From Risk to Resilience

Working Paper 5

Uttar Pradesh Drought Cost-Benefit Analysis, India

Reinhard Mechler, Stefan Hochrainer & Daniel Kull (IIASA)
Praveen Singh & Shashikant Chopde (WII)
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Cover: Damaged paddy due to delayed 2006 monsoon in Betkuian Village of Rupandehi District, Nepal. Photo by Anil Pokhrel.

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Introduction

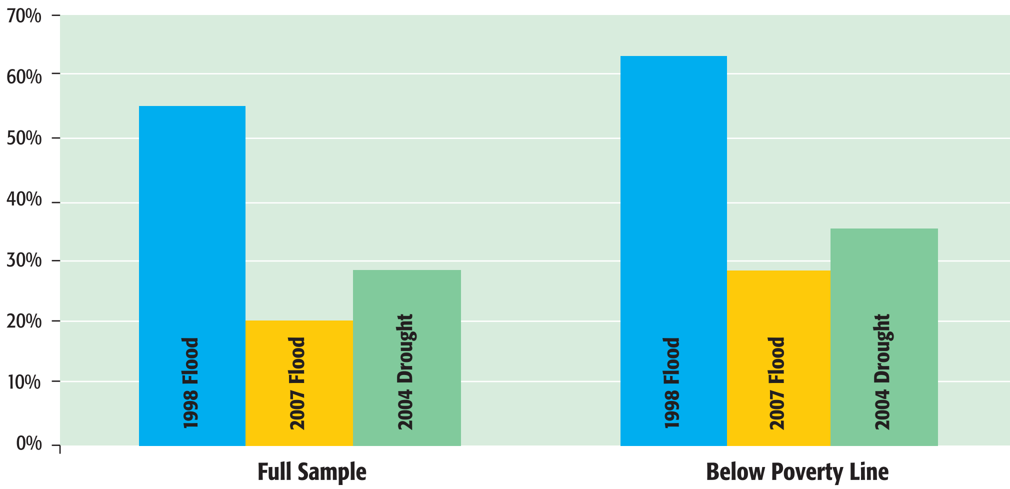
Particularly in developing countries where a large proportion of the population depends on agricultural livelihoods, drought related disasters are a major factor contributing to endemic poverty. Such disasters and the associated impoverishment of large populations are likely to grow if climate variability increases as a consequence of global change processes. Furthermore, while large-scale droughts may have sufficient immediate impact to draw the attention and concern of global actors, the increases in incremental losses associated with changes in the variability and unpredictability of climate conditions may have an equally great impact on vulnerable populations. Strategies for reducing this impact are, as a result, central to poverty alleviation and adaptation to climate change.

The case study presented here analyzes the costs and benefits of alternative strategies for mitigating the impact of drought on rural livelihoods in Uttar Pradesh, India. The case study explores both insurance mechanisms for spreading drought risk and, as an alternative, the development of groundwater irrigation for eliminating such risk. While the study is based on analysis within a relatively narrow case area, the results have more general implications for the development of effective strategies for responding to drought and the challenges associated with global climate change. Specifically, the study suggests that the benefits of insurance are likely to decline in relation to the costs if climatic variability increases substantially as a consequence of climate change. In addition, the study suggests that approaches to drought mitigation that are based on integrated combinations of strategies rather than single set of techniques or mechanisms may perform better. Our analysis indicates that irrigation plus insurance has higher return rates than either technique would if practiced on its own.

The Issue: Drought and Rural Livelihoods

Drought poses a considerable risk to rural livelihoods in rural Uttar Pradesh. In a survey conducted during 2007 for the Risk to Resilience project, farmers reported significant impacts on their livelihoods in the 2004 drought (see Figure 1 below for reported effects for the full sample and those below the poverty line, as well as in comparison to the 1998 and 2007 floods).

| FIGURE 1 | Drought and flood impacts as reported in survey (losses as per cent of income)



In this study, using cost-benefit analysis (CBA), we assess the impact of drought on rural livelihoods and the benefits of reducing and sharing risk, thus stabilizing income and consumption. A focus on livelihoods denotes an analysis at the microeconomic level (focus on households) as compared to a macroeconomic level study (focus on economic aggregates). The unit of analysis is a farming household which mostly derives income from subsistence farming.

The Methodology and Key Findings[1]

Table 1 summarizes the characteristics of the Uttar Pradesh drought CBA. For this case study, we conducted a detailed CBA analysis for assessing the drought risk small-scale farmers in Uttar Pradesh are exposed to and risk management interventions that can help them to reduce or share those risks. We adopted a detailed approach, which may be used for a preproject appraisal or project appraisal or for evaluating of accepting, modifying or rejecting projects. For this purpose, we adopted a forward looking methodology assessing risk explicitly in a risk-based modelling framework. The resource and time commitment for the analysis was large due to the need for conducting statistical analysis, stochastic modelling, and economic modelling of the household income generation process.

We assessed the costs and benefits of donor Disaster Risk Management (DRM) support for helping farmers better deal with drought risk to rice and wheat crops and subsequent income effects. DRM interventions considered were (i) irrigation via the implementation of a borehole for groundwater pumping, with pumping costs

[1] For a more in depth discussion of the CBA methodology refer to From Risk to Resilience Working Paper No.1 on cost-benefit analysis.

TABLE 1 | Key characteristics of the Uttar Pradesh drought CBA

Risks assessed	Drought risk affecting small-scale farmers in Uttar Pradesh in terms of rice and wheat production and related income
Type of CBA	Preproject appraisal or project appraisal for detailed evaluation of accepting, modifying or rejecting project
Methodology	Forward looking, risk based methodology
Focus of analysis and interventions analyzed	Costs and benefits of donor DRM support for helping farmers better deal with drought risk to rice and wheat crops and subsequent income effects. Interventions considered: 1. Irrigation: Implementation of a borehole for groundwater pumping, pumping to be paid by household 2. Subsidized micro crop insurance 3. Integrated package of interventions
Benefits	Stabilization of income and consumption due to DRM
Unit of analysis	Representative farmer household of 7 comprising 80% of the survey sample with income/person of up to 6,570 INR (national poverty line in 2008: 4,400 INR).
Resource and time commitment for the analysis	Large due to statistical analysis, stochastic modelling, and explicit modelling of the household income generation process
Key findings	• All interventions seem economically efficient • Irrigation benefits increase with climate change as rainfall means increased • Insurance benefits decline as volatility becomes less important with climate change • Integrated package delivers similar benefits at lower costs • For harnessing the benefits of integrated packages, cross-sectoral cooperation between different public and private actors is essential.

paid for by the affected household, (ii) subsidized micro crop insurance, and (iii) an integrated package.

The benefits evaluated in our analysis consisted of the reduction in average losses and the variability of income due to DRM interventions. As key findings of the CBA, we found all the interventions including the integrated package economically efficient given the assumptions taken. Insurance seemed less dependent on discount rate assumptions, which can be explained by the fact that it offers a secure, guaranteed payout, while irrigation and its benefits are dependent on the ex-post ability of the household to pay for pumping water. As the household is generally constrained in its financial ability, multiple events over the study period lead to accumulation of debt and an inability to pursue pumping efforts in later periods (which are more heavily discounted than the present). With a changing climate, groundwater irrigation benefits are likely to increase as average rainfall and rainfall variability increases, while insurance benefits are likely to decline as volatility is reduced. Finally, integrated physical (irrigation) and financial (insurance) packages return higher benefits at similar costs, as interventions for higher (irrigation) and lower frequency events (insurance) are combined. As a consequence, it seems highly important to explore such integrated packages in a process involving diverse public and private actors.

The Case Location, Issues and Responses

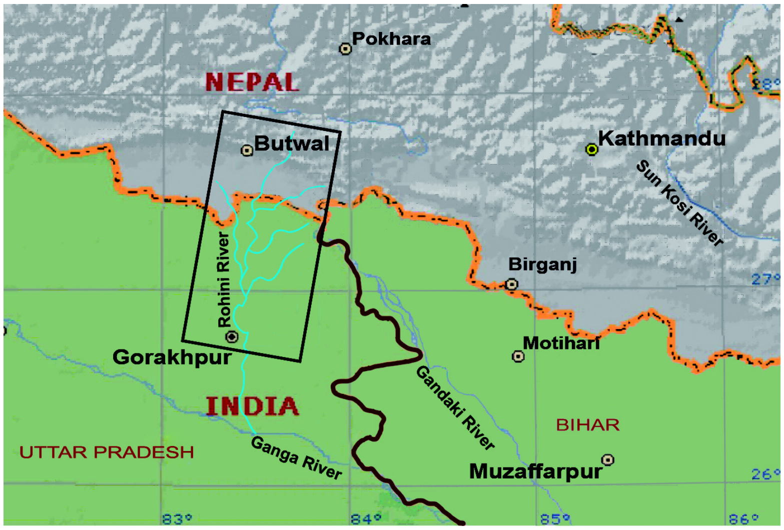
The study was conducted in the Nautanwa *tehsil* (administrative sub-district) which lies in the northernmost part of the Maharajganj district of Uttar Pradesh, India (see Figure 2).

The *tehsil* falls under the Tarai region which is characterized by small undulations, and crossed by numerous streams and drainage channels. The area is traversed by two rivers, the Rohini and Piyas, the latter merging with the former somewhere in the middle portion of the Rohini basin. There are many other hill streams and drainage channels, the banks of which are not well formed; all these merge with the Rohini.

The climate of the area is strongly modulated by the monsoon, with the majority of rainfall occurring during the monsoon months from June-September. Average rainfall is approximately 1,200-1,400 mm/annum. July and August are the wettest months receiving about 60% of the rainfall of the monsoon season. For a more in depth discussion of the basin's hydrometeorology refer to From Risk to Resilience Working Paper No. 3.

About 80% of the area is under cultivation. There are mainly two cropping seasons - the monsoon *kharif* and the winter *rabi* season. A third cropping season, *zaid*, during the summers is also taken in places where some artificial irrigation facility exists. The main crops of the region in these seasons are rice in *kharif*, wheat in *rabi* and vegetables and maize in *zaid*. The growing popularity of 'green revolution' methods, though its entry was late in this region, has changed the composition of agriculture. High

| FIGURE 2 | Case study location



Yield Variety (HYV) seeds have replaced the indigenous varieties of seeds and the use of chemical fertilizers has increased, along with groundwater irrigation. Although this has increased cropping intensity and crop productivity in the region, productivity still remains low by national or state averages.[2] The main causes of low productivity are small land holdings, lack of irrigation facilities and absence of extension services. Absence of infrastructure for food storage, processing, communication, electricity etc. all add to the poor gains in agricultural income. There is ample scope for agricultural diversification and development of off-farm and non-farm activities.

The Risks

Although a predominantly flood prone area, the basin also experiences drought-like conditions which cause widespread distress. Drought happens because of below normal, untimely or poorly distributed rainfall. Considering that rain fed agriculture is practiced in large parts of the basin even a slight deviation in the quantity or time of rainfall causes distress. The areas relatively more vulnerable to drought are the Nautanwa and Laxmipur *tehsils*. These *tehsils* are particularly vulnerable because large parts are uplands where the soil is of an inter-mixture of clay and sand (domat) -- which is less retentive of moisture -- and canal networks are limited. Although irrigation from tube wells is growing in this area, it is not economical to use groundwater to save the rice crop, especially if rains fail during the crucial flowering stage of rice. Drought also affects *rabi* crops in the case of an early cessation of rain; this reduces the moisture content of the soil thereby decreasing the productivity of wheat.

Who is Affected and How

When drought hits the region the entire population, except that falling in the canal command area, is affected, but the extent varies according to location. Those living in uplands are hit hardest as there is no moisture in their land. A number of people whose land is closer to some stream or drainage channel put an obstruction in the water and pump it to their fields while others use groundwater over a small area to protect their crops. Small and marginal farmers and landless labourers, the most vulnerable groups, suffer the effects of drought the most. They not only lose the investments they made in the sowing and other operations but also lose the food grain they rely on for subsistence. The landless are also heavily affected as there is no agricultural work available locally and they lose employment opportunities. Households where one or more members have migrated outside can survive the effects of drought if they receive income from remittances but others have to suffer malnutrition and exploitation at the hands of local moneylenders.

[2] The crop production is quite low as compared to national averages and the grain production is 21.4 and 25.6 quintals/ha in Gorakhpur and Maharajganj districts respectively.

The Main Strategies for Risk Reduction that are Being Implemented

Historically, the main strategy to deal with drought and rainfall variability has been surface irrigation. Parts of this *tehsil* falls under the command of various perennial canal networks - Gandak canals, the Rohini canal and the Danda canal. The Rohini canal is the oldest. It was built in 1954 to irrigate a narrow strip of land on the right bank of the river. Although it was built to secure the *kharif* rice crop, it has also helped in the extension of the area of wheat cultivation in this area. Gandak and Danda canals were built during the 1970s. Although these canals are important, only a small area of the study *tehsil* benefits from canal waters; large stretches of it are outside the command area.

In the 1980s, and even more in the 1990s, there was an increase in the use of groundwater irrigation through borewells. Earlier open dugwells were used only to irrigate a small area under some valuable *rabi* crops and for summer (*zaid*) vegetables. The development of groundwater irrigation started very late in eastern India (compared to north, west and south India) and, although this region has about one-fourth of India's usable groundwater resources, only about one-fifth of the groundwater potential has been exploited (Shah, 2001). The growth of groundwater irrigation in the region is mainly due to private sector initiative rather than government policies. Apart from private borewells, some government group tube well schemes exist. These have not, however, been good models of efficiency or equity, and have largely failed.

Whatever little groundwater irrigation exists is further limited by the inadequate and insufficient electricity supply in the region. Tube wells have to be run on diesel pumps and the cost of irrigation is significant. This has put a limit not only on the total area irrigated but also on securing the main crop - *kharif* rice - from rainfall variability[3]. On the other hand, groundwater irrigation does help save the *rabi* wheat and also gives an option of growing vegetable crops during *zaid*. A water market has developed in this region: those who do not have tube wells buy water from neighbouring wells and rent the diesel pump required to deliver the purchased water to their fields. Generally, the cost of irrigation from a 5 horsepower pump comes to about INR 80 per hour. So the issue is not of irrigation availability but of affordability.

Aside from irrigation, a key strategy of the government to deal with drought is the ex-post distribution of relief to the affected population. For instance, after the drought of 2004, Nautanwa was declared drought affected. All the landholders received cash relief for crops lost on the basis of their landholding size. In some cases the relief amount was as little as INR 50. The relief amount hardly covered one-tenth of the cost of sowing the fields. The timing or delay in relief distribution also makes it more of a politically driven event rather than a sincere attempt to

[3] Further, tube well irrigation for rice is possible only in the nursery preparation stage; if drought occurs anytime in the post transplantation stage then it becomes unviable to save the entire rice crop.

cover the losses of the drought affected people. In most cases the state level politicians use their clout to get their electoral constituency declared as disaster affected to gain popularity. Because of this areas that are affected and need support are often left out.

In contrasty to relying on ex-post relief, crop insurance could serve as an important strategy for helping farmers address drought risk. Crop insurance has not yet, however, become very common in this area. Only a few big farmers have access to financial services such as Kisan Credit Cards (KCC) and historically only some of them have taken loans for agriculture. According to responses in the survey conducted for this project, none of them are aware of the crop insurance that KCC holders have access to. They are only aware of the built-in life insurance benefit of the KCC. This is surprising considering that in some villages, for instance Satguru, farmers are growing high investment, high risk banana crops. In the canal irrigated villages, e.g. Koharwal, about 100 households have KCC. They all consider that it is a good scheme as the loans are provided at low interest rates (7-9%). But even here none of the KCC holders, including the village *pradhan* (the elected village leader), are aware of the crop insurance aspect of the KCC. Obviously banks and extension agencies of the government have not done enough for raising awareness on this issue.

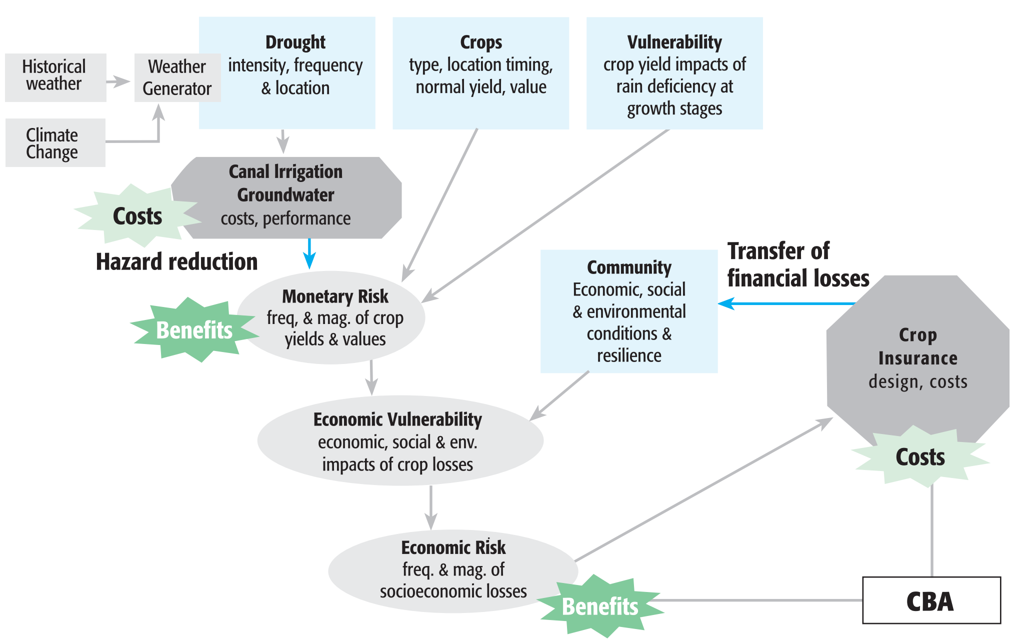
Assessing Risk: The Modelling Approach

In order to systematically assess the costs and benefits of risk management, we developed a risk-analytic modelling approach. The following steps, in line with the general methodology, are taken in the model (Figure 3). This involves:

1. Assessment of direct physical and monetary risk to crop yield as a function of rainfall
2. Assessment of economic risk to farmers' livelihoods
3. Evaluation of the costs of risk management interventions
4. Evaluation of the benefits of interventions
5. Computation of the economic efficiency of different risk management options

The model is stochastic in nature making use of Monte-Carlo simulation to generate probabilistic drought shocks to farmers.

| FIGURE 3 | Model algorithm



Monetary risk due to drought is modelled as a function of hazard, vulnerability and exposure. Hazard is defined as the lack of rainfall over given time periods, vulnerability is determined through a statistical model which relates total rainfall over specific dates with average crop yields in tonnes per hectare, and exposure is determined through the average area over different household's consumptions groups and different prices of crops due to drought events. Economic risk is income risk due to drought as amplified or mediated by the financial vulnerability of the household.

In Table 2 specific risks (impacts commonly incurred as a consequence of drought) are identified which, when avoided or reduced, create benefits. These risks along with important changes in the future are explicitly modelled in our analysis. Climatic changes are incorporated via a statistical downscaling model for different climate change scenarios. Changes in the variance of total rainfall over given time periods are also explicitly modelled with the help of ensemble runs. This assisted in estimating the uncertainty of climate related changes within this integrated modelling approach. In general, the uncertainties the integrated modelling approach are substantial. These uncertainties are addressed in the ensuing discussion whenever they are considered important.

TABLE 2 | Potential impacts of drought assessed in the case

Category		Monetary Impacts		Non-monetary Impacts	
		Direct/financial	Indirect/economic	Direct	Indirect
Social	Households Farmers Farm workers Community Health Education Stability Cohesion			affected people	Food security Malnutrition Migration
Economic	Private sector Households Economic sectors Agriculture Industry Commerce Services Public sector Education Health Water and sewerage Electricity Transport Emergency spending	Crops affected or destroyed	Livelihood income Poverty Debt Production Market activity Trade with outside markets Relief expenses	Drinking water (people & livestock)	
Environmental				Natural habitats Fodder Land degradation Groundwater Water levels Water quality Fuel woods	Biodiversity

In the following sections we discuss the drivers of risk in more detail. Our analysis starts with the level of exposure to the hazard; that is, the lack of precipitation over given areas and time horizons based on past precipitation data as well as climate modelling results coupled with an analysis of rainfall-crop yield relationships. We have done this utilizing past crop yields over two districts in Uttar Pradesh supplemented by the outputs from statistical models for rice and wheat crop production and rainfall characteristics. The resulting rainfall-crop production relationships are translated into monetary production values (the market value of estimated crop yields), which then serve as input to the economic livelihood model. The components of the modelling approach and the sources of data utilized in the analysis are shown in Table 3.

TABLE 3 | Data and model sources

Module	Data/Model source	Approach
Drought hazard and climate change	Observations, SRES model runs	GCM downscaling, statistical relationship
Vulnerability	Observations	Statistical relationship
Exposure	Survey	Survey analysis
Risk	Combination of above	Stochastic modelling
Economic vulnerability and risk	Survey, national statistics	Microeconomic livelihood model
DRM interventions and benefits	Shared learning dialogues	Scenario-type simulation analysis

Exposure

The level of economic exposure to drought hazards in an agricultural region is primarily a function of the cropping system. As a result, the unit of analysis is a farming household which mainly derives income from the subsistence farming of rice and wheat crops[4]. We define a representative household as characteristic of the lower 80% income stratum of the survey sample. We consider such households to be the sole beneficiaries of the DRM interventions evaluated in this study. More wealthy households would thus not be eligible for the donor supported DRM interventions evaluated here. Table 4 shows the characteristics of an average farm household according to the survey.

TABLE 4 | Farm household characteristics

Household characteristics	Values reported in 2008 INR, for year 2008
Household size	7
Income from farming	92%
Land owned	0.8 ha
Total household farming income from crop production	31,000.00 (average). The top of the sampled income range was 45,000.00 (about 1.6 times the poverty line)
National poverty line for household	28,500.00
Debt	2,500.00
Savings	600.00

Data source: Survey conducted by project team.

[4] In order to estimate poverty of subsistence farmers, the poverty line is measured in terms of the caloric intake necessary to sustain a living, and the monetized value of the food consumed. The income metric measures a potential income to be achieved when selling crops in the market after the minimum nutritional requirement has been met (here defined by the national government of India as the national poverty line).

Hazard

A large part of India is located within the semi-arid tropics characterized by low and erratic rainfall. The areas with high to very high climate sensitivity are located in the semi-arid regions, including major parts of the states of Uttar Pradesh, Madhya Pradesh, Rajasthan, Gujarat, Punjab and Haryana. Villages in the Rohini Basin face the double climate hazards of drought and flood. The majority (70-80%) of rainfall in the basin falls during the monsoon months of June-September. The average rainfall in the Gorakhpur and Maharajganj districts has been approximately 1,200-1,400 mm per annum. When the rains are delayed, insufficient or sporadic, drought-like conditions harm the livelihoods of many. The recurrence period of highly deficient rainfall in Eastern Uttar Pradesh at present has been calculated to be six to eight years whereas in Western Uttar Pradesh it is ten years.

TABLE 5 | Projected seasonal per cent changes in median precipitation for the years 2007-2050.

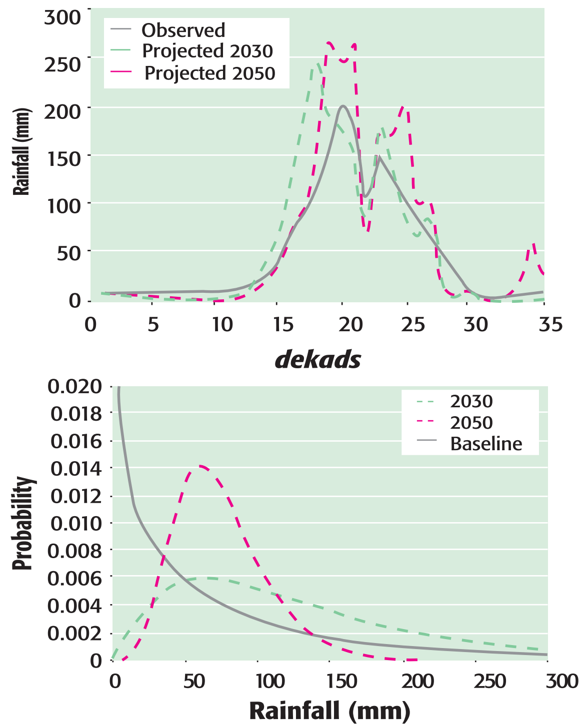
Season	A2	B1
Pre-monsoon (JFMAM)	- 46%	- 45%
Monsoon (JJAS)	1%	2%
Post-monsoon (OND)	- 40%	- 71%

The IPCC (Christensen et al. 2007) broadly projects an overall change in annual precipitation range of -15% to +20% for South Asia by 2099. This projection though, is for an extremely large geographic area, long time scale, and too broad to be of use in deciding the benefits and costs of specific disaster risk reduction and adaptation strategies "on the ground." Furthermore, there are large discrepancies in the amount and timing of rainfall in many areas of South Asia that simply are not captured in the IPCC projections. To this end, a statistical downscaling model was developed for the Rohini Basin to project potential climate change impacts on rainfall patterns in the basin. Using a statistical downscaling method, we estimated the distribution and probability of rainfall in the study area for current and expected future climates. We utilized two representative climate change scenarios (A2 and B1) run by the Canadian Third Generation Coupled Climate Model (CGCM3) (see Flato 2005). In terms of rainfall conditions for the basin, the following broad projections were made by the climate model (Table 5). We considered a total of 5 different model runs for the A2 and the B1 scenarios each and picked the two most representative A2R1and B1R3 scenarios. A complete description of the model methodology and limitations can be found in From Risk to Resilience (Working Paper No. 3)

Predictions of median rainfall for the A2 and B1 scenarios indicate significant drying for the pre-and post-monsoon seasons and a slight increase in monsoon rainfall. The B1 scenario would lead to stronger post-monsoon drying. Climate projections do not estimate daily, weekly or monthly weather variability. As a result, the next step in our analysis involved examining observed "on the ground" data on local rainfall patterns in order to link to the climate predictions. We assessed observed rainfall data for 5 different stations for 1976-2006, and finally picked the station of Bhairhawa Airport in Nepal as the only station leading to satisfying relationships with average crop production in our two study districts.

We examined accumulated rainfall over *dekads* (10 day periods, which is the time period standardly used for studying crop phenology). On the top panel of Figure 4 we show mean rainfall for each dekad for observed as well as future rainfall in the years 2030 and 2050 for the A2 model scenario run. The possible effects of climate change are evident. Compared to observations over the historical period of record, in 2030 the timing of heavy precipitation shifts from dekad 20 (middle of June) to dekad 17 (end of May). There are also shifts in the magnitude and variance of precipitation. Furthermore, in other months rainfall totals are projected to decline in 2030 in comparison to the historical period of record. For the more distant future, e.g. 2050, the magnitude of precipitation during the monsoon months is projected by the model to be more extreme. The model also suggests that heavy precipitation would be more likely at the end of December while in other *dekads* mean rainfall totals would decline in relation to the past.

| FIGURE 4 | **Observed and projected mean precipitation of *dekads* based on observed data and climate change projections for the years 2030 and 2050 (Top panel), and fitted Gamma probability distributions (Bottom panel)**

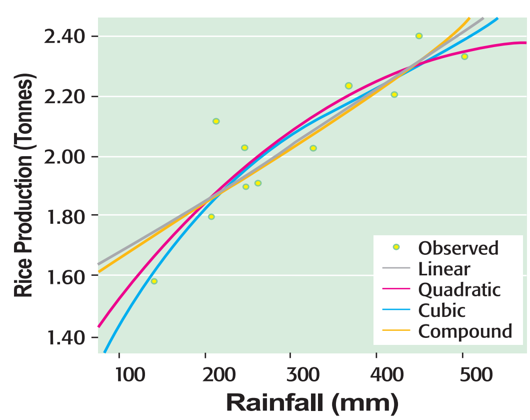


As a next step, we fitted probability distributions for each of the *dekads* to the empirical and projected rainfall data. Generally, for rainfall totals a heavy tailed probability distribution like the gamma distribution is used. Based on the given data, we estimated gamma distributions using maximum likelihood techniques for each dekad for current conditions, 2030 and 2050. The top panel on Figure 4 shows distributions for dekad 16 (beginning of June). These distributions served as the basis for representing the risk due to (lack of) rainfall in the study period 2008-2022. We used one distribution for each of the years of our study period. We find effects for B1 similar to A2, yet especially in the non-monsoon months rainfall effects in B1 are more pronounced than in the A2 scenario. As a result, for the drought analysis we use the A2 scenario leading to a more conservative estimated climate effect as the modelled drying effect is less pronounced.

Vulnerability

In a next and important step, we assessed physical vulnerability in terms of crop production and loss due to lack of rainfall. We utilized a nonlinear statistical model based on the rainfall data and time series for wheat and rice production for the two districts for 1990-2006. Only two types of crops were considered, wheat and rice. While there are two growing seasons for rice there is only one growing season for wheat. For rice the most important growing season is during the monsoon months from June to October, the other season from March and June is less important and it is

| FIGURE 5 | **Observed and estimated curve for rice production in June**



not included in the analysis. Winter wheat is usually grown between October and March. The values for rice and wheat are normalized according to the total land area used for the crop. Various curves were fitted with the observed data however, only the curves with quadratic and cubic fit showed good results and we used the quadratic fit. Figure 5 shows the scatter-plot and the fitted curves for rice as estimated using maximum likelihood techniques[5].

Monetary Crop Yield Risk

Combining exposure, vulnerability and hazard leads to an estimate of monetary risk in terms of crop production lost. The monetary risk is determined by multiplying the crop yields for rice and wheat in tonnes by the average price to be achieved on the market, which is fixed by the government. We calculated loss-frequency distributions (representing direct risk) indicating the probability of monetary crop losses for current climate conditions (as well for future scenarios).

| FIGURE 6 | Loss-frequency curve for crop yield for baseline (2008) and future A2R1, B1R3 climate scenarios

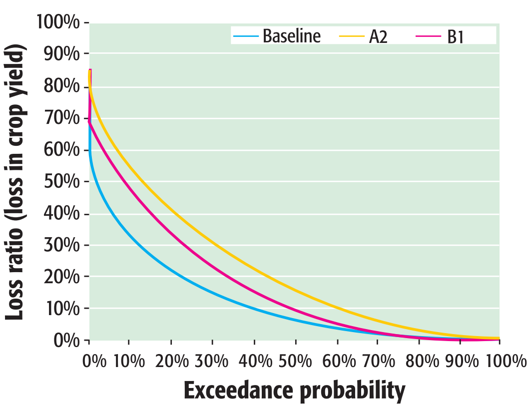


Figure 6 displays the loss-frequency schedule for rice for 2008 (baseline) and future A2R1 and B1R3 climate scenarios with year 2020 chosen for illustration purposes. It indicates that probabilities of a given loss ratio (such as a 10% yield loss) increase under future scenarios; i.e. events that cause losses occur more frequently. According to our analysis, losses of this type have a probability of about 40% today, and this probability may increase respectively to more than 60% or 70% in the future under the two climate scenarios. As the A2R1 and B1R3 climate scenarios appear to be rather similar (the signal being stronger for the latter scenario), in the following we only focus on the A2R1 scenario and we use this as a "marker" scenario for future climatic changes in the study area.

Economic Vulnerability and Risk

We now turn to assessing the livelihood and income consequences of crop risk to households. As discussed, the unit of analysis is one representive of subsistence farming household.

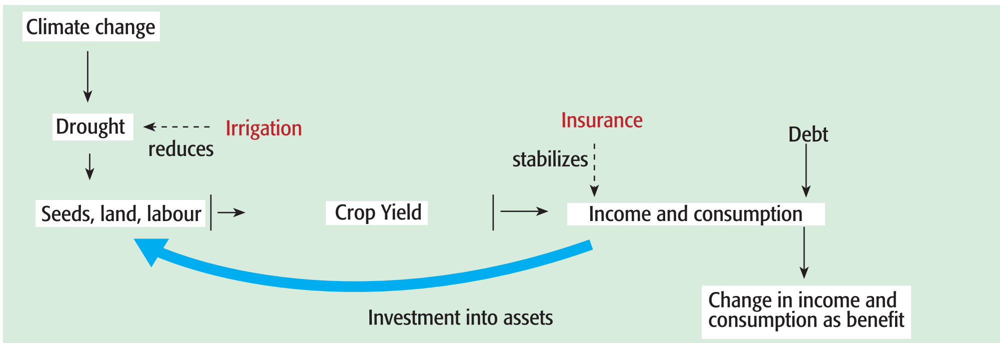
The "livelihood" model

Livelihoods and income are generated and determined by a host of factors. For example, the sustainable livelihoods framework, a well known conceptual framework, defines assets, policies, institutions, as well as vulnerabilities, to critically determine livelihood outcomes such as income, wellbeing and improvements in these outcomes (DFID, 2000). Our model and approach focuses on vulnerability to drought (and

[5] Using a quadratic function, rainfall in June approximately explains 83% of the annual variation of rice yields, and rainfall in October 65% of wheat yield variation.

flood) and physical, natural and financial assets. Particularly, the latter is a key determinant of the analysis, which is based on dynamic debt, investment and income relationships. Conceptually the relation between crop risk (direct) and economic risk to income and consumption (indirect risk) is shown in Figure 7.

FIGURE 7 | Direct and indirect drought risks and risk management interventions



The model is based on dynamic debt, investment and income relationships, is informed by our survey and refers to the literature on debt-poverty dynamics (see for example, Carter and Barret et al., 2006). Crop yield (rice and wheat) is a major source of a farmer's income and is a function of weather and prior investment decisions. The model assumes a critical subsistence level (calorie-based) that needs to be achieved with annual income or additional debt if income falls below this critical level.

Given initial debt and wealth, the farmer faces the following investment decision:

1. Invest into income generation: Farmer increases income by investing into land, labour, technological progress (fertilizers), or buying improved seeds; or
2. Invest into income stabilization: Physical and/or financial risk management, of which a large portion is sponsored/subsidized by donor or government.

This is the key trade-off for assessing the viability of risk management. The costs and benefits of risk management are

BOX 1
Model algorithm

Mechanics of the model are illustrated here for any of the 15 years of the time horizon.

1. At the beginning of the year, given household's initial savings and debt, a minimum savings buffer is determined for
   - smoothing income in case of an event to guarantee a minimum level of consumption;
   - to be used in a drought to implement the backstop option of water pumping.
2. The residual savings may be invested
   - in income generation: seeds, technology etc., or
   - into risk management in order to stabilize income.
3. Stochastic rainfall is calculated determining a possible crop loss
   - Pumping mediates crop loss during event,
   - Income is derived from selling yield,
   - Income in drought event is derived from the insurance claim payment.
4. With total income obtained, a critical subsistence consumption level determined by the poverty line needs to be achieved (for 2008 28,470 INR/household)
5. If income falls below this level, a loan needs to be taken out with local money lenders creating debt dynamics, as the loan has to be paid back in following years. This reduces savings and thus the ability invest and conduct risk management.
6. Pumping has additional benefits by increasing productivity during the non-monsoon *rabi* and *zaid* seasons.
7. Finally savings and debt are determined forming the initial conditions for the next year.

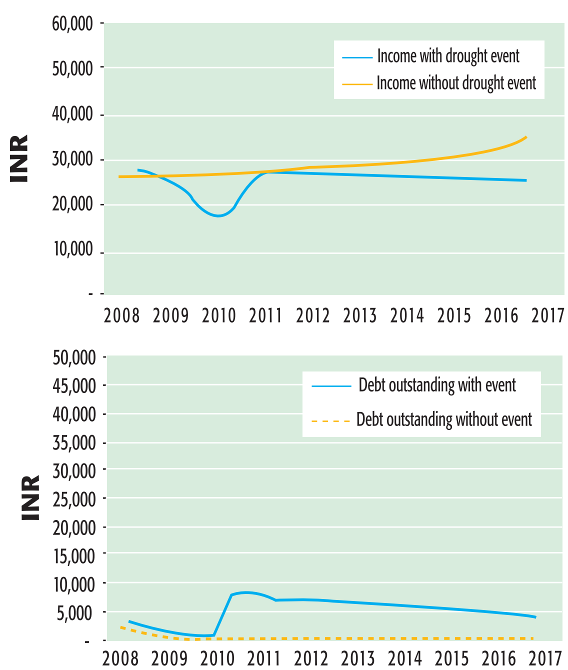
- Cost: Due to limited savings and the need to consume the necessary calories, risk management done by the farmer takes away from income generating investment, thus depressing income;
- Benefit: Risk management reduces the losses and stabilizes income.

This trade-off may be fully relaxed or weakened by donor or government intervention. For example, doners may sponsor a borehole, subsidize insurance or support any other development or DRM intervention. The trade-off is not a complete one, e.g. water pumping may be used in normal, i.e. non-drought, years as well. The costs and benefits of risk management looked at in this report are the costs of an outside sponsor for this risk management. Benefits arise due to an increase in income and increased stability (reduced volatility) in income and consumption. Additionally, benefits arise to the government due to a reduction in relief payments required (this only in the insurance case). The endpoint in our analysis is indirect risk and changes in investment and consumption and we model the dynamics over a 15 year time horizon based on the assumed viability of the irrigation borehole.

Ideally, a model would be comprised of detailed asset-flow relationships using a production function relationship. This would require the representation of technology, land, labour and capital use, as they determine the generation of income. Yet, similarly to the crop modelling, we take a reduced form approach, and relate income statistically to crop yields, then study the financial consequences of crop risk on households.

Figure 8 illustrates the effects of a drought on farm income and debt with and without a loss of crop production of 30% in 2010 for a time horizon of 10 years. Starting from initial income and debt levels in 2008, without a drought event, the household would achieve modest income growth and, as a priority, be able to slowly repay debt with the savings generated. After repaying debt, productive investments would be fostered and income would increase over time.

FIGURE 8 | Income and debt dynamics with and without a drought shock



In contrast, a drought event would severely affect crop income and hamper the ability of the household to achieve the critical income level defined. This would cause income to fall below the critical consumption level. Per model assumption, the remedy chosen would be for the household to incur debt quickly post event from local money lenders at high rates. This substantial debt would have to be paid back consequently over time with savings otherwise earmarked for productive investment. Thus, in our model - as in the survey - ex post coping with the drought to maintain subsistence consumption levels diverts from future consumption opportunities. The key question we address in this study is how and whether those future income, debt and consumption effects can be avoided and reduced by DRM interventions.

Risk Management Interventions: Identification and Costs

Overview

Based on shared learning dialogues conducted with local populations under the Risk to Resilience project we identified two DRM interventions for the purposes of quantitative evaluation.

- Risk reduction with irrigation via groundwater pumping: Construction of a borehole that can be used by drought-affected farmers for pumping water and reducing the water deficit.
- Risk financing via (micro) crop insurance: Crop insurance can be used to transfer crop risk for a premium payment. We examine the establishment of a new micro scheme by a sponsor including technical assistance and premium subsidies.

Table 6 summarizes the costs and benefits of the interventions.

TABLE 6 | Summary of costs and benefits of groundwater irrigation and insurance interventions

Categories of impacts	Irrigation	Insurance
Activity	Groundwater imigation	Parametric micro-insurance
Costs to government	Construction of borehole	Premium subsidies
Costs to farmer	Costs of pumping water	Non-subsidized premium portion
Direct Benefits	Reduces hazard	Compensates direct losses
Indirect Benefits	• Smoothes food supply, consumption & income (farmer) • Reduces relief expenses (government)	• Smoothes consumption & income, reduces variability (farmer) • Reduces relief expenses (government)

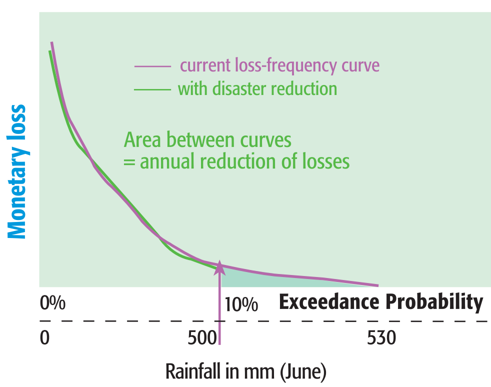
Irrigation

The lack of large- or small-scale irrigation is a key constraint to agriculture in Uttar Pradesh and India more generally. As groundwater depletion is not an issue in this study area we identified groundwater irrigation using boreholes and pumps as an

BOX 2
Key assumptions for irrigation

- Construction of borehole by a sponsor,
  - to be used in drought years as an option for pumping water to alleviate the water deficit,
  - reduces water deficiency, thus rice and wheat crop loss risk is reduced.
- In normal, non-drought years additional benefits due to increased productivity during non-monsoon harvests in *rabi* and *zaid* seasons (productivity increases by 1%/year.
- Total cost of drilling a borewell (60 feet deep): 10.000 INR, no maintenance assumed
- Lifetime 15 years
- One such borewell can irrigate about 10 acres or 4 hectares
- Average land owned by farmer households: 0.8 hectares, so borehole serves 5 families and cost/family is 2,000 INR
- Cost of pump set is 22,000 INR. Poor households do not have pumps. The cost of renting the services (including diesel) are 80 INR/hour
- 10 mm of water can be pumped per hour

FIGURE 9 | Mechanics of irrigation intervention



10% = "10-year event" associated with 500 mm rainfall

intervention to reduce risk. The borehole would be drilled by the sponsor (fixed costs), and the pumping is undertaken during a drought by the affected farmer (variable costs). Key assumptions used to evaluate this intervention are listed in Box 2 and a schematic illustration of these benefits is shown in Figure 9. The yellow line is the unmitigated drought loss curve without pumping, the green line shows risk and risk reduced with pumping.

In this illustrative example, pumping would help to mitigate up to a 10-year drought event (probability 10%) associated with accumulated rainfall in June of 500 mm, a deficit of 30mm. For providing the additional 30 mm required, about 3 hours of pumping would be necessary at a total cost of 240 INR. Given the establishment of a borehole, risks could thus be reduced assuming sufficient savings are available for pumping water.

Insurance

In contrast to irrigation, insurance does not reduce risk, but it spreads out risk by pooling it across a larger population in exchange for a premium payment, and thus providing indemnification against losses. People affected by a disaster benefit from the contributions of the many others who are not affected thus receive compensation that is greater than their premium payments. Micro-insurance is distinguished from other types of insurance by its provision of affordable cover to low-income clients. By providing timely financial assistance following extreme-event shocks, it helps to reduce the long-term consequences of disasters. Affordable insurance can provide low-income farm households with access to post-disaster liquidity, thus securing their livelihoods. Moreover, insurance can improve their creditworthiness and allows smallholder farmers access the capital required to engage in higher-return crop practices. (See Box 3 for a description of calculation of insurance premiums).

Insurance does not reduce the average losses to be expected, but helps with the variance. Another way of paraphrasing this is that insurance helps with the larger, yet more infrequent events, which potentially may have debilitating consequences; it is not a useful mechanism to reduce frequent or even annually-occurring losses.

BOX 3

Calculating the insurance premium

Generally, the basis for the premium calculation is the expected losses, the losses that can be expected to occur on an annual basis. These are also called the pure premium. On top of the expected losses a risk premium will be charged by the insurer consisting of transaction costs, profit margin and loading factor as follows:

Insurance premium = Expected losses + risk premium (loading factor + transaction costs + profit margin)

Natural disasters are low-frequency, but high-consequence events, and the volatility of losses is also taken into account by insurance companies in order to be properly prepared for an event. This is done by charging a loading factor accounting for the variability of losses. Transaction costs arise such as personnel costs for risk assessment and contract delivery. These have to be included in estimating premiums. Last but not least, insurance companies will also charge a profit surcharge.

Uptake of insurance in developing countries has been miniscule owing to its high cost in relation to the low incomes of those at risk, as well as a lack of "insurance culture." Recently, novel micro-insurance instruments have been emerging to address these problems and cater to the poor and vulnerable. Innovation is related to product delivery and claim settling (Hess et al., 2005). Based on achievements and institutional structures set up for providing microfinance, donor supported public private partnerships for providing sustainable and affordable insurance are emerging involving insurers, rural development banks, NGOs, public authorities and international sponsors. A key aim is to provide insurance catered to the needs of the vulnerable and poor at low costs using established delivery channels. The second innovation is related to the claims settling process, where the claim payment is based on physical parameters, such as rainfall measured at a local weather station; this compares with indemnity-based insurance, where the actual loss experience establishes the basis for a claim payment. By using representative indexes for a group of people, the transaction costs of issuing contracts and settling claims can be drastically reduced. The downside to index insurance is the potential lack of correlation of the index with the actual loss ("basis risk"). Insurance can be costly and the premium charged may be considerably higher than expected losses, sometimes amounting to several times the expected losses.

In order to simplify the analysis, we have made the insurance assumptions shown in Box 4 based on a review of crop insurance in India and elsewhere (see Manuamorn, 2005; Mechler et al., 2006).

BOX 4

Key assumptions for insurance

- A novel microinsurance scheme is set up potentially involving an insurance company, NGO, local or state government or a donor, and the insured
- Technical assistance for risk and premium calculation and scheme set-up is assumed to amount to 5,000 INR/household (assuming 1000 farmers are insured, the technical cost would be 5 million INR which corresponds with anecdotal information.
- Based on a survey of micro crop insurance, the (unsubsidized) premium is ca. 3.4 times the expected losses. Given expected losses for the baseline of 1.8%, the full premium would amount to 6.4% of insured value (i.e. monetary crop production).
- The premium subsidy is 50%
- The scheme is based on rainfall, with a claim layer defined by lower (exit point) and upper (exit point) thresholds for rainfall
- Reinsurance is not considered explicitly, but considered to be organized by the insurance scheme
- The government will prorate relief payments in proportion to its premium subsidy provided; maximum relief according to Uttar Pradesh statistics was 400 INR. For example, If the subsidy is 50%, then maximum relief would be 200 INR per year. We are studying this scenario.

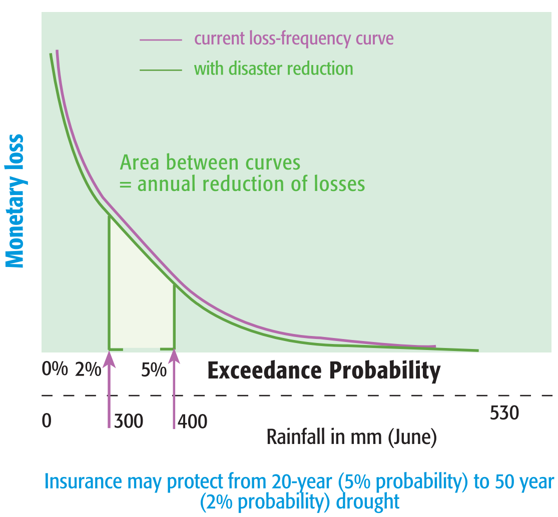
Table 7 lists the costs and benefits of the insurance intervention considered.

| TABLE 7 | Insurance intervention considered

Scenario	Costs to Government (=costs in CBA)	Costs to HH	Benefits in CBA
50% subsidy	50% of premium, technical assistance	50% of premium, leads to substantial diversion of income	Reduced income diversion by the farmer from productive activities, reduced relief expenditure

In the following illustrative example shown below, insurance may protect from losses from 20 year (5% probability) to 50 year (2% probability) droughts, and there would be no compensation for smaller (more probable) or bigger (less probable) events. Generally, it will not be cost-efficient to cover all possible events and purchase full insurance, particularly for disaster risk, due to a high premium mark-up, which can be multiples of the annual average losses.

| FIGURE 10 | Mechanics of insurance interventions



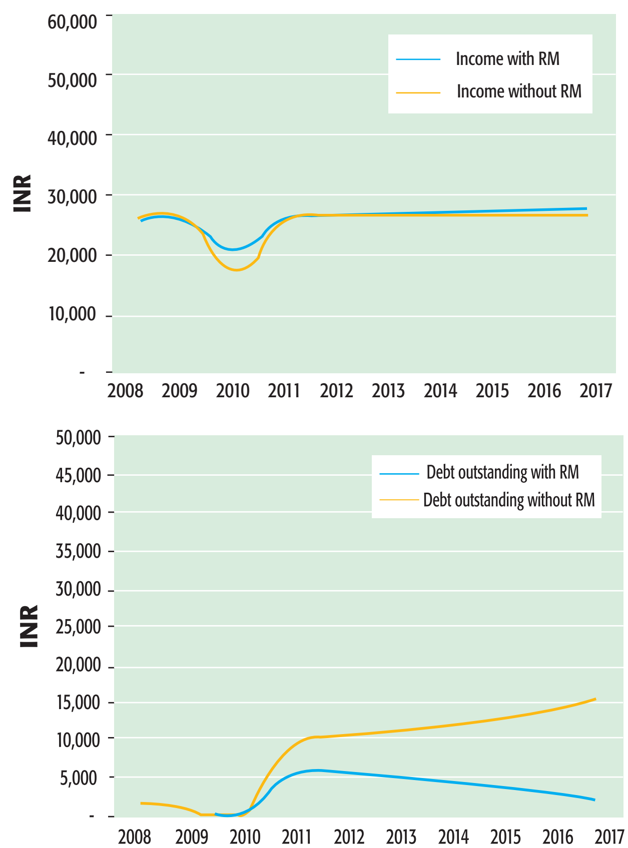
Compared to pumping, where risk reduction (and the income loss effect) would be limited by savings available to meet the cost of pumping, an insurance claim would guarantee a certain payout. This payout would be determined by the entry and exit points, here the 20 and 50 year droughts respectively. On the other hand, for insurance an annual premium payment would be required, while with pumping for irrigation costs are only incurred (i.e. the pump is switched on) when a drought or water deficit is actually experienced.

Risk Management Interventions - Assessment of Benefits

Irrigation

Figure 11 illustrates the mechanics of the two interventions by modelling a 30% crop income shock in 2010. This is a shock of the size of the drought that actually occurred in 2004 and is considered to be about a 50 year event. Based on our approach, such a shock would cause income to fall for both scenarios, yet for a household with the ability to pump, the risk could be partially reduced depending on the (limited) savings available for pumping. While pumping comes at a cost for the household in terms of drawing down and diverting savings from investment into production improvements, the effect here would be that the debt burden to be taken out to guarantee the subsistence level of income, is smaller with irrigation. Additionally, there are benefits to irrigation in normal years. For example, during the non-monsoon, rainfall-deficient seasons, irrigation in the early cropping stages would increase productivity. Overall, over time, in this deterministic illustration with one drought event occurring, there would be a small increment to income.

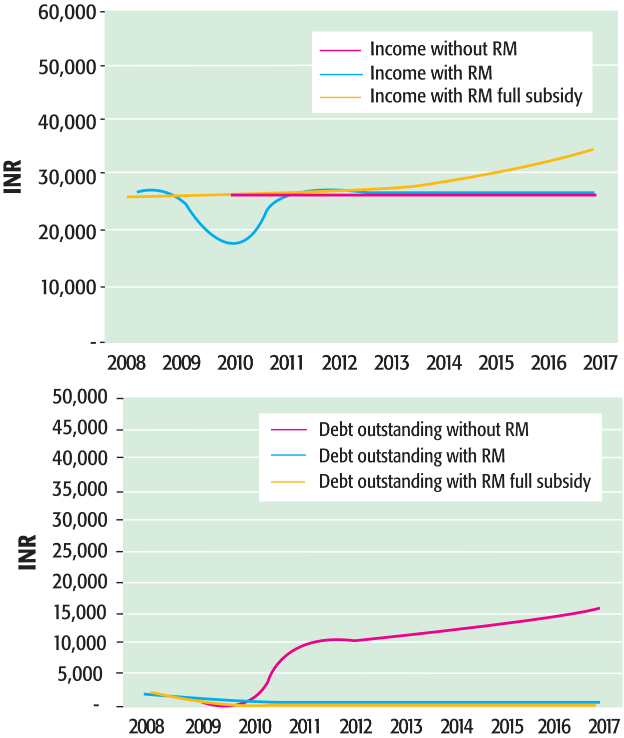
| FIGURE 11 | Effects of irrigation intervention on income and debt streams for a farming household



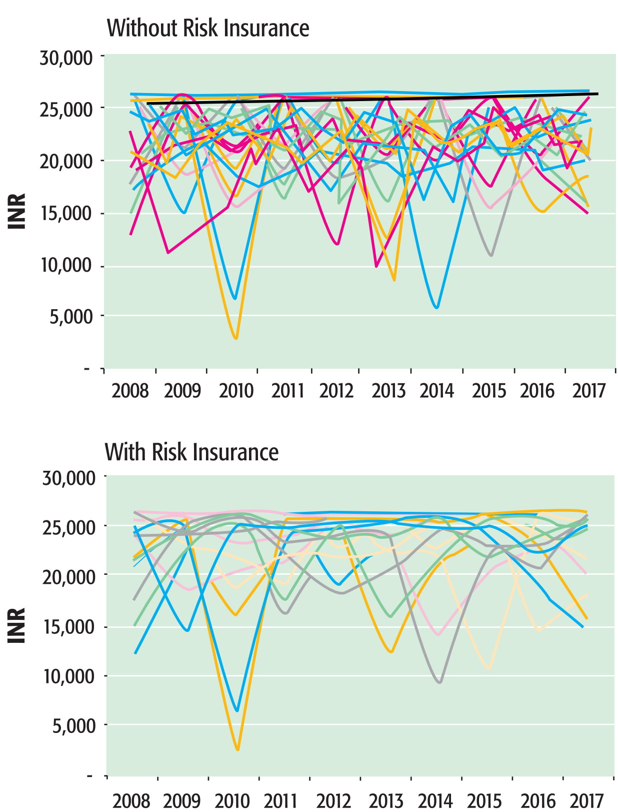
Crop Insurance

Similarly we now deterministically illustrate the benefits of financially managing risk via insurance. In case of insurance, the risk is not reduced, but a claim is received post event in exchange for a fixed annual premium payment.

| FIGURE 12 | **Effects of insurance option on income and debt streams with full insurance**



| FIGURE 13 | **Comparison of stochastic income trajectories without and with risk insurance**



The benefit of insurance is the extra income received after the event and the income stream is smoothed out; also, no new additional debt is necessary. In the less subsidized case, however, premium payments are large and future income stagnates in a similar way as in the uninsured case, where livelihoods are affected by the large debt repayments. For the case of full premium subsidy, there is no income effect of the premium payment and income can increase (although there are no relief payments by the government).

Stochastic Representation of Interventions

Nature is not deterministic, however, and droughts may occur frequently or may not occur at all. Accordingly, benefits of DRM will materialize only in a drought and those benefits are probabilistic. In order to capture the vagaries of nature, we had to simulate the system stochastically and ran a large number of possible "futures." For example, when conducting stochastic analysis for insurance and running the simulation 1,000 times for a time horizon of 10 years (2008-2017), the income stream is smoothed out as its variability is reduced.

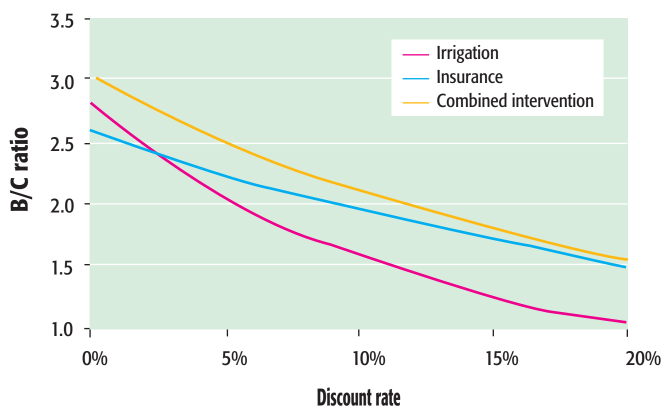
Essentially, insurance cuts out a large number of bad "years" with severe income effects, as the income loss is reduced due to the claim payment received. Although this is difficult to see visually, the effect is illustrated in the greater variability of income stream trajectories shown in the top panel in Figure 13 in contrast to the lower panel.

Economic Efficiency of Risk Management

As a last step in our analysis, we calculate economic efficiency of the interventions via CBA. In the following we present results for the interventions discussed under baseline (constant) climate and changing climate conditions, as well as for different discount parameter assumptions.

Constant Climate

FIGURE 14 | B/C ratios for interventions considered given constant climate



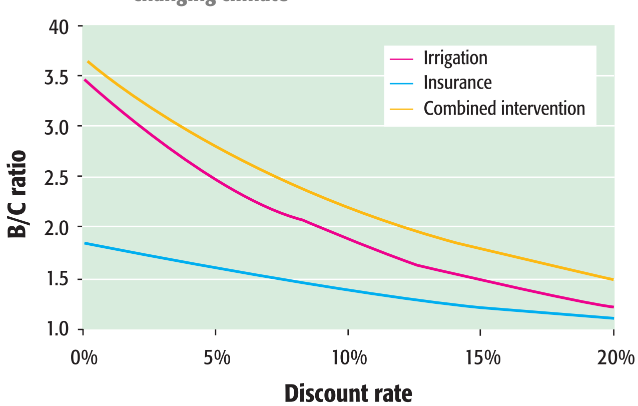
All interventions were considered economically efficient given the assumptions taken (see Figure 14). The B/C ratio for irrigation, which mainly helps to reduce the impact on income of high-frequency, low-magnitude events, is well above the threshold of 1 for the range of discount rates considered. The total cost calculated per household, is assumed to be financed by the government or development bank as the sponsor, would be about 0.4% of farmer's income for baseline and future climates. In contrast, insurance helps to reduce the variability of income when higher magnitude but less frequent events occur. We find B/C ratios to be high for the 50% subsidy scenario; for a less subsidized premium (not shown here), benefits are reduced as more household income is necessary to pay for the premium by diverting income from productive investments. The total public sector cost for sponsoring insurance over the time period considered amounts to a value in the range of 1.5%, the private household's costs for paying the other 50% of the insurance premium would amount to 0.9% of farmer's income[6]. Insurance is less dependent on discount rate assumptions, which can be explained by the fact that it offers a secure, guaranteed payout over the whole time horizon, while irrigation and

[6] As explained, in order to avoid double-counting these private costs do not figure in the CBA, as they are already included via the investment-income relationship, where the premium payment diverts money from productive investment and thus reduces income.

its benefits are dependent on the ex-post ability of the household to pay for pumping water. As the low-income household is generally constrained in its financial ability, multiple events over the study period can lead to accumulation of debt over time and the inability to conduct the pumping efforts in later periods (which are further more heavily discounted than the present).

According to our analysis, the greatest benefits would be achieved with an integrated strategy combining both irrigation and insurance. In such an adaptive strategy, a more efficient insurance layer structure could be implemented: as irrigation reduces the higher-frequency events (irrigation, in effect, cuts off the initial portion of the risk curve), insurance could be adapted to cover more of the lower frequency events. We studied different interventions while keeping the premium constant, and found that with irrigation and a 10 to 50 year event insurance layer, for example, could be changed to a 20 to 80 year event layer, as the 0 to 20 year layer would in effect, be covered by irrigation, and thus more protection could be achieved at the same cost.

| FIGURE 15 | B/C ratios for interventions considered given a changing climate



Changing Climate

In a changing climate with low-magnitude, high-frequency, drought events increasing, (as modelled by the A2R1 scenario) the benefits of irrigation would increase, while the insurance benefits would be reduced when low-frequency/high-magnitude events become less common. Again, a combined package, where the insurance contract is linked to the irrigation intervention and adapted to changing conditions, would reap the highest benefits.

The Policy and Programme Context

The results of this study may be useful for promoting stakeholder dialogue for decision-making on investments and design of schemes in a transparent and coordinated manner within and across the following departments, agencies and NGOs related to groundwater irrigation, crop insurance and drought relief in Uttar Pradesh and India. The three DRM strategies discussed can be put to use for the following institutions and applications:

- Data organization for assessing and monitoring above DRM strategies by the Crop Weather Watch Group (CWWG) and State Planning Department of Government of Uttar Pradesh;
- Systematic assessment of investments needs and tradeoffs in crop insurance and groundwater irrigation management by Grameen (rural) Banks, primary agriculture cooperatives (PACs), the Agriculture Insurance Company of India, private bodies such as Birla Sunlife; departments of rural development - watershed development, agriculture and minor irrigation-groundwater recharge;
- Promoting micro-finance activities through non-government organizations with government support from agencies such as National Bank for Rural Development (NABARD) in the form of matching funds;
- The Uttar Pradesh government may consider shifting its existing focus and investment away from minor (surface) irrigation to funding and supporting an intensive groundwater programme because of the huge groundwater potential and the results of our CBA. Further, it should also learn from schemes from other states (the Jyotirgram scheme in Gujarat) and provide a dedicated electricity connection at non-subsidized rates for groundwater pumping

Conclusions

We conducted a detailed, forward looking, risk based CBA for current and future climates in order to assess the economic benefits of risk management for a typical poor farming household in UP in terms of helping to smooth income and consumption. Risk management approaches within this quantitative methodology framework were chosen to be risk reducing type of interventions (irrigation) as well as risk-sharing instruments (micro crop insurance).

As key findings of the CBA, we find the two interventions and the integrated package economically efficient given the assumptions taken. Insurance seems less dependent on discount rate assumptions (primarily because it offers a secure guaranteed payout in return for annual premium payments), while irrigation and its benefits are dependent on the ex-post ability of the household to pay for pumping water. As the typical household modelled according to our sample findings is generally financially vulnerable, multiple events over the study period lead to accumulation of debt and an inability to afford groundwater irrigation pumping in later periods (which are also more heavily discounted than the present). With a changing climate, groundwater irrigation benefits can be expected to increase as average rainfall and rainfall variability increase, while insurance benefits are likely to be reduced as volatility is reduced. Finally, integrated physical (irrigation) and financial (insurance) intervention packages return higher benefits at similar costs, as interventions for higher (irrigation) and lower frequency events (insurance) are effectively combined. As a consequence, it seems highly important to foster the exploration of such integrated packages in a process involving different public and private actors.

When implementing this data and model intensive framework, we encountered a host of methodological hurdles introducing considerable uncertainty into the assessment process. One of the biggest challenges was to incorporate the different types of information and estimation methods within one modelling approach. For example, rainfall variation pattern analyses require statistical methods, while the generation of future scenarios has to be dealt within a simulation programming approach. Furthermore, outputs should be based on risk measures involving some mathematical complexity. Hence, not everything that is desirable to incorporate into such a framework can and should be incorporated. For example, the crop yield model is based on rainfall only, and detailed crop simulation modelling (accounting for soil conditions, cropping patterns etc.) could not be made use of this analysis due significant data and resource limitations as well as unsatisfactory calibration results.

As generally holds true for CBA, the information about the costs and benefits of risk management strategies by itself is not sufficient for decisionmakers and implementers to devise and implement risk management strategies. There are always limitations to using a modelling approach for determining and assessing risk and risk management strategies, and finally calculating the desirability of interventions as done, for example, by a cost benefit analysis. Models do not and cannot capture everything. Yet, even if caution is required when interpreting B/C ratios, CBA provides important decision support as it requires systematic assessment and estimation of risks, as well as estimation of the degree to which DRM interventions enable those risks to be reduced or shared. Such analysis conducted in collaboration with stakeholders and used as input by decision-makers within a more process-oriented framework is likely to lead to better informed, more economically efficient and also more equitable decisions.

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Annex I: Working Paper Series

Working Paper Number	Title	Lead Authors	Focus
WP 1	The Cost-Benefit Analysis Methodology	Reinhard Mechler (IIASA)	CBA methods
WP 2	Pinning Down Vulnerability: From Narratives to Numbers	Daanish Mustafa (KCL); Sara Ahmed, Eva Saroch (ISET-India)	VCI methods
WP 3	Downscaling: Potential Climate Change Impacts in the Rohini Basin, Nepal and India	Sarah Opitz-Stapleton (ISET); Subhrendu Gangopadhyay (University of Colorado, Boulder)	Climate downscaling methods
WP 4	Evaluating Costs and Benefits of Flood Reduction Under Changing Climatic Conditions: Case of the Rohini River Basin, India	Daniel Kull (IIASA); Praveen Singh, Shashikant Chopde (WII); Shiraz A. Wajih (GEAG)	India floods
WP 5	Uttar Pradesh Drought Cost-Benefit Analysis, India	Reinhard Mechler, Stefan Hochrainer, Daniel Kull (IIASA); Praveen Singh, Shashikant Chopde (WII); Shiraz A. Wajih (GEAG)	India drought
WP 6	Costs and Benefits of Flood Mitigation in the Lower Bagmati Basin: Case of Nepal Tarai and North Bihar, India	Ajaya Dixit, Anil Pokhrel (ISET-Nepal); Marcus Moench (ISET)	Nepal Tarai and North Bihar floods
WP 7	Pakistan Case Study: Evaluating the Costs and Benefits of Disaster Risk Reduction under Changing Climatic Conditions	Fawad Khan (ISET-Pakistan); Daanish Mustafa (KCL); Daniel Kull (IIASA)	Pakistan (urban) floods
WP 8	Moving from Concepts to Practice: A Process and Methodology Summary for Identifying Effective Avenues for Risk Management Under Changing Climatic Conditions	Marcus Moench (ISET); Sara Ahmed (ISET-India); Reinhard Mechler (IIASA); Daanish Mustafa (KCL); Ajaya Dixit (ISET-Nepal); Sarah Opitz-Stapleton (ISET); Fawad Khan (ISET-Pakistan); Daniel Kull (IIASA)	Methodology summary
WP 9	Understanding the Costs and Benefits of Disaster Risk Reduction under Changing Climatic Conditions	Marcus Moench (ISET)	Summary report

Annex II: Acknowledgements

This paper provides insights from an evaluation of the costs and benefits of disaster risk reduction and adaptation to climate change in South Asia. The report is based on a set of work undertaken in the Nepal Tarai, Eastern Uttar Pradesh, and Rawalpindi, Pakistan. The progamme as a whole is financed by DFID and has been undertaken in conjunction with related activities supported by IDRC, NOAA and ProVention. The support of all these organizations is gratefully acknowledged. Numerous organizations and individuals have contributed in a substantive way to the successful completion of this report. The core group of partners undertaking field work and analysis included: Reinhard Mechler, Daniel Kull, Stefan Hochrainer, Unmesh Patnaik and Joanne Bayer from IIASA in Austria; Sara Ahmed, ISET Associate, Eva Saroch; Shashikant Chopde, Praveen Singh, Sunandan Tiwari, Mamta Borgoyary and Sharmistha Bose of Winrock International India; Ajaya Dixit and Anil Pokhrel from ISET-Nepal; Marcus Moench and Sarah Opitz-Stapleton from ISET; Syed Ayub Qutub from PIEDAR, Pakistan; Shiraz A. Wajih, Abhilash Srivastav and Gyaneshwar Singh of Gorakhpur Environmental Action Group in Gorakhpur, Uttar Pradesh, India; Madhukar Upadhya and Kanchan Mani Dixit from Nepal Water Conservation Foundation in Kathmandu; Daanish Mustafa from King's College London; Fawad Khan, ISET Associate and Atta ur Rehman Sheikh; Subhrendu Gangopadhyay of Environmental Studies Program, University of Colorado, Boulder. Shashikant Chopde and Sonam Bennett-Vasseux from ISET made substantive editorial and other contributions to the project. Substantive inputs from field research were also contributed in India, Nepal and Pakistan by numerous dedicated field staff and individuals in government and non-government organizations as well as the local communities that they interacted with.

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