Extended Abstract

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Paper/Poster Title	**Can preventive weed management help increasing herbicide use efficiency? Plot-level evidence from maize fields in Germany**

Abstract prepared for presentation at the 98th Annual Conference of The Agricultural Economics Society will be held at The University of Edinburgh, UK, 18th - 20th March 2024.

Abstract	***200 words max***
Due to the multiple negative environmental effects of the overuse of chemical pesticides, the European Union (EU) aims to reduce pesticide use – including herbicides – by 50%, by 2030. Preventive weed management (PWM), using among others inversion tillage and diverse crop rotations, is considered perhaps the most suitable strategy to reduce on-farm herbicide use. Whether and how these practices relate to herbicide reduction potential and crop yields is not well understood. This paper addresses this gap by investigating the impact of PWM on maize yields and herbicide use with plot-level data for 530 maize fields in eastern Germany. We apply a directional distance function approach in a data envelopment framework and estimate directional and simultaneous improvement potentials for herbicide use and maize yields. Our preliminary results indicate a similar performance with holistic PWM and without PWM in terms of both yields and herbicide use, whereas a partial implementation of PWM leads to an increased herbicide use. We find, however, herbicide reduction potentials of 36-37% irrespective of the PWM suggesting notable improvement potentials by implementing best practices.	

Keywords	Herbicide use efficiency, Data Envelopment Analysis, Plot-level data
JEL Code	Q15, Q12, Q53

Introduction	***100 – 250 words***
Weed control with synthetic herbicides constitutes the main component of weed management in conventional crop rotations in arable farming (Chauhan 2020). Though, overreliance on herbicide application reduces plant diversity (Guerra *et al.* 2022), damages aquatic and soil organisms (Ojemaye *et al.* 2020), and fosters the expansion of herbicide resistant weeds (Davis and Frisvold 2017). With the Farm-to-Fork strategy, the Commission of the European Union (EU) aims at reducing pesticide use – including herbicides – by 50%, by 2030. To reduce herbicide use in arable farming, preventive weed management (PWM), using inversion tillage and diverse crop rotations, is considered perhaps the most suitable strategy (Riemens *et al.* 2022; Triantafyllidis *et al.* 2023). Despite policy efforts, preventive weed management adoption remains heterogeneous across European farming (Traon *et al.* 2018). To increase PWM adoption, preventive weed control needs to be perceived as a beneficial alternative to widely applied practices without inversion tillage, or maize monocultures. Hence the economic benefits of PWM	

needs to be demonstrated. While studies showed the potential of PWM in field experiments and on-farm mainly for cereal crops (Adeux *et al.* 2019; Andert and Ziesemer 2022), how these practices relate to herbicide reduction potential and maize yields remains not well understood.

We aim to close this gap and investigate the impact of PWM practices on maize yield and herbicide use intensity. Using detailed plot-level data on 530 maize fields for 2011-2014 in eastern Germany, we quantify herbicide reduction potentials and yield improvement potentials under three different weed management strategies.

Methodology	***100 – 250 words***

Our data includes 530 observations of maize fields in the Federal States of Brandenburg and Saxony-Anhalt, Germany, for 2011-2014. For each plot, we observe plot characteristics (e.g., soil quality) and maize yield. We also observe plot-specific land management decisions concerning crop rotations, fertilizer application (nitrogen [N] and phosphorus [P]), applied tillage (inversion, non-inversion), and herbicide application (TFI: Treatment Frequency Index).

Based on the crop alteration and the host crop principles (Andert *et al.* 2016), we differentiate three levels of PWM, reflecting different risks of weed infestation: we use pre-crop and tillage to differentiate no PWM (PWM0), some PWM (PWM1), and multiple PWM (PWM2) (see Table 1).

Table 1: Grouping of observations according to risks of weed infestation and number of observations

Pre-crop	**Inversion tillage = Yes**	**Inversion tillage = No**	N
Maize	PWM1 (16)	PWM0 (78)	*94*
Summer crop	PWM2 (26)	PWM0 (34)	*60*
Winter crop	PWM2 (172)	PWM1 (204)	*376*
N	*214*	*316*	

We estimate plot-specific herbicide reduction and yield improvement potentials with a directional distance function in a data envelopment analysis framework (Chambers *et al.* 1996). Improvement potentials are determined in the direction of yields and herbicides separately and simultaneously, keeping the respective remaining factors constant.

Our empirical specification uses N and P fertiliser quantities, a soil quality index, and the herbicide TFI as inputs; maize yields are the single output. We estimate annual frontiers common to all groups to mitigate potential biases from annual fluctuations in agroclimatic conditions. We assume variable returns to scale throughout.

Results	***100 – 250 words***

Our analysis shows simultaneous yield and herbicide improvement potentials for PWM0 and PWM2 of around 20% (see Table 1). That is, yields could be increased by 20% and herbicide application could be reduced by 20% simultaneously keeping all other factors constant. We find notably higher average improvement potentials for the group PWM1 of 28%.

Table 2: Efficiency scores by PWM group – simultaneous improvement

	Min.	Median	Mean	Max.
PWM 0	0.24	0.79	0.78	1
PWM 1	0.10	0.72	0.70	1
PWM 2	0.20	0.80	0.79	1

Directional efficiency scores (Figure 1) show substantially lower herbicide reduction potentials for PWM0 (36% on average) and PWM2 (37%) compared to PWM1 (63%). Less pronounced differences concerning yields with average improvement potentials between 21% and 24% for all groups suggest that simultaneous improvement potentials are driven by herbicide reduction potentials.

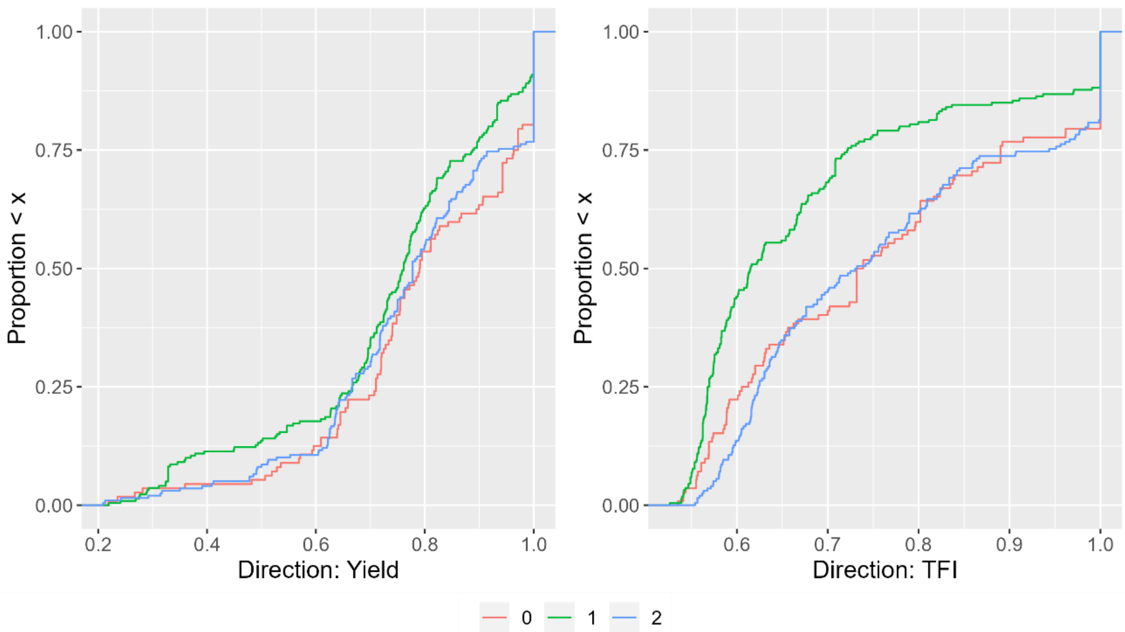

Figure 1: Empirical cumulative distribution functions of directional efficiency scores by PWM: yields (left) and herbicide use (right)

Improvement potentials vary over our observation period suggesting temporal effects (e.g., changing agroclimatic conditions). While average improvement potentials for PWM1 are driven by the first two years of our observation period, PWM0 and PWM2 consistently outperform PWM1 in terms of herbicide improvement potentials. Thus, herbicide use can be reduced by switching to multiple or none PWM.

Overall, similar levels of yields and herbicide use can be achieved without PWM and with holistic PWM strategies. However, as indicated by the directional efficiency scores, notable yield and herbicide improvement potentials are available through the use of best practices.

Discussion and Conclusion	***100 – 250 words***

We find similar improvement potentials in terms of yields and herbicides with (PWM2) and without (PWM0) preventive weed management. Consistent with the literature (e.g., Riemens *et al.* 2022), our results indicate that PWM necessitates a holistic strategy comprising multiple practises to reduce herbicide dependence without compromising yields. Thus, our preliminary results suggest that PWM can contribute to herbicide use reductions intended by the EU's Farm-to-Fork strategy only to a limited extent. Reducing inefficiencies under the present land management strategies by applying the best practices indicated by the sample could, however, reduce herbicide use by 36-37% (cf. Gaba *et al.* 2016; Ait Sidhoum *et al.* 2019).

At first glance, the small difference between no PWM and multiple PWM strategies is surprising. One possible explanation is pre-sowing use of glyphosate under PWM0 decreasing the follow-up herbicide use (cf. Andert *et al.* 2018). Under a potential ban of glyphosate, PWM would provide an alternative delivering similar yields without increasing herbicide use. We currently gather plot-specific information on the applied herbicides to investigate this issue.

To better understand our results, we aim to improve our analysis in several ways: First, by linking our data to agroclimatic conditions, we want to investigate the temporal variability of improvement potentials during the observation period. Second, we intend to investigate the role of other land management decisions and farm heterogeneity for the improvement potentials. Third, to counter potential biases arising from different PWM group sizes, we consider using bias-corrected bootstrapped efficiency estimates (Simar and Wilson 1998).

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