First Use of a New Cropping System Resilience Metric
Analysis of a 30-yr I-State dataset suggests early gains have all been lost

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America's row crop farmers are the most productive in the world, and they do this in the face of an increasing number of unprecedented threats: price shocks on inputs, uncertain local and global markets, trade policy, food system policy, extreme weather events, and a growing number of unfounded environmental claims (e.g., 'Corn Sweat'). For US farmers, this all means that becoming more resilient to the impact of an expanding number of unpredictable shocks is a growing and urgent imperative.

Organizations such as Field to Market have developed metrics intended to encourage farmers to adopt practices that are more 'sustainable' or 'regenerative' – as defined by the consensus opinions of a broad set of stakeholders (e.g., academia, civil society, food industry, government, etc.). Remarkably, however, the suites of current metrics employed by Field to Market and various private sector players do not currently include any that are specifically intended to quantify and/or improve farm-scale resilience.

Instead, there is an unwarranted focus on the alleged environmental harm caused by farming activities, particularly on the reduction of carbon emissions – unwarranted, because America's row crop operations comprise such a tiny slice of global carbon emissions (<1%). And, as noted in a previous blog, the harsh reality is that none of the massive efforts currently being made (mostly in the Western World) to reduce carbon emissions are having any measurable impact at the global scale. This means that US farmers will face an increasing number of climate-related threats (e.g., more intense droughts, heat stress, heavier rainstorms, etc.) and all of the other well-documented results of unbridled global growth in carbon emissions.

Given the reality of what US farmers now actually face, what is needed is a more balanced approach, one that encourages farmers to adopt practices that will make them more resilient to not just climate and weather related shocks, but to all of the other chaos-inducing shocks coming at them. In an earlier blog, I mentioned several of the practices that can help build such resilience: e.g., greater diversity in crop production and rotations, conservation tillage, cover crops, etc.

As a first step in taking a quantitative approach to evaluating farm-scale resilience, I have collaborated with a number of other scientists to develop an initial version of a proposed Cropping System Resilience Metric (see equation 1). It contains a term related to the productivity and diversity of the crop mix (adapted from the general formula for the Shannon Diversity), as well as a term related to the resilience-benefits of specific practices (such as conservation tillage and cover crops):

$$Cropping\ System\ Resilience = -\sum_i P_i \ln(P_i) + \sum_i RB_i Practice_i \qquad (1)$$

For the first summation, P_i is the share (by harvested amount) of the ith crop for the chosen region (e.g., farm, county, state, etc.). (Note that if production of a crop item falls to zero then the contribution for that item becomes zero. This requires application of *L'Hôpital's* rule, due to the undefined nature of ln(0)). Although this diversity indicator was originally developed in the ecological sciences, it has been applied by several author teams as a measure of food production diversity (e.g., Gustafson et al., 2016). The more unequal the distribution, the smaller the indicator value. The summation can reach higher values as the number of crops increases, meaning that a scaling factor (not shown in equation 1) is required when applying this approach to any specific scenario (see below).

The second summation captures the regional resilience benefits that accrue due to the presence of other resilience-building practices on the landscape, such as conservation tillage and cover crops. RB_i is the incremental resilience benefit of the practice and $Practice_i$ is the proportion of the region on which the practice has been adopted. The overall metric is normalized to a 0–100 scale by application of a suitable multiplicative factor, which must be determined based on the number of crops and practices being considered. It should be noted that I have scaled the metric such that maximum system resilience gives a value of 100.[1]

As a first application of this newly proposed Cropping System Resilience Metric (equation 1), it was calculated at the state scale for a 30-year period over five-year intervals (culminating in USDA AgCensus years) for the seven row crops that are cultivated to a meaningful extent in the 'I-States' (Illinois, Indiana, Iowa): alfalfa, barley, corn grain, corn silage, sorghum, soybeans, wheat. The data sources included the USDA NASS and the Conservation Technology Information Center (for the adoption of conservation tillage and row crops). For this initial application of the metric, equal weighting was employed among the three component indicators. I leave it as future work to develop a proper statistical analysis in which the weighting factors are quantified on the basis of their relative importance in improving financial outcomes at the farm-scale.

As for now, accepting this initial method for quantifying the metric (as shown in Figure 1), there has been a recent overall decline in the adoption of the two most important resilience-building practices (crop production diversity and conservation tillage), despite a small increase in cover crop adoption. As a result, this first application of the proposed Cropping System Resilience Metric for the important row crop states of Illinois, Indiana, and Iowa suggests that all of the initial gains in system resilience during the first two decades of this period have been lost, and are now trending in a negative direction. Thus the need for encouraging/incentivizing accelerated and/or renewed adoption of resilience-building practices is seen to be urgent!

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[1] If this metric were to be adopted by Field to Metric, the 'directionality' would need to be flipped, because their metrics are currently scaled such that '0' is good and '100' is bad.
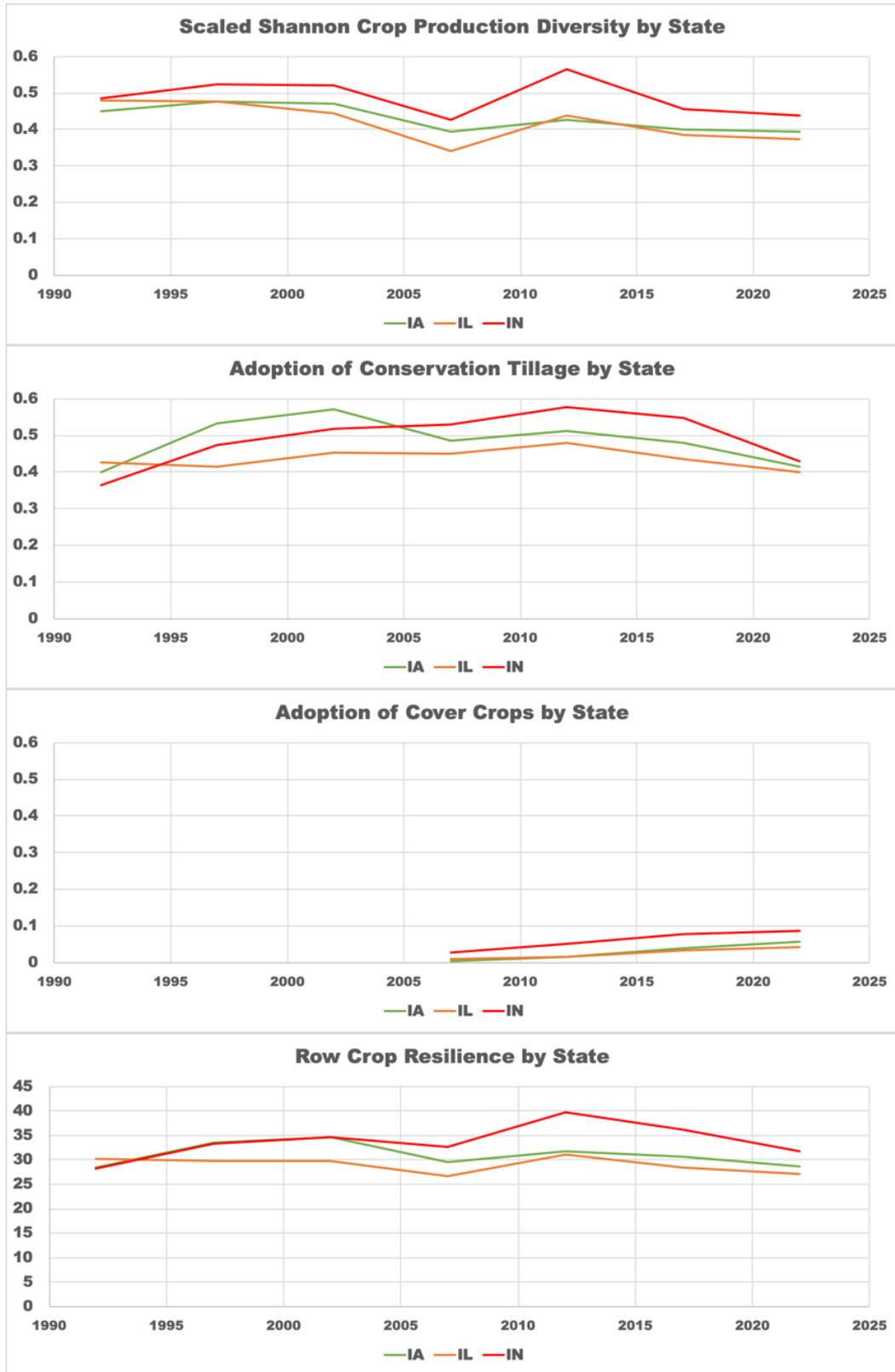
Figure 1. This example is for seven crops (alfalfa, barley, corn grain, corn silage, sorghum, soybeans, wheat) and employs equal weighting among the three resilience-building practices to construct the overall resilience metric.