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Improving performance of index insurance using crop models and phenological monitoring

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Extreme weather events pose significant risks to the livelihoods of smallholder farmers across Asia and Africa. Weather index-based insurance provides a potential solution to mitigate risks caused by crop failures, providing farmers with a payout in the event of a poor harvest. It also reduces costs relative to traditional indemnity insurance by eliminating the need for resource-intensive, in-situ assessment of losses. However, one challenge associated with weather index-based insurance is basis risk – where the payouts triggered by the index do not match actual crop losses. High levels of basis risk are observed across many existing weather index-based insurance products, and represent a key constraint to successful upscaling.

A common feature of existing weather index-based insurance contracts is that payouts are triggered based on weather indices defined over fixed calendar periods, specified to capture the typical duration of the crop growing season or key phenological stages in a given agricultural system. In reality, however, the timing of a crop's sensitivity to weather often varies significantly between individual plots or farmers due to differences in management practices (e.g., sowing date, variety choice) and meteorological conditions (e.g., temperature and precipitation) that affect rates of crop development. Failure to consider this heterogeneity is potentially a significant driver of basis risk, and suggests that opportunities may exist to improve the quality of index insurance by designing phenology-specific insurance contracts.

In this study, we evaluate the impacts of improved monitoring of crop phenology on the performance of index-based crop yield models through a range of synthetic model-based simulated experiments for wheat and rice production in Haryana and Odisha states in India. We use a calibrated process-based crop simulation model (APSIM) to evaluate yields for a range of potential weather realizations and agricultural management practices typically observed in our case study regions. Subsequently, we develop non-linear statistical (i.e. index-based) models using non-parametric regression techniques (Multivariate adaptive regression splines; MARS) to reproduce APSIM-simulated yields as a function of rainfall and temperature conditions during key sensitive crop growth stages.

Our results show that by considering field-level heterogeneity in crop phenology and development, it is possible to reliably estimate (>0.8 r-squared) wheat and rice yields. In contrast, model performance deteriorates significantly when variability in growth stage between individual simulated fields is not considered or when weather predictors are aggregated over the entire growing season as opposed to specific growth stages. These findings show that considering crop phenology can dramatically improve the performance of statistical yield models and, in turn, the accuracy of an index-based insurance product. Nevertheless, reductions in basis risk must also be balanced against the increasing complexity and implementation costs of these potential products in smallholder environments.