**What do we know about the continuous maize penalty?**

The yield reduction from growing maize continuously on the same field has not decreased over time.

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| Chart, scatter chart  Description automatically generated |
| Grain yields for maize grown at high nitrogen fertilization rates (≥180 kg ha-1) continuously (yellow triangles), in rotation with soybean (blue circles), and the difference between the rotated and continuous maize (pink squares) at seven Illinois and seven Iowa sites between 1999 and 2016 for a total of 179 site years |

In any given year, this penalty is composed of both nitrogen- and non-nitrogen components which can be determined from the nitrogen-response curve.

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| Chart, surface chart  Description automatically generated |
| (Top) Nitrogen response curves from IAX in 2003 with quadratic plateau-estimated agronomically optimum nitrogen rates (AONRs) which are used to estimate the contribution of nitrogen- (N) and other factors to the continuous maize yield penalty. (Bottom) Size of each component by site-year, ordered from largest to smallest non-N yield reduction; if quadratic plateaus failed to fit a given site year’s data the components were deemed undeterminable. Fits for all site years is available in supplementary material. |

On average, the non-N yield reduction from growing corn continuously is 14% of the rotated maize yield, but varied from 0-.

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**Intro stuff**

Nitrogen-rate trials provide a means of assessing a maize crop’s agronomically-optimum nitrogen rate (AONR), which occurs at the point where application of additional nitrogen fertilizer does not translate to increases in grain yield. For the past 20 years, two maize-based systems have been included in Iowa and Illinois university nitrogen rate trials: maize grown in alteration with soybean (rotated maize), and maize grown continuously (continuous maize). In a given year, at the rotated maize’s AONR, continuous maize is likely to yield less than the rotated maize. This yield gap can be partially overcome by adding additional nitrogen (N) fertilization (~50 kg N/ha, cite) to the continuous maize system. However, even at high N rates, continuous maize will achieve lower maximum yield levels compared to rotated maize (CITE). This difference in the maximum yields attainable in rotated- and continuous-maize systems is referred to as the ‘continuous maize penalty’. With an estimated XX hectares of land in continuous maize acres, the penalty equates to XX in lost grain production, or $XX. It is also a major issue for process-based crop models (e.g. DSSAT, EPIC, APSIM), as although it is a repeatable, observable, and well-documented phenomena, the underlying mechanisms are unknown. The inability of crop models to incorporate this yield penalty results in consistent over-predictions of continuous maize yields, which has significant implications when predicting long-term impacts of cropping systems on carbon balances, nutrient leaching, residue cover, and fertilizer requirements (CITE), as well as when considering impacts of climate change on crop production (CITE).

The over-arching problems associated with understanding underlying mechanisms driving the continuous maize penalty are as follows:

1. It is unknown whether rotated- or continuous-maize yields are driving the yield gap. This is an important distinction, as it signifies whether rotating maize is increasing the yield potential of the environment, or if continuously growing maize is preventing the crop from achieving its yield potential. The two mechanisms have different implications for both management and modelling, and there has been little work to elucidate this distinction.
2. It is unknown whether genetic improvements over the past 20 years have led to changes in the continuous maize penalty. Understanding trends over time could help shed light on possible mechanisms, leading to model improvement.
3. The penalty can be conceptualized as consisting of two components: one component can be overcome through nitrogen fertilization, while the other cannot. Major crop models (APSIM, DSSAT, EPIC) can only capture the nitrogen-derived component. The relationship between the two components is unclear, and whether there are independent drivers of each component has implications for both management and modelling.
4. To our knowledge, there has been no conceptual diagram proposed for organizing potential mechanisms contributing to the continuous maize penalty into an actionable framework. Additionally, the feasibility of proposed mechanisms has not been investigated.

To address these knowledge gaps, we used XXX site-years of nitrogen rate trials in Iowa and Illinois (i) to explore the variation in the two components (nitrogen, non-nitrogen) of the continuous maize penalty, and (ii) to calibrate the Agricultural Production Systems Simuator (APSIM) model to explore the feasibility of proposed non-nitrogen contributions to the penalty.

Specifically, our objectives were to:

1. Explore the trends in the continuous maize penalty over the past 20 years

High N, gap over time, cont corn yields are driving the gap 🡪 should focus on contin corn in model tweaks. Add definitions of continuous corn penalty, vs rotation effect. Make small viz. X% is nitrogen related, x% not. Fig – gap not changing over time (raw or %)

1. Quantify variation in non-nitrogen components of the continuous maize penalty

They are not related. % env and % site for non-nitrogen component. Rain 2 weeks before. Not residue.

Proposed hypothesis, citation(s). Conceptual figure? Statistical model results?

1. Model exploration study + directions for future research

Sensitivity stuff scenario analysis fig. We need residue msmts to do path analysis

What is driving the gap + gap over time

Two components

Hypothesis testing with models

Future efforts