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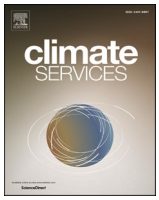

Integrating climate information into decision making for building resilience: A case study on farming communities in Bihar, India

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HIGHLIGHTS

- Climate services are effective when designed as per specific user contexts.
- Co-development process enhances application of climate information.
- Bridging the gaps between forecast producers and users is required.
- Trusted communication mechanism is required to build users confidence.
- Concerted effort to expand climate literacy and access are important.

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ABSTRACT

Effective utilization of available weather and climate information is important to develop efficient and sustainable agricultural production systems. National meteorological agencies supported by global and regional centers are trying to generate climate forecasts tailored to sector-specific operational applications for a wide range of potential users. However, the big challenge is to develop a mechanism that will effectively communicate the information in a language that could be easily understood at different levels to obtain the maximum benefits from the information they receive.

The International Research and Applications Project (IRAP) was a research experiment aimed at improving the livelihoods of rural farmers in Bihar, India, by producing and providing them with tailored weather and climate information. Forecast Application for Risk Management in Agriculture (FARM) schools were conducted to improve the awareness of farmers about the need for climate information and climate adaptation interventions which was applied for Kharif crops in summer monsoon 2018. A communication mechanism was established with the support of local partners to disseminate the tailored forecast and advisories to farmers. Assessment results revealed that the climate information is strongly valued by farmers if provided through a mechanism that they trust. More vulnerable farmers have limited access and ability to use the information, thus capacity building efforts like FARM schools are immensely helpful. Farmers recognize the critical role of climate variability in determining livelihood outcomes and actively seek out information to manage variability. This intervention helped trained farmers to better adjust their farming decisions through enhanced uptake of weather and climate information.

Practical Implications

Major gaps exist between the producers of weather and climate information and those who are intended to be final beneficiaries of the information, such as smallholder farmers. Context-specific

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climate information communicated in usable forms could benefit the farmers in decision making at various stages in field operations. Organizations that can bridge these gaps between forecast producers and users are required to translate scientifically-derived information products into a language common to final users and provided in a form that is suitable for their specific circumstances.

While climate information is often one of many components of risk management, limited access, lack of understanding, and the inadequacy of existing information often limit the potential of information to be used for decision making. The IRAP implementation in Bihar, India was a concerted research effort to foster adaptation and increase the resilience of communities and sectors vulnerable to climate variability and change by supporting decision-making and risk management through improved design, production and provision of user-inspired climate information. This study was designed to identify how the systematic provisioning of climate information—both a general understanding of climate systems and climate products such as forecasts—could provide tools for risk mitigation.

The study confirmed that weather and climate information is strongly valued, both the form of learning to access and use climate information and regular receipt of texted forecasts. There is a strong demand for such information, particularly regarding monsoon onset, rainfall amount and its variation within the season specially in drought-prone areas. There is strong evidence of changes in behavior associated with climate information in the selection of seed varieties (of paddy) and area cultivated. To a lesser extent, farmers alter the timing of planting and transplanting according to the forecasts. The analysis suggests that access to improved climate knowledge and regular forecasts prompted many of the farmers to switch to rice varieties that demand less water or mature more quickly. Climate information is useful to make provisions for access to supplemental irrigation to compensate for rainfall deficit during the cropping season. Since not all farmers have access to pumps and water sources, the climate forecast provides some lead time for farmers to arrange rental agreements and to prepare an "irrigation strategy". Short-term (weather) forecasts are then useful for the timing of irrigation episodes, particularly when dry spells occur during critical crop stages.

The institutional complex in Bihar provides access to agricultural expertise through research and extension, university-based expertise, a strong Civil Society Organization (CSO) presence in communities, and sophisticated meteorological expertise from the National and State Meteorological Centers that produce and disseminate climate information. The major insight of this research is that climate information treated as a stand-alone, one-off forecast is far more limiting than information as the basis of an organizing and negotiating platform that articulates among farmers, climate scientists, agricultural extensionists, CSO field staff, university researchers, and others.

Initiating a regular and sustained dialogue between farmers and institutional actors emerges as an active and participatory process that would provide sustained solutions to climate-related problems that can be co-produced and implemented. This would require the formation of interdisciplinary, inter-institutional task forces that work directly with farmers to not only deliver climate information but to discuss such information and the options that it opens up for farmers and create response plans tailored to a household or community reality.

Introduction

The major role of climate service providers is to provide accessible and useful information through a co-development process with users and to clearly understand user-specific contexts. Delivering climate information (including data and knowledge) in a way that is usable and useful for decision making has had less attention, and society has yet to optimally benefit from the available information (Hewitt et al., 2020).

Agriculture employs the majority of the population (Table 1) in rural India and could benefit from climate information. Traditional knowledge that guided rural communities has eroded or become irrelevant with changing practices and fragmented technology infusion. Climate change is expected to further exaggerate this situation with warmer temperatures, increased rainfall variability and extreme weather that may pose substantial additional risk to food security (Agarwal et al., 2021). Hay (2007) stated that extreme weather events such as droughts, flash floods, frost, untimely rains, storms and hails are major challenges for modern agriculture. In South Asia, Nelson et al. (2009) reported that rice production is set to fall by 14 %, wheat production by up to 49 % and maize production by 19 % by 2050. Without adaptation by farmers, crop yields will decline by 4.5–9 % in the short run (2010–2039) and by 25 % in the long run (2070–2099) (Guiteras, 2009). The growing realization of the need to put unsustainable development into an "environment-friendly path" is now beginning to drive a change in agricultural systems. Climate knowledge is an important and primary driver likely to lead this change (Shanmugasundaram et al. 2017).

High level of preparedness, timely forecast about the timing and magnitude of the event and better adaptability of the crops to recover would help in reducing the negative impacts. Despite the availability of state-of-the-art forecasts and outlooks at different lead times, ranging from 3-days up to a season in advance, using such information to make decisions is still a challenge for the farmers (Njau 2010). The recent advancements in the short term, sub-seasonal and seasonal forecasting along with long term climate projections, enable adoption of a risk-based approach for managing the farming activities (Hay, 2007). One of the crucial needs is to build the capacity of farmers to better manage resources and risks by utilizing climate information of different timescales.

For effective implementation of climate services in agriculture and better management of risk, the farmers need to aware of;

Table 1
Key challenges, potential solutions and approach attempted in IRAP for farmers agro advisory services.

Key challenges	Potential ways to address	Attempted approach within this study
Specificity of the information, trust in the information	By provision of local contextual information delivered through reliable sources and a network of government and private institutions	Local level CSOs were involved in delivering the forecast messages, receiving feedback and follow-up with farmers in the pilot locations
Gender-related social & cultural norms, literacy, size of land, scale of operations, and social factors	Understanding and respecting gender issues, literacy level, hierarchy and financial status of individuals in the society	Village heads were consulted and involved during the whole process Forecast messages were translate into local language (Hindi) for better understanding by farmers
Dense technical language of the forecast, lack of facilities to interpret climate information, limited integration with existing ways people perceive and manage risks	Capacitating users in understanding the simple forecast terminologies Providing simple, actionable and timely information with regular follow-ups	A non-formal education and experiential learning, i.e. FARM School process applied to train CSO participants and Farmers. The training assisted in understanding the technical terminologies in forecasts
Inadequate institutional capacity to effectively deliver and use climate information	Linking the public and private organizations having shared interest and goals and capacitating them effectively deliver climate information	The climate information is being delivered using a multi-tiered network of institutions that links farmers to climate service providers

i.) weather and climate extremes, variability in climate and their impact on farming activities
ii.) extreme weather and climate events in their locality vis-a-vis their farms
iii.) skills for interpreting weather and climate information with respect to their farming decisions
iv.) access to reliable sources of forecasts information, particularly to know about the extreme climate events in advance to that they can manage the associated risks

Current challenges in the utilization of climate information

While climate information is often one of many components of risk management, limited access, misunderstandings, and the inadequacy of existing information often cause the information to be underutilized. The climate information products in usable forms might benefit the farmers in decision making at various stages in field operations. Thus, it is required to involve farmers in exploring available weather and climate information products and align them to the wealth of their traditional knowledge to overcome their on-farm challenges linked to climate variability and change. The confidence of the farming community needs to be enhanced by capacitating them to better manage resources and risks by utilizing the climate information of different timescales. Thus, climate services are expected to play a major role in transforming agriculture practices by integrating relevant climate information in the farmers' decision-making process.

The International Research and Applications Project (IRAP), funded by National Oceanic and Atmospheric Administration (NOAA), USA, was a collaborative project involving the University of Arizona (UA) and Columbia University's International Research Institute for Climate and Society (IRI), India Meteorological Department (IMD), Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) and the Government of Bihar. IRAP focused on Integrating Climate Information and Decision Processes for Regional Climate Resilience, advances research on adaptation and resilience to climate variability and change while also advancing the application of climate services. IRAP implementation in India was a concerted research effort to foster adaptation and increase the resilience of communities and sectors vulnerable to climate variability and change by supporting decision-making and risk management through improved design, production and provision of user-inspired climate information. Experiences from IRAP implementation in Bihar state in India are presented in this study. The major objective of the study was to understand the impact on the farmers' decision-making process by providing customized location-specific user-relevant advisories, produced using short-range, medium-range and seasonal forecast and communicated through a user-designated and trusted communication channel. The study further evaluated the benefits of this process in the management of agricultural practices at farm scale.

Agriculture context in Bihar

According to the Economic Survey 2017–18, the agriculture sector in India employs more than 50 percent of the total workforce and contributes around 17–18 percent to the country's GDP. However, the unpredictability of weather negatively affects Indian agriculture, and the inevitable climate change will worsen such impacts. Bihar, known as India's poorest states, has over 100 million population and most of them (77 %) employed in the agriculture sector. The small-scale intensive agriculture of the state favors rice, wheat, and pulses cultivation in supplement to the fruits and vegetables. The state's highly fertilized large alluvial plain allows double cropping, contributing to state GDP by over 24 % (Buizer et al 2019).

The state is divided nearly in half by the Ganges River. There are several watersheds that flow both north and south, creating a large alluvial plain that provides the state with its fertile and highly productive land resource. Farmers, however, face a range of challenges. Due to its geographical location relative to higher elevation riverine sources, the northern half of Bihar is subject to regular and severe flooding. The southern half of the state, on the other hand, suffers from more erratic climate variability and, consequently to periodic droughts. The northern plains receive an average of 1275 mm, while the southern plains receive an average of 1103 mm, with wide spatial and temporal variability.

The agriculture in Bihar is mostly tied to the annual monsoon cycle, similar to many states in India. The delay or early arrival of monsoon and rainfall distribution within this season affects the yield. The late and less amount of rainfall cause delay in transplantation, poor crop growth, weed infestation and a possible outbreak of diseases and pests (Singh et al., 2014). Thus, the climate variability in the northern and southern plains of Bihar is a major determinant of livelihood success for millions of farm households. All these made Bihar an ideal case to examine the role of climate information and its potential contribution to risk-reducing behavioral change in the farming community.

Four districts (Fig. 1), two in flood-prone northern plains (East Champaran and Darbhanga) and two in the drought-prone southern plains (Nawada and Jehanabad) were selected for this study. There are two distinct growing seasons—the Kharif, monsoon season (typically, June to September), during which most of the annual precipitation falls and the rabi season (dry winter season from November to February). While diverse crops are planted in both seasons, the predominant cropping pattern is rice paddy during the Kharif and wheat during the rabi. However, pulses and vegetables are also grown in these districts.

Farmers agromet advisory services and challenges

Producers of information and the institutional landscape

The recent advances in atmospheric modelling capabilities enhanced the accuracy and skill of operational forecasting, creating more opportunities for the vulnerable farming community to deal with rainfall variations, particularly during the cropping seasons linked to the monsoons (Singh et al., 2018). The India Meteorological Department (IMD) has developed state-of-the-art operational numerical weather prediction systems that enable short-term weather services at the district level (up to five days). For disseminating these forecasts and for building forecast based agricultural advisories, IMD's GKMS (Gramin Krishi Mausam Seva) closely work with Agro-Meteorological Field Units (AMFUs), created across the country in 130 agro-climatic zones (Nesheim et al., 2017). The AMFUs, with support from the Indian Council of Agricultural Research (ICAR) and State Agricultural Universities (SAUs) responsible for the production of 5-days district level agro-advisories, issued twice a week (every Tuesday and Friday) for all districts in India (Maini & Basu, 2016).

The public, private and Civil Society Organizations (CSOs) commonly known as non-governmental organization (NGOs) are also providing similar services in some pockets of the country. The IFFCO KISAN in a joint venture with a telecom company (Bharti Airtel); RML (Reuter Market Light), a private-sector organization and CSOs offering agriculture information (weather forecast, market rates, soil management, crop protection, horticulture, and government schemes) using voice messages, phone messages and through awareness campaigns (Nesheim et al.,2017). The NOKIA-HCL, Handygo, Skymet, Mahindra Sairiddhi, Kisan Sanchar, and NABARD are other players disseminating the agromet advisories in SMS and IVR Format in India (Sikdar et al., 2020).

Dissemination

The "mKisan" portal (https://farmer.gov.in/) of the Department of Agriculture and Cooperation (DAC), Ministry of Agriculture disseminates SMSs to its registered users, free of cost. The extreme weather warning also shared through short message service (SMS) messaging and

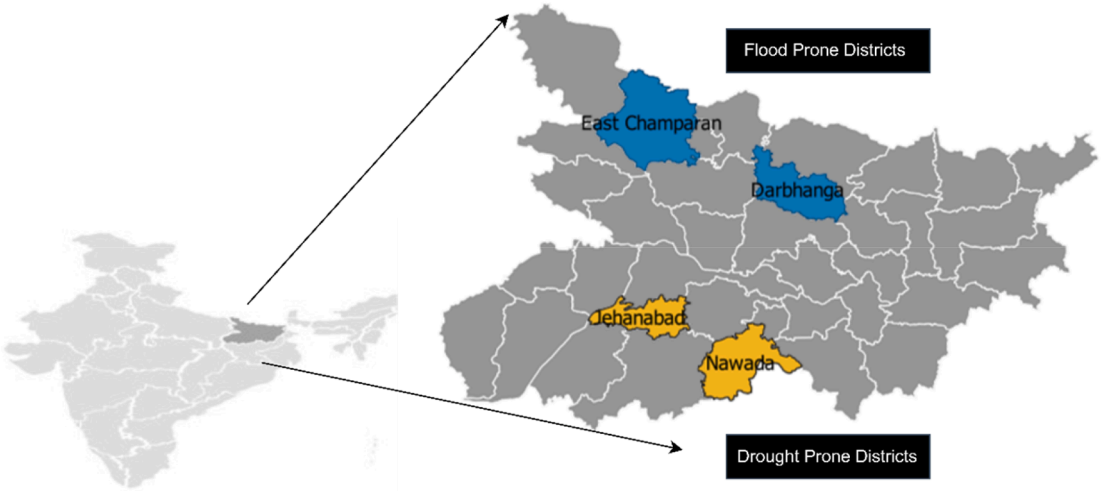


Fig. 1. The location of IRAP pilot districts in Bihar, India.

Interactive Voice Response Technology (IVR) in regional/English language and also available on websites of Universities or National Institutes (Chattopadhyay & Chandras, 2008).

The district-level agro advisories of IMD's GKMS is being issued through short messaging services (SMS) every Tuesday and Friday to more than 18 million farmers also disseminated through a variety of communication channels such as the Krishi Vigyan Kendra (KVK) website, radio, television, newspaper (Nesheim et al.,2017). In addition, the State Composite Bulletins and National Agrometeorological Advisory Services Bulletins are also issued simultaneously. The other sources delivering the daily weather information are TV, Newspaper, radio, Kisan call centre, public announcement and weekly posters put up at the prominent places in some villages.

In India, weather and climate products have been disseminated using several communication channels. However, the big challenge is to develop a mechanism that will effectively communicate the information in simple form and local language that could be easily understood by target users to obtain the maximum benefits from the information they receive (Singh et al., 2018). The uptake of the agromet advisories found encouraging in the case of progressive farmers, but the usefulness of the agromet advisories mainly depends on its access, salience and credibility of the information (Venkatasubramanian et al., 2014).

Challenges

The key challenges in the effective utilization of these products are the specificity of the information, gender-related social & cultural norms, trust in the information, dense technical language of the forecast, limited resource (television, mobile, network), trust in the information, literacy, size of land and scale of operations (Venkatasubramanian et al., 2014), inadequate institutional capacity to effectively deliver and use climate information (Singh et al., 2016), social factors, lack of facilities to interpret climate information, limited integration with existing ways people perceive and manage risks (Singh et al., 2018).

Methodology

Despite the availability of state-of-the-art forecast products and customized services, the application of the information in farmers' decision making process is very limited. This study was designed as a modified randomized control trial intended to bring customized climate information to a selected group of farmers and to measure the impacts of this information on the farmers' decision-making process. Four districts of Bihar, India—two in the northern plains (East Champaran and Darbhanga) and two in the southern plains (Nawada and Jehanabad)—were selected for the study. In 2016, a baseline survey was conducted in 25 villages across these four districts. The baseline survey instrument gathered information from respondents on household characteristics, livelihood assets and outcomes, and a set of climate-related variables, including sources of climate information, types of information, perceptions of reliability, use of information, and related topics.

For detailed assessment, the intervention explicitly targeted 323 farmers who reported access to land and had cultivated their farm in the 2017 agricultural year. Four distinct groups (Figs. 2a, 2b) were identified in all four districts; Treatment 1 (T1) set of such farmers would participate in the Forecast Application for Risk Management (FARM) School and then receive regular climate forecast texts on their mobile phones. Treatment II (T2) group participated in the FARM school but did not receive the regular texts; Treatment III (T3) received only the texts but no FARM school training, and Treatment IV (Control) neither attended the FARM school nor received the texts. The FARM schools were carried out at several sites in the sampled districts during April-May 2018 prior to the arrival of the monsoon season.

The FARM school, adopted in this study, consisted of a detailed orientation on climate characteristics, historical trends, available forecast tools (weather and climate), and how to interpret them. The Indian Meteorological Department (IMD) was the major partner who produced and provided weather and climate forecasts. IMD staff participated and supported the FRAM school sessions. Further details on the FARM school process and customized climate products developed for this study and the dissemination mechanism is discussed in the following sections.

Baseline and endline surveys were conducted with farmers in the target groups to capture the specific impacts of the treatments. Consequently, the research outcomes are reported at two levels of analysis. First, there is a comparison of baseline and endline samples for a set of livelihood variables measured at both points in time. At second level, differences among treatment and control groups are analyzed in the endline survey, comparing changes in behaviour and outcomes between the pre-treatment year, 2017, and the post-treatment year, 2018.

In addition to the baseline and endline samples, a series of focus groups discussions (FGDs) were conducted in October 2018 with clusters of farmers from each district who were part of the various treatment groups. These qualitative sessions were designed to capture farmer perceptions of climate change and variability in their regions, the impacts on local agriculture, and the types of adaptive measures that farmers employed to reduce negative impacts.

Customized products and services

IMD issues extended range forecasts of weekly precipitation up to 4

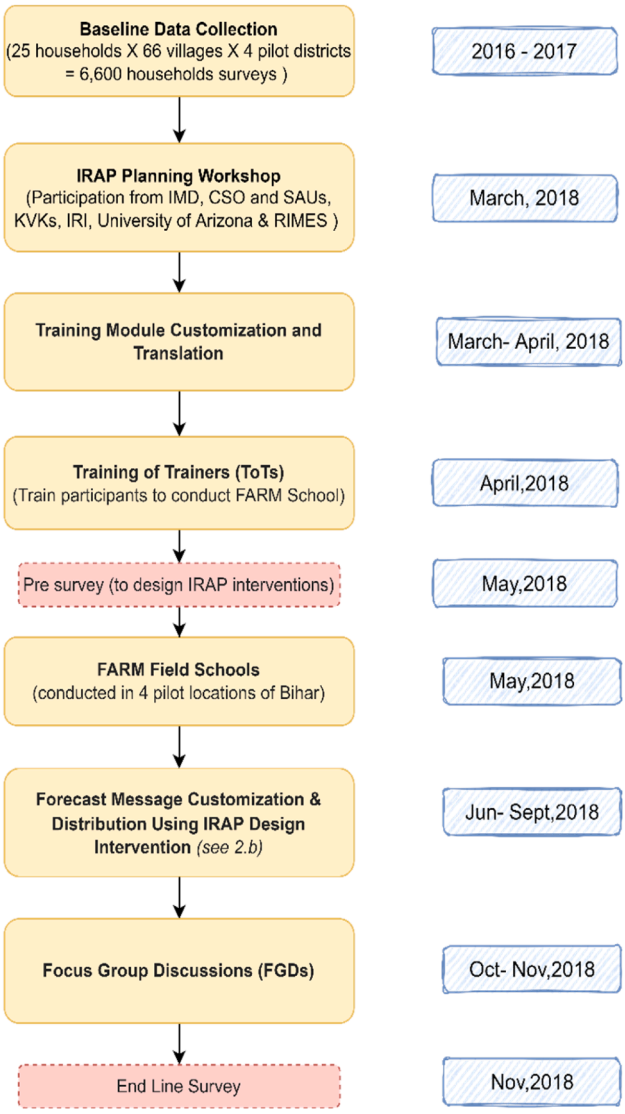


Fig. 2a. Research intervention design, adapted for IRAP implementation in Bihar.

weeks ahead for each meteorological subdivision in India (Pattanaik et al., 2019). Access to timely and relevant climate information to rural communities at the district level is still very limited. The sub-seasonal and seasonal forecast products have limited application for agro advisories in India. This study tested the hypothesis by producing and disseminating sub-seasonal and seasonal forecast in addition to existing IMD products for the rural livelihoods of Bihar to improve the resilience of these farmers against climate variability.

Sub-seasonal forecast

The forecasts generated over Bihar based on the NOAA's National Centers for Environmental Prediction (NCEP) Climate Forecast System, version 2 (CFSv2) global ensemble prediction system, which are publicly available in real-time were used for this study. The forecast maps were produced through a virtual map room. (http://iridl.ldeo.columbia.edu/maproom/Agriculture/Bihar/Forecasts/S2SFcst/index.html) and discussed each week with IMD. Sub-seasonal forecasts were evaluated for their ability to generate the weekly-averaged conditions, which were expressed in a below-normal/near-normal/above-normal tercile categorical format. Due to the lack of skill found at longer lead times, the forecasts were restricted to about two weeks in advance, following the Friday–Thursday definitions of week 1 (average of days 3–9) and week 2 (average of days 10–17) used by IMD. The forecasts were generated in real-time every Thursday during the 2018 Indian summer monsoon season, from June 7 to September 27, making 17 weekly issuances in all (Robertson et al., 2019). The forecast maps were evaluated by IMD and summarized as a text message, a text summary was then sent by IMD to Bihar's State Agricultural Universities, who then forwarded them for dissemination to the farmers through local CSO partners. A sample of probabilistic week 1 and 2 forecasts issued on Thursday, June 14 (from June 13 initial conditions) for the June 15–21 and June 22–28 target periods are shown in the Fig. 3.

Seasonal forecast

Following the same network as of sub-seasonal forecast, a seasonal forecast was also generated and disseminated for the 2018 Summer monsoon in Bihar. The seasonal prediction in a 1° resolution was generated as the forecast probability of the terciles category (i.e., above normal, normal, and below normal) (Robertson et al., 2019). In May 2018, a seasonal forecast was generated for Jun-Sep; in June 2018, a forecast was generated for Jul-Sep and so on, up to and including a seasonal forecast for September 2018 generated in August.

Customized agro advisories by AMFUs

The sub-seasonal and seasonal forecast in local language (Fig. 4), was complemented by the 5-days composite Agromet advisory services

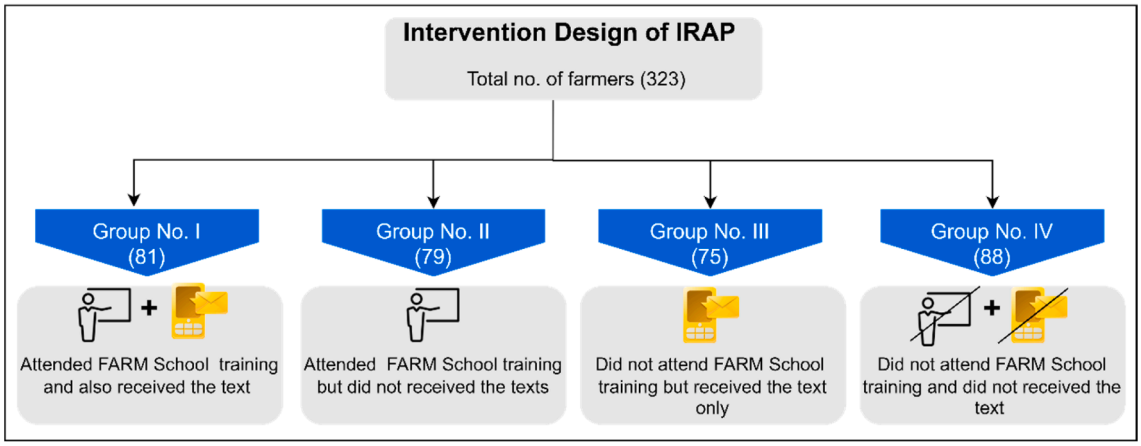


Fig 2b. IRAP intervention Design (the numbers in bracket indicate the number of farmers in specific groups T1, T2, T3 and Control).

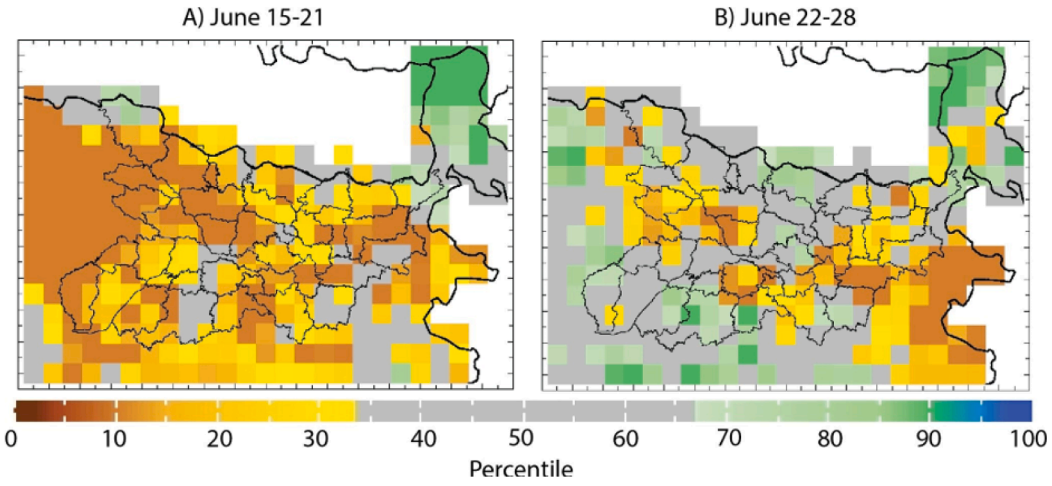
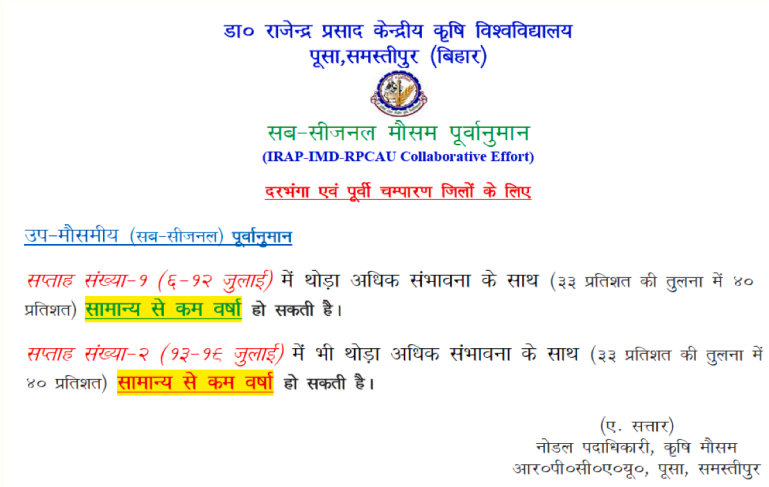


Fig. 3. Calibrated probability forecasts for (a) week 1 (June 15–21), and (b) week 2 (June 22–28), issued on June 14, 2018. Shown is the probability of the dominant tercile category.



डा० राजेन्द्र प्रसाद केन्द्रीय कृषि विश्वविद्यालय
पूसा,समस्तीपुर (बिहार)

सब-सीजनल मौसम पूर्वानुमान
(IRAP-IMD-RPCAU Collaborative Effort)

दरभंगा एवं पूर्वी चम्पारण जिलों के लिए

उप-मौसमीय (सब-सीजनल) पूर्वानुमान

सप्ताह संख्या-१ (६-१२ जुलाई) में थोड़ा अधिक संभावना के साथ (३३ प्रतिशत की तुलना में ४० प्रतिशत) सामान्य से कम वर्षा हो सकती है।

सप्ताह संख्या-२ (१३-१९ जुलाई) में भी थोड़ा अधिक संभावना के साथ (३३ प्रतिशत की तुलना में ४० प्रतिशत) सामान्य से कम वर्षा हो सकती है।

(ए. सत्तार)
नोडल पदाधिकारी, कृषि मौसम
आर०पी०सी०ए०यू०, पूसा, समस्तीपुर

Fig. 4. Customized sub-seasonal forecast sent to farmers in local language (Hindi).

(AAS) bulletins, an operational product of IMD generated every Tuesday and Friday for all districts of India. The Composite AAS bulletin for pilot districts consists of a five-day weather forecast from IMD and includes parameters such as rainfall, cloud cover, Tmax, Tmin, R.H, wind speed and wind direction. The SAUs prepared the agro-advisories for AAS based on the weather forecast. The AAS bulletin was in the local language and advised farmers on the land preparation time, crop selection, pest and disease warnings, and animal husbandry.

Delivery mechanism

Forecast generation and dissemination procedure adapted for this study is as shown in Fig. 5. The seasonal and sub-seasonal forecasts (S2S) were generated by IRI every Thursday and shared with IMD for their

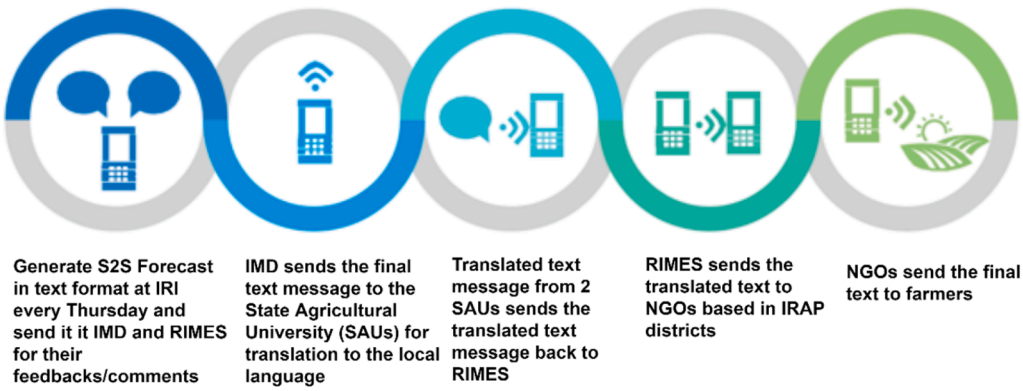


Fig. 5. Forecast generation and dissemination procedure adapted for the study.

feedback. IMD officers review the forecast and shared with the AMFUs of the State Agricultural Universities (SAU) for translations to the local language. The AMFU sent translated text message to RIMES, which was then shared with designated CSOs. Finally, the CSOs were responsible for communicating the text messages with selected farmers in the target districts via WhatsApp or phone calls.

Feedback mechanism

The farmers discussed the outlook within the group and with neighboring farmers before taking farming-related decisions. The performance of the forecast was conveyed verbally to CSO representatives over the phone and during field visits. The CSO representative shared farmers' feedback with Krishi Vigyan Kendra (KVK), RIMES, and local IMD Patna officers during the season. The RIMES team also carried out the midterm review in August 2018, shared feedback with project partners.

Capacity building process

The Forecast Application in Risk Management (FARM) School in agriculture has been introduced by Regional Integrated Multi Hazard Early Warning Systems (RIMES) in many countries across the globe, including Myanmar, Bhutan, Sri Lanka, India. The major goal and objective of the FARM school process is:

Goal: Increase capacity of farmers to understand the weather forecast and make use of it in their regular farming operations.
Objective: To employs methodologies to make scientific processes related to weather and climate understandable to farmers and to enhance its utilization in regular farming activities.

FARM school training as shown in Fig. 6 is a tool to improve farmers' awareness about the need for climate information and climate adaptation interventions that may be applied for Kharif crops in summer monsoon 2018. It is a community-based, hands-on, and practical oriented field study program that allows farmers to learn together.

The FARM school training modules were customized to specific locations in the four pilot districts of Bihar, taking into context local climatology and other characteristics and farmers' perceptions and practices. The FARM school process is designed primarily to demystify science and employ simpler methodologies to make scientific processes related to weather and climate understandable. The consultations with experts from SAUs, CSO, Department of Agriculture (DOA), IRI, and IMD and needs of local farmers were considered in finalizing the training modules.

The training modules were translated into the local language (Hindi). The module introduced basic terms like weather and climate elements, type of forecast, field water balance, forecast probability and crop planning strategies using simple learning techniques. The FARM school approach empowered farmers to understand and effectively utilize climate information and forecasts in their farming activities.

Results and discussion

Baseline scenario

Two critical resources, land and water, determine the overall vulnerability of farmers in the study area. A majority (80 %) relied on agriculture as the main source of economic sustenance, and a few (20 %) referred to agriculture as its secondary income source. The baseline surveys indicated that leasing and sharecropping are the common land access mechanism that constraints farming choices. A major source of irrigation is either through on-site sources (wells, irrigation canals) or from neighbors. When drought has decreased levels of groundwater, the risk level for farmers without wells worsens due to dependence on neighbors. Although there is little chance to change the existing landholdings situations for these vulnerable farmers, improving water management practices could be made through use of available climate information.

The baseline survey shed some light on the status of weather and climate information utilized by farmers in the pilot districts. The agriculture practices in the rural setting of Bihar are mostly instigated by local traditional knowledge. Though the last decade witnessed an increase in the number of channels distributing climate forecast and advisories to farmers, the actual uptake and use were limited by many factors. Access to weather and climate information via radio, television, newspaper, and mobile phones is negligible for rural Bihar. The information from television, radio and newspaper) is usually broad and not localized, limiting the utilization of the weather and climate information products. In some case, farmers lack confidence in utilizing the information from such sources. Only around 25 percent of farmers receive information from the agriculture extension services, and less than half of these took some action based on this information.

Impacts of the intervention

Access to climate information

The famer schools were conducted in May 2018, before the expected arrival of the 2018 summer monsoon. As per the intervention design half of the participants in the FARM School then received regular forecast updates via mobile texts (T1) and half did not (T2). Another group did not attend the FARM School but received the text (T3), and a control group did not participate in the FARM School and did not receive the texts (please refer Fig. 2). The study thus focuses on how farmers responded to these varying levels of climate information. All in all, nearly half the sample of 323 famers attended the FARM school.

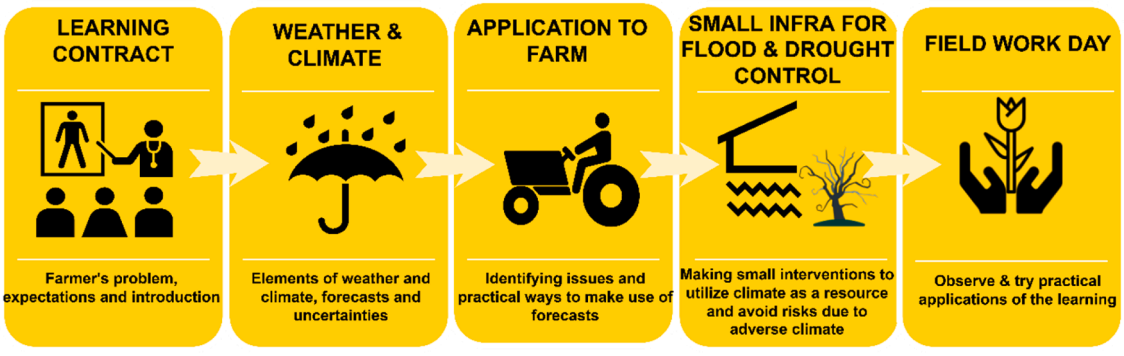


Fig. 6. Forecast Application in Risk Management (FARM) school in agriculture process.
Source: Agarwal et al., 2021

The survey analysis indicates that the provisioning of climate information in Bihar has experienced a rapid evolution through the intervention. The percentage of farmers with access to climate information prior to the IRAP intervention and after the intervention in year 2018 is shown in Fig. 7. The access to climate information to T1, T2 and T3 changed significantly compared to the control group.

Changes in Farmer Decision-Making

The field school curriculum extended beyond the presentation of climate forecasts to include contextual information on climate systems and climate variability, the technology of forecasting, and the range of possible adaptation actions under specific forecast conditions. In the endline survey, about half of those who had participated in the FARM School stated what they had found most useful in the FARM School. The most frequently cited responses were divided between an enhanced understanding of the weather and climate and the application of climate information to agricultural practices, particularly choice of seed variety, land and water management, and crop diversification (Buizer et al., 2019). Two of the treatment groups (158 farmers) received weekly text messages on their mobile phones. Approximately-one-half of these farmers were participants in the FARM school and as a result had benefited from an orientation on the meaning and implications of the texted forecasts, while the other half received these forecast messages with no other information. In the endline survey, most of the beneficiaries in the texted groups stated that they found all the information useful, but most claimed that the five-day forecast was more actionable than the two-week or seasonal forecast. Farmers who changed the farming strategy in different treatment groups as compared to control group is shown in Fig. 8.

The farmers in the treatment groups had significantly greater access to climate information and better understanding of forecasts than in previous years. The forecasts, however, were provided prior to the monsoon season, with little information for the dry season but subsequent sub-seasonal forecast indicated the drought scenarios. Not all farmers changed the farming strategy owing to limited capacity to response. The endline sample overwhelmingly stated that they would look for climate information for the next planting season, emphasizing the timing of the monsoons, the quality of the rains, regular weather forecasts, and agricultural extension support on how to interpret the forecasts.

Changes in Farm Practices

Although the 2018 monsoon resulted in a widespread drought as predicted by the forecasts, the question is whether the treatment groups reacted differently because of the forecast information. Almost half of those farmers that participated in the field school changed to a less water-demanding variety of paddy rice (compared to around a third of the text-only and control groups). Farmers showed a significant level of understanding with regard to paddy varieties and their characteristics, and the shift in variety appears to be a direct management response to expectations of a weak monsoon. This pattern is more pronounced in the drought-prone southern districts than in the northern flood-prone region.

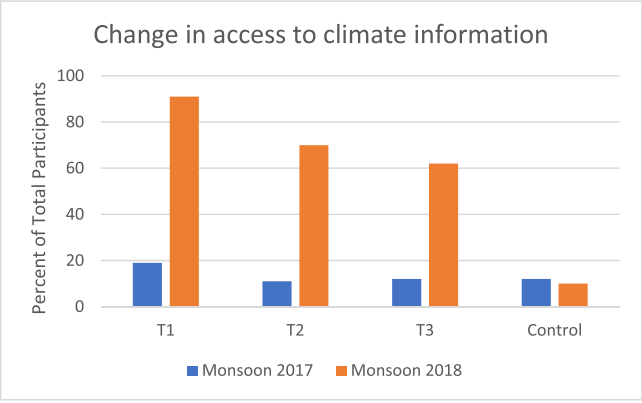


Fig. 7. Percentage of farmers in four treatment groups with access to climate information prior (2017) and after (2018) the intervention.

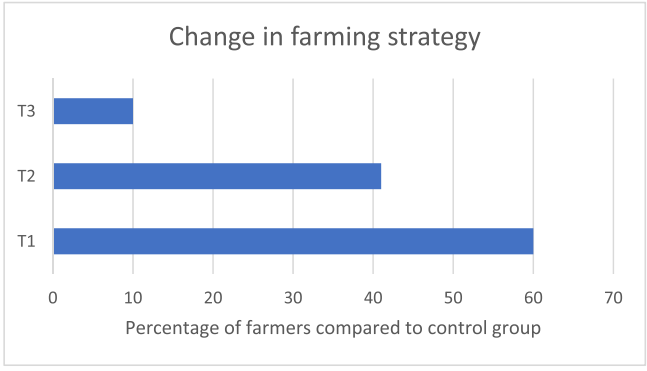


Fig. 8. Percentage of farmers who change the farming strategy in three treatment groups compared to control group in 2018 monsoon season.

Another major change in farm practices related to the 2018 monsoon was in the use of irrigation. The FGD participants from all four districts stated that they use irrigation in the event of moisture scarcity due to low rainfall. Since irrigation entails a cost (equipment and fuel), it is used only when needed. Not all households, however, have access to irrigation, which requires a water source (a well or an irrigation ditch) and a water pump. Drawing upon the survey results, the ownership of an irrigation pump is greater in the drought-prone districts compared to the flood region. According to the FGDs, those who do not have an irrigation capability are forced to rent both the water and pump or face severe reductions in yields. Whether through ownership or renting, the ability to irrigate water-stressed crops is a major management strategy. Similar benefits of agro-advisory services were reported by Ferdinand et al., 2021.

During the 2018 monsoon, three-quarters of the sample declared that they changed their irrigation practices, most likely increasing irrigation frequency than in 2017. The differences between the northern and southern regions were significant— while 93 percent of the flood-prone sample changed their irrigation practices, only 58 percent in the drought zone did so. In Nawada district in the drought region, only 28 percent of the farmers changed irrigation practices, but it is the only district where climate information may have had an influence. The field school graduates, and text forecast recipients were more likely in turn to irrigation as a drought strategy than was the control group. The difference between flood zone and drought zone might be explained by the comparative advantage in access to rivers in the northern region, which would expand the availability of irrigation water; the Nawada exception might reflect and greater overall reliance on irrigation, even in a "normal" year, then not a major change from 2017.

In general, the farmers in T1 and T2 groups who participated in FFS were able to adjust their crop calendar to maximize the advantage of potential favorable climate during the season and manage potential risks. These farmers had better understanding of probabilistic forecasts and further strengthening application of climate information and they understand variability in weather and the uncertainty in forecasts.

Conclusions

The application of climate services is mainly driven by social considerations. Weather and climate information is one of the main inputs in climate services like seeds and fertilizers in agriculture. To make

climate services effective it is very important to build the capacity of the users to contextualize and interpret information to their specific risk management decisions. IRAP experiment helped underline the importance of the basic capacity building of farmers for effective climate services in agriculture, which is just as important as improving accuracy and resolution of the forecasts. Despite challenges in collecting social data, it is important to integrate the social sciences aspect in climate services projects and operational workflow procedures. Baseline survey which was conducted in pilot districts of Bihar to get the baseline data and thus was able to build a very effective case study.

The success in disseminating and utilizing the climate information primarily depends on the strong collaboration among agencies involved. The IRAP approach was to minimize the gap between climate information producers and climate service users by enhancing networking among institutions such as KVK, CSO, AMFU, SAUs and DoA at the local level. A process of co-development emerged during a succession of meetings where the information producer, carrier and distributor and its utilizers got equally involved. The producers of climate products were in touch with the point of demand assessment and could respond directly to some of the stated needs.

Climate-based events such as drought and flood affect all farmers, and more acutely the most vulnerable households. This study was designed to identify how the systematic provisioning of climate information—both a general understanding of climate systems and climate products such as forecasts—could enable risk mitigation. The research results of the IRAP based on base-line survey, co-development process of bringing together institutions and conducting FARM school, generation and communication of sub-seasonal forecasts to sample groups of farmers in the four pilot districts and exit FGDs combined with endline survey provide the following significant insights:

- Participating farmers found weather and climate information, in both as training during the FARM school learning and as regular texted forecasts. There is a strong demand for such information, particularly with regard to the overall rainfall and within the seasonal variations during the monsoon season. It appears that this demand is more urgent in the drought-prone areas of the state.
- Farmers access and use the climate information differently within their respective risk situations. Moreover, the most vulnerable are more limited in their ability to use the information.
- There is strong evidence of changes in behavior associated with FARM School participants in the selection of paddy seed varieties and area cultivated. To a lesser extent, farmers alter the timing of planting and transplanting according to the forecasts. The analysis suggests that access to improved climate knowledge and regular forecasts prompted many of the farmers to switch to rice varieties that demand less water or mature more quickly. The forecast can equally affect the timing of planting and area cultivated.
- Climate information was predominantly used to decide the provision of irrigation during dry spells. Since not all farmers have access to pumps and water sources, the climate forecast provides a signal that farmers should arrange rental agreements and to prepare an "irrigation strategy". Short-term (weather) forecasts are then useful for the timing of irrigation episodes.

The major insight of this research is that climate information treated as a stand-alone, one-off forecast is far more limiting than information as the basis of organizing and negotiating platform that articulates among farmers, climate scientists, agricultural extensionists, CSO field staff, university researchers, and others. Climate risk is not usefully divorced from the complex clash of risks faced by farmers. Therefore, climate information as a risk-mitigation tool is best understood as a social learning process that contributes to problem-solving at the household level.

CRediT authorship contribution statement

Agarwal Anshul: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Sawant Mitesh:** Writing – original draft, Writing – review & editing. **G. Srinivasan:** Conceptualization, Writing – original draft, Writing – review & editing. **J. Buizer:** Conceptualization, Supervision. **T. Finan:** . **K.K. Singh:** Supervision. **S. Kumar:** .

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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