Estimation of the changes in the dynamics of tillage choices in Iowa, 1992-2008

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The benefits of conservation tillage are only fully realized when conservation tillage is used continuously over a number of years. However, little is known about the dynamics of farm’s tillage choices. Panel tillage data are sparse and incomplete. This study presents a method that uses the data on tillage shares to infer the probabilities of rotational and continuous conservation tillage. Using the framework of first-order Markov chains, we model tillage dynamics and estimate the probabilities of transition from one tillage-crop combination to another tillage-crop combination with spatially aggregated data. We use the combination of Quadratic Programming and Generalized Cross-Entropy to infer the transition probabilities for the period of 1992-2008. We estimate that approximately one million acres of corn and soybeans moved away from continuous conservation tillage to greater tillage intensity practices during the period 2001-2008. Geographically, more acreage in the southern and eastern Iowa – where soils are of lower productivity and more likely to be classified as Highly Erodible Land – were taken out of continuous conservation tillage practice between 2001 and 2008, when compared with the rest of the state.

**Introduction**
- The benefits of conservation tillage (CT) are fully realized when conservation tillage is used continuously.
- Farmers often alternate conservation tillage with conventional tillage because farmers’ crop and tillage choices are interdependent; farmers are more likely to adopt CT on soybeans than on corn (Hill, 2001; Wade et al., 2015; Claassen & Ribudo, 2016; Kurkalova & Tran, 2017).
- Tillage adoption data for multiple consecutive years are sparse and often incomplete.
- Due to confidentiality concerns, collected tillage data are often available to researchers in aggregated form only, such as county/state averages (e.g., USDA-NASS Census of Agriculture 2012, USDA ARMS, NRI-CEAP and CTIC tillage data).
- Most of previous studies did not explicitly consider the continuity of tillage (Knowler et al., 2014).
- Tillage dynamics are often overlooked when process-based model (e.g., Soil and Water Assessment Tool) is used (Papagopoulou et al., 2015).

**Objectives**
2) Evaluate the spatial and temporal variability of the use of continuous conservation tillage, rotational conservation tillage, and continuous conventional tillage in the state.

**Data and Methods**
We use county-level tillage data from Conservation Tillage Information Center (CTIC); the data were collected annually 1992-1997, biannually 1998-2004, and annually for selected counties 2006-2008.

**Statistical model**
Estimating transition matrices includes two steps:
1) We use Quadratic Programming to estimate prior transition matrices with time-ordered aggregate data from 1992 to 1997 (Kelton, 1994; Kurkalova & Tran, 2017; Lee et al., 1970; Tran & Kurkalova, 2016).
2) We then estimate non-stationary transition matrices for 99 Iowa counties.
   - We estimate transition matrices using Cross-Entropy approach.

**Cross-Entropy and Markov model**
\[
\begin{align*}
\sum_{i=0}^{n} p_i(t-1) & - \prod_{j=1}^{m} p_j(t) = \sum_{i=0}^{n} p_i(t) - \prod_{j=1}^{m} p_j(t) \\
\sum_{i=0}^{n} p_i(t-1) & - \prod_{j=1}^{m} p_j(t) = \sum_{i=0}^{n} p_i(t) - \prod_{j=1}^{m} p_j(t)
\end{align*}
\]

**Results**
- We estimate that approximately 0.5 million acres of corn and soybeans moved away from CCT during 2001-2008 when 48 out of 99 counties considered.
- Iowa farmers are more often than not rotate CT with conventional tillage; total acres under RCT is always higher than total acres of CCT and CCV combined.

**Conclusions**
- We also found that the increase in CT adoption rates do not always transfer to higher use of CCT. Thus, using CT adoption rates as a criteria to evaluate the success of conservation efforts might be misleading.
- A potential extension of this model is to evaluate the effect of natural and economic conditions on the dynamics of tillage by treating transition matrices as a function of these conditions.

**References**