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# Assessing pricing assumptions for weather index insurance in a changing climate

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Weather index insurance is being offered to low-income farmers in developing countries as an alternative to traditional multi-peril crop insurance. There is widespread support for index insurance as a means of climate change adaptation but whether or not these products are themselves resilient to climate change has not been well studied. Given climate variability and climate change, an over-reliance on historical climate observations to guide the design of such products can result in premiums which mislead policyholders and insurers alike, about the magnitude of underlying risks. Here, a method to incorporate different sources of climate data into the product design phase is presented. Bayesian Networks are constructed to demonstrate how insurers can assess the product viability from a climate perspective, using past observations and simulations of future climate. Sensitivity analyses illustrate the dependence of pricing decisions on both the choice of information, and the method for incorporating such data. The methods and their sensitivities are illustrated using a case study analysing the provision of index-based crop insurance in Kolhapur, India. We expose the benefits and limitations of the Bayesian Network approach, weather index insurance as an adaptation measure and climate simulations as a source of quantitative predictive information. Current climate model output is shown to be of limited value and difficult to use by index insurance practitioners. The method presented, however, is shown to be an effective tool for testing pricing assumptions and could feasibly be employed in the future to incorporate multiple sources of climate data.



## 1. Introduction

### 1.1. Index insurance

Many private and public insurance schemes covering risks in the developed world are considered infeasible in developing countries (Skees et al., 1999). Traditional forms of *claims based* crop insurance cover multiple perils, including weather related perils such as hail and drought, as well as non-weather perils such as pest and disease outbreaks. However, the

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associated premiums are usually unaffordable for low-income small-holder farmers and the speed at which payouts are made is often too slow to alleviate the adverse impacts of loss events on their livelihoods. Alternative forms of crop insurance are being sought and over the past decade, a number of *index* insurance products have been developed, offering lower premiums and speeding up the payout process.

Index insurance products for agriculture can be divided into two types: area yield index insurance and weather index insurance (WII). For area yield index insurance, "the indemnity is based on the realised average yield of an area such as a county or district, not the actual yield of the insured party", while for WII, "the indemnity is based on realisations of a specific weather parameter measured over a pre-specified period of time at a particular weather station" (World Bank, 2011). Thus WII loss estimates are based on a proxy for loss rather than upon the individual loss of each policyholder (Skees et al., 2007) and once the proxy is triggered (e.g. rainfall accumulation falls below a certain threshold) all policyholders in the area covered receive a payout. The administration costs per policy of index insurance are lower than traditional claims-based forms of insurance as the traditional claims-handling process[1] is bypassed. As a consequence premiums can be lower, so index insurance provides an attractive alternative for small-holder farmers and insurers in developing countries. It is unsurprising therefore that over the past decade there has been an increase in the provision of crop index insurance for weather related perils such as drought, excess rainfall and wildfire. Yet from an insurer's perspective, setting the thresholds at which payouts for a given peril are triggered is a difficult task, not least because a relationship between meteorological events and the incurred losses must be established and quantified. As a result WII is associated with "basis risk" which represents the risk that the payout a policyholder receives does not match the actual loss experienced (USAID, 2006; Barnett and Mahul, 2007). Skees (2008) states that because of such risks, index-based schemes are not replacements for traditional insurance but rather serve as a foundation for developing financial risk transfer mechanisms in new markets.

In contrast to traditional claims-based insurance, however, the uncertainties associated with the response of the physical climate system are disaggregated from socio-economic considerations in WII products. It is therefore much simpler to assess the sensitivity of the pricing structure to climate variability and change.

The United Nations advocates the use of WII (Schwank et al., 2010; United Nations, 2012) as a "soft" climate change adaptation measure (Hallegate, 2009) within developing countries but whether or not index insurance policies are themselves resilient to climate change has received little attention in the climate change adaptation discourse. Climate science has an important role to play in addressing this problem (Hellmuth et al., 2009). Alderman and Haque (2007) note that in order for index insurance to be effective, probability distributions of the relevant variables need to be reliably estimated. In the context of climate change, meteorological variable time series are unlikely to be stationary (McGregor, 2006) so WII products designed using observed data alone will be at risk of under- or over-estimating the probabilities of triggering payments. This risk is present for policies designed for use both today and in the future because under climate change past observations do not represent today's climate (Daron and Stainforth, 2013; Stainforth et al., 2013).

Climate models are obvious sources of information on the nonstationarity of the relevant time series (Peicai et al., 2003; McGuffie and Henderson-Sellers, 2005). However, given the much debated uncertainties in their interpretation (Stainforth et al., 2007a), it is questionable whether they can be reliably used to inform WII products. Some research has been conducted to examine the benefits of incorporating seasonal climate model forecasts into the provision of WII (Osgood et al., 2008; Carriquiry and Osgood, 2012). Osgood et al. (2008) present an approach to combine the provision of loans with index insurance using seasonal forecasts. The authors conclude, "a scheme that uses skillful seasonal forecasts to adjust the bundled loan-insurance contract according to expected rains can substantially benefit participating farmers". Considering much longer time scales, Bell et al. (2013) analyse the value of paleoclimate reconstructions (specifically tree-ring data) for index insurance in providing additional information to improve our understanding of the underlying climate distributions and past variability. In this paper the focus is on decadal and multi-decadal time scales and the assessment of WII pricing assumptions both today and in the future, in the context of climate change. The key questions relate to how we evaluate the available probability distributions and how we integrate multiple sources of climate information. While our study is focused on WII, the implications of our results have broader relevance to climate-sensitive decisions across the insurance sector.

Hochrainer et al. (2008) state that the viability of microinsurance schemes[2] can be viewed from two perspectives: from the view of insurers (the supply-side perspective) and from the view of the clients (the demand-side perspective). This study investigates the extent to which climate model information can inform the supply-side. For this purpose a Bayesian Network (BN) structure is presented as a means of combining different sources of quantitative climate information.

### *1.2. Bayesian networks for climate change applications*

A BN is a graphical/conceptual model with an underlying probabilistic framework which characterizes and quantifies an outcome of interest, along with the relevant variables and the causative interactions (Donald et al., 2009). BNs propagate probabilities throughout the network according to Bayes Theorem (Box and Tiao, 1973). They can be used to explicitly quantify risk and uncertainty drawing on evidence from diverse sources, including both subjective beliefs and objective data (Fenton and Neil, 2004). Cain (2001) distinguishes between two potential uses of a BN:

[1] The process of verifying that a loss has occurred and administering a payout appropriate for the level of damage.

[2] Insurance characterized by low premium and low caps or low coverage limits.