UNIVERSITY OF LEEDS

This is a repository copy of *Perceived Climate Variability and Compounding Stressors: Implications for Risks to Livelihoods of Smallholder Indian Farmers*.

White Rose Research Online URL for this paper:
https://eprints.whiterose.ac.uk/164655/

Version: Accepted Version

Article:

Singh, RK, Singh, A, Kumar, S et al. (6 more authors) (2020) Perceived Climate Variability and Compounding Stressors: Implications for Risks to Livelihoods of Smallholder Indian Farmers. Environmental Management, 66 (5). pp. 826-844. ISSN 0364-152X

https://doi.org/10.1007/s00267-020-01345-x

© Springer Science+Business Media, LLC, part of Springer Nature 2020. This is an author produced version of an article published in Environmental Management. Uploaded in accordance with the publisher's self-archiving policy.

Reuse

Items deposited in White Rose Research Online are protected by copyright, with all rights reserved unless indicated otherwise. They may be downloaded and/or printed for private study, or other acts as permitted by national copyright laws. The publisher or other rights holders may allow further reproduction and re-use of the full text version. This is indicated by the licence information on the White Rose Research Online record for the item.

Takedown

If you consider content in White Rose Research Online to be in breach of UK law, please notify us by emailing eprints@whiterose.ac.uk including the URL of the record and the reason for the withdrawal request.

White Rose university consortium
Universities of Leeds, Sheffield & York

eprints@whiterose.ac.uk
https://eprints.whiterose.ac.uk/

Perceived Climate Variability and Compounding Stressors: Implications for Risks to Livelihoods of Small-holder Indian Farmers

Abstract

Micro-scale perspectives are seldom included in planned climate change adaptations, yet farmers' perceptions can provide useful insights into livelihood impacts of interactions between climatic and other stressors. This research aims to understand how climate variability and other stressors are impacting the livelihoods of small-holder farmers in Azamgarh district, eastern Uttar Pradesh India. Data from 84 smallholder farmers were collected using mixed qualitative and quantitative approaches, including interview and participatory methods, informed by multiple stressors and sustainable livelihood frameworks. Results revealed that farmers' are increasingly facing problems caused by the reduced duration and number of rainy days, and erratic rainfall. Anomalies in seasonal cycles (longer summers, shorter winters) seem to have altered the local climate. Farmers reported that repeated drought impacts, even in years of moderate rainfall, are adversely affecting the rice crop, challenging the formal definition of drought. Climate variability, identified as the foremost stressor, often acts as a risk multiplier for ecological (e.g. soil sodicity), socioeconomic (e.g. rising costs of cultivation) and political (e.g. mismatching policies and poor extension systems) stressors. In addition to climate stresses, resource poor marginal groups in particular experienced higher risks caused by changes in resource management regimes. This study provides an important cue to revisit the formal definitions of normal rainfall and drought, accommodating farmers' perceptions that evenly distributed rainfall and not total rainfall is a key determinant of crop yields. Though India has developed adaptive measures for climate change and variability, integration of farmers' perceptions of climate and other stressors into such policies can improve the resilience of small-holder farmers, who have hitherto depended largely on autonomous adaptation strategies.

Keywords Climate variability; Smallholder farmers; Multiple stressors; Perceived livelihood risks.

Introduction

Climate variability induced stressors adversely impact the livelihoods of small and marginal communities, especially in low income developing countries (Chatterjee and Khadka 2011). Model projections can provide a long-term view of the physical aspects of climate scenarios at the macro-scale, but fail to adequately interpret the human dimensions of climate uncertainty and risks at micro-scale (Savo et al. 2016). Processes and dynamics vis-à-vis climate variability within particular small-scale social-ecological systems can be overlooked (McCubin et al. 2015). Climate variations alone may not adversely impact livelihoods at micro-scale, rather, the extent of vulnerability comes from their interaction with different ecological and socioeconomic factors (*multiple stressors*) (McDowell and Hess 2012). Understanding the ways in which these multiple stressors interact with each other to affect livelihoods is vital for developing adaptation strategies.

Evidence suggests that Southeast Asian countries are now exposed to more frequent climate extremes (Ge et al. 2019). Under such situations, understanding farmers' perceptions about climate variability can add strength to formal knowledge (Dang et al. 2014), broadening understanding of how climatic anomalies and associated stressors operate at different scales (McCubin et al. 2015), of climate and associated stressors, and helping to frame more inclusive adaptation strategies.

Farmers' perceptions about climate variability have long been valued in a practical sense (Deressa et al. 2009), especially in relation to shaping adaptive practices in agriculture (Slegers 2008). Despite facing similar levels of climate variability and other stressors, farmers from the same area may vary in their perceptions of such risks (Singh et al. 2017). For example, a rice grower lacking assured irrigation facilities will undoubtedly face greater risks of crop failure under drought or dry-spell conditions than those having access to irrigation. Risk perceptions in agriculture may nevertheless differ with climate (Simeltonet al. 2013), level of technological support and the accessible resource base (Niles and Mueller 2016). These differences shape the adaptive capacities of different social groups (Agrawal 2008), and accordingly, their varied perceptions and adaptation responses (Smit and Wandel 2006).

Prevailing policies also greatly influence adaptation planning. Policies formulated through *top-down* approaches may not always auger well to end-user needs (Donatti et al. 2019). In India, little research has been conducted to explore the links between farmer perceptions and policy recommendations for adaptation. Emphasis has largely been on physical and biological aspects (Asseng et al. 2013) or policy dimensions (Agrawal 2013). Efforts to record farmers' adaptive practices recently started in 122 out of 640 districts of India (NICRA 2016). However, they do not assess how farmers exposed to multiple stressors experience cascading impacts on their livelihoods (Singh et al. 2017).

While O'Brien et al. (2004) and Tripathi (2014) report on the agricultural vulnerability of different states and districts of India, respectively; scant information is available to farmers and local developmental agencies. Virtually no systematic study has been conducted at the micro-scale (village level) to assess farmers' perceptions of multiple stressors in relation to their livelihoods in eastern Uttar Pradesh. This study addresses this gap and seeks to:(i) uncover farmers' perceptions of climate variability; and (ii) identify compounding multiple stressors, in order to (iii) understand the livelihood risks experienced over the period 2000-2015.

Conceptual orientation

This paper considers stressors as incremental increases in a particular event, phenomenon or situation that increases the livelihood risks of farmers (Parry et al. 2007). Multiple stressors include a broad range of factors such as climate variability (drought and flood), ecological stressors (problematic soils and depletion of fresh groundwater), socio-economic stressors (low incomes and labour shortages) and political stressors (lack of credit, infrastructure and technology) (Ribot 2014). Climate variability (and/or other stressors), either alone or in combination with other stressors, may increase the livelihood risks of farmers and shape their perceptions on climate variability (**Fig. 1**).

Variations in knowledge of an event or process or phenomenon are a natural corollary of differences in perception (Raymond et al. 2010). In this study, perceptions about climate variability and other stressors were defined as an individual's ability to see, hear and experience (over the period 2000-2015) any one or combination of stressors caused by climatic phenomena alone and/or ecological, socioeconomic and political factors affecting the activities vital to the farmers' subsistence. Livelihood risks are then the outcome of interactions between several stressors (Birkmann 2007). In this study, *climate-caused* (adverse impacts on the livelihood base) and *social constructivist* (risk within society shaped by the non-climatic factors required to sustain livelihoods) views were taken into account, following Scoones (1998) and Ribot (2014). Taking insights from Simelton et al. (2013), Ribot (2014) and McCubin et al. (2015), we conceptualized a framework in which climate variability was proposed as an *exogenous stressor* and associated risk as consequence. By comparison, stressors relating to ecological, policy-institutional and socioeconomic spheres were considered *internal and compounding stressors* influencing livelihoods or increasing various risks; either directly or through *exogenous* (climate) stressors as perceived by the studied population (**Fig. 1**).

Climate Variability and Other Stressors: Implications in Context of Eastern India

The majority of small-scale and marginal Indian farmers living in fragile ecosystems depend almost entirely on local resources (Tripathi 2014), lacking access to the external resources necessary to adapt to environmental challenges (Singh et al. 2017). Lately, socioeconomic and political changes, including the erosion of social institutions and the continual shrinkage of common property resources (CPR) (Singh et al. 2019), have dealt a further blow to livelihoods, increasing their dependency on external factors to secure a livelihood. Situation became further risky to resource-poor farmers, including of study region, due to changes in climate patterns and globalization-induced market distortions (O'Brien et al. 2004).

India formulated the 'National Action Plan on Climate Change' (NAPCC) in 2008 to accelerate adaptation to climate change. In response to the NAPCC, State Governments have also developed 'State Action Plans on Climate Change' (DoE 2014), though with an almost exclusive focus on *top-down* approaches. The study state of UP, reeling under climate variability and extreme events, has also developed policies to mitigate and adapt to climate and biophysical stressors but has largely overlooked the socioeconomic and political stressors exacerbating such climate impacts (Tripathi and Mishra 2017). As a follow-up to various national and state policies, systematic research on climate change adaptation in agriculture started with the launch of

National Initiative of Climate Resilient Agriculture (NICRA) project (ICAR 2011). Subsequently, contingency measures and long-term plans (MoA&FW 2016) for farmers of states including UP were drafted. Concurrently, State Governments are also refining their agricultural development policies with periodic assessment of climatic variables, and issuing weekly and monthly advisories to farmers (NICRA 2016; MoA&FW 2016). However, the process continues to be led from the *top-down* (DoE, 2014). In many cases, farmers may differ in their perceptions about climate variability induced stressors and associated risk due to their localized knowledge of agriculture management practices and other contextual factors (Limantol et al. 2016). Such on-the-ground concerns, which vary with time and space, although important for sustainable adaptations, are least understood at the formal level, and so fail to feature in assessments of climate induced stressors and the development of adaptation strategies. Addressing such gap, this study provides an insight into how farmers perceive climate variability and how their perceptions can differ from formal ways of understanding climatic events, making an essential contribution to understanding successful adaptation.

Research design and methodology

Study Area

Agriculture and allied activities are the major livelihood activity for about 55% of the 1.25 billion Indian population, with agriculture contributing 14% to Indian GDP (Gopalakrishnan and Thorat 2015). Data were collected from Azamgarh district in eastern UP, India on account of increasing climate variability and extreme events in the recent past (Tripathi and Mishra 2017). Azamgarh district covers 4,054.0 km^2 (Census, 2011) with an average elevation 64 m above mean sea level (MoEF&CC 2010). It has a dry sub-humid hot climate with average annual rainfall of 803 mm, and average minimum and maximum temperatures 5.7°C and 41.4°C, respectively (GoUP 2009). There are three main seasons: winter (mid-October to Mid-March), summer (Mid-March to mid-June) and rainy (Mid-June to Mid-October). From a population of 4.613 million (Census 2011), about 65% of people are engaged in agriculture and allied activities (GoUP 2009). Rice-wheat cropping systems dominate with cash crops such as potato, sugarcane, onion and vegetables cultivated in irrigated areas to varying extents (GoUP 2009). Soils are mostly sodic in nature and over 95% of landholdings are <2.0 ha (GoUP 2009). Privately owned tube-wells cover most (83%) of the net irrigated area,withthe remainder irrigated by canals and other sources (Kumar 2002). About 0.15 million ha are under a CPR system, including wetlands (GoUP 2009). The study district is second in terms of its total number of wetlands in the state (MoEF&CC2010) and these are crucial for agricultural livelihoods (Fuyset al. 2005). The district is relatively less developed in terms of rural infrastructure and agriculture than other parts of the state (GOI 2014; Tripathi 2014)

Sampling of Study Area and Population

Azamgarh District was selected purposively, based on recent high climate sensitivity and high vulnerability levels (Tripathi and Mishra 2017). Some of the previous studies conducted in same localities (Singh et al. 2014) and similar situations at other places (O'Brien et al. 2004) those also confirmed by Tripathi and Mishra (2017), indicated the hidden issues of multiple stressors experienced by farmers. These insights provided a base to conduct a systematic study. Based on the considerable knowledge about issues of selected areas, the research was undertaken in the targeted area and population with available resources (budget and time) (Truelove et al. 2013). Three villages: Sonapur, Gambhirban and Gurehtha, in the Developmental Blocks of Jahanaganj, Rani Ki Sarai and Mehnagar, respectively, were purposively selected with guidance from district agriculture department officials. All selected villages have a predominance of small and marginal farmers, and two major land use systems (rice-wheat and rice-wheat-wetland). Field data were collected during 2012-2015 in May-July and November-December, followed by verification of results with farmers during August and December 2016, and September 2017.

A total of 24 key informants (6, 8 and 10 farmers from the study villages, respectively) were interviewed to record village level information on climate variability, ecological and socioeconomic information and other data. Data were also collected through PRA (participatory rural appraisal) exercises (**Table 1**). Four criteria: (i) small land holding (<2.0 ha) (FAO 2010), (ii) minimum 15 years of agricultural experience, (iii) permanent residence in the village and(iv) thorough knowledge of agricultural history, were used for the selection of key informants by employing a snowball technique. Selection was done with the help of Gram Panchayat members (village level first tier of democratic institutions) who know most of the villagers with whom they interact in most of the village developmental plans. A list of small and marginal farmers was prepared with the help of the Gram Panchayat and key informants to select 20 farmers aged >35 years from each village (a total of 60 respondents) using stratified random sampling. These farmers acted as interview respondents. During a scoping visit, we found that the majority of the younger generation were less interested in agriculture and are migrating to towns for work so we interviewed only those >35 years old, as their interaction with agricultural activities and thereby experiences of climate were assumed to be lower than those who are fully dependent on agriculture and live exclusively in villages.

Data collection

We used a combination of qualitative and quantitative techniques to collect the primary data (**Table 1).**

Quantitative Methods

Quantitative methods were used to collect data on individual perceptions about climate variability and livelihoods risks from 60 farmers using a structured interview schedule (**Table 1**). Day to day agricultural activities in the study area and local literature (collected during a scoping study) was used to frame statements on perceptions about climate variability and related risks or impacts on livelihoods. A questionnaire with a set of positive and negative questions covering different climatic variables was developed (**Table 1 and** 2, Online Resource 1). The purpose of randomly inserting negative statements was to minimize the risk of bias in farmers' responses (Maddison 2006). Questions on 'farm management' (cost of cultivation, labour shortages, farm profits, etc.) were asked to enable us to link farmers' perceptions with documented trends. These questions were pilot tested with 5 farmers before final application following edits where needed to reduce ambiguity. The responses of farmers against each statement were measured using a 5 point Likert scale (1932). District level rainfall (1901-2014) and temperature data (1901-2002) were accessed from the Water Portal (IWP, 2017) and Indian Meteorological Department (IMD 2017), respectively. These sources were also accessed for data on climate variability and related stressors. Policies and MSP (Minimum Support Price) data were taken from MoA&FW (2015), which complemented data on economic and market stressors.

Qualitative Methods

Using Google search engine, data on the susceptibility of the district to extreme climatic events and vulnerability were collected from the Ministry of Agriculture, Government of India and other secondary sources (details provided in online resources). Qualitative data were also obtained from 24 key informants who were asked to participate in 10 different exercises including focus group discussions (FGDs) (**Table 1**). Photographs and videos on floods, droughts, rainstorms and outbreaks of crop insect-pests and diseases were shown to the key informants while conducting FGDs. The same strategy was followed with 60 respondents during interviews. The objective in both cases was to better capture participants' and interviewees' experiences of present and past events. In-depth discussions were held with key informants following FGDs to record perceptions of multiple stressors and their interactions with climate and related livelihood risks. The data on multiple stressors were recorded in FGD through hand raising method, and individual response against multiple stressors was recorded. The weighted score was developed using these responses from across the three study villages. Questions on 'farm management' were further confirmed with key informants in FGDs. Supplementary field notes and photographs of specific climate events, alongside transect walks, were used to complement the qualitative data-set. Audio recordings were made for longer discussions on types of social groups and their socioeconomic and major agricultural activities, associated risks, historical changes in land use patterns and narratives on how changes in CPR regimes have impacted different groups of farmers.

Triangulation of Data

After the first round of data collection, three follow-up visits were made to sampled villages to triangulate the qualitative and quantitative data (Antwi-Agyei et al. 2012). This included discussions with key informants and available interviewees on the pattern of results of compounding stressors (collected through FGD) and climate variability, and perceived risks (collected through interviews). This exercise was a productive, iterative process in terms of identifying circumstances surrounding the key phenomenon of climate and its contextual factors, converging central characteristics with better interpretations and omitting unacceptable points to improve the trustworthiness of results (Lambert and Loiselle 2008).

Data Analysis

Interview data were entered into spread sheets and frequencies and scores were calculated under different categories, effectively translating some of the qualitative information into quantitative information. Using the STAR statistical packages (version 2.0.1) (IRRI 2013), score and rank values for perceptions and livelihoods risks were calculated and tested for their significance applying the Wilcoxon matched pairs sign-rank test. On the basis of highest to lowest score generated using climate and risk related variables, ranks were estimated for the corresponding variables. First of all, the statements (variables) relating to perceptions about climate variability and livelihood risks having the highest score were calculated and assigned rank one according to the Wilcoxon value. This highest score (*e.g.*, rank one) obtained by a statement was then applied as a base value to compare with other subsequent statements until they appeared as significant in the Wilcoxon test. The statements between two significant values were designated to a particular priority group. The score of every next significant statement was considered as a base value for comparing subsequent statement(s) to find out the next priority group.

The major multiple stressors were grouped and ranked in order of their severity by running a Mann-Whitney *U*-test to analyse their significance in relation to livelihood risks. Multiple stressors data were analysed using additive percentages and ranked in STAR. The compounded growth rate was calculated by fitting the exponential function as: y = ae^(bt (Online Resource 1, p. 3) in a spreadsheet. Monthly mean rainfall data (mm) for the period 1901-2014 (100 years) and 2000-2014 (15 years) were analysed in Excel (210) considering percentages, means, standard deviations and coefficients of variation. Qualitative data were thematically categorised and cross-checked with quantitative data, particularly on perceived climate variability, multiple stressors and livelihood risks (Stringer et al. 2017). This enabled complementary patterns to be identified in the characteristics of major variables (Antwi-Agyei et al. 2012). We coded qualitative data using content analysis, and again, the major themes that emerged were analysed for patterns in major characteristics of stressors and associated risks to farmers(Antwi-Agyei et al. 2012). Doubts were discussed with key informants by phone or using social networking media such as WhatsApp. Finally, the results of study were presented to farmers in each village to gain feedback and validate the findings.

Results

Perceptions of Climate Variability

The Wilcoxon test indicated that farmers within priority group (PG) 1 (deep black, **Table 2**) perceived that rainfall had become erratic over the period 2000-2015; that there were alterations in the onset and duration of different seasons and a decrease in the number of rainy days. Farmers within PG 2 (light black colour) perceived that while the duration of winter had significantly (p= 0.05) decreased, there were visible changes in local weather as evidenced by early onset of summers and increasing frequency of drought events. In particular, farmers experienced extended dry-spells and droughts in 2000-2002, 2009 and 2012, while severe droughts were experienced in 2013 and 2014 (**Table 3**, Online Resource 1), but not recorded by planning and developmental agencies. Farmers within PG 3 opined that the frequency of rainstorms, flash-floods and extended dry-spells had increased. Farmers also perceived rainstorms *Phailin* (2013) and *Hudhud* (2014) which were not reported in secondary data (**Table 3**, Online Resource 1), reporting that they found it increasingly difficult to predict the weather using traditional indicators.

Despite increased uncertainty, farmers still depend on 22 bio-meteorological indicators (**Table** 4, Online Resource 1), and knowledge of clouds and winds to predict local weather and rainfall patterns. For example, unseasonal/untimely appearance of insect-pests are considered to be an indication of higher atmospheric humidity in otherwise dry months (**Fig. 1a,b,c,** Online Resource 2). Poor access to weather forecasts from formal sources further enhances uncertainty and greatly reduces farmers' choices in deciding on adaptation strategies, as they first need to know to what they are adapting.

Farmers within PG 4 and 5 (indicated by the lightest black colour) perceived alterations in the occurrence of '*loo*' (hot winds blowing during May-June), excess rains (but without any adverse impacts) and drizzling rains over the 30 year period (**Table 2**). Farmers considered '*loo*' to be a reliable indicator of a 'good monsoon' (*i.e.*, sufficient and evenly distributed rainfall). Drizzling rains (*Sawan Ki Jhadi*, low intensity rains during August), perceived to be critical for the growth and productivity of rice, and in field preparation for *Rabi* (winter)season crops, water harvesting for irrigation and weed decomposition, have now become rare. The importance of drizzling rain is reflected in a local folktale:

> "*Yadi purva aur uttara baras jati hai, to kisan ko pure saal khushal kar jati hai*"….
>
> [Drizzling rains in *ashlesha* (rain water is considered to be of average quality) and *magha* (good quality) constellations (in August) are important for the year round happiness of the farmers] (Key informant: Pujari and Mahajan, April 2014).

The distribution and amount of monsoonal rainfall during mid-June to the end of September determines the success of year-round agricultural activities. The majority (62.4%) of farmers perceived that rainfall had become 'erratic', while 26.6% perceived 'less rainfall' and 5.0% perceived 'excess' rainfall between 2000-2015 (**Fig. 2,** Online Resource 2). A good harvest of two local millets is virtually synonymous with a good monsoon as summarised in the following folktale:

> '*Sanwa, sathi (bhandai) 60 din, barkhapaweraat din*'...
>
> [If *sanwa* (*Echinochloa frumentacea*) and *bhandai* (rainfed paddy variety) receive even modest but continuous rains during July-August, they will mature within 60 days (Key informant: Mahajan, August 2014)].

Evenly distributed rainfall is considered to be a boon for rice and other *Kharif* season crops. Failing to receive such rainfall at critical stages of the crop cycle for rice (especially at transplantation to grain setting stage), is perceived to be a drought. Consequently, we analysed secondary climate data and found that an erratic trend in monsoonal rainfall was observed during 2005-2014, a period that witnessed 5 excess rainfall years (33.33%, *e.g.*, year 2005 and 2007 received heavy rains) and 9 deficient rainfall years (60.0%) (**Table 5,** Online Resource 1). Rainfall received during this period varied from very low (381.2 mm in 2014) to very high (1351.6 mm in 2007). The coefficient of variation (%) also increased during this period as compared to 1975-2014, particularly in June (84.95%) and September (66.33%). The critical months, during which normal and even distribution of rains is a precondition for the better growth of rice, have witnessed decreases in rainfall; *e.g.*, 20.47% in July (period of initial rice growth), 9.07% in August (vegetative growth and tillering) and 10.88% in September (panicle initiation) (**Table 5.1,** Online Resource 1). This trend, and even recent systematic efforts of recording monsoonal anomalies (for issuing agroadvisories to farmers) (**Table 5.2,** Online Resource 1) were similar to farmers' perceptions.

Perceived Climate Variability and Related Livelihoods Risks

Wilcoxon signed-rank test results revealed that with the highest rank score and PG 1, farmers perceived that overall livelihood risks had increased due to climate variability, and that this risk was further compounded by ecological (e.g. high soil pH) and anthropogenic stressors (market, institutional and policy, technological and social factors) (**Table 3**). Higher incidences of diseases and insectpests were perceived to have increased with the use of agrochemicals over the past 20 years resulting in higher costs of cultivation. As a consequence, farmers' dependence on external resources had increased.

Poor groundwater recharge and physical changes in aquatic bodies ascribed to reduced drizzling rains were perceived as the direct consequences of climate variability. Drying of surface water bodies had increased the livelihood risks of the *Bhar* community (who mostly reside around the wetlands and possess sodic lands known to be less productive than normal soils), traditionally dependent on a biodiverse fish catch of about 25 species in the 1980s to 4-5 species at the time of data collection, and the *Yadav* community, primarily dependent on community pond water for livestock. Farmers with PG 2 opined that frequent anomalies in weather (seasonal cycles, rains and heat stress) had necessitated (*significant,* p= 0.05) frequent seed replacement, as home grown seeds were more susceptible to diseases and insect-pest incidence and did not yield well when used successively for more than 3 years. Consequently, farmers perceive the genetic vigour of rice and wheat varieties has reduced, necessitating their replacement every 3-4 years. Erratic rainfall and increases in the maximum (by 0.10°C; CV 1.14%) and minimum temperature (by 0.15°C; CV 2.13%) (**Table 6,** Online Resource 1) over 30 years (1972-2002) seem to have altered the micro-climate.

Resource use efficiency had also decreased, compelling many small and poor farmers to migrate to citiesfor more reliable income-generating jobs (**Table 3**). As noted with PG 3, frequent alternate wetting and drying (*i.e*., flash-floods followed by droughts/extended dry spells) had increased the risk of adverse impact of sodic soils (significance p= 0.05) naturally found in the study area. Migration of agricultural labourers to cities had further compounded farmers' risks as they are now required to pay higher wages than 10-15 years previously. Heat stress had also lowered the efficiency of farm labourers (PG3, **Table 3**). For example, during 1990s one labourer would uproot 6 *Panji* (1 *Panji*= 5 bundles of rice seedlings) per day which had decreased to 3 (at the time of this study). Currently, about 44 labourers are required to transplant rice in 1.0 ha, which is almost two fold higher than the early 2000s when only 24 labourers were needed. Results also indicated that climate variability, along with socio-economic and policy factors, had significantly reduced crop yields and had accelerated the loss of local agrobiodiversity (p= 0.05).

Multiple Stressors

Climate Variability

The additive percentage with rank analysis indicated climatic stressors were predominant among the multiple stressors impacting farmers' livelihoods (**Table 4**). Results on individual subclimatic factors revealed that reduced numbers of rainy days (23.08% response; *significant* at Mann-Whitney *Up*= 0.01) and other rainfall related anomalies were perceived as sub-stressors by 35.58% farmers. Changes in seasonal cycles (21.15% response; *significant* at *p*= 0.01) and sudden changes in weather patterns (20.19% response) were further observed (**Table 4;** see also **Table 7,** Online Resource 1).

Compounding Socioeconomic and Market Stressors

Rising costs of cultivation were perceived (23.23% response) (*significant*) as the most substantial *economic* stressor (**Table 5**). For example, during 2014 the cost of rice cultivation ranged from Rs. 30,000-35,000 ha^{-1} and that of wheat from Rs. 20,000-25,000 ha^{-1} as compared to Rs. 10,000-12,000 and Rs. 7,000-10,000 ha^{-1}, respectively in 2000. A decadal (2005-2015) data trend indicated costs of cultivation increased by about 3.2 times in rice and wheat crops, while MSP increased by only two and half times in both the crops with a compounded annual growth rate of 9.82 in riceand 8.36 in wheat (MoA&FW 2015) (**Fig. 3,** Online Resource 2).

Uncertain and volatile market prices (perceived by 20.20%), unorganized markets and limited financial support from the government (19.19% response for each) (*significant* at *p* = 0.01) have reduced profit margins. Farmers reported that during extended dry spells/droughtyears, as in 2012, crop productivity declined by 30-40%. Inadequate arrangements by the state government for rice procurement, coupled with poor market infrastructure, compelled farmers to distress sale produce through middlemen at considerably lower prices (*e.g.*, Rs. 600-700 and Rs. 1000-1200 q^{-1} for coarse grained riceagainst the fixed MSPs of Rs. 1,250). Low income from rice crops also adversely affects the sowing of ensuing *Rabi* crops as farmers usually purchase seeds, fertilizers and other inputs after rice sales.

Farmers perceived that labour crisis (25.58%) and low income (22.09%) (district average annual income Rs. 9859 $year^{-1}$, Tripathi 2014) have increased their difficulties in undertaking their cropping activities in a timely way (**Table 4**). During rice transplanting and harvest seasons, reduced labour availability compels farmers to spend more money (Rs. 140-150 per half day compared to average wages of Rs. 100 for the same duration of work during other times of the year). Some farmers leased out their lands (called *Adhiya* and *Rai*) to those households with more family labourers, and more financial capital, to reduce risks caused by labour scarcity. Social marginalization (22.09%), declining interest of youth in farming (20.93%) and unproductive education (9.5%) (all *significant* at *p*= 0.01) reduce the prospects of gainful employment.

Compounding with Instituional and Policy Related Stressors

Farmers lacked access to subsidized inputs such as micro-irrigation equipment, while electricity and labour supply were limited (perceived by 24.24%). Despite contingency plans being developed by the relevant institutions, improved seeds and other inputs did not reach farmers, revealing a major *institutional* stressor. Most farmers had no knowledge of government plans and schemes. The MGNREGA (Mahatma Gandhi National Rural Employment Guarantee Act) and PDS (Public Distribution System) have further increased the risksas perceived by 22.68% of farmers (*policy stress*) (**Table 4**). MGNREGA has led to labour shortages affecting agricultural activities over the last 15 years (2005-2015) (**Fig. 4,** Online Resource 2). Those with extended family, having more family labourers and practicing *Adhiya* and *Rai* (lease system), had relatively fewer perceived risks associated with labour availability. It also emerged that labour demands were especially high during rice transplanting season and erratic rainfall/unreliable water supplies tended to further accentuate the problem. In dry years, farmers were compelled to purchase irrigation water (Rs. 50 h^{-1}). As most of the tube-wells were electrically operated, extended power-cuts strengthened the bargaining power of labourers who usually demanded relatively more wages. Under the PDS scheme, economically weaker families are entitled to 35kg of rice and wheat each per month at nominal prices (Rs. 3 and 2 kg^{-1}), respectively, which has also increased the lack of interest among labourers to work on farmers' fields (*policy stress*), as reported by 90.0% of farmers.

During adverse situations, small and marginal communities mainly sustain their livelihoods by accessing CPR. In the past, marginal farmers, like the *Bhar* community, freely accessed the *Badaila* lake and other surface water bodies to harvest wild rice, as well as to grow local rice varieties and catch fish consumption and local sale. The natural drainage water, flowing from *Badaila* lake, was utilized for irrigation.From the 1990s onwards, a *top-down* management regime for CPR led to changes in structures and functioning of these resources. Currently, the Village Panchayat controls such resources (following norms prescribed by the State Government), which are auctioned to private contractor(s) to generate higher revenues. *Badaila* lake and village ponds were leasedout to the highest bidder (private contractors) for a 1 year period. This created a tragedy of the commons situation. The *Bhar* community faced hardships (*policy stress*) as they could only access certain parts of lake for fishing and the collection of other aquatic resources (wild rice, lotus, etc.); the remainder was under control of the contractor, and any encroachment may have invited legal action.

The *top-down* approach to policy implementation by the State Agriculture Department, often overlooking on-the-ground realities and farmers' needs, had also *significantly* (p= 0.01) enhanced farmers' risks (21.65%). Most of the intended policies/inputs did not reach farmers in time. For example, district KVK (KrishiVigyan Kendra) conducting Front Line Demonstrations (FLDs) in wheat, rice and other crops had limited reach. Such FLDs mostly benefit only a few large scale farmers who are in regular contact with KVK and able to manage the required inputs to adopt the new varieties.

Compounding with Ecological Stressors

Due to erratic rainfall, groundwater had declined (22.83% response) between 2000 and 2014 (**Fig. 5,** Online Resources 2). Abandonment of conventional open-wells and changes in structures and functioning of community ponds (perceived by 21.74%) which recharge groundwater (**Table 4**) further aggravated the problem. For example, in Sonapur village, we recorded almost no water storage in 7 community ponds and natural water courses connected to the *Badaila* lake due to low rainfall and inappropriate anthropogenic activities (*e.g.*, encroachment, inappropriate modifications in the form and shape of village ponds by Panchayat without considering traditional ecological knowledge). Landscape modifications and choking of natural drains had altered the hydrological balance resulting in rapid run-off to low lying areas, depriving upland crops of water. Farmers experienced that during rice transplanting, the water table often drops below 10.76 m especially during drought years or delayed monsoon. Low rainfall and water pumping for irrigation not only exacerbate groundwater depletion, but also result additional energy use (increased irrigation hours) and irrigation costs (*cf:* Redfern et al. 2012).

Changes in land use patterns, *i.e*., replacement of millets, oilseeds and pulses with a rice-wheat system, has led to over-withdrawal of ground water and severe erosion of local agrobiodiversity, compounding risks (**Table 4**). Rich agrobiodiversity is considered key to the well-being of economically weaker and socially marginal groups who opined that although climate variability (*e.g*., reduced rainfall) has led to agrobiodiversity loss, land use changes from rainfed (e.g., short duration upland paddy and local pearl millet, maize and redgram and black gram) to an irrigated rice-wheat system seemed to have inflicted more damage. Due to assured availability of irrigation water, the majority of farmers, with relatively bigger size of land holding and more resources, had switched to improved varieties of wheat and paddy crops which also need more inputs, increasing dependence on external resources. Farmers perceived that land use change (19.57%) and soil sodicity (soil pH 8.8-9.2) (18.48%) (both *significant* at $p = 0.01$) caused a decrease in soil quality and fertility, respectively. Sodic soils also have a degraded structure and low infiltration capacity resulting in prolonged submergence and damage to crops even during normal rainfall years (**Table 4**). Farmers perceived that with concomitant impact of green revolution practices (e.g. mono-cropping with intensive use of inputs) that started in the 1960s, mixed and diversified cropping systems, sheep and cow herding in crop fields, collective cropping and resource sharing mechanisms have now become virtually non-existent. Such changes caused many traditional adaptive practices and related social institutions helpful in degraded sodic lands to disappear.

Compounding with Technological Stressors

Farmers had restricted access to improved agricultural technologies (27.71%) attributed to poor extension (26.51%) (*Significant* at p= 0.01). Technologies in rice, wheat and other crops being adopted by farmers, are less suited to farmers' needs and specific recommendations for niche problems (*e.g.*, salt tolerant varieties) are unavailable. Most farmers are unaware of salt tolerant varieties of rice (CSR-43 and CSR-36) and wheat (KRL-210 and KRL-213) (24.10 %, *significant* at p= 0.05). Private input dealers often provide genetically impure seeds and misleading agro-advisories too according to farmers. Further, gypsum and pyrite based technologies implemented by the state government to reclaim sodic soils rarely reached farmers. However, technologies to circumvent soil related stressors like sodicity and erratic rainfall are perceived to be absolutely essential (*significant*) (21.69%).

A summary of analysis of pooled stressor data indicated that although overall climate variability was found to be one of the major significant stressors (**Table 5**), institutional and policy stressors (p<0.000), social stress and technological stress (p<0.000), economic and market stressors (p<0.01) and ecological stress (p<0.02), in that order, were other stressors that significantly influence farmers' risk perceptions.

Discussion

Climatic Stressors

The results revealed that farmers perceived an increase in erratic rainfall, decreases in the duration of rainy season and number of rainy days, and changes to seasonal cycles (**Table 2**), similar to the meteorological data, but in the case of extreme events including recent rainstorms (MoA&FW 2016), the different knowledges diverged. Such differences may be due to meteorological data collection, and farmers' experience being spatially distant (*cf:* Simelton et al. 2013)-sometimes intense rain or rainstorms are a localized phenomenon, not captured in observations due to methodological issues (FAO 2019), and therefore farmers respond to unrecorded events (Callo-Concha 2018). Although the study district is assessed to be occasionally drought prone by developmental agencies (**Table 3,** Online Resource 1) (MoA& FW 2016), in this study, farmers perceived a *significant* increase in the frequency of extended dry-spells and droughts during the study period. This may be based on their past and recent exposure to moderate and severe droughts. These micro level perspectives tend not to be incorporated into policy making at higher levels (O'Brien et al. 2004), resulting in climate policy and planning that does not reflect the realities experienced (England et al., 2018).

Farmers in this study had different perceptions to formal institutions (MoA&FW 2016). They considered rainfall to be normal when it is evenly distributed throughout the season to support the optimum water requirements of the rice crop during its different growth stages, thus they contextualised climatic phenomena in reference to agronomic attributes. The Indian Meteorological Department (IMD) considers a year to be a normal rainfall year if rain is 98% to 104% of LPA (Long Period Average, based on 50 years of data), below normal rain if LPA is 90% to 96% and deficient rain if LPA is below 90%. By this criterion, the real situation droughts experienced may be masked. Das (2010) and Nambiar (2016) also reported that Indian farmers, including those of the study region, are increasingly experiencing droughts.

Evidence suggests that components of the farming system (Simelton et al. 2013), alongside ecological, social and institutional factors (Callo-Concha 2018), all play a significant role in shaping farmers' perceptions of climatic variables. Such a dimension was found where farmers, for example, with access to tube-wells for rice crops, considered drought or delayed rainfall relatively less important as a limiting factor for crop cultivation. However, the same enabler (tube-well) might become a risk multiplier, such as for the *Bhar* group, who lack resources to support their crops during poor weather, and rely more on CPR. Similar risks may also shape differential risk perception of the *Yadav* community, who rely on animal husbandry by accessing communal grazing lands and water bodies.

Other Stressors Compounding Climatic Risks

Overall, climate variability risks were compounded by *economic, market* and *institutional stressors*. Farmers' perceptions of weather events are often shaped by the crops they grow and changes in resource and land use patterns (Slegers 2008; Adimassu and Kessler 2016), infrastructure support (Niles and Mueller 2016), and socioeconomic and political factors (*cf:* Meze-Hausken 2004). These combine to shape uncertainty over agricultural management and associated livelihoods. For example, although groundwater is a reliable source of irrigation for farmers in the study area, poor electricity supply and higher diesel costs, may further multiply their risk perception, especially during extended dry-spells and/or drought (Udmale et al. 2014). Additionally, market prices for rice tend to be lower after harvest (20-30%), irrespective of climatic conditions. But, to meet multifarious needs, farmers (particularly *Bhar* and *Yadav*), have to sell their produce at these prices because they lack storage capacity, and need to repay debts to input dealers. A recent assessment has indicated that climate change can impact farmers' livelihoods by reducing income (15-20%), exacerbating an already difficult situation for many farmers and therefore institutions need to target them with more cost effective and market smart adaptive strategies (GOI 2018).

Risk perceptions of farming communities often vary with resource endowments; particularly landholding size. Despite that some of the large landholders had recently switched from mixed farming to rice-wheat mono-cropping systems, they seem less prone to risks from escalating input costs and market volatilities. Contrarily, small landholders depending more on livestock (*e.g., Yadav* and *Bhar*) were likely to be adversely affected by such changes. To insulate small landholders from such risks, there has been a major policy thrust to promote diversification, growers' associations and cooperatives, improving agri-market infrastructure and market intelligence (MoA&FW 2019), but to little avail because of poor coherence (Birthal et al. 2007) and failure to accommodate differential socio-cultural and biophysical attributes.

Farmers were generally unable to access external resources and policies extended by formal institutions, and tended to rely more on local resources, such as local seeds and local indicators for weather prediction. This was attributed to their lack of awareness but also the lack of suitability for their needs (*cf:* Donatti et al. 2019). This issue was found more among *Bhar* then *Yadav* farmers than those having relatively better resources. Such disparity keeps many farmers from being able to access knowledge and other resources in a timely manner, and also means their voices are not heard in policy decisions (*cf:* Nelson 2011). For example, in the past the crop insurance policy was implemented to assess farmers' risks to climatic hazards and to provide compensation, however, assessments used generic indicators, failing to recognise local contexts (OECD 2018), and so many farmers did not benefit.

Similarly, MGNREGA (Mahatma Gandhi National Rural Employment Guarantee Act) compounded farmers' risks by creating agricultural labour shortages (*policy led social stress*) (RBI 2018), leading farmers to depend on costly technologies funded by increasing debt (*cf:* Bhargava 2014). Such debts extend forward (Antwi-Agyei et al. 2018), affecting both current and future livelihood risks (Agrawal 2008). Such a situation arises due to incoherent policies across developmental agencies (England et al. 2018). Relevant agencies could execute their policy-centric activities through Village Panchayat instead, more in harmony with farmers' activities, while scheduling rural development activities outside agricultural peak activities may provide win-wins here (FICCI 2015). The Public Distribution System (PDS) policy influenced in increasing the area under rice-wheat cropping due to assured returns, decreased conservation and cultivation of local varieties (Sahai 2011; Pingali 2012) and increased dependence of local farmers on external resources and other essential food items like pulses, edible oil, etc., and can be treated as *policy stressor*. Notwithstanding, the PDS and MSP policies inculcate profit-seeking attitudes among farmers, simultaneously eroding their risk buffering capacity (Agrawal 2008; Pingali 2012). Although the National Action Plan on Climate Change (NAPCC 2008) and Sustainable Agriculture Policy (MoA&FW 2010) have attempted to assimilate smallholder farmers' perspectives, multiple-stress led risks were poorly mainstreamed in policy.

Risks are magnified when natural and/or anthropogenic factors diminish the functional ecosystem services of CPRs. For example, decrease in the total annual rainfall (Table 5.1 and 5.2, Online Resource 1) and increased frequency of droughts have reduced the availability of food resources from CPRs with wide ranging ramifications for the livelihood security (Singh et al. 2019). While structural changes in the management of and access to the CPRs were considered prior to implementing National Food Security Mission 2007 in India, knowledge, technology and capacity building supports under NFSM seem to have benefitted the resource rich farmers most. Therefore, more needs to be done to reframe current policies to support e.g. management of CPRs such that risks for farmers depending heavily on such resources for subsistence are not amplified (Agrawal 2003).

Conclusion and Lessons

This research aimed to understand farmers' perceptions of climate variability and other stressors in relation to the livelihood risks. We found that climate variability induced risks have increased over time and are compounded by ecological, socioeconomic and techno-political stressors that remain unaddressed (**Fig. 2**). Although farmers' perceptions of rainfall patterns were more or less similar to the meteorological data from the formal sources, they differed considerably from the formal definition of droughts and rainstorms, due partly to their rather localized impacts, and partly to the compounding effects of non-climatic stressors. Poor access to weather forecasts compels farmers to rely on local indicators for agricultural planning which are increasingly becoming unpredictable and thus enhancing risks. The adverse impacts of climate-induced anomalies, changes in CPR management and land/water degradation were more pronounced among the most marginalized farmers.

We found that differential risk perception among stakeholders can create difficulties in distinguishing '*what is*' and '*what ought to be*' with regard to climate induced risks assessment, and designing micro-scale (village) strategies. We highlight the need for participatory dialogue between farmers and policy makers to reconcile differences and to frame commonly agreed adaptation pathways that avoid lock-ins to maladaptive practices. Most adaptation policies for Indian farmers focussed on adaptation to climatic stressors are still largely based on *top-down* approaches, and lack integration of farmers' perspectives. While several policies have been launched in India to enhance the capacity of smallholder farmers for climate change adaptation, a wide gap still exists, resulting in ineffective risk reduction. Robust coherence between agriculture and rural development policies, as well as infusion of a plural perspective into both *top-down* and *bottom-up* approaches is needed if farming livelihoods are to become more resilient.

Ethical Concerns

Respondents were informed about the objectives of the study prior to their participation, including the expected outcomes in form of print and digital publications. Accordingly, they provided their oral consent to share their knowledge and perceptions, and participated in this study for the data to be used in its outputs. Study respondents wished to remain anonymous; while those quoted in results use pseudonyms. The ethical (NRMACSSRISOL201601600914 & DARE/F.N0.8-6/2016-IC.II) and publication (No. 88/2019) approvals were obtained from Project Monitoring and Evaluation Cell headed by the Director of the lead author's institute, which also looks after the ethical concerns of the institute's research.

Declaration

Authors declare that they have no conflict of interests on this article.

References

Adimassu A, Kessler A (2016) Factors affecting farmers' coping and adaptation strategies to perceived trends of declining rainfall and crop productivity in the central Rift valley of Ethiopia. Environ Syst Res 5:13

Agrawal A (2003) Sustainable governance of common-pool resources: context, methods, and politics. Annual Rev Anthrop 32:243–62

Agrawal A (2008) The role of local institutions in adaptation to climate change. Paper prepared for the Social Dimensions of Climate Change, Social Development Department, The World Bank, Washington DC, March 5-6, 2008. http://siteresources.worldbank.org/EXTSOCIALDEVELOPMENT/Resources/244362-1164107274725/sdp118.pdf. Accessed 18 May 2018

Agrawal P (2013) Enhance adaptation in South Asia. Nature 501: 514

Antwi-Agyei P, Dougill AJ, Fraser EDG et al (2012) Characterising the nature of household vulnerability to climate variability: empirical evidence from two regions of Ghana. Environ DevSust DOI 10.1007/s10668-012-9418-9

Antwi-Agyei P, Dougill AJ, Stringer LC et al (2018) Adaptation opportunities and maladaptive outcomes in climate vulnerability hotspots of northern Ghana.Cli. Risk Manag. 19,83–93

Asseng S, Ewert F, Rosenzweig C, et al (2013) Uncertainty in simulating wheat yields under climate change. Nature ClChange 3: 827-832

Bhargava A (2014) The Impact of India's rural employment Guarantee on demand for agricultural technology. Environment Production and Technology Division. IFPRI Discussion Paper 1381. Washington, D.C.: International Food Policy Research Institute (IFPRI). http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/128468. Accessed 22 May 2016

Birkmann J (2007) Risk and vulnerability indicators at different scales: Applicability, usefulness and policy implications. Environ Haz 7: 20–31

Birthal PS, Jha AK, Singh H (2007) Linking farmers to markets for high-value agricultural commodities. Agri Econ Res Rev 20: 425-439

Callo-Concha D (2018) Farmer perceptions and climate change adaptation in the West Africa Sudan Savannah: Reality check in Dassari, Benin, and Dano, Burkina Faso. Climate, 6(44), doi:10.3390/cli6020044

Chatterjee B, Khadka M (2011) Climate change and food security in South Asia. CUTS International, Jaipur, India. http://www.cuts-citee.org/pdf/climate_change_and_food_security_in_south_asia.pdf. Accessed 1 January 2017

Dang HL, Li E, Bruwer J, Nuberg I (2014) Farmers' perceptions of climate variability and barriers to adaptation: Lessons learned from an exploratory study in Vietnam. Miti Adapt Strat Global Change 19 (5): 531-548

Das A (2010) Farmers' perception on climate change in semi-arid topic region of India.International Crops Research Institute for the Semi- Arid Tropics. http://vdsa.icrisat.ac.in/Include/Internrep/Report6.pdf. Accessed 6 March 2018

Deressa TT, Hassan RM, Ringler C et al (2009) Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environ Change 19(2):248-255

DoE (2014) Uttar Pradesh: State action plan on climate Change. Department of Environment, Government of Uttar Pradesh. http://moef.gov.in/wp-content/uploads/2017/09/SAPCC_UP_final_version_0.pdf. Accessed 5 July 2018

Donatti CI, Harvey M, Martinez-Rodriguez R et al (2019) Vulnerability of smallholder farmers to climate change in Central America and Mexico: current knowledge and research gaps. Climate Dev.11:3, 264-286

England MI, Dougill AJ, Stringer LC et al (2018) Climate change adaptation and cross -sectoral policy coherence in southern Africa. Reg Environ Change 18(7): 2059 -2071

FAO (2010) Characterization of small farmers in Asia and the Pacific. Asia and pacific commission on agricultural statistics: Twenty third sessions. Siem Reap, Cambodia, 26-30 April 2010. http://www.fao.org/fileadmin/templates/ess/documents/meetings_and_workshops/APCAS23/documents_OCT10/APCAS-10-28_-Small_farmers.pdf. Accessed 15 March 2018

FICCI (2015) Labour in Indian agriculture: A growing challenge. Federation of Indian Chambers of Commerce and Industries (FICCI). https://www.slideshare.net/ficciindia/labour-in-indian-agriculture-a-growing-challenge. Accessed 4 June 2019

Fuys A, Mwangi E, Stephan D (2005) Securing common property regimes in a 'modernizing' world: Synthesis of 41 case studies on common property regimes from Asia, Africa, Europe and Latin America. https://dlc.dlib.indiana.edu/dlc/bitstream/handle/10535/1524/fuys_andrew.pdf?sequence=1. Accessed 27 March 2017

Ge F, Zhu S, Peng T et al (2019) Risks of precipitation extremes over Southeast Asia: does 1.5 °C or 2 °C global warming make a difference?. Environ. Res Lett 14, 044015. https://doi.org/10.1088/1748-9326/aaff7e

GOI (2014) Lok Sabha unstarred question no. 4625 to be answered on the matter of development of backward districts of India. Ministry of Panchayat Raj, Government of India (GOI). http://www.panchayat.gov.in/documents/10198/562728/LS%20Unstarred%20Q.No.4625%20for%2021.02.14%20(English%20Version)%20(Final).pdf. Accessed 9 August 2018

GOI (2018) Climate, Climate change, and agriculture. In: Ministry of Finance, Government of India (ed), Econ. Survey I, 2017-18. http://mofapp.nic.in:8080/economicsurvey/pdf/082-101_Chapter_06_ENGLISH_Vol_01_2017-18.pdf, p: 82-101. Accessed 3 May 2019

Gopalakrishnan R, Thorat YSP (2015) What India can do differently in agriculture: Sarthak Krishi Yojana. http://www.rallis.co.in/imagesReusableFiles/Corporate_Sarthak-Krishi-Yojana.pdf. Accessed 9 February 2019

GoUP (2009) Integrated watershed management programmein Uttar Pradesh: Perspective and strategic plan 2009-2027. Department of Land Development and Water Resources, Government of Uttar Pradesh (UP). https://dolr.gov.in/sites/default/files/SPSP_Uttar%20Pradesh.pdf. Accessed 22 June 2019

ICAR (2011) National Initiative on Climate Resilient Agriculture: Launched. Indian Council of Agricultural Research, New Delhi, India. https://icar.org.in/hi/node/203. Accessed 5 July 2018

IMD (2017) Rainfall data of Azamgarh district, Uttar Pradesh, India from 2003 to 2014.Indian Meteorological Department (IMD), New Delhi, India.http://imd.gov.in/section/hydro/distrainfall/up.html. Accessed 2 July 2016

IRRI (2013) Statistical tool for agricultural research (STAR), Version: 2.0.1 (2013 – 2020). International Rice Research Institute (IRRI), Philippines. http://bbi.irri.org/products. Accessed 2 1 May 2017

IWP (2017) Precipitation of Azamgarh district, Uttar Pradesh, India.India Water Portal (IWP), Bangalore, India. http://www.indiawaterportal.org/met_data/. Accessed 10 June 2016

Kumar B (2002) District model land use plan district – Azamgarh Uttar Pradesh. Final Report.State Land Use Board, Uttar Pradesh Department of Planning, Government of Uttar Pradesh. https://www.snrd-asia.org/download/land_use_planning_and_management/District-Model-Land-Use-Plan-District.pdf. Accessed 1 June 2018

Lambert SD, Loiselle CG (2008) Combining individual interviews and focus groups to enhance data richness. J Adv Nursing 62(2): 228-37

Likert R (1932) A technique for the measurement of attitudes. Archives of Psych 140:1–55

Limantol AM, Keith BE, Azabre BA et al (2016) Farmers' perception and adaptation practice to climate variability and change: a case study of the Vea catchment in Ghana. Springer Plus 5:830.DOI 10.1186/s40064-016-2433-9

Maddison D (2006) The perception of and adaptation to climate change in Africa.CEEPA. Discussion paper No. 10, Centre for Environmental Economics and Policy in Africa, University of Pretoria, Pretoria, South Africa

McCubin TS, Smit B, Pearce T (2015) Where does climate fit?. Vulnerability to climate change in the context of multiple stressors in Funafuti. Global EnvironChange 30: 43–55

McDowell JZ, Hess JJ (2012) Accessing adaptation: Multiple stress o livelihoods in the Bolivian highlands under a changing climate. Global Environ Change 22:342-352.

Meze-Hausken E (2004) Contrasting climate variability and meteorological drought with perceived drought and climate change in northern Ethiopia. Climate Res 27:19–31

Mitchell J, Shepherd (2006) Productive strategies for poor rural households to participate successfully in global economic processes: Final report. Overseas Development Institute, https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/1682.pdf. Accessed 8 May 2019

MoA&FF (2010) National mission for sustainable agriculture strategies for meeting the challenges of climate change.Department of Agriculture and Cooperation, Ministry of Agriculture and Farmers Welfare (MoA&FF), New Delhi. http://www.nicra-icar.in/nicrarevised/images/Mission%20Documents/National%20Mission%20For%20Sustainable%20Agriculture-DRAFT-Sept-2010.pdf. Accessed 12 March 2019

MoA&FW (2015) Minimum support price (MSP) of agricultural crops of India (data in public domain). Directorate of Economics and Statistics. Ministry of Agriculture and Farmers' Welfare (MoA&FW), Government of India. http://eands.dacnet.nic.in/MSP.htm. Accessed 16 August 2017

MoA&FW (2016) Agriculture contingency plan. Ministry of Agriculture and Farmers' Welfare (MoA&FW), Government of India. http://agricoop.nic.in/agriculture-contingency-plan-listing. Accessed 23 March 2019

MoA&FW (2019) Ministry major schemes.Department of Agriculture and Cooperation, Ministry of Agriculture and Farmers Welfare (MoA&FW), New Delhi. http://agricoop.nic.in/ministry-major-schemes. Accessed 4 June 2019

MoEF&CC (2010) National wetland atlas: Uttar Pradesh. National wetland inventory and assessment. Ministry of Environment and Forests, and Climate Change (MoEFCC), New Delhi. http://saconenvis.nic.in/publication%5CNWIA_National_atlas.pdf. Accessed 25 July 2018

Nambiar N (2016) Drought years may become more frequent in India. Indian Express, Pune, India, May 31, 2016. https://indianexpress.com/article/india/india-news-india/maharashtra-gujarat-drought-waterless-monsoon-crisis-years-may-become-more-frequent-in-india-says-study-2826500/. Accessed 24 September 2019

NAPCC (2008) National action plan and climate change of India.Government of India, New Delhi. http://www.nicra-icar.in/nicrarevised/images/Mission%20Documents/National-Action-Plan-on-Climate-Change.pdf. Accessed 17 March 2018

Nelson V (2011) Gender, generations, social protection and climate change: A thematic review. Overseas Development Institute, London, UK.https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications...files/7283.docx. Accessed 4 June 2019

NICRA (2016) Contingency planning bulletins from 2010 to 2015.National Innovation on Climate Resilient Agriculture.Indian Council of Agricultural Research, New Delhi, India. http://www.nicra-icar.in/nicrarevised/index.php/seasonal-bulletin. Accessed 5 May 2016

Niles MT, Mueller ND (2016) Farmer perceptions of climate change: Associations with observed temperature and precipitation trends, irrigation, and climate beliefs. Global Environ Change 39:133-142

O'Brien K, Leichenko RM, Kelkar U et al (2004) Mapping vulnerability to multiple stressors: climate change and globalisation in India. Global Environ Change 14: 303–313

OECD (2018) Review of agricultural policies in India.Trade and Agriculture Directorate for Committee for Agriculture.Organisation for Economic Co-operation and Development (OECD). http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=TAD/CA(2014/FINAL&docLanguage=En. Accessed 4 May 2019

Ostrom E (2000) Private and common property rights.Workshop in Political Theory and Policy Analysis, and Center for the Study of Institutions, Population, and Environmental Change, Indiana University. https://www.sfu.ca/~allen/common%20property.pdf. Accessed 11 March 2019

Parry ML, Caniani OF, Palutikof JP et al (2007) Climate Change 2007: Impacts, Adaptation and Vulnerability. Cambridge, UK: Cambridge University Press

Pingali P (2012) Green Revolution: Impacts, limits, and the path ahead. PNAS.109(31), 12302–12308

Raymond CM, Fazey I, Reed MS et al (2010) Integrating local and scientific knowledge for environmental management. J Environ Manag 91:1766-1777

RBI (2018) Impact of MGNREGS on rural labour market: An assessment using survey data: Economic review. Reserve Bank of India (RBI).https://rbidocs.rbi.org.in/rdocs/AnnualReport/PDFs/2ECONOMIC88A5CC5468FA4639A767862F5921304A.PDF. Accessed 11 April 2019

Redfer SK, Azzu N, Binamira JS (2012) Rice in Southeast Asia: Facing risks and vulnerabilities to respond to climate change. In: Meybeck A, Lankoski J, Redfern SK, Azzu N,Gitz V (eds) Building resilience for adaptation to climate change in the agriculture sector. Food and Agricultural Organization, Rome, Italy. http://www.fao.org/3/i3084e/i3084e.pdf. Accessed 2 May 2019

Ribot J (2014) Cause and response: vulnerability and climate in the Anthropocene. The J Peasant St 41 (5): 667–705

Sahai S (2011) Ensuring food security and genetic diversity. LEISA, September 2011, 13.3. https://leisaindia.org/regional-food-systems/. Accessed 11 April 2019

Savo V, Lepofsky D, Benner JP et al (2016) Observations of climate change among subsistence-oriented communities around the world. Nature Cl Change 6:462-473

Scoones I (1998) Sustainable rural livelihoods and rural development. https://www.staff.ncl.ac.uk/david.harvey/AEF806/Sconnes1998.pdf (12.05.2018).

Simelton E, Quinn CH, Batisani N et al (2013) Is rainfall really changing? Farmers' perceptions, meteorological data, and policy implications. Climate Deve 5(2): 123-138

Singh NP, Bantilan MCS, Byjesh K et al (2012) Vulnerability to climate change: Adaptation strategies and layers of resilience. Policy Brief No. 18. ICRISAT, ADB, pp: 1-8. http://oar.icrisat.org/5935/1/Policy%20Brief%2017.pdf. Accessed 20 July 2019

Singh RK, Zander KK, Kumar S et al (2017) Perceptions of climate variability and livelihood adaptations relating to gender and wealth among the *Adi* community of the Eastern Indian Himalayas. Applied Geog 86: 41-52

Singh RK, Kumar S, Jat HS, Singh A, Raju R, Sharma DK (2014) Adaptation in rice-wheat based sodic agroecosystems: A case study on climate resilient farmers' practices. Indian J Trad Know 13(2):377-389

Singh RK, Singh A, Kumar A et al (2019) Autonomous adaptation strategies to multiple stressors: A case study with marginal communities in eastern Uttar Pradesh, India. In: Dagar J, Yadav R, Sharma PC (eds) Development in salinity research. Springer Nature, India, New Delhi, pp. 853-882

Slegers MFW (2008) ''If only it would rain'': Farmers' perceptions of rainfall and drought in semi-arid central Tanzania. J Arid Environ72: 2106– 2123

Smit B, Wandel J (2006) Adaptation, adaptive capacity and vulnerability. Global Environ Change 16: 282–292

Stringer LC, Reed MS, Fleskens L et al (2017) A new dryland development paradigm grounded in empirical analysis of dryland systems science. Land Degrad Deve 28: 1952–1961

Tripathi A (2014) Socioeconomic backwardness increases vulnerability to climate change: Evidence from Uttar Pradesh. IEG Working Paper No. 337. Institute of Economic Growth, New Delhi, pp. 1-40. http://www.iegindia.org/upload/publication/Workpap/wp337.pdf(05.06.2019)

Tripathi A, Mishra AK (2017) Knowledge and passive adaptation to climate change: An example from Indian farmers. Cl Risk Manag 16: 195–207

Truelove HB, Carrico AR, Thabrew L (2015) A socio-psychological model for analyzing climate change adaptation: A case study of Sri Lankan paddy farmers. Global Environ Change 31: 85-97

Udmale P, Ichikawa Y, Manandhar S et al (2014) Farmers' perception of drought impacts, local adaptation and administrative mitigation measures in Maharashtra State, India. Int J Dis Risk Red 10: 250–269