**Decomposing the continuous maize penalty**

The continuous maize penalty has not changed over time.

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| Map  Description automatically generated |
| (Left) Geographic location of the 14 sites included in this dataset, with each site representing 8-18 site-years for a total of 179 site-years. (Right) Grain yields for maize grown at high nitrogen fertilization rates (≥180 kg ha-1) continuously (pink triangles), in rotation with soybean (blue circles), and the difference between the two (continuous maize penalty, green squares) from 1999-2016. Trends are the same within a site, see supplementary material. |

In any given year, this penalty is composed of both nitrogen- (closable with additional nitrogen fertilization) and non-nitrogen (not closable) components. The relative contribution of each can be determined from the nitrogen-response curve.

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| Graphical user interface  Description automatically generated with medium confidence |
| (Left) Nitrogen response curves from IA-4 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. (Right) Size of each component by site-year, ordered from smallest to largest non-N yield reduction; if quadratic plateaus failed to fit a given site year’s data the components were deemed undeterminable. Quadratic plateau fits for all individual site-years are available in supplementary material. |

The continuous maize yields are driving the un-closable yield gaps.

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| Chart, scatter chart  Description automatically generated |
| (Top) The size of the continuous corn yield penalty is not related to rotated maize yields, but is negatively associated with continuous maize yields. (Bottom) Conceptual demonstration of continuous maize yields driving yield gap, with accepted hypothesis having bolded colors. |

Site explains very little variation in the N- and non N-derived components of the gap, meaning the variation in both components is mainly driven by weather. The two components are not correlated, meaning they have different drivers.

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| Diagram  Description automatically generated with low confidence |
| (Left) Variance decomposition site (green), Midwest year (pink), and site-specific year (yellow) contributions to variation in nitrogen- (N) and non-N components of the continuous maize penalty, and (right) lack of co-variation between the two components with non-N gaps tending to be larger |

We built a simplified, testable causal diagram. Using a combination of literature, statistical models and APSIM, we tested the feasibility/evidence for pathways.

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| Diagram  Description automatically generated |
| Pathways with confirmed (bold solid arrows), disaffirmed (dashed arrows), and unknown (solid arrows) contributions linking the previous crop (maize, soybean) to the subsequent maize crop yield based on literature, statistical models, and/or APSIM modelling. |