106. Is there reason to adapt fertilizer rates along field boundaries?

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Abstract

By analysis of a national field polygon database, it was found that about one fourth of Sweden's cropland (fields >10 ha considered) is within 20 m of a field edge. In 16 observation transects bordering forest or other fields, it was found that winter wheat (*Triticum aestivum* L.) yields were significantly smaller in field margins compared with field interiors. Effect sizes were larger along woody vegetation; yields were about 2 t/ha smaller at 8 m from the edge compared with at 26 m from the edge. It was concluded that field margins deserve special attention in site-specific management.

Keywords: field edge, land use, protein, thousand kernel weight, yield

Introduction

Field margins are special. There may be more soil compaction (Etana *et al.*, 2020; Sunoj *et al.*, 2021) and sometimes stagnant water due to more traffic, compared to the rest of the field. Soil chemistry (pH and plant available nutrient contents) may differ as a result of higher/lower yields over many years. The crop may be more uneven in field margins due to sowing gaps and overlaps (Kharel *et al.*, 2020), and weed pressure may be larger closer to field borders (Marshall 1989; Romero *et al.*, 2008). Soil organic matter content, soil moisture and micrometeorological conditions, may be different, especially along woody vegetation. In some cases, the border cardinal direction may be important for the edge effect. In Sweden, there are environmental regulations about field margins; a 2 m wide zone should be kept unfertilized and a zone of 2–6 m width should be left unsprayed, along trenches and waterbodies etc.

The exact fraction of a field's area that is within a certain distance of a field boundary depends on the size and the shape of the field. Quantifications on how much of the cropland area that is within different distances (e.g. 5 m, 10 m or 20 m) of a field border in different cropping systems are scarce (or possibly non-existent). There are, however, national spatial databases of field boundaries available within the European Union (e.g. Swedish Board of Agriculture, 2009), which means that assessments can be made.

Relatively little is known about crop growth conditions and optimal fertilisation rates in field margins. Yield mapping by combines or satellites is less reliable along field edges (Nissen and Söderström, 1999), soil samples are seldom taken, and field trials are not placed in the border zones of fields.

The present work aimed to:

1. assess the portions of Swedish cropland fields >10 ha that can be considered a field border zone.
2. increase the knowledge of crop yields and soil properties in field border zones versus the rest of the field.

It is a pilot study aimed at assessing whether it is worth studying field margins further and, if so, how to design such a study. Depending on the results, the study may have an impact on recommendations for fertilisation and/or crop and soil sampling schemes.

Materials and methods

Area assessment

For the assessment of cropland area within certain distances of field edges, field polygons from the Swedish database of arable land (the ”block database”, Swedish Board of Agriculture, Jönköping, Sweden) for 2021 was used (example in Figure 1). Here, fields larger than 10 ha were focused on, since large fields are more relevant for site-specific management. In Sweden, such fields constitute 40% of the cropland (≈1 Mha) according to the block database of 2021. The percentage varies in different parts of the country, e.g., in the intensively cultivated south-western part of the country it is as much as 70%. The assessment was done as follows:

1. Ten thousand points were randomly distributed over the rectangular extent of the field polygon dataset.
2. Polygons not classified as cropland (e.g., permanent ley) were discarded.
3. Polygons smaller than ten hectares were discarded.
4. For all points inside the remaining polygons, the distance to the nearest point on a field boundary was determined.

All spatial analyses were done in the national projected coordinate system for Sweden Sweref99TM (EPSG: 3006).

Grain sampling

Four observation transects were set up in each of four winter wheat fields (n=16), in a 7×10 km^2 area in south Sweden. Two transects per field bordered forest, while the other two bordered another field (in some cases separated by a small road). Each transect consisted of three observation plots, at a distance approximately 8 m, 26 m and 45 m from the field boundary (in total, n=48). The plots were placed to avoid tramlines. Grain samples were collected by hand-harvesting: two samples of 1/3 m^2 each were taken within 3–5 m of the centre point of each of the 48 plots.

Lab analyses

The samples were threshed using a Zürn z150 thresher (Zurn, Milwaukee, WI, USA) and weighed on a EK-2000i balance (A&D Medical, Tokyo, Japan) for determination of yield (kg/ha at 15% water content). They were also analysed for protein content (% of dry weight) by near infrared transmittance (NIT) analysis using an Infratec TM 1241 (Foss, Hillerød, Denmark). Thousand kernel weight at 15 % water content (TKW) was determined using an MLN sample cleaner (Pfeuffer, Marksteft, Germany).

Statistical analyses

For yield, a two-way analysis of variance (ANOVA) with interactions was performed. The factors were distance (levels: 8 m, 26 m and 45 m) and type (levels: “Forest” and “Open” land). In case of a significant distance effect, the Tukey Honest Significant Differences (HSD) test was done to elucidate which pairwise differences were statistically demonstrated. The analyses was done in R (R Core Team, 2024), using the stats package.

Results

Area assessment

It was found that 6% of Swedish cropland (fields >10 ha, i.e. fields of interest for variable rate fertilization) were within 5 m of a field boundary, 13% were within 10 m, 26% were within 20 m and 48% were within 40 m of a field boundary. The percentages of cropland constituted by field margins were somewhat smaller in three counties with relatively intensive crop production compared with the rest of the country (Figure 2), presumably since fields are generally larger in such regions.

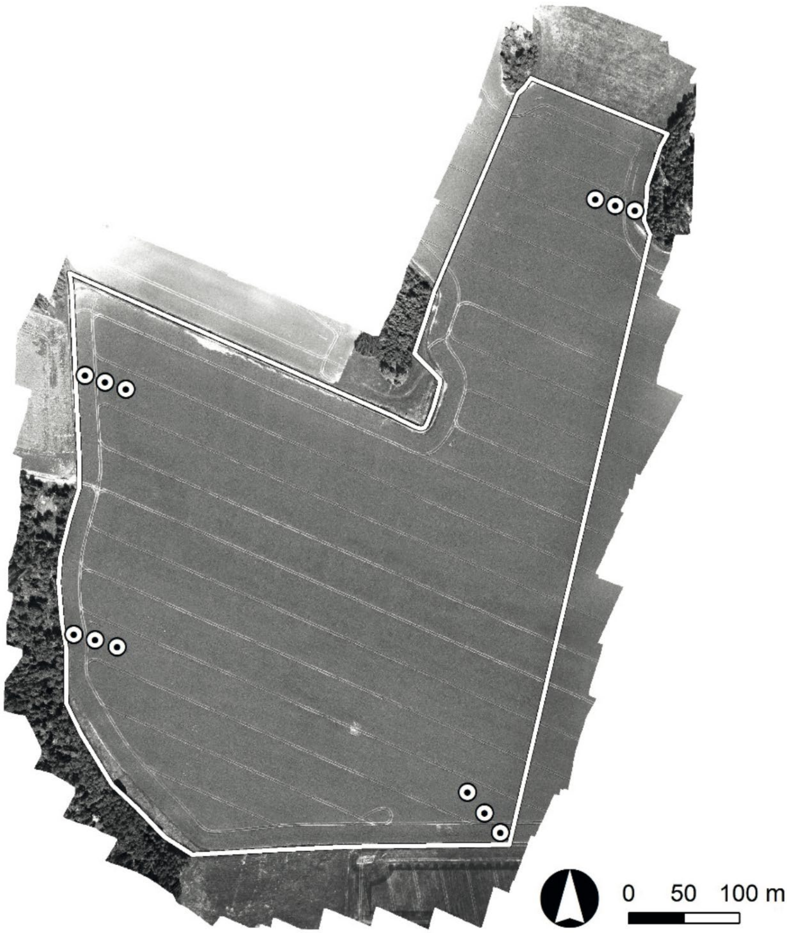

Figure 1. Example of grain sampling locations (points) and field boundary data (polygon). Background map is a drone mosaic.

Grain yield and quality

By forest borders, crop yields were 6.8±1.5, 8.9±0.9 and 9.5±0.7 t/ha (mean±SD) at the short (8 m), medium (26 m) and long distance (45 m), respectively (Figure 3). For borders to open land, the corresponding crop yields were 8.8±1.1, 9.0±0.8 and 9.3±1.2 t/ha. The ANOVA showed a statistically significant yield difference between the three distances ($p<0.001$) and the Tukey HSD test showed that the yield differences between the short and the medium distances, and the short and long distances were statistically significant ($p<0.05$ and $p<0.001$). The yield difference between the two longest distances was not significant. The yield difference between the bordering land uses (forest vs. open land) was also statistically significant ($p<0.05$), and there was a statistically significant interaction between the two factors ($p<0.05$), with a larger edge effect close to forest.

The TKW largely followed the variation pattern of grain yield (Figure 3). The mean protein content was relatively high in all groups (means >12 %), albeit somewhat higher in samples taken closest to the field edge. These findings indicate that observed edge effects on yield were not due to insufficient N fertilization, but rather to other factors limiting grain filling.

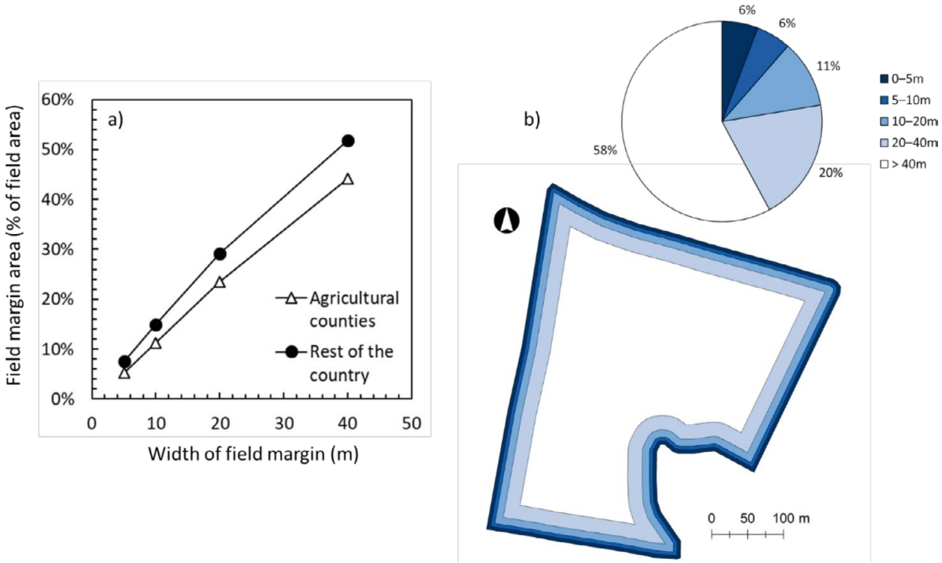

Figure 2. Fraction of area within certain distances from a field edge in three agricultural counties (Skåne, Västra Götaland and Östergötland), and for the rest of Sweden (a). Area fractions within the same distances from a field edge for an example field of 15 ha in Västra Götaland County (b).

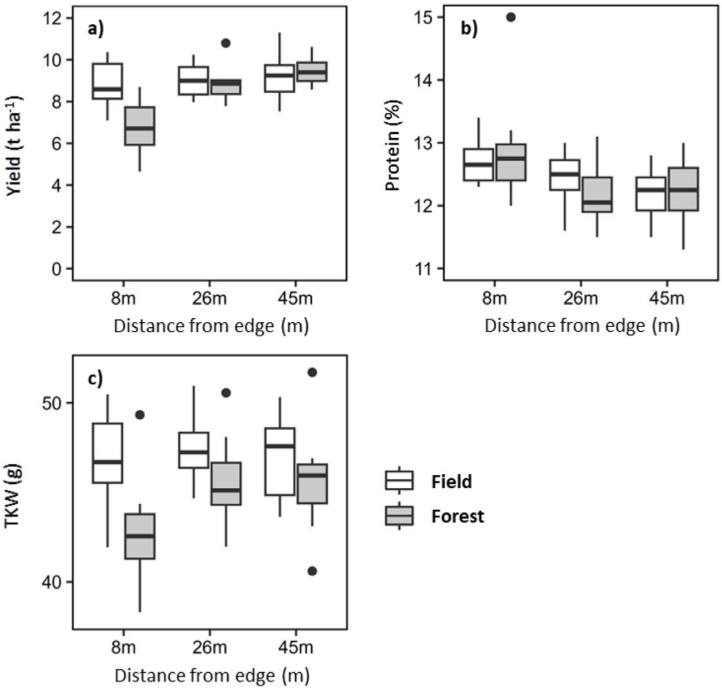

Figure 3. Yield (a), protein content (b) and thousand kernel weight (c) in the 48 grain samples, categorized by distance from field boundary and bordering land use. Note that the y-axes do not start at 0 in b and c. The boxes show the interquartile range (IQR) (the difference between the first and the third quartile) and the whiskers extend to the largest value within 1.5×IQR from the box. Observations beyond the whiskers are considered outliers and are shown as points.

Discussion

The effect-size of the statistically demonstrated yield differences close to borders was more than 2 t/ha along forests but only about 0.2 t/ha in field margins bordering open land. Based on recommendations (Swedish Board of Agriculture, 2023), a difference in target yield of one t/ha would justify adaptation on N, P and K rates by 20, 3 and 5 kg/ha, respectively, to cereals and with the presently observed yield reduction close to forest border the rate corrections would be twice those numbers.

The present results are in agreement with findings from earlier studies. Fincham *et al.* (2022) studied drivers of within-field yield variation in yield maps from 1,174 fields in England and found that yield reduction due to field edge effects caused an approximate total yield reduction of 10% in wheat and 18% in oilseed. It may be noted that the study was based on combine harvester yield maps, which – as mentioned – are prone to errors in the border zone. In a Germany study, Raatz *et al.* (2019) quantified edge effects on winter wheat yield in borders zones with different adjacent land in use, and found that yield was reduced by 11%–38% close to field borders. The effect was larger in border zones next to forest and hedges compared to in border zones with other neighbouring land use. In that study, yield was determined by manual cutting of 1 m^2 plots in transects perpendicular to the field edges (Raatz *et al.*, 2019).

Soil properties, and soil/crop management practices (e.g., fertiliser rates) will be examined for further interpretation of observed effects. Detailed data of the fields were also collected with multispectral drone cameras in the end of flowering. It remains to compare and calibrate that data with the plot harvest data in order to spatialize and explore fine scale patterns of the analysed crop variables. Using drone-based yield maps, it should be possible to make area-based assessments that capture possible effects of more tramlines, which expected especially in headlands. The effects of a denser pattern of tramlines is not captured by the presently reported yield observations, as the tramlines were avoided in the hand harvesting (Figure 1). With the more detailed drone-based yield mapping, it should also be possible to determine in how wide a zone fertiliser rate should be adapted.

In future studies, it would be interesting to (i) assess the portion of cropland that is bordering different land use types, (ii) assess how far into the field there are notable edge effects on soil properties and crop yield, (iii) to derive general recommendations (tabulated values) on how to adapt management in different types of field margins and *iv*) investigate whether current methods to map soil and crop properties (e.g. soil sampling and yield mapping) should be adapted to better guide fertilisation in field border zones.

Conclusions

About one fourth of Sweden's cropland area (fields >10 ha) is within 20 m from a field edge, yet there is not much knowledge on how crop growth conditions in different types of field margins differ from the rest of the field area. Observations in four fields showed that yield levels were lower in field margins (8 m from the edge) bordering woody vegetation compared to field interiors (26 m into the field), by a magnitude that would motivate reductions of N, P and K rates by 40, 6 and 10 kg/ha, respectively. Observed yield reductions were associated with reduced TKWs and slightly increased protein contents, albeit all protein contents were relatively high. Yield levels and grain properties were much less affected in field margins bordering other fields. This one-year pilot test indicate that it would be useful to test fertilisation requirements in field margins more extensively, such that management recommendations for field margins can be derived.

Acknowledgements

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