# Using farmer field data and crop modelling to benchmark crop yield and resource use efficiency of arable crops in The Netherlands

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## Introduction

Arable farming systems in the Netherlands exhibit relatively small yield gaps, with actual yields (Ya) obtained by farmers reaching 70 – 80% of climatic potential yields (Yp) for most crops (Silva et al., 2017). These high yields are associated with up-to-date technologies and intensive use of inputs, particularly mineral and organic fertilizers, as well as with water pollution and greenhouse gas emissions. Irrigation is not a default in the country, due to the humid climate and shallow depth of groundwater, but it is getting increasing attention as an adaptation strategy to dry summers. In this context, it is important to understand the scope to increase/maintain crop yields while improving resource use efficiency. The objective of this paper is to quantify the magnitude of crop yields and resource use efficiency of arable cropping systems in the Netherlands.

## Materials and methods

Individual field data from Dutch arable farms during the period 2015 – 2017 were used. These were obtained from a crop management software used by farmers. The sample used in this study was selected from a database of ca. 350.000 farm x field x crop x year combinations using as criteria the crop species and the completeness of the crop cycle and, water and nutrient management practices. This resulted in 1293 ware potato (WP) fields, 294 seed potato (SP) fields, 1034 starch potato (StP) fields, 783 sugar beet (SBt) fields, 196 spring onion (SO) fields, 1080 winter wheat (WW) fields and 531 spring barley (SB) fields located in the main agricultural regions of The Netherlands.

A crop modelling framework based on crop coefficients (kc) was used to estimate Yp (Villalobos & Fereres, 2017), and associated yield gaps (Yp – Ya), for each crop. Water productivity (WProd, kg $ha^{-1}$ $mm^{-1}$) was estimated as the ratio between Ya and total seasonal water available (TSWA) for crop growth. The latter included the growing season rainfall, applied irrigation, capillary rise from groundwater and soil available water at sowing. Finally, the framework of the European Union Nitrogen Expert Panel (EUNEP, 2015) was applied to benchmark nitrogen use efficiency (NUE = N output / N input) and N surplus (Ns = N input – N output) in each individual field. N output equals the actual yield times the N concentration in the harvested product of each crop and N input consists of the total amount of plant available N, including mineral and organic fertilisers, atmospheric deposition, biological N fixation and N in seeds.

## Results

Yield gaps were smallest for SBt (less than 20% Yp), intermediate for WP, SO, WW and SB (between 30 – 40% Yp) and largest for StP and SP (40 – 50% Yp; Figure 1A). Ya and Yp were on average 86.5 and 93.7 t FM ha$^{-1}$ for SBt and 58.9 and 90.5 t FM ha$^{-1}$ for SO. Consistent differences in Ya and Yp were observed for potato production systems: yields were greatest for WP (Ya = 52.7 and Yp = 78.5 t FM ha$^{-1}$), intermediate for StP (Ya = 44.8 and Yp = 76.1 t FM ha$^{-1}$) and lowest for SP (Ya = 36.6 and Yp = 71.9 t FM ha$^{-1}$). For cereals, Ya and Yp were on average 9.6 and 15.3 t FM ha$^{-1}$ for WW and 6.7 and 10.1 t FM ha$^{-1}$ for SB, respectively.

WProd was generally greater for the horticultural crops than for cereals (Figure 1B). For the former crops, WProd ranged between 20.9 for SBt and 13.7 kg DM ha$^{-1}$ mm$^{-1}$ for SO, with potato fields exhibiting an average WProd of 16.1 kg DM ha$^{-1}$ mm$^{-1}$ independently of the production system. For cereals, WProd was on average 9.3 kg DM ha$^{-1}$ mm$^{-1}$ but slightly greater values were observed for SB than for WW. The variation

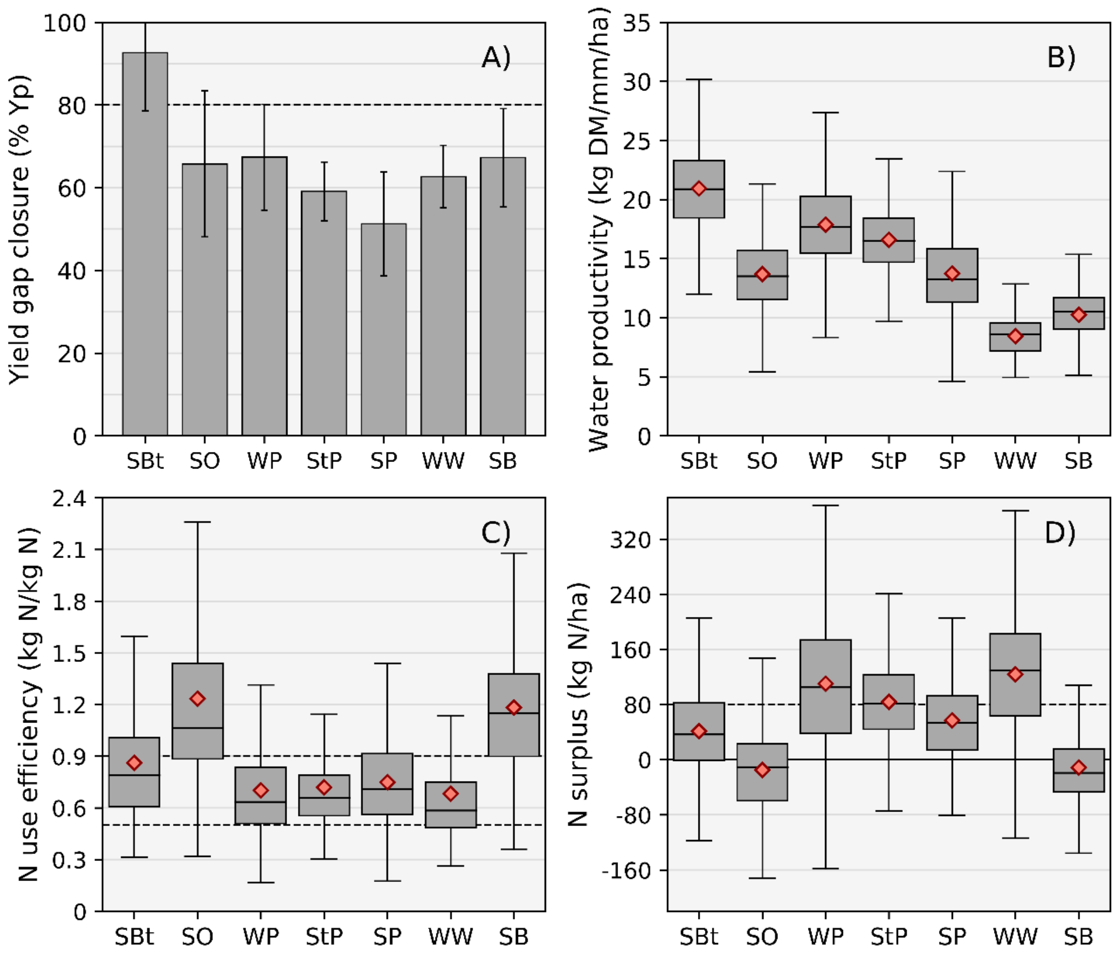


**Figure 1. Yield gap closure (% Yp), water productivity (kg ha$^{-1}$ mm$^{-1}$), N use efficiency (kg N kg N$^{-1}$) and N surplus (kg N ha$^{-1}$) for the main arable crops in The Netherlands. Error bars in A) show the standard deviation of the mean. Dashed lines in C) and D) show the NUE and Ns thresholds proposed by EUNEP. Red symbols in B), C) and D) show the mean of each indicator for a given crop. Crop codes are explained in the main text.**

observed in WProd for each crop suggest there is scope to improve the use of water by arable crops in The Netherlands. This is best achieved through increases in Ya, as the TWSA in most fields is greater than the potential evapotranspiration needed to achieve Yp (data not shown).

NUE was within the desirable range of 0.5 – 0.9 kg N kg $N^{-1}$ for most fields of all crops except SO and SB, for which greater values were common (Figure 1C). These NUE values were associated with high Ns (> 80 kg N $ha^{-1}$) for WP, StP and WW and relatively low Ns for the other crops. While the variation in NUE and Ns was large for all crops, we found poor relationships between N input and N output (data not shown). These suggests there is considerable scope to increase NUE and decrease Ns for arable crops in The Netherlands, especially through decreases in the rates of plant available N applied. However, we reckon a number  a uncertainties in these indicators (e.g., N in soil and replacement values of organic manures) and recommend to interpret such conclusion cautiously.

## Conclusions

Yield gaps were relatively small for most crops, ranging between 10% Yp for SBt and 50% for SO and were between 30 – 40% Yp the other crops. Further increases in WProd are possible, which is best achieved through increases in crop yields as rainfall is the largest source of total seasonal water available. Regarding N, it is clear than high efficiency does not equate low losses. Our findings suggest that improving NUE while reducing Ns in Dutch arable farming requires a decrease in the rate of N applied with mineral and organic fertilisers.

Further research will focus on developing sustainability targets for Dutch arable cropping systems and on understanding the biophysical and management drivers of variability of NUE and Ns in these cropping. This will done through group comparisons of highest-, average- and lowest-yielding fields as well as comparison between fields with contrasting NUE and Ns.

## References

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