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Risks and responses in rural India: Implications for local climate change adaptation action

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ABSTRACT

People in drylands face multiple climatic and non-climatic risks and subsequently engage in various response strategies to manage these risks. Research on risk management has typically focussed on a static, location-specific understanding of risk and response. However, empirical evidence suggests that risks and vulnerability vary across space and time. Increasingly, responses traverse multiple locations e.g. people move across rural and urban areas, women move beyond the household/community to earn additional incomes. To highlight this dynamic reality of risks and responses, we study livelihood transitions in South India. We unpack risk and response portfolios across scales – household, community, and sub-national (district) levels – and classify them as coping, adaptive and maladaptive. Our findings emphasise that present responses do not necessarily qualify as climate change adaptation strategies. While certain strategies do improve household wellbeing in the short run, there is relatively lower evidence to suggest an increase in adaptive capacity to deal with climatic risks in the future. These findings point to critical gaps in understanding current risk management and how it can contribute to local adaptation policy-making and implementation.

1. Introduction

Livelihood vulnerability in drylands is characterised by a range of interacting social, economic, political, and environmental changes (Reynolds et al., 2007; Tucker et al., 2015; Stringer et al., 2017), which impact agricultural and non-agricultural livelihoods. This vulnerability is exacerbated by inherently low agricultural productivity (Thornton et al., 2009), rapid and increasing natural resource degradation (Stringer et al., 2017), inadequate governance responses to aid diversification and adaptation processes (Tucker et al., 2015), and an overall poor performance on development indicators due to economic marginalisation (Tucker et al., 2015). Climate change is projected to exacerbate these problems, pushing dryland systems to cross biophysical thresholds with long-term implications on local livelihoods and agricultural sustainability (Fraser et al., 2011; Tucker et al., 2015).

The drylands of India face similar challenges. Home to 40% of the country's population, (Harriss-White, 2008), these regions are characterised by low and erratic precipitation, heterogeneous soil profiles, a relatively short growing season, and a complex system of agricultural production. Increasing climatic variability has already halved agricultural incomes in parts of dryland India (Bantilan and Anupama, 2002). Real rural incomes across India have increased by only 34 percent from 2003 to 2013 (Chandrasekhar and Mehrotra, 2016). Further, uneven regional development, low investment in rainfed agriculture, and a policy focus on irrigated agriculture have undermined local survival and adaptive capacities (Raina, 2014; Kumar et al., 2016; Yadav and Lal, 2017). Despite

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being exposed to these risks, there is a rich literature documenting how dryland communities adjust livelihoods through experimentation; drawing on past experiences of variability and leveraging human and social capitals (Mehta, 2000; Thomas et al., 2007; Forsyth and Evans, 2013; Eakin et al., 2014; Kattumuri et al., 2015; Raina, 2015; Singh et al., 2016b). However, these practices of adjustment are increasingly being challenged by growing climate variability and longer-term manifestation of climate change.

Extant vulnerability and adaptation research has typically focussed on a static, location-specific understanding of risk and response. In India, a systematic literature review of 120 vulnerability assessments found very few studies examine how vulnerability is changing over time (Singh et al., 2017a). However, empirical evidence suggests that risk and response portfolios are spatio-temporally dynamic (Cutter and Finch, 2008; Kasperson, 2017). Increasingly, risk management strategies and spaces traverse multiple locations through, for example, higher human mobility and changing social norms (Benz, 2014; Nguyen, 2014). Emerging vulnerability and adaptation literature highlights the necessity of capturing this temporality through novel methodological approaches (Fawcett et al., 2017; Singh, 2018a) and using it to understand how adaptive capacity (a latent property) is realised as adaptation (a desirable outcome) (Mortreux and Barnett, 2017).

To understand this dynamic reality of risks and responses in the context of climate change, we examine livelihood responses and their outcomes at household, community, and sub-national scales in rural Karnataka – a large state in Southern India. We unpack household risk portfolios and assess their responses for their long-term implications on household wellbeing and systemic sustainability. We use the heuristics of survival, accumulation, erosion (see Table 1 for details) to highlight the variations in risk management across households. While reaffirming the argument that interventions to build adaptive capacity must be contextual (Adger et al., 2005; Smit and Wandel, 2006), our findings push this thesis further to suggest that many responses that may not necessarily fall under 'adaptation' help households cope with the risks they face. Moreover, while certain strategies are improving household wellbeing, there is little evidence to suggest an increase in their adaptive capacity to deal with future climatic risks. Our findings thus, identify critical gaps in understanding current risk management and how it can contribute to local adaptation policymaking and implementation.

The structure of the paper is as follows. In the next section, we review the literature on risk and responses, with a geographical focus on drylands, and thematic focus on temporality. Section 3 describes the methodology and study sites followed by Section 4 which presents the results. In Section 5, we conclude by reflecting upon our findings and suggest some entry points for enabling local adaptation.

2. Characterising risks, responses, and wellbeing outcomes

Risks to livelihoods include biophysical drivers (extreme events, natural resource quality) and structural factors (inequality, poverty, infrastructure), all of which are embedded in specific social contexts (norms, rules, networks), (Otto et al., 2017). These drivers are inherently dynamic, rooted in historically shaped pathways (Wisner, 2004; Reynolds et al., 2007; Ribot, 2010; Tschakert et al., 2013; Kasperson, 2017), and mediate individual responses (Singh et al., 2016b). Capacities to adjust livelihoods and cope or adapt to dynamic risks are further influenced by financial capital and infrastructure, social norms and practices, wider institutional regimes and agendas, and the ability to harness and share knowledge (Berrang-Ford et al., 2011; Sietz et al., 2011; Patnaik and Das, 2017).

Household responses can be understood as falling along a continuum from no response to coping to adapting (Singh et al., 2016b). Responses can be categorised by scale (individual, household, community-level or regional), by actor (vulnerable communities, non-state actors, government) and by timing of response (autonomous, planned). Autonomous responses, which are spontaneous responses to non-climatic changes such as market dynamics or ecological change, include strategies such as livelihood and income diversification (Ellis, 2000), investment in assets or social capital (Olsson et al., 2014), and shifts in sociocultural practices such as regulating food intake by some household members, inclusion of children into the workforce (Singh et al., 2016b; Choudhury and Sindhi, 2017).

Planned responses, on the other hand, are the result of deliberate policy decisions which recognise or pre-empt certain risks and aim to maintain status quo or transition towards a desired state (IPCC, 2014). In India, planned responses to strengthen rural livelihoods were mostly undertaken through the Green Revolution. This policy focus prioritised cereal cultivation, benefited irrigated regions, and privileged large farmers best endowed with natural, financial and social capitals (Pingali, 2012). Smallholder farmers in drylands were rendered particularly vulnerable, as they could not benefit from increasing returns to scale (Harriss-White, 2008). Furthermore, agricultural policy has seen relatively lower support for strengthening allied sectors such as livestock rearing and non-agrarian rural livelihoods, which are crucial for dryland economies.

Responses may be specific to climatic risks or leverage generic capacities that enhance economic and human wellbeing outcomes (Eakin et al., 2014; Lemos et al., 2016). At an individual level, responses are typically autonomous and cover a range of actions such as livelihood security and management functions (e.g. diversification of livelihood, investment etc.), adoption of technological solutions (e.g. irrigation facilities), management of societal ties and knowledge (e.g. fall back options enabled by social cohesion) (Ravera et al., 2016).

While several studies examine response strategies in rural India (Panda et al., 2013; Tripathi and Mishra, 2016), the outcomes of these responses for adaptation and future adaptive capacity remain understudied. In an attempt to address this gap, we map out responses as coping, adaptive or maladaptive and further differentiate between generic strategies (e.g. to improve agricultural incomes, meet daily sustenance) and specific strategies that are in direct response to climatic risks (Table 1). This heuristic of generic versus specific draws from Eakin et al., (2014) and distinguishes climate change adaptation from ongoing development interventions that strengthen household capacities. It also embeds individual responses within wider development interventions aimed at providing

Table 1
Mapping coping and adaptive responses and their outcomes. The upward, downward and sideways arrows represent doing better, doing worse, and negligible change respectively. *Source:* Authors.

Response		Directionality			Illustrative example from literature
		Ecological	Economic	Social	
Short-term coping	Surviving	↔	↓	↓	Survival strategies such as reduced food intake or distress sale of livestock (Bhatta and Aggarwal, 2016) can erode personal assets and human capitals, especially if practiced over long periods
	Eroding	↓	↑	↓	Trade-offs and externalities associated with shared resources such as groundwater can lead to conflicts as well as resource over-extraction (Lele et al., 2013)
	Accumulating	↔	↔	↓, ↔	Overreliance on microfinance institutions in rural Andhra Pradesh disenfranchised certain social groups, led to social reproduction of poverty, and aggravated farmer distress and suicides in the mid-2000s (Taylor, 2013)
	Moving	↔	↑	↓	Entrenched 'powerlessness in labour relations' drives inequality, undermines wellbeing and perpetrate social vulnerability of seasonal migrant labourers (Bhagat, 2017; Jha et al., 2017)
Long-term adaptive	Adaptive behavioural change	↑	↑	↔	Changes in cropping practices such as shifting planting dates and growing less water requiring crops in the face of recurrent drought or water scarcity (Jain et al., 2015)
	Institutional shifts	↑	↑	↔	Access to crop insurance is particularly effective and increases chances of farmers engaging in yield-raising adaptations (Panda et al., 2013)
Long-term generic	Development interventions	↓	↑, ↔	↔	Green Revolution trajectory increased incomes and food security but undermined ecological systems and heightened regional inequality (Pingali, 2012; Gajjar et al., 2018)
	Livelihood security and management	↑	↑	↔	Co-benefits of employment generation (e.g. MGNREGS) that has helped livelihood diversification, drought proofing, natural resource management and reclamation, reclamation of commons (such as tanks, wells etc.) and in some cases, stemmed migration (Adam, 2015; Esteves et al., 2013)
Potentially maladaptive	Ecological	↓	↓	↓	Well-intentioned interventions such as farm ponds for rainwater harvesting have shown to have potentially maladaptive outcome such as high initial investment and maintenance costs (Rao et al., 2017) and negative externalities such as higher groundwater abstraction (Kale, 2017)
	Institutional	↓	↓, ↔	↓	Negative externalities of heavily subsidised electricity on groundwater abstraction (Kumar et al., 2013) Investment inefficiencies in drip irrigation subsidies are widening economic disparities (Fishman et al., 2015)

infrastructure and services.

The possible outcomes of planned or autonomous response strategies on household wellbeing are discussed using a sustainability lens and its three pillars (ecological, economic, social). The direction of these outcomes are informed by literature, with examples from India.

Table 1 also highlights that while some autonomous responses operate within local social-ecological limits (e.g. leaving land fallow), others may, over a longer timescales, erode people's capacity to cope and thus lead to maladaptive outcomes (for e.g. reduced food intake, increasing school dropouts). Further, practices like reduced food consumption might entrench some people into cycles of poverty and differentiated vulnerability (Sen, 1981; Krishna, 2006), with implications for inter-generational wellbeing (Pande, 2003). However, there remain few studies that chart such inter-generational aspects of response behaviour, especially in climate change vulnerability studies (Singh et al., 2017a). Outcomes of large-scale planned interventions can also have maladaptive outcomes. The Green Revolution in India is one such example where shorter-term gains have created severe ecological and social negative externalities at a longer timescale (Pingali, 2012; Gajjar et al., 2018).

3. Study area and research design

This research used a mixed methods approach to collect data, which included a structured household survey, participatory focused groups discussions (FGDs) (Singh et al., 2016a), multi-stakeholder key informant interviews, and in-depth life histories (Singh, 2018a). The methods helped us explore local livelihood trajectories and risk and response portfolios at three scales: settlement-level (village), household-scale, and intra-household scale. Since migration is an important livelihood strategy adopted in response to climatic and non-climatic risks, we specifically interviewed migrant and non-migrant households to understand implications of migration. Such a mixed method, multi-scalar approach highlights how households negotiate their fast-changing environmental, social, and institutional landscape with some coping, others adapting, and several others undertaking potentially maladaptive strategies. Similar to studies on social vulnerability (e.g. Burnham and Ma, 2017), we deliberate on the circumstantial drivers of vulnerability at the local scale, going beyond the immediate, observable impacts to more structural drivers of vulnerability (Ayers and Dodman, 2010; Ribot, 2010).

Our study is based in Karnataka, a predominantly semi-arid state in South India (KSNDMC, 2017). Within Karnataka, we chose two districts – Kolar and Gulbarga, which are among the least developed districts in the state and face severe water scarcity, recurrent droughts, and increasing natural resource degradation (Government of Karnataka, 2014; Singh et al., 2017b). Kolar falls in the southern part of the state and is relatively more developed on account of its proximity to the state capital, Bengaluru while Gulbarga, part of North Karnataka, is recognised as a 'backward district' and performs poorly on most human development indicators (Government of Karnataka, 2014).

Villages and households were chosen using a two-stage sampling strategy. In the first stage, we purposively identified four blocks (sub-districts) within Kolar and Gulbarga, with a focus on adequately representing the diversity of rural semi-arid districts in terms of livelihoods, socio-demographic, agro-climatic, and geographic characteristics as described below. This purposive sampling was informed by extensive scoping visits and interviews with local key informants. In the second stage, we randomly chose two villages from each blocks. Within the chosen villages, households were randomly chosen based on a proportional representation basis. Before randomly selecting the villages, we applied three criteria to represent farming households sufficiently – the village should have a

Table 2
District wise summary statistics.

	Gulbarga		Kolar	
	Total	%	Total	%
No. of households	419		406	
Gender of household head				
Male		85		81.5
Female		15		18.5
No. of households with migrants	134	32	190	46.8
Caste group				
General		1		1
Muslim		7.6		5.7
Other Backward Castes (OBC)		37.4		46.8
Scheduled Castes (SC)		22.7		40.3
Scheduled Tribes (ST)		8.1		3.2
Others		23.2		3
Land categories				
Landless		45.5		18.6
Marginal holders(< 1 ha)		11.1		56.2
Smallholders (1–2 ha)		19.3		14.7
Semi-medium holders (2–4 ha)		12.8		7.5
Medium and large holders (4 ha <)		11.4		3

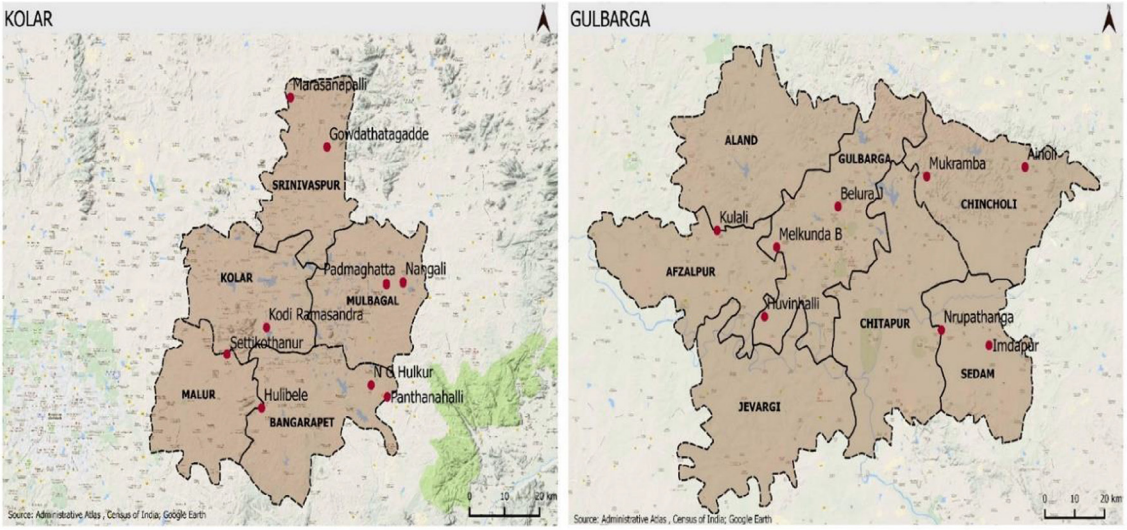

Fig. 1. Village sites in Kolar district (left) and Gulbarga (right). *Source:* Authors.

population of more than 200 households, agriculture is the primary livelihood, and the village should have cultivated land greater than 20 ha. This sampling strategy led to the identification of 17 villages and 825 households across Kolar and Gulbarga (Table 2).

In addition to using information from the Population Census 2011 to familiarise with the basic socio-economic profile of the settlements, we developed detailed village profiles through transect walks, focus group discussions, key informant interviews, and participatory resource mapping. The qualitative research tools included gender-differentiated FGDs (18 in Kolar, 8 in Gulbarga) to capture broad risk perceptions, response strategies, and information networks in the research sites and seventeen life history interviews with migrant and non-migrant families to explore response outcomes at an inter and intra-household level (Fig. 1.).

4. Findings

Using narratives of risk from the FGDs, KIIs and village profiles, we first describe village-level perceived risks and reported responses. We discuss how risks to agricultural and non-agricultural livelihoods and associated responses have been shaped by wider policy imperatives and institutional arrangements. To unpack the variability of these risks and responses across various households, we then discuss household-level risks and multi-scalar planned and autonomous responses observed.

4.1. Overview of risks

Kolar and Gulbarga are experiencing more erratic rainfall patterns, groundwater depletion and natural resource degradation (BCCI-K, 2012; Kolar District Office, 2015; Kumar et al., 2016; Singh et al., 2016a). There is substantial variability in rainfall amount in the past decades with a significant declining trend in rainfall amount in Kolar district (Fig. 2).

To understand perceptions of risk, during the FGDs, we asked respondents to map the major risks related to key livelihoods:

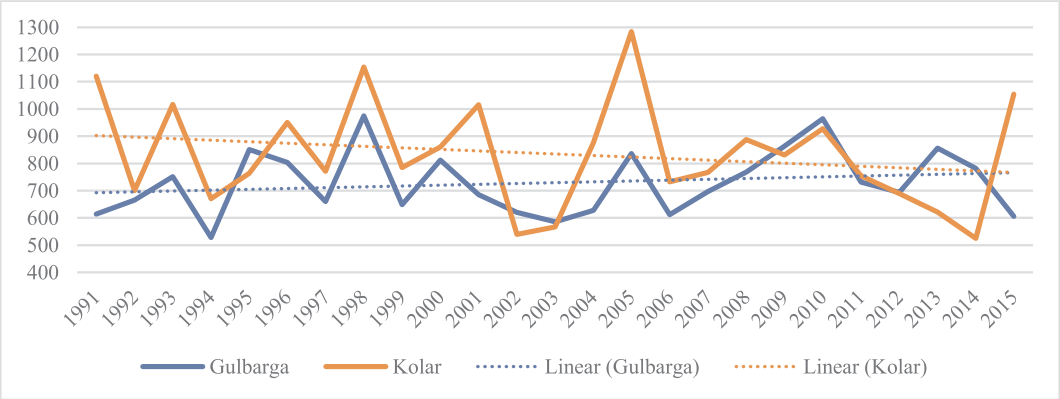

Fig. 2. Average annual rainfall in study sub-districts. *Source:* Karnataka State Natural Disaster Monitoring Centre.

agriculture and allied activities, agricultural and non-agricultural wage labour, and running businesses. Overall, both men and women groups identified untimely rainfall and water scarcity as significant risks to agriculture, corroborating meteorological trends of more erratic rainfall. Market issues such as inadequate transportation, long distance from markets, and price fluctuations were prominently raised by men, since they were responsible for selling farm produce in markets. Women, on the other hand, focussed on issues related to sowing such as poor soil quality and lack of seeds.

In livelihoods such as wage labour, women spoke of risks such as uncertain timing and work being physically strenuous due to heat. Many women (50%) also identified low wages as an important issue which when corroborated with wage rates for men and women (Rs. 160–180 for women and Rs. 250–300 for men) was found substantial. In running petty shops and small businesses, women identified the issue of troublesome middlemen, referring to safety and cultural issues that result because of women encountering men outside their immediate sphere. Both men and women noted the lack of credit facilities and access to finances at crucial times in the agricultural calendar as critical livelihood constraints. Despite the extensive development of microcredit institutions across Karnataka, they were reported too small to provide credit for key inputs, especially for agriculture where cash crops are pushing up costs (e.g. tomato in Kolar).

Respondents also alluded to cognitive risks, which were mental barriers in undertaking certain strategies. For examples, several respondents noted seeing 'no alternative' to wage labour or youngsters' disinterest in farming as undermining the family agricultural enterprise. While these risks are often not tangible, they manifest as concrete risks with implications for response decisions.

4.1.1. Perceptions of risk

Overall, respondents reported increasing environmental change: longer dry spells, groundwater levels had fallen sharply over the last 40 years accompanied by decreasing crop diversity and higher out-migration.

In Kolar, water resources have considerably declined since the 1970s (see Supplementary Material 1 for a detailed timeline on village-level changes). Respondents observed that there was sufficient water in lakes along with attached pasture and forest land in the 1970s and 80s. Diets were nutritionally diverse with farmers typically growing millets, groundnut, tomato, potato, cabbage, cauliflower, radish, field bean, horse gram, Bengal gram, sugarcane, paddy and beetroot. In the mid-1980s, however, the state government endorsed eucalyptus cultivation, promising economic benefits from timber. Mango and mulberry (for sericulture) were also identified as promising cash crops and actively promoted. In the late 1990s, these shifts in the farming landscape manifested through declines in groundwater levels, decreased soil fertility, drying up of traditional open wells, and water shortages in man-made tanks. Farmers reported cases of conflict over dwindling water resources with powerful social groups (typically upper caste households) encroaching on lakes.

Across the eight study villages in Kolar, respondents perceived decreasing rainfall amount, increasing rainfall variability (becoming more erratic and uncertain) and seasonal shifts as key climatic risks. Using cultural markers such as local festivals and traditional calendars, there was consensus that in the 1970s, monsoonal rains would start by *Ugadi* (March–April) and end by *Diwali* (September–October).[1] These cultural markers were reported to no longer being able to accurately signal the monsoon season. A shorter rainy season has led to reduced rice and mulberry cultivation.

Known for its silk workshops till the 1990s, Kolar has also registered a decline in sericulture with critical implications for local livelihoods. Being sensitive to rising temperatures, silkworm mortality has increased since 2000. Fluoride contamination was an issue that figured prominently among most villages, especially after 2000 when villagers reported digging deeper borewells for drinking water. The cumulative effects of unsustainable groundwater extraction, erratic rainfall, and growing water scarcity have impacted farming (reduced crop variety), social cohesion (increased conflicts over water resources), and livelihoods (out-migration). More recently, government subsidies are incentivising farmers to shift to efficient irrigation systems such as drip and sprinkler irrigation, to reduce over-extraction of groundwater.

In Gulbarga, while perceptions of risk were dominated by narratives of recurrent drought and increasing water scarcity, there were accompanying reports of recent projects to revive local water bodies and provide local employment.[2] Around the 1970s and 80s, most villagers reported that crops cultivated (pigeon pea, onion, banana, *jowar*, *bajra*, sunflower, groundnut, sesame, soyabean, black gram and green gram) were suited to the local climate, terrain, and soil conditions. Over the next two decades, mining and stone quarrying increased in the region. Groundwater extraction began (although relatively lower than in Kolar) and the increased water availability for irrigation allowed farmers to grow fertiliser-intensive cash crops (Supplementary Material 1 details these changes across villages).

By 2015–16, most villages saw significant reduction in groundwater levels, with water table falling as low as 1050 feet in *Melkonda* (District government official, *pers. comm.*). Farmers reported more erratic rainfall and longer dry spells since 2005. As a result, crop diversity and livestock numbers have reduced drastically compared to the 1970s. Historically drought-prone, Gulbarga has seen waves of out-migration (Iyer, 2017). Since 2002, however, drought, land fragmentation, deteriorating soil quality, and lack of alternate livelihoods in rural areas has driven further migration to nearby towns and cities. After 2010, there have been several efforts to shift to efficient irrigation practices such as drip and sprinkler irrigation, but these have not been adopted uniformly.

To understand the heterogeneity of these responses across households, the household surveys captured risk perceptions, which are

[1] *Ugadi* is a festival which signals the end of harvest and start of a new agricultural year. Variants of this are celebrated across India, with slight shifts in timing to suit local conditions. *Diwali* is a key Hindu festival marking victory of good over evil and is a prominent marker for the start of the *rabi* (winter cropping season).

[2] The Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) mandates 100 days of employment a year. Over the past few years, the scheme has been reoriented towards using the labour to build climate resilience and have adaptation co-benefits (Godfrey-Wood and Flower 2017; Adam 2015).

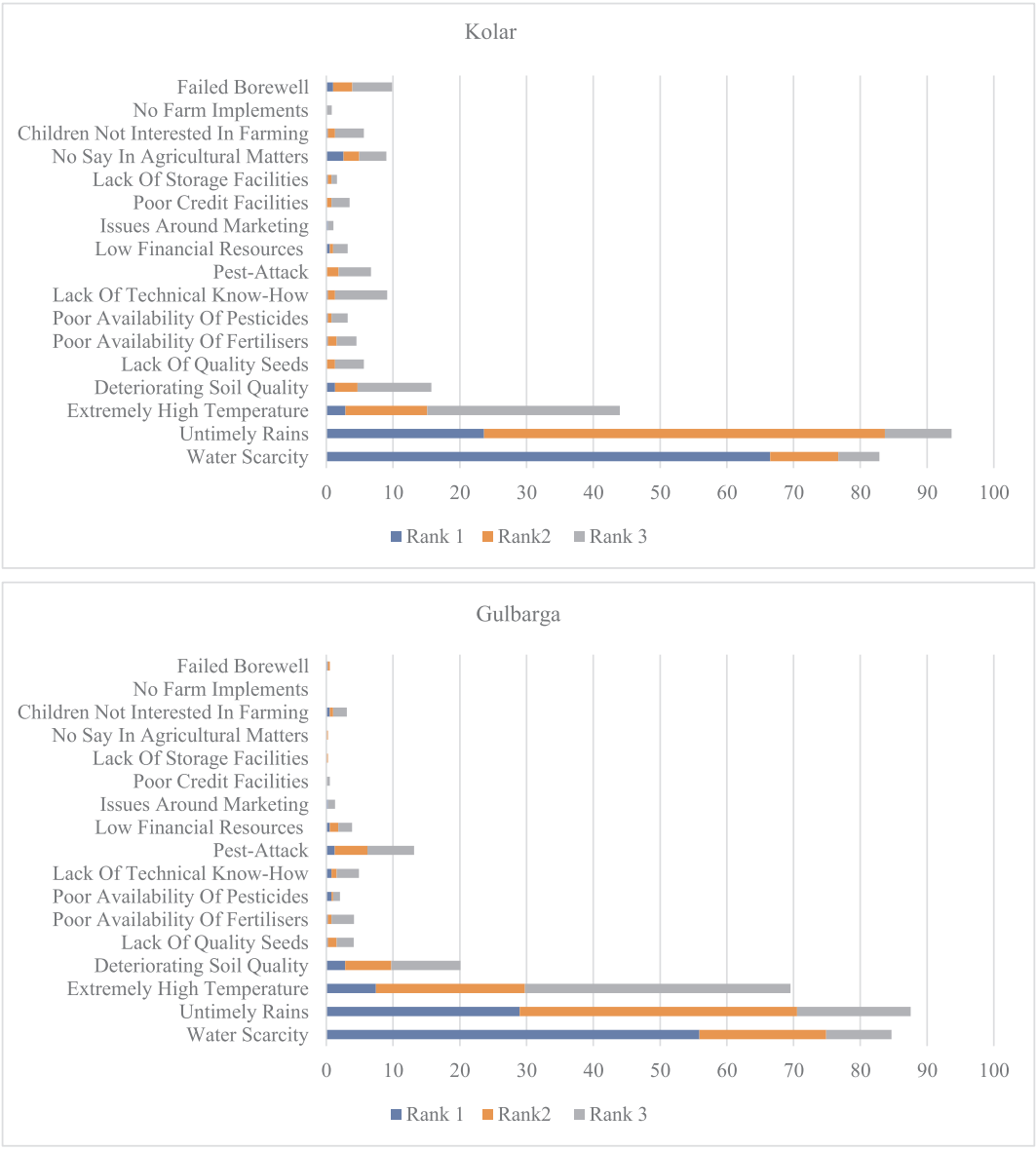

Fig. 3. Risk ranking profile from household surveys in Kolar (top) and Kalaburgi (below).

presented in Fig. 3. Across Kolar and Gulbarga, water scarcity was identified as the biggest risk to livelihoods followed by climate variability, experienced as untimely rains and extreme temperatures.[3] Deteriorating soil quality was also reported a key risk, corroborating reports of land degradation.[4] In Kolar, many households also reported borewells failing to yield water as a significant risk. This is reflective of the dire groundwater situation in Kolar: where compared to a 10-year mean, all blocks have seen groundwater yield reductions of 20%, with borewell depth going up to 2000 feet and groundwater extraction at 189% (District Commissioner Office, *pers. comm.*). The overall borewell success rate in the district has decreased from 83% in 2009 to 66% in 2015. Crucially, successful borewells also fail after a few extractions: 33% of borewells dug in 2014–15 stopped functioning after a year (District Commissioner Office, *pers. comm.*).

The poor quality of agricultural extension services was a critical issue, especially in Gulbarga, with farmers reporting inadequate agricultural inputs and advisory support provided by the government. High incidence of pest attacks was also identified as a key risk, which was exacerbated by the unavailability of pesticides at the right time.

[3] In the household survey, respondents were asked to rank fifteen major risks (identified through scoping visits and FGDs, triangulated by KIIs). For details on the risks and ranking process, see Supplementary Material 2.

[4] In Kolar, increasing Eucalyptus cultivation on private and public lands has resulted in loss of soil fertility (Shiva et al., 1988) and increased pressure on groundwater (Joshi and Palanisami, 2011).

Table 3
Perceptions regarding rainfall amount over the past 10 years (in %).

	Gulbarga	Kolar	Total
Decrease	90.8	52.4	71.7
Increase	1.2	33.9	17.5
No Answer	3.2	1.8	2.5
No Change	4.7	12.0	8.3

4.1.2. Perceptions of climate variability and change

Household perceptions of climate variability were captured for rainfall, temperature and extreme climatic events by asking about perceptible change over the last ten years. Regarding climatic variability, most households in both districts reported lack of sufficient rainfall and increasingly erratic frequency and intensity over the year (Table 3). There were widespread reports of increased incidence of dry spells within the rainy season and changes in timing of rainfall, with strong perceptions of late season onset.

Most households in both districts reported facing drought in the last ten years (Table 4), corroborating official records (KSNDMC, 2017). Water availability was also a recurrent risk with 80% households in Kolar, and 61% in Gulbarga, reporting shortage of water for farming. Farming has become precarious on account of declining ground water levels, especially in Kolar.

Perceptions of climatic risks were complex and tended to be experienced and perceived through the impacts on livelihoods such as lowered agricultural yields because of untimely rains or tougher working conditions due to higher temperatures (Table 5).

To sum up, lack of water due to erratic rainfall and declining ground water levels were the most significant risks across Kolar and Gulbarga. These risk perceptions square well with the overall narrative of declining water tables, failure of borewells, and rainfall deficit in the region (CGWB, 2014).

4.2. Response strategies

This section discusses planned and autonomous responses to the risks discussed above. Across both research locations, risk management is undertaken by many actors (farmers, community groups, subnational government officials, and NGOs), at different scales (community, village, *Panchayat*, district, State), and to different risks (climatic and non-climatic). Overall, responses ranged from short-term coping strategies such as reducing food intake during lean months or taking up non-farm activities to earn extra money, to longer-term adaptive strategies such as investing in water-saving infrastructure such as drip irrigation. In the surveys, however, we found that 36% of the households, undertake no response. We discuss the nuances within these categories in the following section.

Table 4
Perceptions of households regarding water shortage and drought (in %).

	Drought		Water shortage for farming		Change in Groundwater	
	Gulbarga	Kolar	Gulbarga	Kolar	Gulbarga	Kolar
Yes	68.2	53.9	61.4	80	56.3	74.6
No	31.8	46.1	38.6	20	43.7	25.4

Table 5
Illustrative quotes of perceptive climatic risks in Kolar District.

Climate variable	Illustrative quotes
Rainfall amount	*"(The year)1990 was the tipping point. The rains have started decreasing since then. The last good rains were in the year of 2000. There is increased uncertainty following 1990. Even the monsoon season has more dry spells."* (K13, Male FGD, Kolar)
Erratic rainfall	*"Rainfall is steadily decreasing. The rainfall season usually starts at the end of April (Bharani rain). The pre-monsoons followed by the monsoons and the retreating monsoons. The season would typically last till end of November. Now there are dry spells and the quantity of rain is falling too….Frankly, there has been a drought-like situation in this village since 2002, when the rains started failing. The variability and fluctuation in rainfall has also increased."* (K10, Male FGD, Kolar)
Dry spells	*"Rains have been deficient since 1995. The rains used to start at Ugadi (April), however the season has shifted forward to June. Even in the rainy season, there are increasing instances of dry spells (almost 2 months at time). And we get unseasonal heavy rains in November which affects the ragi (millet) crop."* (K14, Male FGD, Kolar)
Extreme events	*"Since the past 15 years, we have a long-term drought and scarcity situation since; 2001–2002 is the year which is a demarcating time period for good and bad rainfall. Since then the rainfall and agriculture has become less promising."* (K25, Female FGD, Kolar)
High temperatures	*"Very high temperatures are affecting our productivity and discourage people from doing labour work."* (K19, Female FGD, Kolar) *"It is so hot now that tomatoes wilt due to the heat. They get jaundice (turn yellow)."* (K12, Male FGD, Kolar)

4.2.1. Government-driven planned response strategies

Several national-level programmes focus on poverty alleviation (e.g. Integrated Rural Development Programme (IRDP)), strengthening livelihoods (e.g. National Rural Employment Guarantee Scheme (NREGS) and National Rural Livelihoods Mission (NRLM)), and providing social safety nets (e.g. food distribution through Targeted Public Distribution System (PDS) and mid-day meals for school children). Focussing on water management and drought proofing in particular, are schemes such as the National Watershed Development Programme for Rain fed Areas (NWDPRA) and *Pradhan Mantri Krishi Sinchayee Yojana* (PMSKY) for improved irrigation.

At the Karnataka state level, current policies promote organic farming, crop diversification, integrated watershed development, and improved irrigation efficiency. For example, the Karnataka State Policy on Organic Farming (KSPOF) adopted in 2006, uses a community-driven participatory approach to provide an enabling environment for small farmers to practice organic farming; which has benefitted small and rain-fed farms more than large and irrigated farms (Purushothaman et al., 2013). The state drought management processes includes drought forecasting, monitoring, and mitigation, down to the sub-district level (KSNDMC, 2017).

Other examples of planned interventions in the state are the World Bank-assisted *Sujala* Project for integrated watershed development, *Bhoochetana* (Soil Awareness) Project for improving soil health and farmer awareness on soil fertility issues, and *Suvarna Bhoomi Yojane* (Golden Earth Scheme) for market-oriented development of the horticulture sector. When implemented effectively, such schemes can have adaptation co-benefits as seen in the case of Serinala Watershed Project in Gulbarga (Box 1).

Box 1

Watershed development to strengthen natural resources and rural livelihoods with adaptation co-benefits.

Details: Serinala Watershed Project covering 1259 ha (2010-2015)

Funding: NABARD Watershed Programme

Beneficiaries: 512 farmers from 4 villages

Activities: Constructing farm ponds, check dams, recharge pits; desilting open wells; loans to SHGs purchase of cattle, sewing machines, for education-related expenses.

Institutions: Membership is not restricted to a specific social group. 50% percent women in the Watershed Committee, many of whom are proactive in SHGs as well.

Benefits for ecological health and agriculture:

- Earlier the village didn't have any source of irrigation, so large tracts of land were left fallow. Under this project, 45 wells were desilted to increase recharge and limit runoff, offsetting deficits due to decreasing rainfall trend.
- Groundwater levels have increased due to rainwater harvesting and improved recharge.
- Noticeable improvement in soil fertility, better water availability, increased soil moisture, and nutrient content has enabled farmers to grow two crops a year.
- Better water access has incentivised organic farming, drip irrigation, and solar pumps unlike earlier when they used to depend on electricity and diesel engines.

Social and livelihood-related impacts

- Capacity building of 50 Self Help Groups (SHGs) on vocational skills such as tailoring, embroidery, welding, driving.
- Reduced migration because of improved profits from agriculture.

Multiplier effects

- Demand-led engagement with the Krishi Vignana Kendra (KVK) has contributed to better yields. Farmers attend trainings and demonstrations and feel empowered to approach scientists to get customised solutions. Farmers have introduced

mixed cropping for enriching soil nutrients on the advice of KVK scientists.
- Complementing the watershed development interventions, MGNREGS is now providing employment on activities such as the construction of bunds, check dams and farm ponds.

Across Kolar and Gulbarga, we witnessed examples of planned responses aimed at natural resource restoration and livelihood strengthening. These were typically government-funded watershed development programmes implemented by local NGOs and have been integrated with the national rural employment guarantee scheme (MGNREGS) to build water storage structures and mitigate drought impacts.

Respondents discussed how overall, government interventions have improved quality of life over time through better access to electricity, improved road connectivity, availability of primary schools nearby, and stronger social safety nets in the form of food rations (see Supplementary material 1 for detailed institutional changes over time). People also noted that watershed development programmes started in the 2000s such as *Sujala* and *Bhoochetana* had improved water availability but these were typically only reported by direct beneficiaries within a village.

4.2.2. Autonomous household strategies

Livelihood strategies to manage and response to risk fall along a 'response continuum' ranging from no response to coping, adaptive, or potentially maladaptive responses (Singh et al., 2016b). Within adaptive strategies, we distinguish between those that build generic capacity (to meet human development goals such as access to food, improved health) and those that build specific capacity (to deal with climatic risks) (Eakin et al., 2014). In the research sites, we categorise household responses as agricultural practices, land management, water management and livelihood practices (Fig. 4).

In Gulbarga, land sale, possibly due to agrarian distress, was a significant response while in Kolar, crop diversification, especially into vegetable and horticultural crops, was the most common strategy. Watershed activity and irrigation, particularly drip irrigation is more prevalent in Kolar. In both districts, there is a trend towards greater usage of inputs such as pesticides and fertilizers. Participation in public works through the MGNREGS is more prevalent in Gulbarga, primarily due to an active sub-national government actor promoting intensification of public works in response to the successive years of drought (NGO KII G10, *pers. comm. 27/11/2015*). In Kolar, 65% households reported diversifying livelihoods, pointing towards more availability of non-agrarian livelihood opportunities due to its proximity to Bengaluru.

Migration emerged as a key livelihood response strategy across both districts, with almost one-third households in Gulbarga having a member who has migrated. These households typically migrate towards Bengaluru (600 km) as well as other major urban centres such as Pune (380 km) and Hyderabad (215 km). Increasingly, families are migrating seasonally to work in brick kilns across Maharashtra, often for low wages and poor working conditions. In Kolar, 47% of the households report out-migration. Cheap and frequent connectivity and proximity to Bengaluru allow people in Kolar to commute daily. Across both districts, we observe the following; 65% of the migrants traveling out for work for less than 6 months in a year. 78% of the migrants travelled to urban areas for work. The major reasons for outmigration were perceived availability of better jobs (55%) and increasingly unprofitable agriculture (29%). Migrants tend to take up informal livelihoods: 59% work as casual daily labour, with construction being the largest industry of employment (32%).

Across the villages, some response strategies that have been honed over generations, such as adjusting cropping practices and risk spreading through loan taking are practiced even today. Some new strategies have emerged such as diversifying into new livelihoods (e.g. people from Kolar working in garment factories near Bangalore). However, overall, we found there has been a shift in the *nature* of responses over time. While migration has been a common response in both districts, we noted more women are moving out now, signalling a change in gendered norms of work. Also, younger men increasingly reported moving out to fulfil aspirations beyond agrarian livelihoods. Finally, those who were moving previously, tended to do agricultural wage labour in neighbouring villages. With better connectivity and changing aspirations, several respondents noted moving into non-agricultural wage labour, typically into nearby towns and cities. In the in-depth interviews, respondents (typically landed, well educated) spoke of more opportunities being available such as setting up greenhouses for floriculture in Kolar or growing plantation crops such as bananas due to upstream irrigation projects in Gulbarga. However, this expansion of opportunities was not uniform with several poorly-connected villages reporting being 'stuck' in situations of inadequate coverage by public services and lack of livelihood opportunities that better connected villages reported.

4.2.3. Implications of response strategies

In both districts, most responses build generic capacity, not so much specific (climate-centric) adaptive capacity. In fact, larger landholders or those with access to additional water or financial capital to invest in farming, tended to undertake potentially maladaptive strategies such as growing water-intensive crops, digging multiple borewells, and using groundwater unsustainably, especially in Kolar. We were also able to corroborate this differential implication of response strategies through assessing people's self-reported subjective wellbeing.[5] We find that overall, people reported low subjective wellbeing around agriculture and this was differentiated by caste, assets and gender of household head. Upper caste households assigned higher scores to satisfaction with

[5] The question asked during the survey was "On a scale of 1–10, how do you rate your satisfaction with the following factors?". The options were "children's education, family's health care, family's housing, family's total income, agriculture".

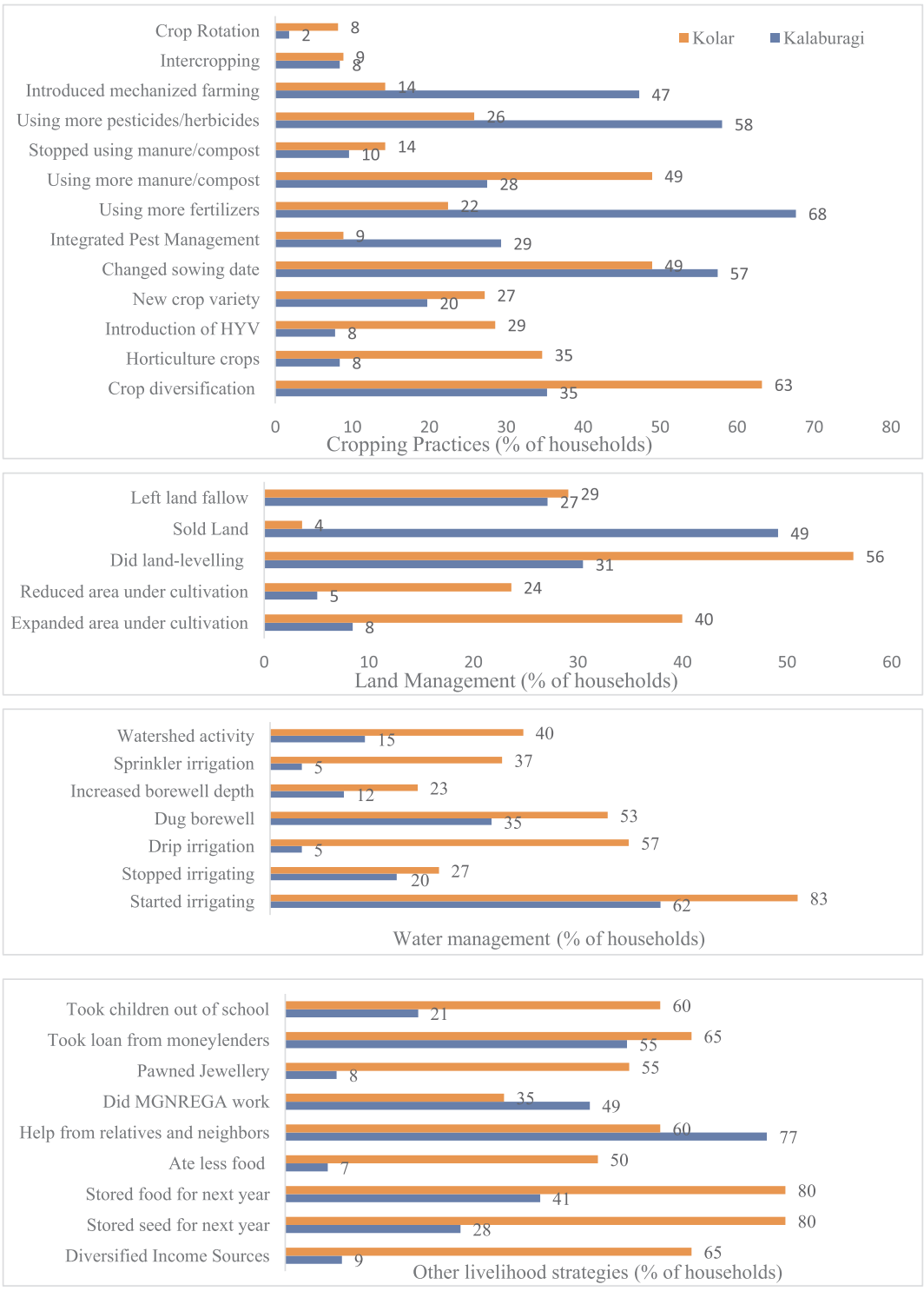

Fig. 4. Household response strategies within agriculture, land, water, and livelihoods respectively. X axis denotes number of households saying yes to a particular response strategy. Households could choose more than one option within a response category. *Note:* We report percentage of households reporting these responses based upon whether they have taken any response under the broader categories. No. of households = 825.

agriculture than Scheduled Caste and Scheduled Tribe households. Expectedly, landless households and marginal farmers reported lower satisfaction than larger landholdings. Female-headed households are also less satisfied with the status of agriculture than the male-headed households.

Table 6
Matrix of response strategies and their social, economic, and ecological impacts.

Response		Directionality			Illustrative example from study sites
		Ecological	Economic	Social	
Short-term coping	Surviving	↔	↓	↓	Leaving land fallow
	Eroding	↓	↔	↓	Reliance on water tankers in summer
	Accumulating	↔	↑	↓, ↔	Taking loans from moneylenders
	Moving	↔	↑	↓	Daily commuting for agricultural labour in villages nearby
Long-term adaptive	Adaptive behavioural change	↑	↑	↔	Investing in water saving technologies
	Institutional shifts	↑	↑	↔	Subsidies for sprinkler sets
Long-term generic	Development interventions	↓	↑, ↔	↓, ↔	Input-intensive, mechanised agriculture improved incomes but at the cost of ecological sustainability
	Livelihood security and management	↑	↑	↔	Employment generation through MGNREGS
Potentially maladaptive	Ecological	↓	↓	↓	Shift to cash crops and floriculture
	Institutional	↓	↓, ↔	↓	Diesel and borewell subsidies which incentivise groundwater extraction

To examine whether household strategies were contributing to improved adaptive capacity, we assessed their impacts on three axes (Table 6). Building on the three pillars of sustainability we assess the strategies on ecological outcomes (do they impact natural resources such as land, water, pasturelands?), economic outcomes for the household (do they change household income, material wellbeing, asset holdings?), and social outcomes (are the changes equitable within and across households or are benefits and costs unequally distributed, further accentuating marginalisation and inequities, both across people and across time?). While the assessment is subjective and researcher-driven, we argue that it provides a useful lens to begin interrogating response strategies through the lens of equity, ecological sustainability, in addition to economic gains.

Coping strategies were either for survival and maintaining status quo, accumulating (of material or intangible assets) or erosive (either for social or ecological systems). Survival strategies ranged from reducing food intake (more in Gulbarga than Kolar) and leaving lands fallow, distress migration (especially in Gulbarga). For example, one respondent from Kolar mentioned, *"…in times of drought, there's not much food for the family and that automatically reduces food intake in terms of types (supplements), narrows options."* (K8 VP Panthanahalli) Across both locations, moving out of agriculture to earn was common. Few farmers spoke of drawing on networks during periods of distress or shortages. This could involve asking large farmers for water from borewells (G17 Melkunda B Female Respondent) to relying on social safety nets like food rations (K18).

Most coping strategies were around soil and water management practices. These included shifts towards chemical fertilisers which have, in retrospect, accumulated to lead to a longer-term behavioural change that might be erosive resulting in deteriorating soil quality and negative impacts on human health (G15 Imdapur Women's FGD). There were several instances of exploitative water use practices from relying on private water tankers during periods of water stress (K8, VP Panthanahalli) to digging borewells: "*Bore wells do fail once in two-three years, and people dig more bore wells"* (K1. VP Hulibele). In some cases, especially in larger, well-connected villages where the youth were educated, youngsters resorted to erosive coping strategies such as illegal sand mining, soil extraction for brick making, timber business (tamarind, neem, acacia trees), and at an extreme, complete disinterest in agriculture as a livelihood, especially in past 4–5 years, coinciding with recurrent droughts (G21). Other cases of such measures were seen among the most marginalised, i.e. landless households, people with no property (K6).

Several coping strategies also suggested accumulation (e.g. of water, by digging borewells) in the short term. Accumulation of financial assets was reported as critical to farm and non-farm livelihoods. At the start of the agricultural seasons and to invest in non-farm livelihoods (E.g. autorickshaw for drivers, travel expenses for migrants), respondents mentioned relying on informal channels such as money lenders and more recently, microfinance groups over banks where the entry barriers are high. Many respondents spoke of fears of having their land taken away (K2 VP NG Hulkur) if loans were not repaid, alluding to familiarity and approachability as key factors enabling certain response strategies (here, borrowing from moneylenders at higher and often exploitative rates).

Although migration has always been a coping strategy (more so in Gulbarga than Kolar), given the change in opportunities available within the village and surrounding areas, the *nature of movement has changed.* For example, in Kolar, respondents noted that in years with normal rainfall, there was greater out-migration by women. Women tended to travel upto 20–30 km in search of agricultural labour (K20 NG Hulkur). With trends of decreasing rainfall and higher uncertainty, women have recently started traveling as far as Bengaluru (K20, G21). Conversely, development of industrial hubs (cement factories in Gulbarga and garment factories in Kolar) provide livelihood opportunities within the district. However, these opportunities are unevenly available and mediated by multiple factors such as social networks, minimum education levels, access to transport, gender, and distance from village.

Long-term adaptive strategies typically included shifts in agricultural practices such as switching to organic manure or moving away from lift and flood irrigation towards investing in water saving infrastructure such as drip or sprinkler irrigation (K2 VP, NG Hulkur). However, not all farmers do this and the FGDs showed that those who have animals and those who recognise that manure is better than fertilisers, apply animal manure.

Government initiatives towards longer-term adaptation processes included incentivising positive behaviour through subsidies (for example, farmers can avail a 90% for sprinkler irrigation), watershed development and ecological restoration, and information sharing on improved agricultural practices. However, these interventions are often done in specific locations and intra-district and inter-village difference are high (for example, watershed development activities or farm ponds through MGNREGA do not benefit all).

In certain villages in fact, watershed interventions have caused problems: *"This village is a site for an Integrated Water Resource Management Programme through the Public Private Partnership model. The scheme was introduced three years ago in this village and involved building a check dam three years ago. But since this check dam was built, our lake doesn't have water."* (K18, Shettikothannur Female FGD). Such responses highlight how well-meaning projects can have negative externalities at a larger spatial scale (here, downstream of the check dam) or longer temporal scale (e.g. diesel subsidies driving groundwater extraction).

Drip irrigation was very popular in Kolar (for most plants) and in Gulbarga (for horticultural species such as banana). It is critical to note that while adaptive interventions focussed mainly on natural resource management, there was lesser evidence on capacity building, and incentivising behavioural changes such as reducing water demand, shifting away from fertiliser or towards climate resilient crops. This echoes warnings by other scholars on the focus on supply augmentation (more water, more fertiliser) rather than demand management (Bharucha et al., 2014; Singh, 2018b).

Long-term generic strategies are a function of wider dynamics of rural transformation (of livelihoods, of practices, ecologies, and social structures). Overall, farming in Kolar and Gulbarga has seen a shift away from indigenous varieties to high-yielding commercial crops. While this shift has led to resource degradation and exploitation of common resources (Singh et al., 2016a), some farmers, especially those educated and connected to extension officers, demonstrated a sophisticated understanding of the implications of the varieties they grow on their soil and water.

In some cases, external actors (e.g. research institutes like ICRISAT, NGOs such as MYRADA, Gram Vikas) have helped diversify crops and incomes. Apart from this, government interventions have contributed to generic capacity through rural development schemes, natural resource management through watershed development projects, and livelihood strengthening through schemes on growing horticultural species, diversifying into dairy etc. (see Section 4.2.1 and Box 1 for details). However, the efficacy of these programmes was differentiated by location in the district (e.g. proximity to district headquarters and good road connectivity increases interaction with extension agents) and who you are in the village (e.g. higher caste large landholders tend to have land near water sources and benefit from watershed activities).

Potentially maladaptive strategies were also observed. The first kind involved practices undermining ecological bases. There were several examples of people undertaking potentially maladaptive practices, especially in response to successive drought years. Strategies such as illegal sand mining, growing Eucalyptus on farmland, and extracting soil for brick making were reported as affecting the local lakes and land. The respondents drew a direct relation between the introduction of Eucalyptus by the Forest Department in the 1970s and borewells drying out. *"Nilgiri is like a communicable disease. It not only bleeds the groundwater, but also ruins the fertility of the surrounding land"* (K18 Settikothanur Male FGD). Second, perverse subsidy regimes have locked in agricultural practices into cycles of dependence and overexploitation. For example, for diesel engines, there is a 50% subsidy for general category and 90% for SC/STs. This has resulted in water stored in ponds and wells being drawn out, often exploitatively.

5. Discussion and conclusion

Located at the crossroads of rapid development, high climate sensitivity, and an ever-expanding demographic, India has seen tremendous research interest, policy intervention, and financial flow into understanding climate change vulnerability, its interaction with other structural vulnerabilities and supporting local adaptation processes. Our research examines to what extent multi-scalar adaptation interventions affect local risk and response behaviour.

Drawing on empirical evidence from two rural districts in Karnataka, a semi-arid state in South India, we use household perceptions of risk and their subsequent responses to provide insights for rural development policy in general and climate change adaptation policy, specifically. We used a typology of coping, adapting and maladapting to categorise reported response strategies and assess them for their implications on economic, ecological, and social sustainability.

We find that while people are responding to multiple risks, of which environmental changes are a significant part, confirming previous literature (Kattumuri et al., 2015), these responses are not necessarily climate change adaptation strategies. Many interventions are helping build generic capacity to deal with non-climatic risks and alleviate development deficits but may not be building specific adaptive capacity to climate change (see Section 4.2.2). In some cases, in fact, interventions can be maladaptive in nature (see Section 4.2.3). Local adaptation response has always been a complex endeavour within the programmatic response of the State. While climate-specific interventions have gained momentum during the post National Action Plan on Climate Change (NAPCC) phase; they remain predominantly divorced from contextual realities (Singh et al., 2016c). For example, we still do not have adequate clarity on how climate-specific interventions build adaptive capacities (as highlighted in this paper) but more so, we lack a comprehensive understanding of assessing various synergies and trade-offs that form the basis of long-term structural response to locally experienced challenges, within the larger narrative of long-term environmental changes. Thus we do see significant gaps in programme design, implementation, and monitoring which have implications for sustainable risk management.

Thus, while efforts to build generic capacities, such as focus on improving household economic conditions and access to services, are successful, we call for a comprehensive risk-response framework that recognises the contextual reality of everyday risk, assesses scale implications of interventions and explicitly regards climate adaptation as a central component of risk management.

5.1. Risk and response are spatio-temporally differentiated

Overall, risks from environmental change, climate change, and increased climate variability are important but mediated by existing structural conditions such as poor market linkages, inadequate credit, low asset bases, and caste- and gender-based differences. The participatory timelines demonstrated how risk accumulates over time with recurrent drought, natural resource degradation, and deteriorating common pool resources being significant drivers of biophysical vulnerability. The nature of risks also changes over time with increasing reports of drought incidence and dry spells. When seen through a livelihoods lens, these environmental risks interacted with institutional risks (e.g. pervasive agricultural policies favouring irrigation-based farming), financial risks (e.g. reliance on moneylenders in the absence of adequate credit facilities), and social risks (women unable to travel long distances for work) to shape household vulnerability.

Our findings on response strategies highlighted that most households undertake a suite of activities to manage and prepare for risk. These activities are predominantly coping strategies (whether negative or positive) with fewer examples of longer-term adaptive action (Section 4.2.2 and 4.2.3). Many households reported not undertaking any response, echoing findings of 'the fatalistic farmer' (Singh et al., 2016b) in other dryland regions in India. Crucially, government-funded planned interventions tended to build generic capacities effectively with lower clarity on their efficacy in building specific capacity to deal with climatic risks. This is not to undermine the positive interventions in watershed development, livelihood strengthening, and natural resource management undertaken in Karnataka but highlights that to meet challenges posed by climate change, existing responses will need to be reoriented to be more flexible and forward-looking in nature.

Responses were also multi-scalar in nature: policy shifts such as diesel subsidies or promotion of organic farming at the state level, percolated into household response strategies and had negative or positive outcomes as detailed in Section 4.2.3. Across time, some responses (e.g. digging farm ponds, shifting to water-intensive cash crops) are highlighted as having potentially maladaptive outcomes. This calls for growing awareness about trade-offs that a particular intervention entails and a careful pre-project exploration of potential maladaptive outcomes becomes necessary and desirable. Finally, some responses are changing either in type (shifting away from farm livelihoods) or in nature (migrating farther away, into non-agriculture wage labour), demonstrating how livelihood portfolios are increasingly dynamic and complex. Critically, these changes in responses also signal changing aspirations, especially among rural youth. While the role of aspirational change in climate adaptation is beyond the scope of this paper, we highlight it as an important field for further research.

5.2. Assessing response outcomes using a sustainability lens

Our findings underscore the importance of exploring response outcomes (conceptualised as falling across a response continuum) using a sustainability lens. This provides insights on how planned and autonomous responses impact ecological systems, household material wellbeing, and social equity (Table 1). Such an approach builds on growing recognition that effective adaptation must integrate development interventions, climate adaptation action, and disaster risk reduction (Eriksen and O'Brien, 2007; Davies et al., 2009; Taylor, 2013; Gajjar et al., 2018). We then used this framing to diagnose response outcomes in the research sites (Table 6).

We found that outcomes of planned and autonomous responses differ between and within villages. Responses were multi-scalar and masked heterogeneity due to geography, identity, social capital, and economic status. For example, larger landholders were able to intensify crop production by introducing new varieties and diversify by adding horticultural crops while marginal landholders or landless groups, tended to take up informal wage labour, often entering precarious, poorly paying sectors. At a finer scale, outcomes of responses such as migration tended to have differential impacts on different household members. More importantly, response outcomes had implications at wider spatio-temporal scales. Thus, a watershed development project making a check dam upstream could negatively impact downstream water availability while shorter-term interventions aimed at improving agricultural incomes (e.g. shift from drought-tolerant millets to water-intensive tomato in Kolar) could have wider sustainability outcomes on water extraction. Further, changes in risks and consequently responses have implications on household wellbeing and overall capacities to deal with future risks.

5.3. Way forward: Entry points for enabling adaptation

Overall, an enabling institutional environment was key to strengthening autonomous household responses. Based on the results, we identify specific entry points for enabling local adaptation.

First, risks are perceived and acted upon in an integrated manner. While climatic risks are important and increasingly perceived as crucial for rural livelihoods, they are experienced in conjunction with non-climatic risks. Thus, *a focus on perceived risks, in addition to observed risks, is a critical starting point for adaptation interventions.* Additionally, risks change over time and space. Current vulnerability assessments – the basis on which adaptation interventions are built – and adaptation interventions, tend to overlook or inadequately account for this dynamic nature of risk.

Second, current development and adaptation interventions are building a robust base of generic capacity for rural areas, such as better infrastructure and services, stronger assets, and higher incomes. Although these positive impacts are differentiated between households, there is an overall perception of better quality of life (Singh et al., 2016a). However, in order to prepare for climatic risks, building specific capacity to adapt is essential and currently rather ambiguous, as observed in the research sites. While we acknowledge that the connections between generic and specific capacities are loose, we argue that building both capacities and considering spatio-temporal scales can result in better risk management. Interventions to build specific capacity would involve forward-

looking actions such as using climate information to shape appropriate cropping regimes, incentivising mixed crop-livestock systems to spread risk (as opposed to mono-cultivation of cash crops), institutional reform where local governance structures are flexible in the face of increasing climate vulnerability, and provision of safety nets for responses spanning the rural and urban such as migration. Thus, a *greater emphasis on building specific capacity is recommended, in addition to establishing an explicit understanding of the linkages between generic and specific capacities; with a particular focus on synergies and trade-offs*. It is argued that an approach guided by building specific adaptive capacities would also have positive spill-overs in the generic capacity domain. We believe that such forward-looking adaptation focused plans will also be able to pre-empt potentially maladaptive outcomes of current response strategies.

Declaration of interest

None.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.crm.2018.06.001.

References

Adam, H.N., 2015. Mainstreaming adaptation in India – the Mahatma Gandhi National Rural Employment Guarantee Act and climate change. Clim. Dev. 7, 142–152. http://dx.doi.org/10.1080/17565529.2014.934772.
Adger, W.N., Arnell, N.W., Tompkins, E.L., 2005. Successful adaptation to climate change across scales. Glob. Environ. Change 15, 77–86. http://dx.doi.org/10.1016/j.gloenvcha.2004.12.005.
Ayers, J., Dodman, D., 2010. Climate change adaptation and development I. Prog. Dev. Stud. 10, 161–168. http://dx.doi.org/10.1177/146499340901000205.
Bantilan, M.C.S., Anupama, K.V., 2002. Vulnerability and Adaptation in Dryland Agriculture in India: Experiences from ICRISAT'S Village Level Studies.
BCCI-K, 2012. Karnataka State Action Plan on Climate Change. Bangalore, 251 pp. http://www.karnataka.gov.in/empri/web/EMPRI_KSAPCC_2014-03-27.pdf.
Benz, A., 2014. Mobility, multilocality and translocal development: changing livelihoods in the Karakoram. Geogr. Helv. 69, 259–270. http://dx.doi.org/10.5194/gh-69-259-2014.
Berrang-Ford, L., Ford, J.D., Paterson, J., 2011. Are we adapting to climate change? Glob. Environ. Change 21, 25–33. http://dx.doi.org/10.1016/j.gloenvcha.2010.09.012.
Bhagat, R., 2017. Migration, gender and right to the City. Econ. Polit. Wkly. LII, 35–40.
Bharucha, Z.P., Smith, D., Pretty, J., 2014. All paths lead to rain: explaining why watershed development in India does not alleviate the experience of water scarcity. J. Dev. Stud. 50, 1209–1225.
Bhatta, G.D., Aggarwal, P.K., 2016. Coping with weather adversity and adaptation to climatic variability: a cross-country study of smallholder farmers in South Asia. Clim. Dev. 8, 145–157. http://dx.doi.org/10.1080/17565529.2015.1016883.
Burnham, M., Ma, Z., 2017. Multi-scalar pathways to smallholder adaptation. World Dev. http://dx.doi.org/10.1016/j.worlddev.2017.08.005.
CGWB, 2014. Ground Water Year Book 2013–2014 Karnataka. Bangalore.
Chandrasekhar, S., Mehrotra, N., 2016. What would it take? Doubling farmers' incomes by 2022. Econ. Polit. Wkly. 51.
Choudhury, P.R., Sindhi, S., 2017. Improving the drought resilience of the small farmer agroecosystem. Econ. Polit. Wkly. 52, 41.
Cutter, S.L., Finch, C., 2008. Temporal and spatial changes in social vulnerability to natural hazards. Proc. Natl. Acad. Sci. 105, 2301–2306. http://dx.doi.org/10.1073/pnas.0710375105.
Davies, M., Guenther, B., Leavy, J., Mitchell, T., Tanner, T., 2009. Climate Change Adaptation, Disaster Risk Reduction and Social Protection: Complementary Roles in Agriculture and Rural Growth ?.
Eakin, H.C., Lemos, M.C., Nelson, D.R., 2014. Differentiating capacities as a means to sustainable climate change adaptation. Glob. Environ. Change 27, 1–8. http://dx.doi.org/10.1016/j.gloenvcha.2014.04.013.
Ellis, F., 2000. Rural Livelihood Diversity in Developing Countries: Evidence and Policy Implications. Overseas Dev. Institute, London. http://hdl.handle.net/10535/4486.
Eriksen, S.H., O'Brien, K.L., 2007. Vulnerability, poverty and the need for sustainable adaptation measures. Clim. Policy 7, 337–352. http://dx.doi.org/10.1080/14693062.2007.9685660.
Esteves, T., Rao, K., Sinha, B., Roy, S., 2013. Agricultural and livelihood vulnerability reduction through the MGNREGA. Econ. Polit. Wkly. xlviiI, 94–103.
Fawcett, D., Pearce, T., Ford, J.D., Archer, L., 2017. Operationalizing longitudinal approaches to climate change vulnerability assessment. Glob. Environ. Change 45, 79–88. http://dx.doi.org/10.1016/j.gloenvcha.2017.05.002.
Fishman, R., Devineni, N., Raman, S., 2015. Can improved agricultural water use efficiency save India's groundwater? Environ. Res. Lett. 10, 84022.
Forsyth, T., Evans, N., 2013. What is autonomous adaption? Resource scarcity and smallholder agency in Thailand. World Dev. 43, 56–66. http://dx.doi.org/10.1016/j.worlddev.2012.11.010.
Fraser, E.D.G., Dougill, A.J., Hubacek, K., Quinn, C.H., Sendzimir, J., Termansen, M., 2011. Assessing vulnerability to climate change in dryland livelihood systems: conceptual challenges and interdisciplinary solutions. Ecol. Soc. 16, 1–17. http://dx.doi.org/10.5751/ES-03402-160303.
Gajjar, S.P., Singh, C., Deshpande, T., 2018. Tracing back to move ahead: a review of development pathways that constrain adaptation futures. Clim. Dev. 1–15. http://dx.doi.org/10.1080/17565529.2018.1442793.
Godfrey-Wood, R., Flower, B.C.R., 2017. Does guaranteed employment promote resilience to climate change? The case of India's Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA). Dev. Policy Rev. 38, 42–49. http://dx.doi.org/10.1111/dpr.12309.
Government of Karnataka, 2014. Human Development: Performance of Districts, Taluks and Urban Local Bodies in Karnataka, 2014 – A Snapshot. Bangalore.

Harriss-White, B., 2008. Introduction: India's rainfed agricultural dystopia. Eur. J. Dev. Res. 20, 549–561. http://dx.doi.org/10.1080/09578810802493291.
IPCC, 2014. Annex II: glossary [Agard, J., E.L.F. Schipper, J. Birkmann, M. Campos, C. Dubeux, Y. Nojiri, L. Olsson, B. Osman-Elasha, M. Pelling, M.J. Prather, M.G. Rivera-Ferre, O.C. Ruppel, A. Sallenger, K.R. Smith, A.L. St Clair, K.J. Mach, M.D. Mastrandrea, and T. Bilir]. In: Barros, V.R. (Ed.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1757–1776.
Iyer, S., 2017. Circular migration and localized urbanization in Rural India. Environ. Urban Asia 8, 109–115. http://dx.doi.org/10.1177/0975425316683866.
Jain, M., Naeem, S., Orlove, B., Modi, V., DeFries, R.S., 2015. Understanding the causes and consequences of differential decision-making in adaptation research: adapting to a delayed monsoon onset in Gujarat, India. Glob. Environ. Change 31, 98–109. http://dx.doi.org/10.1016/j.gloenvcha.2014.12.008. doi: 10.1016/j.gloenvcha.2014.12.008.
Jha, C.K., Gupta, V., Chattopadhyay, U., Amarayil Sreeraman, B., 2017. Migration as adaptation strategy to cope with climate change: a study of farmers' migration in rural India. Int. J. Clim. Change Strateg. Manage. http://dx.doi.org/10.1108/IJCCSM-03-2017-0059. IJCCSM-03-2017-0059.
Joshi, M., Palanisami, K., 2011. Impact of eucalyptus plantations on ground water availability in south Karnataka [Impact Des Plantations D ' Eucalyptus Sur La Disponibilite Des Eaux Souterraines Au Sud Du Karnataka]. Int Comm Irrig Drain 255–262.
Kale, E., 2017. Problematic uses and practices of farm ponds in Maharashtra. Econ. Polit. Wkly. LII, 20–22.
Kasperson, R.E., 2017. Risk Conundrums: Solving Unsolvable Problems. Taylor & Francis.
Kattumuri, R., Ravindranath, D., Esteves, T., 2015. Local adaptation strategies in semi-arid regions: study of two villages in Karnataka, India. Clim. Dev. 5529, 1–14. http://dx.doi.org/10.1080/17565529.2015.1067179.
Kolar District Office, 2015. Kolar District Statistics at a Glance. Kolar.
Krishna, A., 2006. Pathways out of and into poverty in 36 villages of Andhra Pradesh, India. World Dev. 34, 271–288. http://dx.doi.org/10.1016/j.worlddev.2005.08.003.
KSNDMC, 2017. Drought Vulnerability Assessment in Karnataka: A Composite Index: Using Climate, Soil, Crop Cover and Livelihood Components. Bengaluru. 114 pp.
Kumar, M.D., Scott, C.A., Singh, O.P., 2013. Can India raise agricultural productivity while reducing groundwater and energy use? Int. J. Water Resour. Dev. 29, 557–573.
Kumar, S., Raizada, A., Biswas, H., Srinivas, S., Mondal, B., 2016. Application of indicators for identifying climate change vulnerable areas in semi-arid regions of India. Ecol. Indic. 70, 507–517. http://dx.doi.org/10.1016/j.ecolind.2016.06.041.
Lele, S., Srinivasan, V., Jamwal, P., Bejoy Thomas, K., Eswar, M., et al., 2013. Water Management in Arkavathy Basin: A situation analysis. Ashoka Trust for Research in Ecology and the Environment.
Lemos, M.C., Lo, Y.J., Nelson, D.R., Eakin, H., Bedran-Martins, A.M., 2016. Linking development to climate adaptation: leveraging generic and specific capacities to reduce vulnerability to drought in NE Brazil. Glob. Environ. Change 39, 170–179. http://dx.doi.org/10.1016/j.gloenvcha.2016.05.001.
Mehta, L., 2000. Drought diagnosis dryland blindness of planners. Econ. Polit. Wkly. 35, 2437–2443.
Mortreux, C., Barnett, J., 2017. Adaptive capacity: exploring the research frontier. WIREs Clim. Change 1–12. http://dx.doi.org/10.1002/wcc.467.
Nguyen, M.T.N., 2014. Translocal householding: care and migrant livelihoods in a waste-trading community of Vietnam's Red River Delta. Dev. Change 45, 1385–1408. http://dx.doi.org/10.1111/dech.12130.
Olsson, P., Opondo, M., Tschakert, P., Agrawal, A., Eriksen, S.H., Ma, S., Perch, L.N., Zakieldeen, S.A., 2014. Livelihoods and poverty. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change 2, pp. 793–832.
Otto, I.M., Reckien, D., Reyer, C.P.O., Marcus, R., Le Masson, V., Jones, L., Norton, A., Serdeczny, O., 2017. Social vulnerability to climate change: a review of concepts and evidence. Reg. Environ. Change. http://dx.doi.org/10.1007/s10113-017-1105-9.
Panda, A., Sharma, U., Ninan, K.N., Patt, A., 2013. Adaptive capacity contributing to improved agricultural productivity at the household level: empirical findings highlighting the importance of crop insurance. Glob. Environ. Change 23, 782–790. http://dx.doi.org/10.1016/j.gloenvcha.2013.03.002.
Pande, R.P., 2003. Selective gender differences in childhood nutrition and immunization in rural India: the role of siblings. Demography 40, 395–418.
Patnaik, U., Das, P.K., 2017. Do Development interventions confer adaptive capacity? Insights from Rural India. World Dev. 97, 298–312.
Pingali, P.L., 2012. Green revolution: impacts, limits, and the path ahead. Proc. Natl. Acad. Sci. 109, 12302–12308. http://dx.doi.org/10.1073/pnas.0912953109.
Purushothaman, S., Patil, S., Patil, I., Francis, I., Nesheim, I., 2013. Policy and governance for sustaining livelihoods and natural resources in small farms – a case study in Karnataka. Indian J. Agric. Econ. 68.
Raina, R.S., 2014. What rainfed farming communities need? Hindu Surv. Indian Agric.
Raina, R.S., 2015. In: Researching the Drylands, pp. 1–9.
Rao, C.S., Rejani, R., Rao, C.A.R., Rao, K.V., Osman, M., Reddy, K.S., Kumar, M., Kumar, P., 2017. Farm ponds for climate-resilient rainfed agriculture. Curr. Sci. 112, 471–477.
Ravera, F., Martin-Lopez, B., Pascual, U., Drucker, A., 2016. The diversity of gendered adaptation strategies to climate change of Indian farmers: a feminist intersectional approach. Ambio 45, 335–351. http://dx.doi.org/10.1007/s13280-016-0833-2.
Reynolds, J.F., et al., 2007. Global desertification: building a science for dryland development. Science (80-) 316, 847–851. http://dx.doi.org/10.1126/science.1131634.
Ribot, J., 2010. Vulnerability does not fall from the sky: towards multi-scale, pro-poor climate policy. In: Soc. Dimens. Clim. Chang. Equity Vulnerability a Warm. World, pp. 319. http://dx.doi.org/10.1088/1755-1307/6/34/342040.
Sen, A., 1981. Poverty and Famines: An Essay on Entitlement and Deprivation. Oxford University Press.
Shiva, V., Sharatchanra, H., Bandyopadhyay, J., 1981. Social Economic and Ecological Impact of Social Forestry in Kolar. Indian Institute of Management, Bangalore, India.
Sietz, D., Lüdeke, M.K.B., Walther, C., 2011. Categorisation of typical vulnerability patterns in global drylands. Glob. Environ. Change 21, 431–440. http://dx.doi.org/10.1016/j.gloenvcha.2010.11.005.
Singh, C., 2018a. Using life histories to understand temporal vulnerability to climate change in highly dynamic contexts. SAGE Res. Methods Cases. http://dx.doi.org/10.4135/9781526440358.
Singh, C., 2018b. Is participatory watershed development building local adaptive capacity? Findings from a case study in Rajasthan, India. Environ. Dev. 25, 43–58. http://dx.doi.org/10.1016/j.envdev.2017.11.004.
Singh, C., Basu, R., Srinivas, 2016a. Livelihood Vulnerability and Adaptation in Kolar District, Karnataka, India: Mapping Risks and Responses. Cape Town, South Africa, 6 pp. http://www.assar.uct.ac.za/sites/default/files/image_tool/images/138/South_Asia/Reports/Kolar%20Focus%20Group%20Discussions%20-%20Short%20Report%20-%20July%202016.pdf.
Singh, C., Dorward, P., Osbahr, H., 2016b. Developing a holistic approach to the analysis of farmer decision-making: implications for adaptation policy and practice in developing countries. Land Use Policy 59, 329–343. http://dx.doi.org/10.1016/j.landusepol.2016.06.041.
Singh, C., Gajjar, S.P., Deshpande, T., 2016c. Policies, Projects and People: Exploring the Adaptation-development Spectrum in India. CARIAA Working Paper 2, IDRC, Ottawa, Canada. http://www.assar.uct.ac.za/sites/default/files/image_tool/images/138/South_Asia/Reports/Kolar%20Focus%20Group%20Discussions%20-%20Short%20Report%20-%20July%202016.pdf.
Singh, C., Deshpande, T., Basu, R., 2017a. How do we assess vulnerability to climate change in India? A systematic review of literature. Reg. Environ. Change 17. http://dx.doi.org/10.1007/s10113-016-1043-y.
Singh, C., Michael, K., Bazaz, A., Basu, R., Srinivas, A., Kaur, H., 2017b. Barriers and Enablers to Climate Adaptation: Evidence from Rural and Urban India. http://www.assar.uct.ac.za/sites/default/files/image_tool/images/138/South_Asia/Barriers%20and%20enablers%20to%20climate%20adaptation%20in%20India%20-%20March%202017.pdf.
Smit, B., Wandel, J., 2006. Adaptation, adaptive capacity and vulnerability. Glob. Environ. Change 16, 282–292. http://dx.doi.org/10.1016/j.gloenvcha.2006.03.008.
Stringer, L.C., Reed, M.S., Fleskens, L., Thomas, R.J., Le, Q.B., Lala-Pritchard, T., 2017. A new dryland development paradigm grounded in empirical analysis of dryland systems science. Land Degrad. Dev. 28, 1952–1961. http://dx.doi.org/10.1002/ldr.2716.
Taylor, M., 2013. Climate change, relational vulnerability and human security: rethinking sustainable adaptation in agrarian environments. Clim. Dev. 5, 318–327. http://dx.doi.org/10.1080/17565529.2013.830954.
Thomas, D.S.G., Twyman, C., Osbahr, H., Hewitson, B., 2007. Adaptation to climate change and variability: farmer responses to intra-seasonal precipitation trends in

South Africa. Clim. Change 83, 301–322. http://dx.doi.org/10.1007/s10584-006-9205-4.
Thornton, P.K., van de Steeg, J., Notenbaert, A., Herrero, M., 2009. The impacts of climate change on livestock and livestock systems in developing countries: a review of what we know and what we need to know. Agric. Syst. 101, 113–127. http://dx.doi.org/10.1016/j.agsy.2009.05.002.
Tripathi, A., Mishra, A.K., 2016. Knowledge and passive adaptation to climate change: an example from Indian farmers. Clim. Risk Manage. 1–13. http://dx.doi.org/10.1016/j.crm.2016.11.002.
Tschakert, P., van Oort, B., St. Clair, A.L., LaMadrid, A., 2013. Inequality and transformation analyses: a complementary lens for addressing vulnerability to climate change. Clim. Dev. 5, 340–350. http://dx.doi.org/10.1080/17565529.2013.828583.
Tucker, J., Daoud, M., Oates, N., Few, R., Conway, D., Mtisi, S., Matheson, S., 2015. Social vulnerability in three high-poverty climate change hot spots: what does the climate change literature tell us? Reg. Environ. Change 15, 783–800. http://dx.doi.org/10.1007/s10113-014-0741-6.
Wisner, B., 2004. Assessment of capability and vulnerability. In: Mapp. Vulnerability Disasters, Dev. People. Earthscan, London, pp. 183–193.
Yadav, S.S., Lal, R., 2017. Vulnerability of women to climate change in arid and semi-arid regions: the case of India and South Asia. J. Arid Environ. http://dx.doi.org/10.1016/j.jaridenv.2017.08.001.