CGIAR Transforming Agrifood Systems in South Asia

CSISA

Evaluating the value of agricultural climate services using hindcast experiments Methods development in India and Bangladesh

Research Note 5, Work Package 5
December 2022

ABOUT THIS RESEARCH NOTE

This research note offers insights to a new method for understanding the economic benefits of utilizing climate services for decision making in agriculture, which can provide justification for the public and private investment in provision of climate services to farmers. In order to understand the potential benefits of weather information for improved farm decision making, case studies from wheat farming in India and Bangladesh are presented.

KEY STUDY FINDINGS

1. Simulations using estimated regression regimes show that a potential yield gain of 15% can be achieved by wheat farmers in in India and Bangladesh if they utilize weather information for making more informed decisions regarding crop management.
2. Simulations also suggest that a 60% yield gain could potentially be attained in Bihar (India) if farmers utilize climate information to fine-tune their farming practices.
3. Weather-informed decisions include planting dates, timely irrigation to avoid heat stress, and timely harvesting to avoid post-crop maturity losses.

BACKGROUND

Farmers typically make decisions on agricultural operations based on traditional agricultural calendars and market information that are developed based on knowledge gained previous farming experience. Due to increasing climatic variability, it is generally widely agreed that the past climatic conditions are not a good measure of current and future conditions. Hence, farmers are increasingly in need of science-based, location-specific, and user-tailored climate services in short-, seasonal- and longer-time scales. However, there are only limited tools available to evaluate the usefulness of agricultural climate services and understand their value proposition. This in turn can limit investments in and use of climate services. In this research note, we present preliminary research towards the development of an *ex-ante* evaluation method to quantify the value of the short-term weather advisory services in South Asia. The method identifies the key crop management decision points that – as assessed through statistical modeling – could potentially lead to yield gains. This method also develops a counterfactual assessment if forecast weather information is provided to farmers.

CIMMYT International Maize and Wheat Improvement Center | IFPRI International Food Policy Research Institute | IRRI International Rice Research Institute | IWMI International Water Management Institute | CIP International Potato Center | WorldFish | ILRI International Livestock Research Institute

BACKGROUND

Increasing climatic variability threatens the livelihood of millions of smallholders globally who depend on agriculture (Tesfaye et al., 2019; Amjath-Babu et al., 2016). Farmers typically make decisions on agricultural operations based on traditional agricultural calendars and market information that are developed based on knowledge gained previous farming experience. Due to increasing climatic variability, it is now widely agreed that the past climatic conditions are not a good measure of current and future conditions (Hewitt et al., 2012). It is often reported that the provision of weather forecasts (seasonal, short-term) combined with agricultural advisories can increase the efficiency of farmers in handling year-to-year and within-season variability of weather and improve farm profits (Meza et al., 2008; Lourenco et al., 2016; Kim et al., 2022). Findings also suggest that climate services account for diverse social structures, behaviours and contexts to demonstrate their applicability in real world context (Findlater et al., 2021).

There is however a scarcity of tools and methods to evaluate the value proposition of climate services for farmers. This is is a limiting factor to meet the demand for understanding the economic and social benefits of using agricultural climate services to justify the public and private investment in provision of the services to farmers (Soares et al., 2018; Findlater et al., 2021). The value of a forecast or a climate service is the differential between the outcomes with and without access to them or the potential outcome if the users had access to the service (Soares et al., 2018, Hossain et al., 2021; Lourenco et al, 2016; Kim et al., 2022). Existing studies on economic evaluation of climate forecasting mainly focus on seasonal forecasts (Roudier et al., 2012, Zinyengere et al., 2011, Amegnaglo et al., 2017) and evaluations of short-term forecasts are seldom reported (Roudier et al., 2017; Hewitt et al., 2017). In addition, types of decisions that are considered most studies are limited to changes in crops and varieties and their planting dates on a seasonal rather than within-season basis (Meza et al., 2008), or to aquaculture sector (Hossain et al., 2021). Moreover, the factors that may hinder the efficient use of climate services are also not well investigated. Integration of local and scientific knowledge such as that used in early warning systems in disaster risk reduction (Hermans et al., 2022) would be equally useful in developing and applying climate services based on hindcast experiments.

OBJECTIVES

The International Council for Science (ICSU) identified the need of enhancing usefulness of weather forecasts and future climate changes as one of the grand challenges of sustainability science. Given the historical evidence of societies being collapsed when they were unable to cope-up their farming with climate variability underlies the importance of climate advisory services (Hewitt et al., 2012, 2017). This in part lead to the development of the global framework of climate services (Hewitt et al., 2012). However, the absence of rigorous evaluation of such services in generating economic value for the stakeholders may hinder investment and farmer adoption of climate services and advisories. To contribute to this research gap, the current study focuses on:

1) Understanding the farmer-to-farmer variability of decisions and their willingness to change their decisions, given the availability of high-quality weather forecasts.

2) Quantifying (ex ante) the value of short -term forecast based agro-advisory using a switching regression model for wheat farmers in India (Bihar) and Bangladesh.

DATA AND METHODS

Though there are methodological options of contingent valuation, decision theory-based models, benefit transfer, etc., (Whitehead et al., 2015, Karni, 2022), the current work presents a decision-based analysis. In this method, farmers are presented with the weather data of past year (hindcast) and asked for potential changes in their farming decisions if the information was available to them with a lead time of five days. The assumption made is that the short-term forecast-based climate services can only influence the timing of agricultural operations and hence can benefit farmer without any change in actual input use. The method captures the behavioral changes of farmers in terms of farming operations, given the forecasts and its uncertainty and assesses the economic value of the short-term forecast-based changes in agricultural operations.

This "hindcast" method presents daily data of key weather variables like maximum temperature, minimum temperature and rainfall for the past cropping season with line graphs to farmers and asks them to mark their crop husbandry decisions (planting, irrigating, weeding, fertilizing, harvesting, etc.) to capture the decision they would have altered if they were provided with forecasts with five days of lead time. The sampling method followed a random selection of villages within a 10 Km radius of meteorological stations to ensure accuracy of the data presented to farmers. Farmer's use of inputs including fertilizer and irrigation, and yields obtained by farmers are collected separately. This approach generates the dataset with yields, inputs, dates of key agricultural operations, and the operations farmers are willing to change given five day weather forecasts. A statistical approach is used to create "what if" scenario to capture the yield shifts if farmers altered their operations within the lead time (five days) of the forecast. In case of wheat, the change in planting date, irrigation on the days that breaches threshold high temperature, and harvesting before a rainfall event are taken as key decisions that can be considered using the forecasts and examined the additional benefits that would have realized by the farmers. The possible factors that may hinder forecast-based decision making are also captured. The method captures on the possible yield benefits of accessing climate services to address the climate variability but doesn't capture cost savings (e.g., avoiding irrigation in cases of forecasted rains) due to climate services and gains from mitigating extreme climate events.

Switching regression Model

The data are segregated to two regimes by creating an indicator of sum of deviations from critical dates of planting, irrigation (on days of temperatures above a biologically critical crop-species specific threshold), and harvesting (e.g., before a rainfall event that could reduce yield). The first regime is the farmers that performed operations that are closer to critical dates

Regime 1: $Y^i = \gamma_1 X_1^i + \epsilon_1^i, \text{if } F^i = 1$ (1)

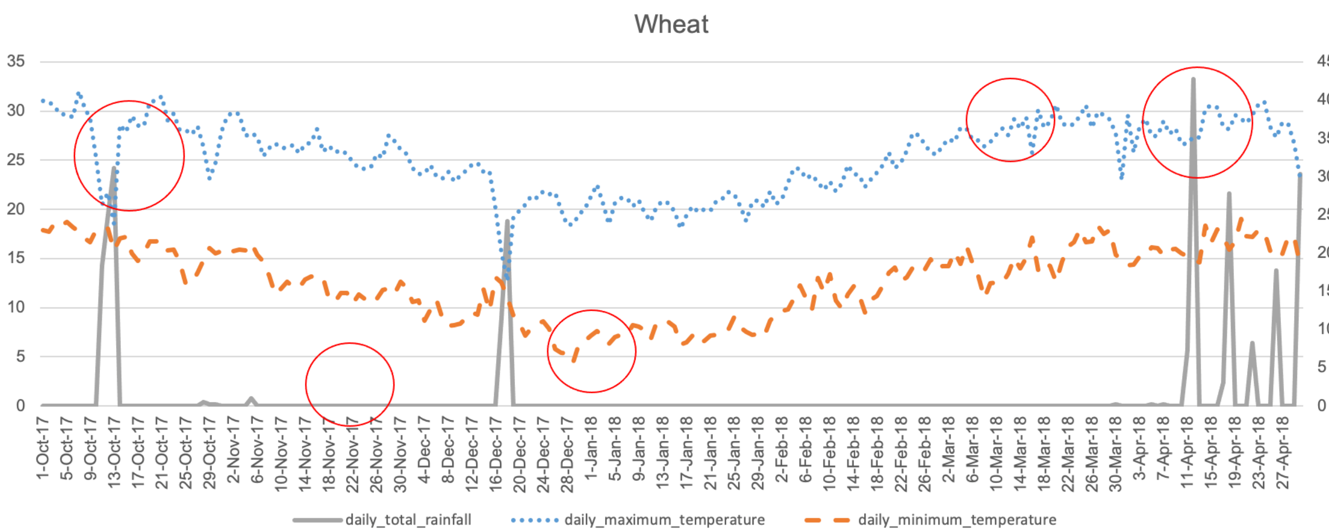
Regime 2: $Y^i = \gamma_2 X_2^i + \epsilon_2^i, \text{if } F^i = 0$ (2)

Equation 1 indicates the wheat yield if farmers plant, irrigate and harvest wheat based on decisions considering the weather conditions ('weather smart' farmers), while Equation 2 represents potential yield when farmers grow wheat without considering the weather conditions. The model is estimated using the "Movestay" package of STATA software.

STUDY FINDINGS

Using a decision-based analysis, we attempt to understand the value of short-term forecast-based agricultural advisory using a climate sensitive decision frame for wheat farmers in India (Bihar) and Bangladesh. For the first time to our knowledge, a systematic method is being developed to evaluate short term-climate advisory services. It is expected that this method can be fine-tuned for use in smallholder farming systems in Asia and throughout out the global south where quality historical weather data are available from meteorological services.

This novel "hindcast" approach presents the daily data of key weather variables including maximum temperature, minimum temperature and rainfall for the past cropping seasons with line graphs (Figure 1) and, following an orientation on how to interpret graphs, asks farmers to mark their crop husbandry decisions (planting, irrigating, weeding, fertilizing, harvesting, etc.) in the date lines. This captures the decisions farmers could have modified if they had been provided with forecasts with five days of lead time.
Figure 2 shows that sampled farmers were willing (yes response) to make changes in their practices based on weather forecast information. Options include changing sowing dates, practicing irrigation at critical temperature thresholds to avoid drought stress, or harvesting quickly in case of



Wheat (Mark the Planting date (P) , irrigations (I) , fertilizer applications,(F), Weeding (W) , Harvesting (H) on the above date line

October 2017 (Aasshin 15 Kartik 14)	November 2017 (Kartik 15 to Augrahayon 14)	December 2017 (Augrahayon 15 to Poush 16)	January (Poush 17 to Magh 17)	February (Magh 18 to Falgun 16)	March (Falgun 17 to Chaitra 17)	April (18 Chaitra to 18 Boisakh)

Tick the feasible operations in presence of 5 day forecast

Figure 1: A graphical example of a model hindcast sheet that presented the weather-based decision framework to farmers. This graphic is designed to capture the possible intervention points that farmers could utilize to change their crop management practices based on hypothetical short-term forecast-based climate services in Bangladesh.

untimely rainfall events that may significantly damage mature crops left in the field. The least acceptance to changes in irrigation were observed in Bihar. This could be due to restrictions stemming from the lack of economic or physical access to irrigation water resources in many areas. This indicates that additional development and infrastructural investments are likely to be needed to realize the potential value of forecast-based advisory services.

Figure 3 depicts the variability in the dates of current farming operations, and (notwithstanding other logistical constraints) indicates the possibility of applying timelier according to the weather forecasts.

Above: Preparing fields for irrigation based on weather advisories. Dinajpur, Bangladesh. Photo Credit: Abdul Momin.

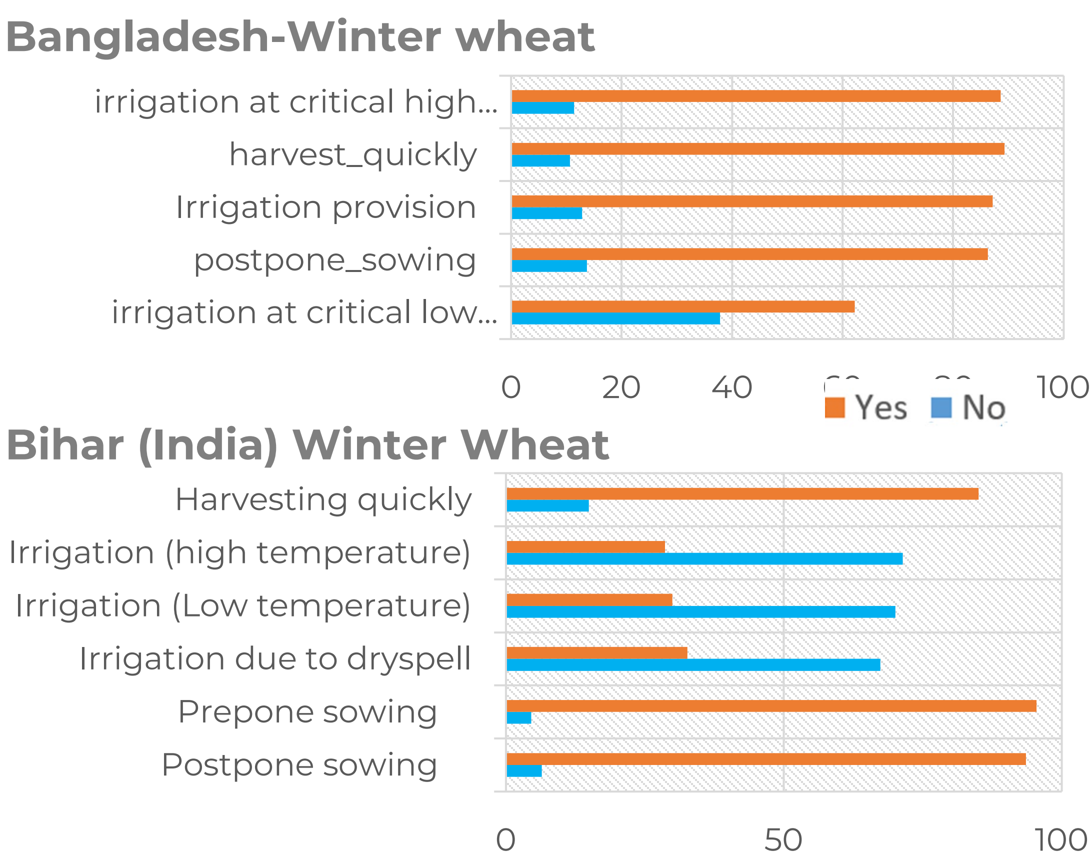


Figure 2: Farmer's willingness to use climate services for altering agricultural operations captured by hindcast experiment. The X-axis describes the number of farmer respondents participating in hindcast experiments.

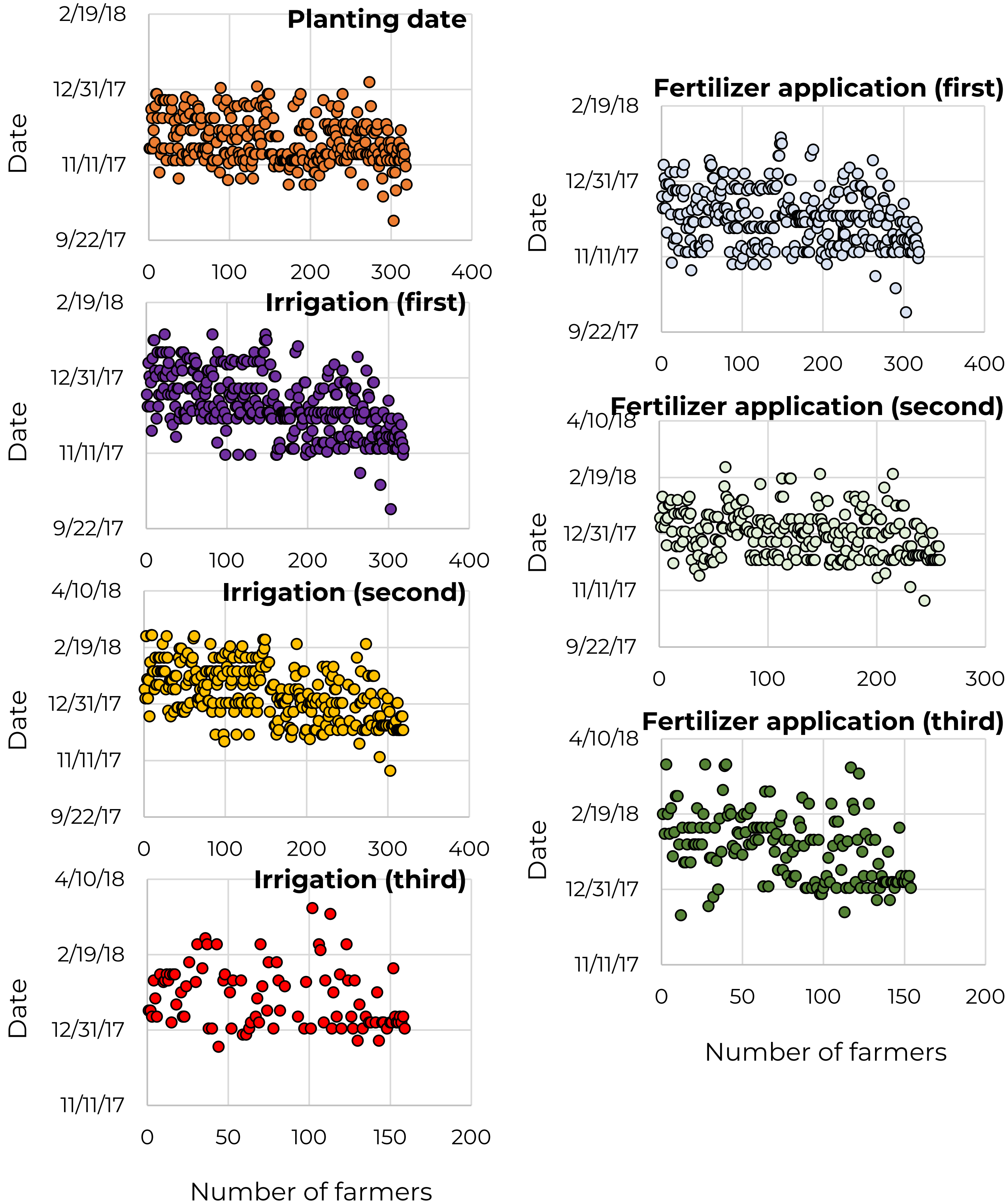


Figure 3: Distribution of agricultural operations by date (*Y*-axis) applied by famers (number of farmers in the *X*-axis) captured during hindcast experiment trials in Bihar, India.

Economic value of forecast based advisory services

A witching regression approach is used to create "what if" scenario to capture the yield shifts if farmers altered their operations within the lead time (five days) of the forecast. In case of wheat, the change in planting date, irrigation on the days that breaches threshold high temperature and harvesting before rainfall event are taken as key decisions that can be taken using the forecasts and examined the additional benefits that would have realized by farmer. The portfolio of factors that may hinder forecast based decision making is also captured.

Table 1: Switching regression model using the hindcast experiment data among wheat farmers in Bangladesh and Bihar (India).

	Variables	Bangladesh (*n* = 800)		Bihar (*n* = 350	
		Coefficient	Standard error	Coefficient	Standard error
Regime 1	Deviation from critical planting date	-13.27**	6.36	-6.2	24.28
	Deviation of irrigation from the date crossing critical temperature limit	-0.0087	0.0058	-22.17	18.24
	Deviation from the date of rainfall during harvest period	-2.23	10.2	17.89	22.8
	DAP fertilizer	-6.3	3.7	1.0	2.11
	Urea fertilizer	2.53**	1.17	9.00**	2.1
	Potash fertilizer	42.49**	4.57	-6.26	12.4
	Constant	499.22	371.62	2077*	1137
Regime 2	Deviation from critical planting date	-0.69	3.78	27.2	25.58
	Deviation of irrigation from the date crossing critical temperature limit	-0.01639**	0.0058	-16.26	20.81
	Deviation from the date of rainfall during harvest period	15.15**	4.7	117.33**	39.04
	DAP fertilizer	-5.88	3.71	-1.3	2.4
	Urea fertilizer	7.12**	2.1	3.6**	1.1
	Potash fertilizer	15.15	4.74	1.9	0.21
	Constant	32.75	145.38	4601.34	1192.408

Farmers' actual timing of management decisions (Figure 3) were compared to a location-specific 'ideal' decision set (planting date, irrigation at critical temperature thresholds and harvesting before rainfall events). Deviations of actual farmer decisions from the ideal were then used to construct a composite index. Employing the index, the dataset is divided two regimes (near and far from ideal) and counterfactuals are generated using the switching regression model.

The simulations using estimated regression regimes show that farmers can achieve a potential wheat yield gain of 15% in Bangladesh and more than 60% in Bihar if they switch to ideal weather sensitive practices (Regime 1) by following the climate sensitive decision making using the forecasted agricultural advisory. Irrigations to avoid heat stress above critical threshold and reduced crop damage due to heavy rainfall events could result in significant yield gains in Bangladesh, though these simulations require field experimental validation. Similar strategies could also lead to moderate gains in Bihar. The negative sign of coefficients in irrigation deviation indicates that the yield penalty will be low if the irrigation is closer to dates of critical temperature stresses, indicative of the potential drought-stress abating effect of irrigation. Similarly, a positive sign for deviations from damaging rainfall at harvest period show the potential benefits of harvesting before crop-damaging extreme rainfall events. The negative sign in case of planting dates deviations indicates the yield penalties associated for days when wheat is sown late. We also collected information on factors affecting planting date decisions of farmers other than weather, which is a key variable determining wheat yield.

Results show that in Bihar, membership in farmers' groups was identified as a major influencing factor while such groups were not a major factor in influencing planting date decisions in Bangladesh. Cash constraints can stifle the planting dates in Bihar farmers, while this appears to be less of a concern in Bangladesh. Drought spells are nonetheless an important factor affecting in planting dates in both countries.

These preliminary results show considerable potential for climate advisory services that aims to reduce the effect of untimely planting dates, heat stress at critical temperature thresholds, and harvest time heavy rainfall damage. However, it is important to note that this initial did not evaluate the potential effect of disease forecasts, which could generate additional economic benefits.

In addition, farmers indicated they were generally interested in accessing these services. Our *ex-ante* evaluation shows that linking agricultural advisory to weather forecasts could potentially aid in improving yield and income levels of wheat farmers in Bihar and Bangladesh. The provision of services however may not be sufficient to achieve changes in productivity without additional strategic development actions. For example, support will also be required to improve timely seed supply, access to credit, timely availability of inputs, and irrigation provision. In conclusion, the results from this study provide preliminary evidence to support further investment in climate services that could generate significant social welfare effects, though further research is needed to validate the hindcast method and to assess climate service effectiveness through rigorous post-hoc studies or randomized control trial approaches.

REFERENCES

Amegnaglo, C.J., Anaman, K.A., Mensah-Bonsu, A., Onumah, E.E. and Gero, F.A., 2017. Contingent valuation study of the benefits of seasonal climate forecasts for maize farmers in the Republic of Benin, West Africa. Climate Services, 6, pp.1-11.

Amjath-Babu, T.S., Krupnik, T.J., Aravindakshan, S., Arshad, M. and Kaechele, H., 2016. Climate change and indicators of probable shifts in the consumption portfolios of dryland farmers in Sub-Saharan Africa: Implications for policy. Ecological indicators, 67, pp.830-838.

Cai, X. and Wang, D., 2007, The Value of Weather Forecast in Irrigation. In AGU Fall Meeting Abstracts. December

Findlater, K., Webber, S., Kandlikar, M. *et al.* Climate services promise better decisions but mainly focus on better data. *Nat. Clim. Chang.* **11**, 731–737 (2021). https://doi.org/10.1038/s41558-021-01125-3.

Hermans, T.D.G., Šakić Trogrlić, R., van den Homberg, M.J.C. et al., 2022. Exploring the integration of local and scientific knowledge in early warning systems for disaster risk reduction: a review. Nat Hazards 114, 1125–1152. https://doi.org/10.1007/s11069-022-05468-8.

Hewitt, C., Mason, S. and Walland, D., 2012. The global framework for climate services. Nature Climate Change, 2(12), p.831.

Hewitt, C., Stone, R. Tait, A., 2017. Improving the use of climate information in decision-making. Nature Clim Change 7, 614–616. https://doi.org/10.1038/nclimate3378

Hossain, P.R., Amjath-Babu, T.S., Krupnik, T.J., Braun, M., Mohammed, E.Y., Phillips, M., 2021. Developing climate information services for aquaculture in Bangladesh: A decision framework for managing temperature and rainfall variability-induced risks. Front. Sustain. Food Syst. 5:677069. doi:10.3389/fsufs.2021.677069.

Karni, E., 2022. A Theory-Based Decision Model. Journal of Economic Theory. 201. 105444. doi:10.1016/j.jet.2022.105444.

Kim, K.H., Hewitt, C.D., Kanamaru, H., Alvar-Beltri,J., Heureux, A.M.C., Park, S., Jung, M., Stefanski, R., 2022. Prospects for enhancing climate services in agriculture. Journal Bulletin of the American Meteorological Society. doi:10.1038/NCLIMATE3378

Lourenço, T., Swart, R., Goosen, H. et al., 2016. The rise of demand-driven climate services. Nature Clim Change 6, 13–14. https://doi.org/10.1038/nclimate2836

Meza, F.J., Hansen, J.W. and Osgood, D., 2008. Economic value of seasonal climate forecasts for agriculture: review of ex-ante assessments and recommendations for future research. Journal of applied meteorology and climatology, 47(5), pp.1269-1286.

Roudier, P., Alhassane, A., Baron, C., Louvet, S. and Sultan, B., 2016. Assessing the benefits of weather and seasonal forecasts to millet growers in Niger. Agricultural and Forest Meteorology, 223, pp.168-180.

Soares, M.B., Alexander, M. and Dessai, S., 2018. Sectoral use of climate information in Europe: A synoptic overview. Climate Services, 9, pp.5-20.

Tesfaye, K., Khatri-Chhetri, A., Aggarwal, P.K., Mequanint, F., Shirsath, P.B., Stirling, C.M., Jat, M.L., Rahut, D.B. and Erenstein, O., 2019. Assessing climate adaptation options for cereal-based systems in the eastern Indo-Gangetic Plains, South Asia. The Journal of Agricultural Science, 157(3), pp.189-210.

Whitehead, J.C., Morgan, O.A., Huth, W.L., 2015. Benefit Transfers with the Contingent Valuation Method. In: Johnston, R., Rolfe, J., Rosenberger, R., Brouwer, R. (eds) Benefit Transfer of Environmental and Resource Values. The Economics of Non-Market Goods and Resources, vol 14. Springer, Dordrecht. https://doi.org/10.1007/978-94-017-9930-0_7

Zinyengere, N., Mhizha, T., Mashonjowa, E., Chipindu, B., Geerts, S. and Raes, D., 2011. Using seasonal climate forecasts to improve maize production decision support in Zimbabwe. Agricultural and Forest Meteorology, 151(12), pp.1792-1799.

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SUGGESTED CITATION

Amjath Babu, T.S., Krupnik, T.J., Timsina, J. 2022. Evaluating the value of agricultural climate services using hindcast experiments Methods development in India and Bangladesh. Work Package 5, Research Note 5. CGIAR research initiative on Transforming Agrifood Systems In South Asia (TAFSSA). International Maize and Wheat Improvement Center. Dhaka, Bangladesh.

FUNDING ACKNOWLEDGEMENT

We would like to thank all funders who supported this research through their contributions to the CGIAR Trust Fund: https://www.cgiar.org/funders/

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