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What shapes vulnerability and risk management in semi-arid India? Moving towards an agenda of sustainable adaptation

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ABSTRACT

In drylands across the global South, rural livelihoods are challenged by existing development deficits, and are now increasingly vulnerable to climate variability and change. People, governments, and a range of non-state actors are responding to these climatic and non-climatic risks through planned and autonomous response strategies. While several studies examine the drivers of vulnerability and range of response strategies undertaken, few distinguish development interventions from climate adaptation actions, making it difficult to identify particular entry points for enabling and strengthening adaptation action. In this paper, we apply Eakin et al.'s (2014) framework of generic versus specific capacity to data from three semi-arid regions in India to examine the implications of multi-scalar response strategies on local adaptive capacities and adaptation processes. We find that current arguments of good development translating into effective adaptation are not always seen: building specific capacities to deal with climatic risks is essential to leverage wins through development interventions. This can help semi-arid regions and people living in them to move towards sustainable adaptation pathways.

1. Introduction

The overwhelming narrative from rural India is one of crisis. Between 2010 and 2017, nearly 45,000 farmers and agricultural labourers have committed suicide (National Crime Records Bureau, 2016). Agrarian livelihoods are undermined by market fluctuations and erratic input availability (Merriott, 2016; Dhanagare, 2016; Djurfeldt and Sircar, 2017). Shrinking landholdings and falling groundwater levels are driving out-migration and poverty (Venot et al., 2010; Zaveri et al., 2016; Gupta, 2016). In this context of precarity, climate variability and change exacerbate existing risks, especially in semi-arid regions (SARs) that are characterised by high levels of water scarcity and land degradation. These biophysical risks interact with structural inequalities such as historical socio-economic and political marginalisation, high levels of poverty, lack of livelihood opportunities, and caste and gender-based hierarchies (Gaiha and Imai, 2004; Banerjee et al., 2013; Singh et al., 2016b) to shape local vulnerability. Climate change can tip these social-ecological systems (SESs) to cross biophysical thresholds (Dilling et al., 2015; Perez et al., 2016), with critical consequences for local vulnerability and risk management.

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In semi-arid India particularly, past climatic trends (1951–2005) indicate a significant annual warming and drying trend (Ramarao et al., 2018). Across Maharashtra, Karnataka, and Tamil Nadu (the three states studied in this paper), average summer monsoon rainfall has decreased by 0.01–1.40 mm/year, and monsoon onset and rainfall patterns have become more erratic; there has also been a noticeable increase in hot days and heat waves between 1961 and 2010, lasting as long as 12–16 days in some areas (Ramarao et al., 2018). In these regions, climate projections[3] indicate a significant increase in annual mean temperature and variability in precipitation, with significant impacts on agricultural productivity and local livelihoods.

Semi-arid regions across India have always been sites of contestation over resource use, livelihood opportunity, and social mobility. These dynamics are embedded in national and local development trajectories, institutional and political shifts, and socio-cultural changes. In present-day rural India, aspirations are also changing: they are increasingly becoming non-agrarian in nature,[4] leading to growing disinterest in agriculture. Together, these factors shape present-day livelihood vulnerability and adaptation processes in rural areas (Gajjar et al., 2018).

In their daily lives, people in SARs manage risks by pooling resources, accumulating assets, diversifying livelihoods, moving out of risk-prone areas and livelihoods, and drawing on social safety nets (Kattumuri et al., 2015; Nambi et al., 2015; Patnaik et al., 2017; Singh et al., 2016b). Concurrently, there have been various government policies and projects to minimise climatic and non-climatic risks and overcome existing development deficits. For example, successive governments have invested in social protection programmes such as the Mahatma Gandhi National Rural Employment Guarantee Scheme and watershed development schemes to strengthen rural livelihoods (Esteves et al., 2013), restore natural resources (Wani and Coauthors, 2008), and more recently, build local adaptive capacity (Godfrey-Wood and Flower, 2017; Singh, 2018a; Adam, 2015).

Growing concerns of climate change impacts and increasing global pressure to demonstrate climate action have spurred national policy in India. For example, the National Action Policy on Climate Change promotes climate smart agriculture and adaptation interventions through policy instruments such as the National Sustainable Agriculture Mission and National Water Mission (Dubash, 2013). At a sub-national level, State Action Plans on Climate Change involve sectoral adaptation and mitigation strategies. These policies have explicitly used a co-benefits agenda (i.e. investing in actions that meet development goals while reducing climate vulnerability or reducing carbon emissions) and mainstreaming framing (i.e. centralising climate action in ongoing development projects) (Prasad and Sud, 2018; Sami et al., 2016; Dubash, 2013). India has also seen increasing adaptation investment by international and national donors and civil society (Adhikari and Taylor, 2012), but these are difficult to differentiate from 'development-as-usual' programmes (Singh et al., 2016c). This differentiation has been difficult because the actors involved in and the actions undertaken under development and adaptation projects are often overlapping (Singh et al., 2016c; Brown, 2011). Further, development and adaptation aim to alleviate poverty and vulnerability, respectively, and while categories of the poor and vulnerable are often overlapping, they might also be significantly exclusive (Nelson et al., 2016). Also, empirical studies argue that 'good' development is an important and increasingly necessary step towards effective adaptation (Eakin et al., 2014; Brown, 2011; Eriksen and Brown, 2011; Eriksen et al. 2011; Osbahr et al., 2010), but how the two are linked remains understudied (Nagoda, 2015; Inderberg, 2015).

Against this background of rural livelihood vulnerability and the multi-scalar response strategies by different actors, as well as obfuscation between adaptation and development interventions and their outcomes, there is a need to critically examine whether current development and adaptation interventions are building local capacities and how synergies can be strengthened.

In this paper, we examine how development and adaptation interventions are shaping local capacities to deal with risk. We use three cases from semi-arid India to delineate between adaptation and development interventions and understand their synergies. In doing so, we identify entry points to strengthen and leverage existing adaptation and development interventions in India. In the following section (Section 2), we briefly discuss our working definitions of important concepts used in this paper and review existing scholarship on the links between adaptation and development. In Section 3, we describe the three case study sites and the methodology followed. Section 4 details the findings, using a narrative style to profile the risk landscape in each case, the autonomous and planned responses undertaken, and the implications of these on local adaptation. The paper concludes with a discussion linking the case-based findings to broader development and adaptation trajectories in India and semi-arid landscapes and suggestions on how to leverage synergies between adaptation and development interventions.

2. Risk management in semi-arid regions

2.1. A note on terminology: vulnerability, risk management, adaptive capacity, and adaptation

Climate change vulnerability and adaptation (CCVA) research has a rich conceptual lineage from different disciplines and practice communities (Singh et al., 2017; Crane et al., 2017; Ford et al., 2018). The literature has converged to describe vulnerability as the

[3] These projections are under RCP 4.5 (balanced) and RCP 8.5 (business-as-usual) greenhouse gas (GHG) concentration trajectories going into the long term (up to 2066–2095). These levels of GHG are symptomatic of a certain kind of socio-economic activity and energy use profile (e.g. RCP 8.5 corresponds to a world with no significant shift towards non-fossil energy). Representative Concentration Pathways or RCPs correspond to certain levels of warming: RCP 4.5 denotes emissions peak around 2040 and then decline (with an associated average warming of 1.8 °C) while in RCP 8.5, emissions rise throughout the 21st century leading to an average 3.7 °C rise.

[4] The most recent Situation Assessment Survey in India found that given a choice, 40% of all farmers would prefer another source of livelihood than farming (Agarwal and Agrawal, 2017).

propensity or predisposition to be adversely affected (IPCC 2014) and driven by a set of conditions of people that derive from their historical and prevailing cultural, social, environmental, political, and economic contexts. In this sense, vulnerable groups are not only at risk because they are exposed to a hazard or climate change but also because of marginality, everyday patterns of social interaction and organisation, their access to resources, and their capacity to respond to and plan for multiple risks (McLaughlin and Dietz, 2008; Tucker et al., 2015).

Adaptation to climate change is most commonly defined as the process of adjustment to actual or expected climate and its effects, which in human systems, can seek to moderate or avoid harm or exploit beneficial opportunities (IPCC 2014). Adaptation often denotes a process, while adaptive capacity, which is the ability or potential of a system to adapt (Smit et al., 2000), is widely used as a measure of the *potential* of adaptation of the system and not necessarily actual adaptation (Mortreux and Barnett, 2017). Adaptation actions are typically combinations of reactive and planned strategies based on past experiences that are incorporated into forward-looking strategies (Adger et al., 2004). Adaptation needs can vary spatially (between communities, states etc.) and temporally (urgent immediate needs vs. long-term needs) (IPCC, 2014: 840). Depending on the spontaneity and timing of the response, adaptation can be autonomous or reactive, or anticipatory or planned (Smit et al., 2000; Smit and Wandel, 2006). Adaptation can also be distinguished based on the extent of adaptation where incremental adaptation denotes relatively small adjustments made to deal with risks, while transformational adaptation denotes “changes (in) the fundamental attributes of a system in response to climate and its effects” (IPCC, 2014: 1758).

In this paper, we draw on CCVA literature to capture the multiple, intersecting, and dynamic drivers of vulnerability to climatic and non-climatic risks. In doing so, we acknowledge that in semi-arid areas, climate change and variability, in conjunction with current resource management practices, livelihood dynamics, and institutional systems, can tip existing social-ecological systems to cross biophysical thresholds. This can cause long-term decline in critical ecological services, second-order impacts on local livelihoods, increased risk exposure, and exacerbated vulnerability (Tucker et al., 2015; Singh et al., 2018). Such a conceptualization also forefronts the role of structural drivers, such as social injustices, unequal power relations, and poor governance (Tschakert et al., 2013) and changing social identities, relationships, and norms (Cohen et al., 2016), in shaping present-day vulnerability to climatic risks. We thus situate our work under the broader umbrella of risk management (Hansen and Coauthors, 2018; Singh et al., 2018), climatic or otherwise, which pushes us not to privilege climate change above other risks and emphasises the dynamic, interacting nature of different risks and responses.

2.2. Adaptation and development: generic versus specific capacities

Local adaptation is influenced by multi-scalar environmental, infrastructural, institutional, and political conditions as well as local socio-economic and cultural contexts (Eriksen et al., 2015; Taylor, 2013; O'Brien and Coauthors, 2004). These variables interact in complex ways across space and time to shape adaptation outcomes (Mortreux and Barnett, 2017; Ribot, 2014).

In SARs across India, these interactions play out in various ways. Biophysical factors such as water scarcity, land degradation, and desertification interact with structural inequalities such as historical socio-economic and political marginalisation, high levels of poverty, lack of livelihood opportunities, and caste and gender-based hierarchies (Banerjee et al., 2013; Singh et al., 2018; Gaiha and Imai, 2004) to shape local vulnerability. The criticality of these interactions is explained by Gaiha and Imai (2004), who note that even relatively affluent households (upper caste, educated, large landholders) are sensitive to persistent crop shocks, often being hit harder than poorer households because the latter spread risks through diversification. In the face of this complexity, there is a growing call for adaptation and development policy in SARs to shift emphasis from meeting income shortfalls of the poor to *enabling* the vulnerable to protect themselves better against risks such as erratic rainfall or fluctuating crop prices.

To deal with these multiple challenges, there has been a surge in calls for climate-resilient development (van Ruijven and Coauthors, 2014; Denton and Wilbanks, 2014) where climate action, disaster risk reduction, and development goals are targeted in a concerted manner (Schipper, 2009). Linked to this is a growing consensus that sustainable development can have adaptation co-benefits (Eriksen and Brown, 2011; Lemos et al., 2007). However, teasing out the implications of various development and adaptation interventions on local adaptive capacity is notoriously difficult (Singh et al., 2016c; Sherman and Coauthors, 2016).

Among adaptation researchers, there has been a concerted effort to address this gap. On the one hand, studies have attempted to identify characteristics of ‘successful’ adaptation (Osbahr et al., 2010; Adger et al., 2005) noting that while collective action, strong social capital, and flexible institutions can facilitate successful adaptation, trade-offs across spatio-temporal scales undermine this success (Gajjar et al., 2018). On the other hand, there is growing acknowledgement that development interventions are a critical part of successful adaptation but delineating them is difficult and often artificial (Lemos et al., 2007; Singh et al., 2016c; McGray et al., 2007; Schipper, 2007). More importantly, poverty eradiation may not necessarily lead to vulnerability reduction (Nelson et al., 2016) but can definitely support local adaptation processes (Patnaik and Das, 2017; Clay, 2018). A third strand of research on sustainable adaptation draws on sustainability studies to forefront concerns of intergenerational equity and impacts of actions across spatial scales, calling for attention to trade-offs and longer-term implications of adaptation interventions (Brown, 2011; Eriksen and Brown, 2011; Eriksen et al. 2011; Inderberg, 2015; Gajjar et al., 2018).

In countries such as India, adaptation imperatives are constantly competing with needs to address development deficits (Halsnæs and Verhagen, 2007; Singh et al., 2016c) and financial, technical and institutional capacities are stretched between adaptation and development priorities (Sami et al., 2016; Prasad and Sud, 2018). India formulated its National Policy on Climate Change in 2008; however, the Ministry of Environment and Forests in 2008 acknowledged that ‘India has yet to draw up programs aimed exclusively at addressing critical vulnerabilities to climate change’ (Ray 2008 cited in Dupuis and Knoepfel, 2013, p. 5). The government has mainly focused on integrating adaptation in *ongoing* development programmes (for examples, see Adam, 2015; Dubash and Jogesh, 2014). Similarly, bilateral and multilateral agencies have concentrated on mainstreaming adaptation into development projects in India with a few notable exceptions[5] explicitly focusing on adaptation (Dupuis and Knoepfel, 2013).

To address this fuzzy space between adaptation and development, Eakin et al. (2014) put forth a useful heuristic framework to understand adaptive capacity by delineating it into generic capacity, which addresses deficiencies in basic human development needs, and specific capacity, which addresses the tools and skills needed to anticipate and effectively respond to specific risks. As per the framework (Fig. 1), societies are categorized into four quadrants: '*poverty trap*' (where individuals and communities have low specific and generic capacities and face chronic stress and remain trapped in a situation of deprivation); '*safety-first populations*' (individuals and communities are asset poor but have capacities to manage current risks); '*safe development paradox*' (a situation where system-level generic capacities are high, populations have high levels of education, health, economic productivity but have limited ability to cope with climatic risks); and '*sustainable adaptation*' (conditions where specific and generic capacities are high and lead to outcomes of sustainable and potentially transformative adaptation). Importantly, the sustainable adaptation quadrant refers to conditions that lead to adaptation that is effective over longer timescales and does not erode social equity.

Such a framing explicitly engages with building capacities to meet adaptation and sustainable development goals (Lemos et al., 2016; Eakin et al., 2014). The approach is also a departure from typical adaptation studies, which are dominated by assessing adaptive capacity through the five 'capitals' of the sustainable livelihoods framework (Brown et al., 2018; Patnaik and Das, 2017; Aulong et al., 2012) that often erroneously strengthen the pervasive assumption that possession of capitals and capacities automatically leads to adaptation (Mortreux and Barnett, 2017; Mclean, 2015).

As Eakin et al. (2014) explain, the generic properties of a system are associated with socio-economic development indicated through poverty reduction, higher education, better nutrition, and improved infrastructure. While there has been considerable progress on understanding how to effectively build generic capacity (Eakin and Lemos, 2006; Brooks et al., 2005; Eakin et al., 2014), there has been relatively less work on understanding specific capacity to adapt and its relation to generic capacity (Nelson et al., 2016).

We argue that an understanding of how adaptation processes occur, especially within the context of broader development interventions, is critical to begin addressing these gaps. In this paper, we apply the heuristics of generic vs. specific capacities to three empirical cases to examine capacities present within the system, structural vulnerabilities that mediate these capacities, and entry points into enabling sustainable adaptation.

3. Methods and site description

This paper draws on data from a larger, five-year-long project called Adaptation at Scale in Semi-arid Regions (ASSAR), which examines the barriers and enablers to effective, widespread and sustainable adaptation in Africa and India (www.assar.uct.ac.za). In this paper, we discuss findings from the research in India where we conducted research in three semi-arid states: Maharashtra (Ahmednagar district), Tamil Nadu (Moyar Bhavani watershed, covering Coimbatore district) and Karnataka (Kolar and Gulbarga districts) (Fig. 2). The three states were chosen for being predominantly semi-arid with unique trajectories of development and adaptation practice. While Maharashtra and Karnataka allow us to examine the impacts of state-led watershed development (going back as far as the 1970s), Tamil Nadu offers insights into how the regional political economy shapes development and adaptation implementation.

3.1. Site description

Biophysically, all three districts studied are semi-arid with predominantly rainfed farming systems (except Coimbatore where irrigated farming is expanding rapidly) (see Table 1). The majority of the rural poor are small and marginal farmers dependent predominantly on agriculture and allied sectors with a small percentage from non-farm sectors (particularly in Karnataka and Tamil Nadu).

3.2. Sampling, data collection, and analysis

Villages (17 in Ahmednagar district, Maharashtra; 9 in Kolar and 8 in Gulbarga, Karnataka; and 4 Panchayat villages in Coimbatore, Tamil Nadu) were selected through stratified random sampling to cover the range of biophysical and socio-economic conditions seen in the sites. Within each village, households were selected randomly and detailed sampling is discussed in (Kuchimanchi et al., 2018) for Maharashtra (Singh et al., 2018) for Karnataka, and (Solomon and Rao, 2018) for Tamil Nadu. A mixed methods research design was followed. Household surveys were conducted across the selected villages in Karnataka (Kolar (n = 419) and Gulbarga (n = 424)) and Tamil Nadu (n = 400). Within the chosen villages, households were randomly chosen based on a proportional representation basis, and structured interviews were carried out with the household head. The survey questionnaire captured demographic data at household and individual levels, as well as key livelihoods engaged in, major risks, and how they changed over time; a ranking of response strategies, perceptions of climate change and variability; and detailed information around

[5] The Swiss Agency for Cooperation and Development's Vulnerability and Adaptation program, which started as early as 2005 in Rajasthan and the Watershed Organisation Trust's (WOTR) Climate Change Adaptation program of 2009 in Maharashtra are some examples.

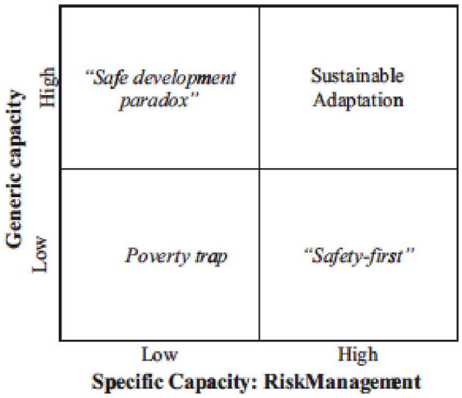

Fig. 1. Capacities matrix. Source: Eakin et al. (2014).

social networks, government schemes availed of, and subjective wellbeing.[6]

Gender-differentiated focussed group discussions (FGDs) (34 in Maharashtra, 26 in Karnataka and 4 in Tamil Nadu) were carried out to understand community scale perceptions of risk, collective responses, and local institutional dynamics. To capture multi-stakeholder perspectives of adaptation and development interventions at the district and village level, the barriers faced, and examples of success, key informant interviews (KIIs) (4 in Maharashtra, 20 in Karnataka and 16 in Tamil Nadu) were conducted with district government officials, local NGO staff, village leaders, shopkeepers, and bank officials. Repeated village visits were conducted to understand the local context and dynamics. Based on these scoping visits, the research tools were piloted and tailored to the livelihood profile, biophysical characteristics, and socio-institutional setup of each site. A multidisciplinary research team collected data by engaging in the sites over two years (2015–2017). In Maharashtra, an additional participatory tool – Community Driven Vulnerability Evaluation (Co-DriVE-PD) (WOTR, 2013), was used to capture differential vulnerability and risk management within and across communities.[7]

The data were analysed to identify drivers of vulnerability, current adaptation practices, and the broader development programmes being availed. We applied the heuristic framework by Eakin et al. (2014) to understand generic and specific capacities in the different sites and their implications on current vulnerabilities and abilities to adapt to future change. The analysis was conducted through one in-person write-shop and several conference calls between the authors to discuss if and how the coded data fit into the framework. The risk management practices were 'placed' into each of the quadrants, and the authors discussed reasons for doing so. In several cases, the practices were shifted based on the discussions and Fig. 3 signifies the endpoint of this collective and iterative analysis process. Where disagreements arose, we explored the underlying data to support placement of a practice in a quadrant and took decisions based on consensus. This was a time-intensive and often difficult activity with multiple rounds of discussion. The placement in quadrants was also triangulated against household data on subjective wellbeing, adaptive capacity, and income levels. For example, the researchers placed climate information services in the 'sustainable adaptation' quadrant. This was cross-checked with household data that reported people using climate information to improve cropping practices (e.g. adjusting sowing and watering timings), which had led to better risk management during unforeseen weather events. However, on further discussion, the team noted that climate information services were mainly improving specific capacities to climatic risks, and as yet were not accruing to lead to increased incomes. With wider adoption and more tailored information, climate services could be nudged towards sustainable adaptation.

4. Findings

The risks in each site were a function of biophysical changes, socio-economic dynamics, and politico-institutional structures. We first discuss these contexts of risk followed by strategies undertaken by different actors to manage and plan for these risks (Section 4.1). Next, we use the capacities matrix (Fig. 1) to examine the implications of observed risk management strategies (Section 4.2).

4.1. Risk landscape and risk management strategies in semi-arid India

Across the three sites, risks to livelihoods were mostly a function of regional climatic and biophysical characteristics, market and financial connectivity, socio-economic and livelihood dynamics, and the state's approach to human and economic development.

[6] The survey instrument was part of a larger study and for this paper, only certain sections on vulnerability and adaptation are used. For other aspects, we recommend related papers from the project such as Kuchimanchi et al. (2018) for Maharashtra, Singh et al. (2018) for Karnataka, and Solomon and Rao (2018) for Tamil Nadu.

[7] Ethical clearance was obtained from the researchers' organisations (IIHS, ATREE and WOTR). In all cases, audio and visual recording was done only with consent. All data was stored securely and anonymised.

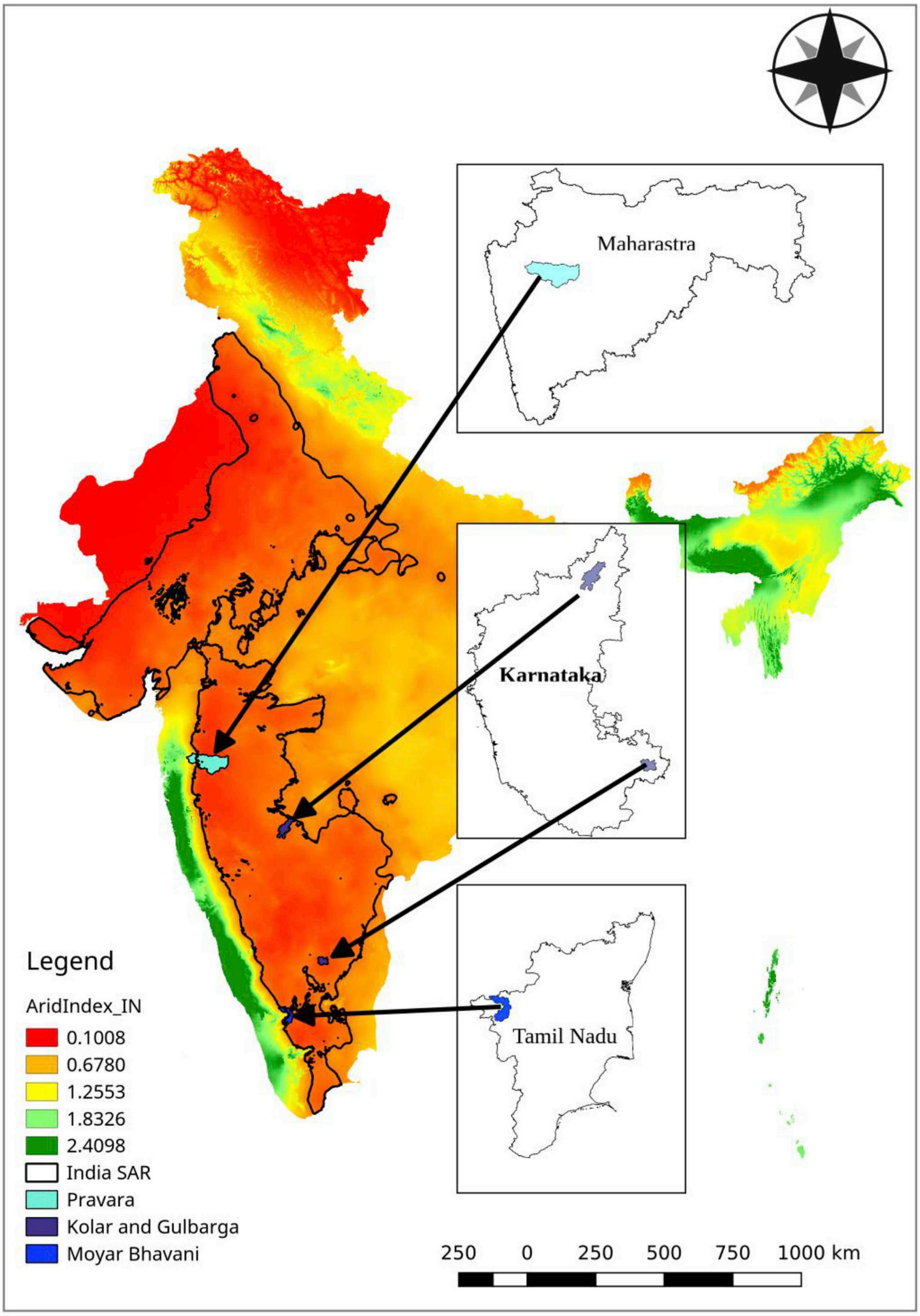

Fig. 2. Map of semi-arid regions in India and research sites. Low index values in the legend represent high aridity Source: Authors.

These risks interact with and mediate one another. Further, they are differentiated by household composition and asset bases, social networks, and attributes of individual members (education, gender etc.). Risk management practices included changing agricultural practices (mostly through crop choices towards cash crops and high yielding varieties and to a lesser extent, leaving land fallow), land management (using more pesticides and fertilisers or engaging in mechanised farming), water management (using drip or sprinkler irrigation, increasing well depth) or livelihood strategies (taking help from relatives, credit from moneylenders, seasonal migration). These strategies were often used concurrently, and shifting between practices was common.

Table 1
Key characteristics of research sites.
Sources: Karnataka: Economic survey of Karnataka, 2014–15; Tamil Nadu Human Development Report, 2017 and Coimbatore district statistical handbook; Maharashtra: Economic Survey of Maharashtra 2016–17, District Statistical Abstract – Ahmednagar, Agricultural Census- Maharashtra 2010-11

Variable	Maharashtra	Karnataka	Tamil Nadu
District studied	Ahmednagar	Kolar and Gulbarga	Coimbatore
Climatic conditions	Annual mean rainfall: 560 mm Average temperature: Ranges between 9 °C (Winter) to 41 °C (Summer).	Annual mean rainfall: 724 mm in Kolar, 777 mm in Gulbarga Average Temperature: Kolar - 40 °C (summer), 10 °C - Winter Gulbarga Summer (40–48 °C), and Winter (7–26 °C)	Annual mean rainfall:618 mm Average Summer 35.7 °C Average Winter 19.5 °C
Climate projections (under A1B scenario 2021–2050)[a]	Nashik division (comprising Ahmednagar district): 17.5–40% decrease in monsoonal rainfall; 1.4–1.68 °C increase in annual mean temperature for the 2030s (TERI, 2014). Increase in number of dry days by 6–9 days in Ahmednagar District.	Kolar: 3.6% decrease in monsoon rainfall and an increase of 1.96 °C in annual average temperature; Gulbarga: 1.4% decrease in rainfall and a 2.19 °C increase in temperature (BCCI-K 2012)	Coimbatore: 3% decrease in annual rainfall and 1.3 °C increase in maximum temperature and 1.2 °C increase in minimum temperature (Government of Tamil Nadu, 2013)
Irrigation status	Irrigated area in Ahmednagar district– 16.9% of total cultivated area	Irrigated area – 5.2% of total cultivable area in Gulbarga district, 35.8% of total cultivable area in Kolar district	Coimbatore district Rainfed area: 35.4% Irrigated area: 65.5%
Landholding[b]	Small and marginal landholders: 60.8% in Ahmednagar	Small and marginal landholders: 88% in Kolar, 67% in Gulbarga	Small and marginal land holders: 94.2% in Coimbatore district
Demographic details [c] (Census, 2011)	Total population: 4.5 million SC: 12.6%; ST: 8.3% • Average literacy rate: 79 • Human Development Index (HDI): Ahmednagar district 0.72 • Below poverty line (BPL) population: 25%	SC population: 30.3% in Kolar, 25.3% in Gulbarga; ST population: 5.1% in Kolar, 2.5% in Gulbarga • Literacy rate: 74.4% in Kolar, 56% in Gulbarga • HDI: 0.625 (Kolar); 0.56 (Gulbarga) • BPL: 42% (Kolar); 27% (Gulbarga)	SC 15.5% ST 0.8% • Literacy rate: 76.2% • HDI: 0.84 (2017) • BPL population: 39.3%

[a] Climate projections are based on scenarios with certain assumptions. Here, we use scenario A1B, which assumes rapid economic growth, global population reaching 9 billion in 2050 and then gradually declining, and the quick spread of new and efficient technologies. More details at: http://sedac.ciesin.columbia.edu/ddc/sres/.
[b] Landholding classes are marginal holders (< 1 ha), smallholders (1–2 ha), semi-medium (2–4 ha), medium and large holders (> 4ha).
[c] Scheduled Castes (SC), Scheduled Tribes (ST), Other Backward Castes (OBC). SCs largely cover communities have been historically disadvantaged and marginalised and are often associated with the socially degrading occupations such as scavenging, sweeping, tappers etc. STs are characterised by geographical isolation and low economic status, typically distinct from mainstream society in culture, livelihoods etc. OBC is a collective term used by the Government of India to classify castes which are educationally and socially disadvantaged. Source: Department of Social Justice and Empowerment, Government of India.

4.1.1. Tamil Nadu

Coimbatore is a drought-prone, semi-arid district in Tamil Nadu, and farmers reported increased climate variability. Of the 400 farmers interviewed, 62.5% reported number of rainy days reducing, 60.5% noted increased summer temperatures, 50% indicated a decrease in the intensity of the North East monsoon (the dominant monsoon in the region) and 72.5% perceived a delay in the NE monsoon. Over the last decade, there has been a shift from rain-fed agriculture to irrigated agriculture, motivated by the availability of borewell irrigation, increased losses from rainfed agriculture due to raids from wild animals (peacocks, wild pigs, elephants), and growing climate variability (Janakarajan and Moench, 2006).

State subsidies on electricity for agriculture and easy availability of loans for borewell drilling have fuelled exponential growth of borewell-dependent irrigation in the region and groundwater over-extraction. Presently well irrigation covers 71.5% of the total irrigated area in Coimbatore district (Coimbatore District, 2016). Other biophysical risks include reduced soil fertility, chromium and arsenic water pollution from cottage industries in the region impacting health and agriculture, and degradation of traditional water tanks and grazing lands.

Bhavani basin has also seen a socio-economic transition. The emancipation of *Dalits* in the early eighties coupled with land redistribution and the migration of upper castes to cities, shifted patterns of caste dominance, with the Other Backward Castes (*Gounder, Vellara-Gounders*) emerging as the landholding class, establishing their hegemony as 'Backward Caste elite'. Caste-based political parties play a vital role in influencing local development policies at the cost of excluding *Dalits* and Scheduled Tribes (STs). Furthermore, historical practices of bonded labour of *Dalits* and STs have limited access to education and other services, which limit their livelihood options (Carswell and De Neve, 2013).

There has been widespread relocation of tribal communities (*Irula, Kurumba*) from adjacent protected forest after it was declared a

Tiger Reserve in 2012, to the fringes of nearby villages where they were given smaller, largely unproductive, compensatory land. Displacement from forest land has changed livelihood patterns from forest-based livelihoods (e.g. harvesting non-timber forest products (NTFPs) such as gooseberry, honey, broom grass): our surveys show that 76% of the tribal population (which was 18% of the sample) rely on casual labour in agriculture as their main source of income. FGDs highlight that low levels of education and exclusion from village kinship networks have exacerbated the marginalisation of relocated communities, lowering their capacity to draw on social capital to manage risk.

Increasing environmental stressors and changing aspirations (away from farming livelihoods) have led to a decline of agriculture in the region. In-depth interviews with men and women aged 19–28 years indicated a preference among youth to move out of agriculture into blue collar jobs. Increasing levels of education and the arrival of automobile and software firms to nearby towns like Coimbatore are motivating migration, resulting in an aging rural population and diluted kinship ties.

In risk perception exercises conducted in farmer FGDs, reduced water availability from rainfall deficits and depleting groundwater tables, crop raiding by animals, and unstable markets emerged as the top three risks to farming livelihoods. Increased connectivity, particularly to the neighbouring state of Kerala, has resulted in additional competition, depressing cash crop prices (banana and marigold). These market fluctuations coupled with poor productivity and higher input costs have led to decreasing net benefits. Flowers such as jasmine, marigold, and cockscomb, which are grown extensively through contracts with pigment and fragrance factories, are facing poor prices set by contractors. Floriculture also has negative knock-on effects such as water pollution and soil deterioration due to intense pesticide application.

To deal with these dynamics, livelihood diversification is the most common risk management strategy: 91% respondents (n = 400) reported agriculture as their primary livelihood, and 62% reported engaging in secondary activities (24% in petty business, 45% in livestock rearing). Farmers in drier regions grow mulberry and rear silk worms to cater to the growing silk industry in Coimbatore; in areas close to towns and cities, smallholders are diversifying into poultry rearing with the assistance of local NGOs. The main coping strategy undertaken by 50% farmers surveyed was shifting from water-intensive crops to crops that require lesser irrigation such as curry leaf, rainfed millets, and horticulture crops but these strategies are contingent upon farm size and asset base. Farmers with larger farms and asset bases tend to either dig deeper borewells or reduce water use by using drip irrigation. Smaller farmers prefer to shift to less water-intensive crops such as dryland millets, reduce dependence on agriculture, and move into wage labour.

Taking loans from multiple sources (formal banking institutions, moneylenders, family, and friends) is a prevalent coping strategy but over time, it has locked many families, especially poorer households with small landholdings, into intergenerational debt cycles (Solomon and Rao, 2018). Formal credit sources are mainly accessed by larger farmers, while smaller farmers (particularly STs) are dependent on local money lenders, who are often the village elite.

The dominance and intense competition between the two largest political parties with a strong representation from the Backward Castes has led to strong State welfarism. Tamil Nadu is a pioneer in public provisioning, which acts as a crucial social safety net for the poorest. However, over the last two years, political instability coupled with failed monsoons have impacted the functioning of these social welfare systems. Social protection schemes such as the Public Distribution System (PDS) and Mahatma Gandhi National Employment Guarantee Scheme (MGNREGS) have been embraced by *Dalit* communities and smaller farmers, providing nutritional security and reducing the need to migrate for seasonal work during the drier months (*pers. obs.*). However, this has led to increased tensions between farmers (particularly OBC) and agrarian labourers because of the impacts of such welfare schemes on local labour availability. At a system level, OBC farmers noted that this has eroded community cohesion and weakened relationships of kinship and patronage.

4.1.2. Karnataka

Kolar and Gulbarga are water scarce districts in Karnataka. In Kolar, declining rainfall, uncontrolled groundwater extraction, and encroachment on lake beds has severely eroded water availability. Lake degradation has accelerated in the last 10–12 years, with a concurrent increase in borewells and groundwater extraction. This shift from common water resources to individual borewells (Singh, 2018b) has had severe impacts on water availability. Acute shortages, especially during summer months, have increased significantly in the past decade. Since 2005, borewells across Kolar have plunged from a depth of 350–400 feet to 1200–1500 feet since (*pers. comm.* Horticulture Department Officer, December 2015). The widespread promotion of water-intensive, non-native species such as *Eucalyptus* and *Grevillea robusta* (silver oak), through a government-led social forestry and afforestation programme in the 1970s, has also driven groundwater abstraction, soil deterioration, and changes in farming practices (Singh et al., 2016a; Shiva et al., 1981). Globalisation is exposing farmers to previously unknown market fluctuations. For example, cheap Chinese silk flooding the local market has undermined Kolar's famed silk production. In Gulbarga, dominant environmental dynamics are recurrent drought, increasing water scarcity, decreasing pastureland, and decreasing soil fertility. The region also scores low on human development indicators and is comparatively poorly connected to market centres.

In both districts, historical marginalisation based on caste and social norms shape present-day vulnerabilities. For example, historically, *Lambanis* (pastoral, nomadic community) in Gulbarga subsisted on livestock rearing and NTFP extraction. In lean periods, they would migrate to cities for wage labour. Poor rainfall and shrinking forests have reduced fodder and NTFP availability while institutional shifts (co-option of common pasturelands by upper castes) have made the *Lambanis* extremely vulnerable. Increasingly, they are migrating but encountering new risks in the city that might be beyond their experiences or response capacity (Singh and Basu, 2019).

However, social structures and norms are not static. In both study sites, FGDs and life history interviews highlighted decreasing community cohesion, changing aspirations away from farming, and loosening of gender norms around where women can work (Singh and Basu, 2019; Singh, 2018b). For example, with better connectivity, women in Kolar reported travelling up to 80–100 km to work in garment factories (Singh et al., 2018), which was a shift away from typical jobs such as weeding and sowing in neighbouring villages or home-based activities such as making garlands, making tamarind snacks etc. While such livelihood shifts yield higher wages and steady incomes around the year, women reported being less connected within their community and reduced time for leisure (Singh et al., 2016a). Drought and increasing climate variability are also reshaping caste and gender relations. Due to prevailing drought-like conditions and consequent agricultural losses, several *Gowda* and *Lingayat* households (traditionally landholders) are gradually selling their lands. In a reversal of social roles, some lower caste households who have accumulated capital through long-term migration, are procuring land from higher castes.

Most coping strategies were in response to changing rainfall patterns and shifting market demand. For example, in Gulbarga, 27% landowning households (54% of the sample) reported diversification of crop in the last ten years, such as shifting from pigeon pea (*tur*) to soybean as the main *kharif* (rainfed) crop in some instances. In Kolar, 16% landowning households (81% of the sample) reported shifting to horticultural crops. In Kolar, farmers have reduced cultivation of millets such as *ragi* towards horticultural crops such as tomatoes and flowers. Although the latter give higher returns, they require more water and are more perishable. Change in the date of sowing are also widely practised (42% and 22% landowning households in Gulbarga and Kolar respectively).

Across households, risk management strategies differed by assets (landholding, followed by water availability), networks (with labour contractors, in nearby towns and cities, within the community and with local leaders) and personal factors (such as education levels, gender, risk aversion). For example, large landowners (those owning > 4 ha) practice crop diversification more than small and marginal landholders (owning < 1 ha) do. Landless and marginal landholders tended to participate in social protection programmes such as MGNREGS and made up most of the beneficiaries of schemes on watershed development or microcredit access.

Livelihood diversification differed between social groups, with 45.5% of Muslim households and 52.5% of Scheduled Caste households from both districts reporting at least one migrant member, higher than that of any other social group. Migration, a significant livelihood strategy, tended to be gendered: for example, in Kolar, 68.8% of migrants are men. Men tend to commute to Bangalore while women undertake agricultural labour up to 10–15 km from their homes (Singh and Basu, 2019). Location also significantly shaped livelihoods and risk management. Villages closer to railway stations and connected to prominent bus routes have higher migration to cities like Bangalore, whereas villages near state borders travel to neighbouring states such as Andhra Pradesh to work as agricultural labourers (on cotton or sugarcane farms).

Strategies were typically undertaken independently but were often buttressed by state-sponsored assistance. For example, subsidies by the horticulture department facilitated the adoption of drip irrigation, and a convergence of drought-proofing activities with employment schemes subsidised digging of farm ponds. However, these schemes were typically profitable for large landholders because they had economies of scale (*pers. comm.* Horticulture Department Officer, December 2015). In Gulbarga, drought proofing through MGNREGS emerged as a key risk management strategy, especially in severe drought years.

4.1.3. Maharashtra

In Ahmednagar district, more erratic monsoonal rainfall, higher average temperatures, and more dry days are key climatic risks (TERI, 2014). From 1991 to 2016, semi-arid regions in Maharashtra have seen significant land use and land cover changes: 98% uncultivable and fallow lands have been converted into agricultural land, and built-up area has increased by 195% (Duraisamy et al., 2018). There has been a shift from food crops to commercial crops, observed through the steep increase of land under horticulture by 1601% from 2001 to 2016. Within agricultural land, pomegranate and sugarcane plantations have increased, driven by policies such as the National Horticulture Mission (for pomegranate) and financial incentives by regional factories for sugarcane. The increase in area irrigated through groundwater has necessitated over-extraction, from 74% of net annual availability in 2004 to 82% in 2014 (Central Ground Water Board, 2014). Current practices of excessive groundwater extraction coupled with reducing rainfall have exacerbated water scarcity and almost 87% area in the region is classified as 'high' to 'extreme' groundwater vulnerable zones (Thomas and Duraisamy, 2018).

Agriculture, especially among large and medium farmers, has become resource intensive, with preference for horticulture and commercial crops and livestock based on crossbred animals (Kuchimanchi et al., 2018). In Ahmednagar, from 2001 to 2011, area under soybean, cotton, and maize increased by 24%, 23%, and 11%, respectively. While such crops give higher returns, they increase farmer exposure to market fluctuations. Increased connectivity and market access has encouraged hybrid cattle ownership (up by 24%) and decreased buffalo and indigenous cattle ownership by 8% and 9.4%, respectively (Livestock Census, 2012). Such shifts can have long-term risks through added pressure for fodder and water availability, erosion of genetic diversity, and second-order impacts on nutritional security.

Large and medium farmers are increasingly taking crop loans through nationalised and regional banks to meet short and long-term credit needs. However, incidents of non-repayment by some farmers due to crop loss and crop loan waivers has discouraged banks from sanctioning loans to small and marginal farmers. Small and marginal farmers are dependent on informal credit, often at higher interest rates through loans from large farmers, moneylenders, and Self-Help Groups (Kuchimanchi et al., 2018).

The participatory vulnerability assessment exercises found that common risk management strategies include increasing pesticide and fertilizer use, higher seed sowing per acre over time, multiple sowings, and experimenting with different seed companies (particularly for cotton). To manage market-based risks, farmers rely on middlemen to sell produce of lower quality as a way to overcome transportation costs and insufficient credit availability. To combat degradation of common pasturelands, large and medium farmers have shifted from open grazing system (by reducing the number of indigenous cattle) to more sedentary livestock rearing (with fewer, high-yielding crossbred animals). Small and marginal farmers have reduced livestock numbers and shifted into a mixed crop-livestock system with small ruminants. During severe drought conditions, distress sale of livestock is common and undermines

Table 2
Summary of risk landscape and risk management strategies across the three case sites with implications on generic and specific capacities. The symbols suggest a positive (+), negative (−), or neither negative nor positive (=) relationship between a strategy and the generic and specific capacities. A question mark (?) suggests the evidence was too low or contradictory to make a judgement at the case study level. The symbols are based on the authors' analysis of data collated from the FGDs, village profiles, and household surveys. We acknowledge that implications of risk management strategies are differentiated across households and these nuances are discussed in text.

Current risk landscape in the case sites	Risk management strategies	Generic capacity	Specific capacity
Tamil Nadu • Increased rainfall variability and temperatures, shifting monsoon patterns • Depleted groundwater levels due to exponential growth of borewell-dependent irrigation • Limited livelihood options and access to education for Dalits and Scheduled Tribes • Livelihoods affected due to relocation of tribals from protected areas • Limited access to formal credit systems by small and marginal farmers • Migration into precarious livelihoods in urban centres • Price fluctuations	• Shift from rain-fed agriculture to intensive irrigated agriculture fuelled through groundwater extraction	+	–
	• Taking loans	–	–
	• Relying on social protection programmes	+	?
	• Out-migration to nearby towns such as Coimbatore	+ in short term	?
	• Livelihood and crop diversification (e.g. silk rearing)	+	?
	• Altering farm management practices such as changing crop varieties, cropping patterns	+	+
	• Water management (e.g. adoption of drip irrigation)	=	+
Karnataka • Erratic rainfall, higher summer temperatures, longer dry spells • Degradation of local water bodies • Groundwater depletion • Decreasing pastureland • Decreasing soil fertility • Price fluctuations, especially affecting cash crops • Historical marginalisation based on caste and social norms • Migration of rural communities to urban centres and associated new risks	• Shift from common water resources to individual borewells	+	–
	• Growing water-intensive, non-native species such as Eucalyptus and silver oak	+ in short term	–
	• Out-migration to cities such as Bangalore, Mumbai, Hyderabad	+ in short term	?
	• Casual labour work from agriculture to non-agrarian work.	=	?
	• Crop diversification (to vegetables and flowers in Kolar, and soyabean and sugarcane in Gulbarga)	+	?
	• Adoption of drip irrigation, undertaking soil and moisture conservation activities.	–	+
Maharashtra • Growing rainfall variability, erratic monsoonal rainfall, increased dry spells • Groundwater-based agriculture, groundwater overexploitation • High inputs and resource intensive crop and livestock production • Market shocks (price fluctuations) in cash crops • Limited access to formal credit systems by small and marginal farmers • Degradation of common pasturelands • Distress sale of livestock during drought conditions	• Over-extraction of groundwater	+	–
	• Shift in cropping patterns towards groundwater-dependent horticulture and commercial crops	+	–
	• Shifts in cropping practices such as increasing pesticide and fertilizer use, multiple sowings with higher seed density	+	–
	• Livelihood diversification towards hybrid cattle rearing	+	–
	• Loan taking	–	–
	• Soil and water conservation measures under watershed development programmes	+	+

local livelihoods significantly.

Various soil and water conservation measures under watershed development programmes have recharged groundwater and strengthened local ecosystem services (Gray and Srinidhi, 2013; Srinidhi and Souza, 2018) but demand-side management practices such as improving water efficiency or reducing competitive borewell drilling remain poorly followed (Kale and D'Souza, 2018). This is mostly because adequate support mechanisms for adaptation (e.g. subsidies that encourage sustainable crop-farm management or water management) are not in place or difficult to access. In such a scenario, to cope with periods of distress often resulting from poor or failed monsoons, farmers, irrespective of farm size, rely on government compensation for crop loss, crop insurance, and loan waivers (Kuchimanchi et al., 2018). More recently, climate information services such as the provision of weather-based agro-meteorological advisories and few climate change adaptation projects have seen early successes in strengthening on-farm capacity to deal with erratic weather and climatic risks (Lobo et al., 2017).

4.1.4. Summary of risks and responses across the three sites

Across the three sites, biophysical and climatic risks included reports of high natural resource degradation (especially decreasing soil fertility and groundwater extraction), rapid land use land cover change, more erratic rainfall and shifting seasons, and increasing temperatures (Table 2). However, these risks interacted with market dynamics, social transitions, and livelihood changes to shape local risks. For example, in Kolar and Ahmednagar, shifting agricultural practices are reshaping caste and gender relations (e.g. high returns from horticulture crops have made the historically marginalised *Mali* social group extremely wealthy in Ahmednagar; recurrent droughts are making upper caste landholders sell land in Gulbarga, while lower caste migrants who have accumulated wealth are buying these lands for farming).

Several factors considered to improve adaptive capacity, can have negative second-order impacts on vulnerability and risk. For example, improved road connectivity, commonly considered to improve adaptive capacity (Rama Rao et al., 2013), had mixed impacts in Ahmednagar. While increased road connectivity improved market access and facilitated shifts to cash crops such as pomegranate, it had second-order impacts such as higher groundwater extraction. In Tamil Nadu, improved road connectivity has dampened the prices of some cash crops (e.g. banana and marigold) because of increased competition.

Across the three sites, some of the same risks (drought, water scarcity) unfolded differently across different places (e.g. groundwater extraction in Kolar, Moyar-Bhavani, and Ahmednagar has reached alarming levels while Gulbarga hasn't seen such rapid extraction because of restricted market connectivity and large-scale out-migration) and within the same place (differentiated by socio-economic factors). Households undertook a range of strategies to manage risk such as adjusting cropping practices, diversifying crops and livelihoods, and relying on government social safety nets such as wage employment through MGNREGS, PDS for subsidised food, and drinking water supplied through tankers during summer. Individual and household strategies were typically autonomous and in response to current or expected risks (e.g. adjusting farm practices). Government strategies were more planned and tended to improve household wellbeing (e.g. subsidised food rations), with lower implications for local climate change adaptation.

Table 2 demonstrates how the unique risks in the three sites and the ensuing risk management strategies have implications for generic and specific capacities. Most risk management strategies tend to build generic capacities, mostly through improved incomes, which can have knock-on development benefits such as improving food security, spending on health needs etc. However, several of these strategies tend to work in the short term with longer-term implications either being unclear (e.g. as in the case of out-migration to cities) or negative (e.g. loan taking that can lock families into debt or shifting to cash crops that may make farmers dependent on competitive borewell digging). Thus, the risk management strategies as seen through the heuristic of generic and specific capacities allows us to examine their implications for development and adaptation respectively. These implications are discussed in more detail next.

4.2. Implications of risk management strategies: generic and specific capacities

Risk management strategies identified across the research locations tend to contribute to either generic or specific capacity but very few do both (Table 2). In Fig. 3, we map key risk management strategies to examine how they map onto the four capacity quadrants (as explained in Section 2.2). Erosive strategies (left bottom quadrant) were 'moving out of farming' and 'taking loans', which tended to score low on generic and specific capacity and potentially pushed households into a poverty trap.

Responses such as changes in production systems (e.g. crop diversification into pomegranate in Maharashtra, floriculture in Moyar-Bhavani and Kolar) improved incomes and scored high on generic capacity but exposed farmers to market fluctuations,

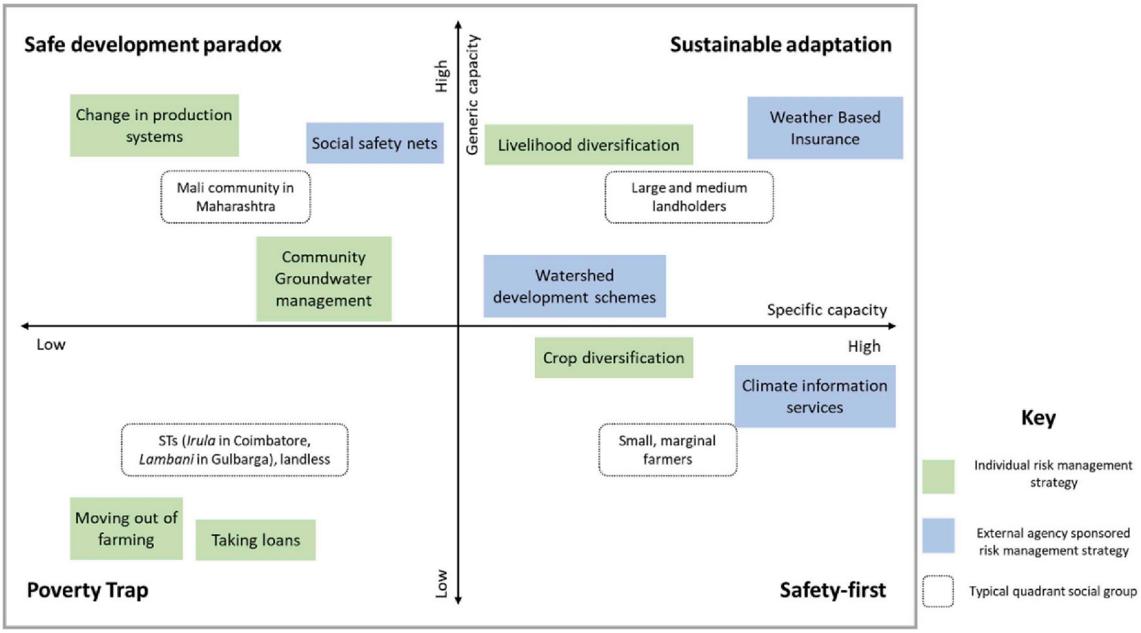

Fig. 3. Common risk management strategies assessed using the capacities matrix (Eakin et al., 2014). The assessment was done by the authors to highlight whether a strategy contributes to specific or generic capacity (relative to other strategies). Based on this, they fall within one of four quadrants: 'safety-first' denoting strategies that focus on building capacities to deal with and prepare for climatic risks specifically; 'poverty trap' signifying erosive coping strategies that undermine household material wellbeing and do not address climatic risks; 'safe development paradox' which includes strategies that help perform well on development indicators but do not necessarily build adaptive capacity, thus presenting a paradox of potentially making people more vulnerable to future risks; and 'sustainable adaptation', an aspirational quadrant where specific and generic capacities are built.

weather-based risks and nutritional insecurity, thus scoring low on specific capacity. Tamil Nadu, in particular, demonstrated a case of the 'safe development paradox'. Structural investments over the last three decades have shown payoffs with better education and infrastructure than other states (Joshi and McGrath, 2015), reflected it Tamil Nadu's Human Development Index being one of the highest in India. Despite relatively high generic capacity Tamil Nadu's farmers are repeatedly identified as highly vulnerable – rural indebtedness is third highest in the country (National Sample Survey Office, 2013), agrarian distress is acute, and farmer suicides are common and increasing (Vijayabaskar, 2010; Djurfeldt et al., 2008). Our research in Coimbatore district confirmed this: small and medium farmers remain particularly susceptible to climate variations because of their continued dependence on groundwater and growing indebtedness (Solomon and Rao, 2018). In such a situation, events such as the recent 2014–16 drought, which led to widespread crop failure, deepens distress for the most marginal and exposes how limited specific capacities to deal with climatic shocks are.

Livelihood strategies of small farmers in Ahmednagar belonging to the *Mali* community provided an example of the 'safe development paradox'. These farmers have high generic capacity (relatively high incomes, high literacy, good post-harvest facilities, and strong asset bases), fuelled by pomegranate cultivation and heavy reliance on groundwater. This reliance on pomegranate, undermined individual specific capacities making them more sensitive to market fluctuations, disease outbreaks, and rainfall variability. The lack of knowledge on climate-compatible farming methods, input-intensive agricultural practices, mono-cultivation production system, depleting groundwater resources, and lack of alternate livelihood skills makes them vulnerable to future climatic and non-climatic risks impacting long-term sustainability (Kuchimanchi et al., 2018).

Other strategies such as diversifying crops and using climate information services (bottom right quadrant) contribute to specific capacity since they enable households (across landholding categories) to deal with and prepare for climatic risks but do not necessarily lead to increased income or better performance on development indicators. Further, many farmers are diversifying into water-intensive crops such as flowers and vegetables, which may exacerbate existing exposure to climatic risks. This 'safety-first' quadrant is typified by small and marginal farmers in Maharashtra of the *Banjara* community. During periods of water and fodder scarcity, these farmers reduced their livestock holdings and shifted into a mixed crop-livestock system with small ruminants and bullocks, which have low fodder requirements but provide an additional source of income. Despite this highly developed and flexible form of specific capacity to deal with rainfall variability, these small and marginal farmers have poor generic capacity – they own little physical infrastructure (irrigation sources, micro-irrigation, farm equipment and post-harvest structures), low natural capital (land), and have limited access to subsidies, all of which undermine their long-term wellbeing.

Finally, the top right quadrant is an aspirational quadrant where strategies contribute to specific *and* generic capacities and lead to 'sustainable adaptation'. However, in our study sites we found little evidence of strategies strengthening specific and generic capacities effectively. While livelihood diversification (e.g. through migration in Gulbarga) is increasing incomes, it can undermine specific capacity (e.g. migrants entering precarious livelihoods in urban areas and live in risk-prone locations). Some watershed development schemes are helping build generic and specific capacities, but their outcomes beyond project cycles is evident only where social capital is high.

Importantly, examples from the three research locations are spread *across* the quadrants, and no location falls into any one quadrant, highlighting the differential capacities present within each location. Certain groups can inhabit multiple quadrants and strategies and people can move across the two dimensions of specific and generic capacities over time. For example, large and medium farmers possessed high generic capacities in terms of better land holdings, access to formal credit, asset base and political connectivity and high specific capacities. However, these farmers tended to take up resource-intensive farming based on groundwater extraction (for example pomegranate farmers in Ahmednagar, Maharashtra), with preference for commercial crops and crossbred livestock. Therefore, even though it appears that this category of farmers possesses high generic and specific capacities, it is difficult to place them in the 'sustainable adaptation' quadrant as they are extremely vulnerable to consequences of groundwater depletion. Potentially, without proper management of groundwater resources, there is a high possibility of such groups finding other options to meet their water requirements, which might be even more unsustainable and have wider negative consequences for the socio-ecological system.

5. Discussion

5.1. Current risk management is predominantly autonomous and short-term

Understanding how household risk management strategies interface with planned development and adaptation interventions is complex and often difficult to delineate. Across the three research sites, households perceived and responded to multiple risks in their biophysical, financial, social, and institutional environments (Sec 4.1), confirming prevalent narratives in vulnerability and adaptation literature of households negotiating multiple risks concurrently (Burnham and Ma, 2016; Singh et al., 2016b). We found that in increasingly connected systems, risks traverse scales (e.g. global market fluctuations impacting silk rearers in Kolar), and structural drivers of vulnerability (e.g. caste-based livelihood opportunities) intersect with emerging drivers such as depleting groundwater. Household risk management strategies were typically autonomous and reactive but drew on planned interventions such as social safety nets or employment guarantee schemes, especially during periods of stress. These strategies were highly differentiated, and typically, households with fewer assets tended to remain in cycles of erosive coping.

Importantly, while there were commonalities across the three sites (located in three different states of India), there was discernible variation *within* these SARs. These internal variations were based on local production systems and socio-economic characteristics but more significantly on State-specific governance regimes, adding to the growing empirics around the political economy of adaptation (Tanner and Allouche, 2011; Sovacool et al., 2015; Birkenholtz, 2012; Taylor, 2014). For example, in Tamil Nadu, a welfarist state government has shown remarkable successes in poverty alleviation (Joshi and McGrath, 2015; M Vijayabaskar, 2017) contributing to building generic capacities. In Karnataka and Maharashtra, a long history of participatory watershed development has fostered strong capacities in local NGOs to implement natural resource management projects. Increasingly, these capacities are being leveraged to implement adaptation projects, with moderate and growing success (Kuppannan et al., 2015; Kattumuri et al., 2015).

We found little evidence to suggest people were adapting – a process denoted by a behavioural change towards proactive risk management to climate change – and argue that most responses were reactive, coping strategies to shorter-term climate variability (Table 3 shows how most risk management practices build generic capacities rather than specific capacities to deal with climatic risks). There were few examples of forward-facing risk management, either by people themselves or other actors such as the state or civil society. These included NGO-driven participatory groundwater budgeting in Maharashtra and mainstreaming of adaptation concerns in development programmes such as MGNREGS. These findings indicate that at present, Indian SARs are seeing incremental adaptation, which may be insufficient to address the growing challenges of climate change and calls for transformational adaptation.

5.2. Indian policies are building generic capacities but progress on specific capacity is slow

To understand how development and adaptation interventions are shaping local capacities to manage risk, we plotted key risk management strategies based on whether they build generic or specific capacities (Fig. 3). Encouragingly, large-scale development interventions such as nationalised food distribution or investments in basic infrastructure, are improving incomes and wellbeing, thus building generic capacities. However, across the sites, socially marginalised groups (such as tribal communities, marginal farmers, the landless) tend to fall through these nets, into 'poverty traps' where households 'find themselves constantly coping with drought, but are unable to overcome the conditions that make them vulnerable' (Lemos et al., 2016, p. 177). These households were caught in cycles of debt tended to move out of agrarian settings into precarious livelihoods and were unable to improve generic or specific capacities.

The 'safe development paradox' quadrant demonstrated that state support mechanisms (public food distribution, disaster relief, loan waivers) that help coping with immediate stressors also foster the status quo, disincentivising farmers from adapting to future stressors. In Tamil Nadu, for example, unsustainable policy focusing on welfarism has potentially undermined incentives for individual adaptation where smaller farmers often opt for unsustainable coping strategies such as the distress sale of cattle to tide them over till they receive payouts from the state. Furthermore, unsustainable financial risk management strategies, using multiple sources of credit to feed unsustainable loan-taking, and dependence on the government for loan waivers have led to one in two farmers being chronically indebted. This highlights how high generic capacity does not always translate into high specific capacity and provides insights into development funding and adaptation prioritisation.

6. Conclusion: moving towards an agenda of sustainable adaptation

As a rapidly growing nation with critical development challenges and climate vulnerabilities, India faces multiple challenges to managing risks and facilitating sustainable adaptation. Rooted in tenets of being socially equitable, environmentally feasible, and economically viable, 'sustainable adaptation' is an aspirational goal to make concurrent progress on development and adaptation goals (Eriksen and Brown, 2011; Eriksen and O'Brien, 2007; Sherman and Coauthors, 2016; Inderberg, 2015).

In this paper, we identified how in some areas, development interventions that address human wellbeing needs and leverage institutional reforms are improving livelihood opportunities and incomes, thus strengthening generic capacities (the ability of people to meet their basic needs). We also found adaptation interventions such as delivering climate information or diversifying crops are seeing success but need to be strengthened to truly harness their potential in building specific capacities (to deal with present and projected climatic risks). In between, (housed in the 'safety-first' and 'safe development paradox' quadrants of Fig. 3) are risk management strategies that are working for some, sometimes, but need to be reimagined by all stakeholders involved (vulnerable populations, NGOs, the State) to meet the twin challenges of climate change and development deficits in an equitable manner. Of high concern are strategies in the quadrant 'poverty trap' which houses strategies that tend to lock people into cycles of poverty and vulnerability. It is the actions in this area (farmers quitting agriculture, erosive loan-taking) that need to be addressed through targeted policy interventions.

We argue that the quadrant of "sustainable adaptation" is where adaptation policy, practice, and research should 'nudge' existing risk management strategies towards. The findings suggest some early successes in India in this space such as through livelihood diversification (into remunerative crop-livestock systems, diversifying into non-farm sectors) and watershed development (success stories are seen across the three sites). We believe these findings on how current development and adaptation interventions can be nudged towards sustainable adaptation hold lessons for other rapidly changing semi-arid contexts across the global South.

The three illustrative cases from semi-arid India echo findings by Lemos et al. (2016) to demonstrate that while development interventions build the critical bedrock of generic capacities; they do not necessarily translate into building adaptive capacity to deal with *climatic* risks. To facilitate moving towards sustainable adaptation actions that meet development needs and adaptation goals, we identify entry points to strengthen existing adaptation interventions in India specifically and dryland rural systems in general. Overall, we found the (Eakin et al., 2014) framework useful for diagnosing risk management strategies observed in dryland India and demonstrate its application in similar dynamic contexts. The framework can become a powerful policy-facing tool to identify entry points to enable local adaptation. It is also a useful visual representation of an aspirational goal of 'sustainable adaptation', which we find particularly useful for practitioners. Future research could test the efficacy of such visuals in motivating policy change towards sustainable adaptation.

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Appendix A. Supplementary data

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