

EGU21-9534

<https://doi.org/10.5194/egusphere-egu21-9534>

EGU General Assembly 2021

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Overcoming basis risk in agricultural index insurance using crop simulation modeling and satellite crop phenology

Mehdi H. Afshar¹, Timothy Foster¹, **Thomas P. Higginbottom**¹, Ben Parkes^{1,2}, Koen Hufkens³, Sanjay Mansabdar⁴, Francisco Ceballos⁵, and Berber Kramer⁵

¹Department of Mechanical, Aerospace and Civil Engineering, University of Manchester, Manchester, UK

²Centre for Crisis Studies and Mitigation, University of Manchester, Manchester, UK

³Computational & Applied Vegetation Ecology Lab, Ghent University, Ghent, Belgium

⁴Dvara E-Registry, Hyderabad, India

⁵Markets, Trade and Institutions Division of the International Food Policy Research Institute (IFPRI), Washington, D.C., United States

Extreme weather causes substantial damage to livelihoods of smallholder farmers globally and are projected to become more frequent in the coming decades as a result of climate change. Index insurance can theoretically help farmers to adapt and mitigate the risks posed by extreme weather events, providing a financial safety net in the event of crop damage or harvest failure. However, uptake of index insurance in practice has lagged far behind expectations. A key reason is that many existing index insurance products suffer from high levels of basis risk, where insurance payouts correlate poorly with actual crop losses due to deficiencies in the underlying index relationship, contract structure or data used to trigger insurance payouts to farmers.

In this study, we analyse to what extent the use of crop simulation models and crop phenology monitoring from satellite remote sensing can reduce basis risk in index insurance. Our approach uses a calibrated biophysical process-based crop model (APSIM) to generate a large synthetic crop yield training dataset in order to overcome lack of detailed in-situ observational yield datasets – a common limitation and source of uncertainty in traditional index insurance product design. We use this synthetic yield dataset to train a simple statistical model of crop yields as a function of meteorological and crop growth conditions that can be quantified using open-access earth observation imagery, radiative transfer models, and gridded weather products. Our approach thus provides a scalable tool for yield estimation in smallholder environments, which leverages multiple complementary sources of data that to date have largely been used in isolation in the design and implementation of index insurance

We apply our yield estimation framework to a case study of rice production in Odisha state in eastern India, an area where agriculture is exposed to significant production risks from monsoonal rainfall variability. Our results demonstrate that yield estimation accuracy improves when using meteorological and crop growth data in combination as predictors, and when accounting for the timing of critical crop development stages using satellite phenological monitoring. Validating against observed yield data from crop cutting experiments, our framework is able to explain

around 54% of the variance in rice yields at the village cluster (Gram Panchayat) level that is the key spatial unit for area-yield index insurance products covering millions of smallholder farmers in India. Crucially, our modelling approach significantly outperforms vegetation index-based models that were trained directly on the observed yield data, highlighting the added value obtained from use of crop simulation models in combination with other data sources commonly used in index design.