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Integrating high resolution soil data into federal crop insurance policy: Implications for policy and conservation

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ABSTRACT

Well-designed and executed policies are critical for aligning sustainability incentives and enabling future agricultural productivity growth. In the U.S., government-administered crop insurance is the primary direct mechanism through which agriculture is subsidized and represents over $100 billion in liabilities annually. Despite the importance of soil properties in determining crop yield formation and risk, the Government does not consider any soil information in generating premium rates under the Federal Crop Insurance Program. The purpose of this study is to investigate the potential of integrating high-resolution soil data into modeling of field-level insurance rates in large-scale applications. Here, using the actual distribution of soil quality across crop fields in a high production region, models are developed to incorporate soil data into insurance rates and then evaluated to investigate the magnitude of risk differentials across different soil qualities. These soil-conditioned results were then compared to rates that would have been generated by the Government's current soil-naïve methodology. This study indicates that the degree to which soils vary within a county is highly significant, leading to rating errors of 200% or greater. Implications of ignoring soil information and operational considerations of modifying this cornerstone program are discussed.

1. Introduction

Maintenance of soil health is critical to ensuring the future of agricultural productivity and adapting to climate change. Likewise, well-designed policies are necessary for fostering appropriate production incentives and accommodating innovations in conservation and sustainability. The “Big Data” revolution has led to an increased interest in exploring opportunities to employ high-resolution data in large scale policy applications to improve sustainability of the agricultural system, which previously were impractical or impossible. Given the pervasiveness of economic policy on production decisions, it is important to have a sound understanding of how agricultural policy in major markets impacts incentives.

In the U.S., government-administered crop insurance is the primary direct mechanism through which agriculture is subsidized and represents over $100 billion in liabilities annually (Woodard, 2013). The Federal Crop Insurance Program (FCIP) is a public-private partnership. The Federal Government–via the United States Department of Agriculture Risk Management Agency (RMA) and Federal Crop Insurance Corporation (FCIC)–is solely responsible for determining the set of insurance products, rules, subsidies, and rates/prices for the insurance. The program works by insuring farmers against yield or revenue losses in the event of low prices, drought, or other perils. Private companies sell the insurance and bear the primary financial risk, but do not have authority over rate-setting or rule-making procedures. Insurers must sell insurance to any producer who wishes to buy it, under the prices and rules set by the government, and in return the Government provides a partial layer of reinsurance coverage to the insurance companies. Farmers pay part of the premium, and participation is optional. Farmers also have the option of insuring at different coverage levels/deductibles (with higher coverages having higher premium rates). Premium rates vary based on region, crop, coverage level, and product type.

Of fundamental importance to any insurance market is the ability to set insurance rates that properly reflect risk, and by law the Government should attempt to price premiums as actuarially fair so that the expected insurance loss payments equate to the unsubsidized premium (Woodard et al., 2012a). Failure to do so can lead to what is known as adverse selection, whereby the insured

Abbreviations: RMA, Risk Management Agency; FCIC, Federal Crop Insurance Corporation; APH, Actual Production History; CLUs, Common Land Units; FSA, Farm Service Agency; SPR, soil productivity rating.

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may be incentivized to only buy insurance when they have a high likelihood of collecting a claim, due to possessing some risk factor not being observed by the insurer or rate setting authority (in this case, the Federal Government). Lower risk producers will then be less likely to participate, which can lead to higher rates over time, higher and less predictable insurer losses, low participation, higher taxpayer costs, and less efficient markets. Relatedly, inefficient rating of risk can lead to adverse incentives. For example, severely mispriced crop insurance could potentially result in producers choosing to produce on higher risk or environmentally sensitive land they might not otherwise (Lubowski et al., 2006). There have been documented cases in which poorly designed government insurance policy can lead to adverse incentives regarding which management practices producers adopt, potentially dis-incentivizing conservation-oriented cropping practices (Woodard et al., 2012b).

Soil type is an important factor in determining crop yield potential and subsequently would be expected to affect insurance losses. Previous work has highlighted the importance of such intra-regional yield variability (e.g., Claasen and Just, 2011; Lobell et al., 2007; Popp et al., 2005; Woodard, 2014), yet little work has been done on evaluating the impact of soil on probabilistic yield models in large-scale, high resolution contexts. Surprisingly, soil information is not utilized by the Government when determining premium rates under the current U.S. crop insurance program, and no study has yet linked high-resolution soil data back to field-level yield data explicitly on large scales for evaluating or pricing insurance. The RMA's rating procedures rely on a noisy measure of average historical yields across mixed fields as the primary basis for classifying rates within a county. Thus, rates do not reflect full information regarding soils, specific years reported, nor even fields reported. In 2009, the RMA began collecting data matched to individual contiguous farming parcels, Common Land Units (CLUs, or roughly speaking, fields), and reached 100% target reporting by 2016. High-resolution soil type data are also readily available in the U.S.; however, despite availability of these data, the information is yet un-used by RMA for pricing this program.

The purpose of this study is to investigate the potential of integrating high-resolution soil data into the modeling of micro-level (field) yield distributions and insurance rate-setting for large-scale applications. Here, using the actual distribution of soil quality across crop fields in a high production region, models are developed to incorporate soil data into insurance rates. Results are evaluated to assess the magnitude of risk differentials across different soil qualities and compared to rates that would have been generated by the Government's current soil-naïve methodology. Implications for policy and operational considerations are also discussed.

2. Methods and data

High resolution soil type data from the SURRGO soil dataset (Natural Resources Conservation Service, 2015), along with Common Land Unit (CLU) field boundary maps maintained by the Farm Service Agency (FSA), are matched with yield models estimated from a large multi-decade field level dataset consisting of over 120,000 annual field level observations covering 1980–2008 to conduct an insurance rating analysis for the state of Illinois for corn. Statistical crop yield models are estimated to obtain soil and location conditional yield distributions and insurance rates. These models are then overlaid onto the CLU field maps maintained by the Farm Service Agency (FSA), and compared to the rates which the current RMA rating system would generate in order to evaluate the magnitude and importance of omitting soil information in administering the crop insurance program. The documentation regarding the RMA rating system is contained in various data files and publications on RMAs website; an installation of this system was constructed by the authors, and a public web API is available online at *Ag-Analytics.Org* (Woodard, 2016a,b). The premise of the methodology is to first construct estimates of what RMA would have charged for insurance on different fields/farms, and then to estimate yield models conditional on soil data to estimate actual risk of loss (i.e., insurance premium rates) for those fields; these implied loss rates which take into account soil are then compared to the RMAs published rates. Cropland Data Layers from the National Agricultural Statistics Service are also employed to filter land units for the specified crop to ensure evaluation is conducted only on fields where corn crops are grown. Next an explanation of the insurance structure is provided, followed by a discussion of the estimation of crop yield distributions and their use in rating (or pricing) the insurance.

2.1. Crop insurance product structure

Crops insurance is structured such that it pays an indemnity when realized yields or revenue is below some elected coverage level multiplied by a yield or revenue baseline. The coverage level is equal to one minus the deductible percent, and typically ranges between 50%-85%, with higher coverage levels demanding a higher premium rate; the farmer elects the coverage level amount, and pays more for insurance with a higher coverage level. The amount the farmer pays for coverage to the insurer is known as the premium. Payments for losses to the farmer are called indemnities. The baseline yield against which losses are evaluated, known as the Actual Production History (*APH*), is an average of between the last 4 and 10 years of data (depending on how many years of reportable data the producer possesses). Explicitly, the standard yield insurance contract works by insuring yield losses, with the payment per acre of land insured (indemnity/acre) calculated as:

$$Indemnity/Acre = Max(0, APH \cdot Cov - y) * BP$$

where, *Cov* is percent coverage level insured as elected by the producer (between 50%-85%, similar to a deductible), *y* is the end of season yield per-acre (for corn, measured in bushels per acre), and *BP* is the base crop price per unit of the crop being insured (currently around $4/bushel for corn). Thus, the contract pays the farmer for any eventual yield losses below some known baseline amount (the historical average times the coverage level elected, minus the actual yield at the end of the season) at the stated base price. Note that higher coverage levels imply larger insurance payments when there is a loss, so higher coverage level products also have a higher premiums. For example, if the APH is 100 bu./acre, the BP is $4.00/bu., and coverage level is 50%, and the eventual yield is 40 bu./acre, then the indemnity would be equal to $40/acre.

2.2. Yield distribution modeling

Statistical yield models are employed for the basis of this study, as is standard in insurance contexts. While mechanistic crop models are useful in many branches of science, direct estimation of yield models using historical data has been argued on empirical grounds in many contexts (see e.g., Peng et al., 2004). Indeed, in insurance applications, empirical/statistical approaches are virtually exclusively employed, and are thus adopted here. Farm level yield data are obtained from the Illinois Farm Business Farm Management dataset from 1980 to 2008. The data report annual corn yields and acreage by farm along with which county the farm exists. The data also report a field specific soil productivity rating (SPR) using the Illinois Bulletin 810 Soil Series (Olson et al., 2000). The main dataset consisted of 121,416 observations. First, I