Site-specific land use as demonstrated by planning variable seeding rates

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Abstract

To enhance the establishment and development of cereal crops, variable plant densities might be used on heterogeneous sites. Prerequisites for this method are a reliable determination of the spatial distribution of the yield potential within the site and seed application varied according to planning. In the study presented, the seed rate (kg ha^{-1}) for winter wheat were calculated by means of a PC- and GIS-based software module developed for this purpose. This "seed module" accounts for several factors of influence. Their impact on the seed rate is demonstrated. The success of the sowing algorithm can be established by a comparison of the planned and actual density of germinated plants in several locations of the site.

Keywords: site-specific seeding, winter wheat, GIS application, seed rate

Introduction

Site-specific management of crops was developed as a reaction to the common experience that sites, and thus also crop stands, are in many cases not homogeneous. This is shown by soil and yield maps or aerial photographs. This heterogeneity results in an insufficient use of the yield potential of the better areas of a field and a waste of seed, fertilizer etc. in other areas. Strategies of handling this heterogeneity and their results are investigated by various research institutions as the Cranfield Centre for Precision Farming, UK, the Site-Specific Management Center at Purdue University, USA, or the College of Agriculture and Biological Sciences at South Dakota State University, USA.

Site specific crop management includes several working steps such as soil tillage, seeding, fertilizer and pesticide application. Within the framework of the *pre agro* project, software modules were developed by various sub-project groups to facilitate the planning of these steps; additional groups were included in the project to provide soil and remote sensing information for the experimental fields, to analyse the economic results of site-specific management, and to deal with practical issues. The project is described in detail elsewhere (e.g. Jarfe & Werner, 2000; project web-page http://www.preagro.de).

Since site-adapted seeding is an important part of crop management, an established heterogeneity of the field should be taken into account when planning seed rates. Therefore, one of the software modules developed is a decision support tool for planning seeding rates of winter wheat in accordance with the within-field variation of soil properties and of the resulting yield potentials. The underlying algorithms were derived from the literature as well as from field experiments. Results of the work with this module are presented in the present text.

Materials and methods

A PC- and GIS-based software module developed within the framework of the *pre agro* project was used to calculate seed rate for winter wheat in correspondence with the yield potential of different parts of a field. Seed rates (kg·ha^{-1}) were chosen as final output value of the module because they can be directly transferred to application cards for the drilling machine.

The calculation starts from the yield potential of the field in question and the within-site variation of this parameter. These data can be derived from yield observations over several years or other sources. If such information is not available, the module calculates a potential mean yield from the soil quality according to the German Soil Survey (Reichsbodenschätzung; Rothkegel & Herzog 1935), where soils are classified on a scale of 1 (worst) to 100 (best) soil points, and the long-term mean annual precipitation of the site. If necessary, this mean yield potential can be corrected by the farmer on the basis of his experience from previous years. It is then differentiated within the area according to the soil quality. The result is a pattern of polygons with different yield potentials. The yield potential of each polygon is then modified according to the actual conditions by accounting for the date of seeding (-1.5% for each week of delay), the previous crop (between +10% e.g. for potatoes and -10% for cereals), and the terrain inclination (between +15% e.g. for a drained depression and -35% e.g. for hilltop). The resulting value, the yield expectation, is the basis for the calculation of the seed rate by using information on cultivar, time of sowing relative to the optimal time, seedbed quality, soil moisture at time of seeding, previous crop etc. A detailed description of the algorithms used for calculating the seed rate from the yield expectation is given by Roth, Kühn & Werner (2001).

The validity of the assumptions and calculations made by the seeding module is tested by comparing the anticipated plant densities with on-site counts. For this purpose, measuring points were defined for the seed polygons of all fields; around each point, plant densities were counted in 8 squares with an area of 0.5 x 0.5 m each. In some cases, additional microplot harvests for yield determination were taken on an area of 1 x 1 m each.

Results

The influence of some of the input variables used for the calculation of seed rates is demonstrated in Figure 1, where the seed rates are varied according to soil moisture content and relative time of seeding in the range of soil quality from 25 to 85 points. The most important influences are soil quality and precipitation factors. The discontinuities in the curves around 40 soil points are due to the internal calculation of the ear yield in steps of 0.1 g·ear^{-1}.

A summary of all input and internal variables of the module and their impact on the seed rate is given in Table 1.

Due to the method of calculation described under materials and methods, a comparison of soil quality or yield potential with actual yields is not straightforward. This can be demonstrated by the following example. The yield potential of a site with 50 soil points will vary, depending on the precipitation, between 5 t ha^{-1} for an annual precipitation of 450 mm and 8.4 t ha^{-1} for 850 mm. Assuming a yield **potential** of 6 t ha^{-1}, the yield **expectation** is influenced by several factors, especially by the previous crop and the terrain structure. In this example, the yield expectation for a previous crop of potato (+10%) and a drained depression (+15%) will result in a yield expectation of 7.5 t ha^{-1}, while a previous crop of wheat (-10%) and a hilltop (-35%) would reduce the yield expectation to 3.3 t ha^{-1}.

The same applies to the comparison of seed mass or seedling density, respectively, and yield. As wheat cultivars vary in the parameters, "yield per ear" and "ears per plant", use of a high tillering cultivar could result in higher yields than a cultivar with fewer tillers at the same plant density.

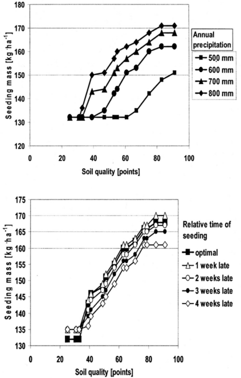

Figure 1. Variation in seed rate with different soil quality for various annual precipitations (top) and relative times of sowing (bottom).

An examination of the module results is, however, possible by comparing the anticipated density of germinated plant with the actual density. Figure 2 shows this comparison for the fields "Am Berg" (mean annual precipitation 780 mm, mean soil quality 41 points) in Nordrhein-Westfalen and "Finkenherd" (mean annual precipitation 450 mm, mean soil quality 80 points) in Sachsen-Anhalt. The seeding module was applied over 3 years on 48 fields with a total area of 1,362 ha and 151 seeding polygons. In 40 % of the polygons, the actual number of germinated plants was within a range of ± 10 % of the anticipated number; in 51 % it was within a range of ± 15 %. In some other cases, however, the numbers differed more widely or even showed a reverse trend (number of germinated plants decreasing with increasing seed rate). This can be due to several factors. One factor is weather events between sowing (September) and count of germinated plants (November - January) that cannot be forecast by the module. Other possibilities are insufficient soil information or technical problems during drilling.

Table 1. Variables used in the module and their influence on seed rate.

Variable	Range	Step Width	Δ seed rate [kg ha⁻¹]	
			Per Step	Max. Range
• soil quality [points]	25 to 85	1	2	120
• annual precipitation [mm]	450 to 810	10	3	110
• yield potential [$t\ ha^{-1}$]	2.0 to 9.5	0.1	2	130
• relative time of seeding [weeks too late]	optimal to 4 weeks too late	1	1	6
• time until emergence [days]	≤10 to ≥21 d	10	4	12
• previous crop	---	---	---	45
• seeding depth [3 classes]	≤3 to ≥6	---	---	4
• soil contact of seeds [3 classes]	---	---	2	4
• soil moisture content at seeding [3 classes]	---	---	2.5	5
• seedbed quality [3 classes]	---	---	2	4
• cultivar [72 classes]	---	---		20
• inclination / relief [% resulting change in yield potential]	+10 to -50	5	---	46
• yield per ear [g]	0.9 to 2.0	0.1	12	130
• ears per plant	1.0 to 3.0	0.1	9	130
• stand density [plants per m^2]	350 to 650	10	3	90
• emergence rate [%]	75 to 95	1	2	40
• germination capacity [%]	70 to 100	1	2	60
• 1000-grain weight [g]	40 to 70	1	3	90

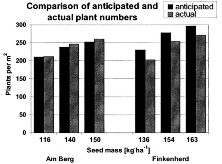

Figure 2. Comparison of plant numbers calculated by the seeding module (anticipated) and counted (actual) for two fields in different regions of Germany.

Possible variations caused by drilling can be demonstrated by a comparison of the seed rate maps produced by the module ("planned") with the maps produced during the drilling process ("as applied") in figure 3. These maps show that the actual seed masses applied on a defined point, though in general within a reasonable range of the "planned" values, cannot be expected to be exactly as planned.

As a summary, Figure 4 shows a plot of germinated plants anticipated by the module versus actual numbers of germinated plants.

As discussed above, some fields showed larger deviations than ± 15 % or even a negative relation between anticipated and actual plant numbers. These fields (n=12) have been excluded from the plot in Figure 4. Since 4 of these fields are situated near the northern border of Germany (Schleswig-Holstein and Mecklenburg-Vorpommern) and 6 fields are in the furthest south (Bayern), a further analysis of the data seems necessary to investigate a possible influence of the North-South gradient.

For a second examination of the module results, Figure 5 shows yields anticipated by the module versus yields from the microplot harvests. The r^2 shown in the plot is considerably larger than that in the comparison of germinated plants (Figure 5). This demonstrates that the time elapsed between the planning and the measurement is probably important, due to a higher probability of unforeseen events that cannot be accounted for by the module.

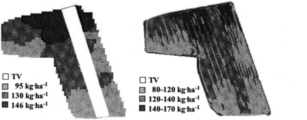

Figure 3."Planned" (left) and "applied" (right) seed rates ("TV" = traditional management variant according to farmer's decision).

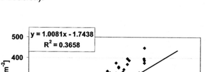

Figure 4. Anticipated plant numbers vs. actual plant numbers - data from 36 fields during 3 experimental years in different regions of Germany.

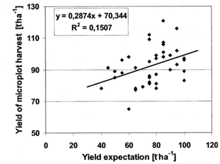

Figure 5. Anticipated yield vs. yield determined from microplot harvests - data from 15 fields in different regions of Germany.

Conclusion

The results show that site-specific seeding rates are a promising technique that could be applied in practice. The seed module developed facilitates the planning of variable seed rates. Actual problems can be probably mitigated by improving the spatial information on soil properties and the drilling technique.

Acknowledgements

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References

Jarfe, A., Werner, A. 2000. Development of a GIS-based management system for precision agriculture. 2nd International Symposium on New Technologies for environmental Monitoring and Agro-Applications, 18. - 20. October 2000 Tekirdag/Turkey.

Roth, R., Kühn, J., Werner, A. 2001. Decision support system to derive site specific sowing rates for managing winter wheat within precision agriculture. - In: Proceedings of 3rd European Conference on Precision Agriculture, eds G Grenier, S Blackmore. agro Montpellier, France, Vol. 2.: 701-706.

Rothkegel, W.. Herzog, R. 1935. Das Bodenschätzungsgesetz. (*The soil survey law*) Heymann Verlag, Berlin.