.01%
Natural Resources Forum	5	5.05%
Nature Climate Change	1	1.01%

Philosophical Transactions of the Royal Society A	1	1.01%
Physics and Chemistry of the Earth	1	1.01%
Proceedings of the Institution of Civil Engineers	1	1.01%
Regional Environmental Change	2	2.02%
Resources, Conservation & Recycling	1	1.01%
Science Advances	1	1.01%
Science of the Total Environment	3	3.03%
South African Journal of Science	1	1.01%
Sustainability	1	1.01%
Sustainability Science	1	1.01%
Sustainable Cities and Society	1	1.01%
Water	5	5.05%
Water (South Africa)	2	2.02%
Water Alternatives	2	2.02%
Water History	1	1.01%
Water International	3	3.03%
Water Policy	3	3.03%
Water Resources Management	5	5.05%
Water Resources Research	2	2.02%
Water Science & Technology	1	1.01%
WIREs Water	1	1.01%
World Development	1	1.01%

APPENDIX D: List of included journal articles

1. Agholor, I. A. (2013). The revitalisation of water resources for sustainable agricultural development in South Africa: A review. *Journal of Agricultural Science*, *5*(5), 1–8.
2. Al-Bakri, J., Salahat, M., Suleiman, A., Suifan, M., Hamdan, M., Khresat, S., & Kandakji, T. (2013). Impact of climate and land use changes on water and food security in Jordan: Implications for transcending "The Tragedy of the Commons." *Sustainability*, *5*(2), 724–748.
3. Al-Faraj, F. A. M., & Tigkas, D. (2016). Impacts of multi-year droughts and upstream human-induced activities on the development of a semi-arid transboundary basin. *Water Resources Management*, *30,* 5131-5143.
4. Alcon, F., Tapsuwan, S., Brouwer, R., Yunes, M., Mounzer, O., & de-Miguel, M. D. (2018). Modelling farmer choices for water security measures in the Litani river basin in Lebanon. *Science of the Total Environment*, *647*, 37–46.
5. Azhoni, A., & Goyal, M. K. (2018). Diagnosing climate change impacts and identifying adaptation strategies by involving key stakeholder organisations and farmers in Sikkim, India: Challenges and opportunities. *Science of the Total Environment*, *626*, 1–11.
6. Baleta, H., & Winter, K. (2016). Towards a shared understanding of water security risks in the public and private sectors. *International Journal of Water Resources Development*, *33*(2), 233–245.
7. Bekchanov, M., & Lamers, J. P. A. (2016). Economic costs of reduced irrigation water availability in Uzbekistan (Central Asia). *Regional Environmental Change*, *16*(8), 2369–2387.
8. Bichai, F., Grindle, A. K., & Murthy, S. L. (2016). Addressing barriers in the water-recycling innovation system to reach water security in arid countries. *Journal of Cleaner Production, 171*(10), S97-S109.
9. Bitterman, P., Tate, E., Van Meter, K. J., & Basu, N. B. (2016). Water security and rainwater harvesting: A conceptual framework and candidate indicators. *Applied Geography*, *76*, 75–84.
10. Borgomeo, E., Hall, J. W., & Salehin, M. (2017). Avoiding the water-poverty trap: Insights from a conceptual human-water dynamical model for coastal Bangladesh. *International Journal of Water Resources Development, 34*(6), 900-922.

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15. Cetinkaya, C. P., & Gunacti, M. C. (2018). Multi-criteria analysis of water allocation scenarios in a water scarce basin, *Water Resources Management, 32,* 2867-2884.
16. Chegwin, M. R., & Kumara, S. (2018). Energy, land and water nexus in Sri Lanka's Mahaweli basin. *Proceedings of the Institution of Civil Engineers - Energy*, *171*(3), 93–111.
17. Cheng, K., Fu, Q., Li, T., Jiang, Q., & Liu, W. (2015). Regional food security risk assessment under the coordinated development of water resources. *Natural Hazards, 78,* 603–619.
18. Chiarelli, D. D., Rosa, L., Rulli, M. C., & D'Odorico, P. (2017). The water-land-food nexus of natural rubber production. *Journal of Cleaner Production*, *172*, 1739–1747.
19. Chinnasamy, P., & Agoramoorthy, G. (2015). Groundwater storage and depletion trends in Tamil Nadu State, India. *Water Resources Management*, *29*(7), 2139–2152.
20. Colloff, M. J., Doody, T. M., Overton, I. C., Dalton, J., & Welling, R. (2018). Re-framing the decision context over trade-offs among ecosystem services and wellbeing in a major river basin where water resources are highly contested. *Sustainability Science*, *14*(3), 713–731.
21. Conway, D., van Garderen, E. A., Deryng, D., Dorling, S., Krueger, T., Landman, W., et al. (2015). Climate and southern Africa's water–energy–food nexus. *Nature Climate Change, 5,* 837–846.

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33. Foster, S., Tuinhof, A., & Van Steenbergen, F. (2012). Managed groundwater development for water-supply security in Sub-Saharan Africa: Investment priorities. *Water SA (South Africa)*, *38*(3), 359–366.
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APPENDIX E: Data collection instrument

Data Collection Form

शुभ प्रभात / दुपारी माझे नाव निर्मिती तारा डॅ आहे आणि हे श्री समीर शाह आहे जे कॅनडातील ब्रिटिश कोलंबिया विद्यापीठातून आहे. आपल्या गावातील शासनाच्या परवानगीसह, सरकारच्या "जलयुक्त शिवार अभियान" या मोहिमेद्वारे आम्ही आपल्या गावातील पाणी प्रश्न आणि व्यवस्थापन समजून घेण्यासाठी एक सर्वेक्षण करत आहोत. तसेच आपल्या गावात किती लहान प्रकल्पांची अंमलबजावणी करण्यात आली आहे, हे समजून घ्यायचे आहे. यासाठी प्रश्नावलीचा वापर करणार आहोत, ज्यासाठी 45 मिनिटांपेक्षा जास्त वेळ लागत नाही. तुम्ही सांगितलेल्या माहितीचा वापर श्री शाह यांच्या पीएचडी प्रबंध, प्रकाशने आणि स्थानिक शासन तसेच भारत सरकारकडे संवाद साधण्यासाठी वापरले जाणार आहे आणि कागदपत्रे व व्याख्यान यामध्ये वापरले जाईल. आपण प्रदान केलेली माहिती केवळ संशोधन हेतूसाठी वापरली जाईल आणि आपली ओळख कधीही आमच्या शोध कार्यसंघाबाहेरील कोणासही उघड केली जाणार नाही. आपण कोणत्याही वेळी सर्वेक्षणातून /अभ्यासातून आपले खाते मागे घेऊ शकता आणि आपणांस एखाद्या प्रश्नाचे उत्तर द्यावयाचे नसल्यास तर त्याचा आम्ही आदर करतो तसेच तुम्हांला उत्तर न देण्याचा अधिकार आहे. आपण सहभागी होण्यास संमती देता? _____ (होय / नाही)

Good morning/afternoon. My name is [Interviewer] and this is Mr. Sameer Shah, from the University of British Columbia in Canada. With permission from your village government, we are conducting a survey to understand water access and management in your village. We want to understand how small water projects implemented in your village by the government's "Jalyukt Shivar Abhiyan" campaign is making a difference in your lives. These questions that should take no more than 45 minutes of your time. What we hear from you will be used in Mr. Shah's Ph.D. thesis, publications, and documents and lectures used to communicate the interests of the village to the Government of India. The information you provide will be used only for research purposes and your identity will never be disclosed to anyone outside our research team. You may withdraw from the study at any time and if there are questions that you would prefer not to answer then we respect your right not to answer them. Do you consent to participate? ____(Yes/No)

दिनांक & स्थळ **(Date & Site)**		
तालुका आणि गावाचे नाव (Village/Taluka)		
गाव सर्वे क्र (Survey Number)		
दिनांक:	/० / २०१८	
Is water used for livelihood purposes?		
तुम्ही या गावात राहता का? (Do you live in this village?)	होय	नाही
ह्या गावात तुमच्या घरातील कोणी शेती ,मस्त्य शेती, शेळीपालन इत्यादी व्यवसाय करत आहे का? (Does anyone in your household use land in this village to farm, fish, or raise livestock?)	होय	नाही
Part 1: तुमच्याबद्दल **(About You)**		

लिंग: (Gender of the respondent)	पुरुष			स्त्री			
कुटुंब प्रमुखाशी असलेले तुमचे नाते? (What is the relationship of main respondent to household head?)	प्रमुख Head	पती – पत्नी Spouse	पालक Parent	मुलगा मुलगी Son/ Daught	नातू / नात Grandchild	भावंडे Sibling	इतर Oth.
जात (उपजाती,जात प्रवर्ग), धर्म (What is your community [ethnicity, caste]?)	यादी /List:						
तुमच्या कुटुंबाचे वर्णन (Please describe your household type)	पुरुष प्रमुख: एक /अनेक पत्नी Male headed with wife	पुरुष प्रमुख: घटस्पोटीत /अविवाहित /विधुर Male headed, divorced/single/ widowed	स्त्री प्रमुख: घटस्पोटीत/अविवाहित/विधवा Female headed, divorced/ single/ widowed	स्त्री प्रमुख: पती स्तलांतरित Female headed with husband away.	इतर Other:		
कुटुंबातील उच्च शिक्षणाचा स्तर काय आहे? (What is the highest level of education obtained by any household member?)	निरक्षर No formal education	प्राथमिक Primary (1st- 8th standard	माध्यमिक शिक्षण / Secondary (9th- 12th standard)	उच्च माध्यमिक शिक्षण Post-secondary (e.g., college, university)			
कुटुंबाचा धर्म (Which religion does your household practice?)	यादी / List:						
तुमच्या कुटुंबात ५ वर्षाच्या आतील आणि ६० वर्षा पेक्षा जास्त वय असलेले किती लोक आहेत? (How many people in your household are under the age of 5 years old, or over the age of 60?)	यादी/List: ५ वर्षाच्या आतील संख्या: ६० वर्षापेक्षा जास्त संख्या:						
तुमच्यासहित कुटुंबात किती प्रौढ आहेत? (How many people, including yourself, are in your household?)	यादी/List: वय-गट/ Age-group(५-१८): वय-गट/ Age-group(१८-६०):						
वर्षाचे किती महिने तुमच्या कुटुंबाला उत्पन्न मिळते? (How many months per year does your household have income?)	३ लाखापेक्षा कमी (Under three)	३ लाखाचे दरम्यान परंतु ६ च्या आत / (Between 3 but under 6)	६ पेक्षा अधिक परंतु ९ च्या आत (Over 6 but under 9)	९ आणि १२ दरम्यान (Between 9 and 12)			
सरासरी महिन्याचे किती उत्पन्न मिळते? (During the months you earn income, how much is it on average?)	०-५०००(५ लाख) Under Rs. 5,000	५०००- १०,००० खालील Between Rs. 5,000 but under Rs. 10,000	१०,००० पेक्षा जास्त Over Rs. 10,000	उत्तर देण्यास नकार Prefer not to answer			

तुमच्या कुटुंबाचे उत्पन्नाचे मुख्य साधन काय आहे? आणि खरीप हंगाम तसेच पावसाळ्यातील उत्पन्न (What is/are your household's central source of income or livelihood in the *kharif* or wet season?)	शेती Agriculture मुख्य पिक Primary crop: _____ –	पशुसंवर्धन/पशुपालन Animal husbandry	शेती कामगार Agricultural labourer	शेतीविषयक इतर कामे Other "on-farm" activity (e.g., fishpond)	शेती व्यतिरिक्त इतर कामे Non-farm related activities (specify): _____
तुमच्या कुटुंबाचे उत्पन्नाचे मुख्य साधन काय आहे? आणि रब्बी हंगाम तसेच कोरडवाहू शेतीतील उत्पन्न (What is your household's central source of income or livelihood in the *rabi* or dry season?)	शेती Agriculture मुख्य पिक Primary crop: _____	पशुसंवर्धन/पशुपालन Animal Husbandry	शेती कामगार Agricultural Labourer	शेतीविषयक इतर कामे Other "on-farm" activity (e.g., fishpond)	शेती व्यतिरिक्त इतर कामे Non-farm related activities (specify): _____

जमीनीचे वर्णन (How would you describe your landholding?)	सीमान्त Marginal (< 1 hectare)	लहान Small (Over 1 hectare but under 4)	मध्यम Medium (Over 4 hectares but under 10)	मोठ्या प्रमाणात Large (10 or more ha)	सामान्य जमीन Common held land	भूमिहीन Landless

जमिनीची गुणवत्ता (How would you describe the quality of your land?)	पडीकजमीन Wasteland	सीमान्त/किरकोळ जमीन Marginal	सुपीक/उत्पादक Productive
स्थानिक शासकीय संवाद करू शकता का?ते तुम्हांला मदत करतात?(कृषिविषयक धोरणांची कितपत व त्यासंदर्भात माहिती) (How much voice do you have in local government? If not much, why is that?)			

Part 2: तुमच्या गावाबद्दल **(About Your Village)**	
तुमच्या गावची माहिती सांगू शकाल काय? जसे की कोण राहते,काय प्रकारचे काम इथे मिळते? (Can you describe your village to me – who lives here, what jobs are here, etc.?)	
या गावात पाण्याचा वापर कसा केला जातो?(उदा. शेती,मत्स्यपालन इत्यादी (How is water used in this village?)	
इथे प्रत्येकास मुबलक पाणी मिळते का? (Does everyone have good -- clean, plentiful, and affordable -- access to water here? If not, why?)	

Part 3: जलयुक्त शिवार अभियान **(Jalyukt Shivar Abhiyan)**		
तुम्ही जलयुक्त शिवार अभियानाच्या विषयी तसेच तुमच्या गावातील पाण्याच्या व्यवस्थापनाविषयी ऐकले आहे काय? (Have you ever heard about the Jalyukt Shivar Abhiyan program *or* the initiatives to improve water infrastructure in your village?)	होय/Yes	नाही/No **Note:** Participants might not know the JSA by *name* but know about its projects.
छोट्या पाण्याच्या विकासाच्या प्रकल्पासाठी आपल्या गावाला सरकारी निधी मिळाला आहे काय? (Do you know whether your village has received government funds to develop small water projects under this scheme?)	होय/Yes	नाही/No
जलयुक्त शिवार अभियानाचा मुख्य उद्देश काय आहे तुम्हांला काय वाटते? (What do you think the purpose of this *Jalyukt Shivar Abhiyan*is in your village?)		
तुमच्या गावातील प्रत्येकाला या अभियानाचा लाभ मिळाला काय? (In your village, does everyone benefit from these projects?)		
त्यांनी तुम्हांला कसे निवडले आणि कसा लाभ दिला तसेच तुम्ही त्यांना सेवा देण्याची संधी दिली? (How was it decided they / you were to be served?)		
तुम्हांला असे गाव माहिती आहे काय ज्यांना असे प्रोजेक्ट मिळाले आहेत? (Do you know other villages who received these projects?)	होय/Yes	नाही/No
तुम्हांला काय वाटते कुठल्या आधारवर हा प्रोजेक्ट त्यांना मिळाला असेल? (If so, why do you think they received them, on what basis?)		

ह्या प्रोजेक्ट चा लाभ कोणाला मिळाला?असा कोणता सोर्स आहे जो लोकांना पाणी मिळवण्यापासून थांबवतो? (Do you know which villages get access to these projects? Why is that the case?)	
ह्या प्रोजेक्टच्या अमलबजावणी नंतर तुमच्या गावात काही बदल झाले आहेत का? तुम्हांला वाटते का या प्रोजेक्टमुळे भविष्यात काही बदल होतील? हा प्रोजेक्ट कसा वापरला जाईल आणि कोण वापरेल? (Has anything changed in your village after these projects were implemented? Do you think anything will change in the future because of these projects?)	
Part 4: इथे पाण्याचे व्यवस्थापन सुधारू शकते का? **Can water's management be improved here?**	
पाण्याचे नियोजन तुमच्या गावात चांगले आहे असे तुम्हांला वाटते का? (Do you think water could be better managed here in your village?)	
ज हो / [If yes]: का? कशाप्रकारच्या अडचणी आहेत? (Why does it need better management? What are the problems here?)	
अशा कोणत्या सोयी-सुविधांचा वापर केल्याने पाण्याचा भरपूर सोर्स आणि दीर्घकाळ साठवणूक करता येऊ शकतो? (What are some of the ways in which water could be more plentiful and long-lasting?)	
असे कोणते मार्ग आहेत ज्यामुळे पाण्याचा वापर एकमेकांना सहजपणे होऊ शकतो? (What are some of the ways in which water could be shared better?)	

इतर सामान्य माहिती /Other General Notes:

जर तुमची हरकत नसेल तर तुम्ही आम्हांला तुमचे नाव आणि फोन नंबर देवू शकता, ज्यामुळे तुमच्याशी पुन्हा संपर्क करता येऊ शकतो. ह्या माहितीचा वापर इतर कोणालाही उपलब्ध होणार नाही.

*You can provide us your name and contact information **if you wish to do so.** This will be used for following up with you **only** and will not be made available to anyone outside the research team:

----------TEAR OFF ----------

Certificate of Participation

सदर पी एच डी अभ्यासांमध्ये संशोधनासाठी तुम्ही वेळ दिलात त्याबद्दल खूप धन्यवाद. सदर महिती शासनाच्या अशा छोट्या पाण्याच्या प्रोजेक्टची अमलबजावणी तुमच्या गावात कशी झाली,तसेच जलयुक्त शिवार अभियानामुळे तुमच्या शेती करण्यात काय बदल झाले आणि त्यामुळे तुमचे जीवन कसे बदलले या विषयीचा अभ्यास करण्यासाठी. तुमच्या गावासोबत आणि प्रशासकीय मंडळ यासोबत या प्रोजेक्ट संधर्भात संशोधन करताना प्रोजेक्टचे यश आणि अपयश समजण्यास मदत होईल आणि मिळालेली माहिती शासनाकडे सुपूर्त करण्यात येईल. तुम्हांला आमच्या प्रोजेक्टची अधिक माहिती हवी असल्यास तुम्ही आम्हांला संपर्क साधू शकता. तुमच्या स्थानिक प्रशासकीय अधिकाऱ्यांकडे सदर प्रोजेक्टची छापील प्रत दिली आहे. तसेच तुम्ही दिलेल्या माहितीचा वापर आम्ही ध्येय-धोरणे तयार करणाऱ्यां लोकांसोबत काम करताना करणार आहोत. तुमच्या गावातील काही लोकांच्या शिफारसीचा एक छोटा प्रोजेक्ट रिपोर्ट तुमच्या गावाला पाठवणार आहोत.

We greatly appreciate your time for taking part in this Ph.D. research study. Our study wants to understand how small water projects implemented in your village by the government's "Jalyukt Shivar Abhiyan" are making a difference in farming, and in your lives. By working with your village council and the people living here, we will be able to understand the projects' successes and failures and take this information to higher-level governments. If you want to learn more about our project, feel free to contact us. Your village government has a longer copy of our project information. We will also be working with policy makers about what we heard from you and others here. We will be sending your village a short report based on the recommendations of villagers.

<table>
<tr><th>संपर्कासाठी माहिती/ Stay in Touch?</th><th>इतर काही प्रश्न असल्यास? / Questions or Concerns?</th></tr>
<tr><td>Mr. Sameer Shah (इंग्रजी)
Ph.D. Student (विद्यार्थी) at The University of British Columbia
[Personal information redacted for online version]</td><td>Local Partner (स्थानिक भागीदार): Ms. Seema Kulkarni (इंग्रजी, मराठी आणि हिंदी)
The Society for Promoting Participative Ecosystem Management (SOPPECOM)
[Personal information redacted for online version]</td></tr>
<tr><td>Ms. Nirmiti Tara Daw (इंग्रजी, मराठी आणि हिंदी)
Research Help / Assistant (संशोधन सहाय्यक)
[Personal information redacted for online version]</td><td rowspan="2">Principal Investigator (प्राध्यापक): Dr. Leila Harris (इंग्रजी), Institute on Resources, Environment and Sustainability, The University of British Columbia
[Personal information redacted for online version]</td></tr>
<tr><td>Ms. Pooja Tanna (इंग्रजी, मराठी आणि हिंदी)
Research Help / Assistant (संशोधन सहाय्यक)
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<tr><td colspan="2">You can also contact the University (Office of Research Ethics) at +1 604-822-8598 or e-mail RSIL@ors.ubc.ca or call toll free 1-877-822-8598

आपण विद्यापीठाशी देखील संपर्क साधू शकता (+1 604-822-8598 / 1-877-822-8598 / RSIL@ors.ubc.ca)</td></tr>
</table>