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Variability of spatial areas with sensor controlled fertiliser application

Spatially-specific nitrogen fertiliser application still requires uniform application within the spatial areas. Of course in the context of a whole field, these amounts naturally vary according to the requirements of the individual spatial areas. The parameters of these areas are investigated in the following paper using reflection-optical measurements in line with the tramlines to describe the sensor values of the crops in the different areas. According to geostatistical analysis crops were shown to be almost uniform within a working width (24 m) even in Schleswig-Holstein's strongly heterogeneous „östliches Hügelland".

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In sensor-controlled nitrogen (N) fertiliser application, information on the crop plants is gathered by sensors during the tractor pass. In practice the Hydro N-Sensor is used. This measures the reflection of sunlight from the plant leaves (Kiel method [1]). Other methods such as pendulum sensor [2], and fluorescence emission [3] are possible too. Common factor for all methods is that an application amount can be calculated and then applied based on the sensor values.

Contrary to this, the so-called „mapping approach" involves the creation of an „application card" before the fertilising, with the pass over the field then controlled via GPS. Information bases for this include yield maps, soil nutrition maps, aerial photographs and similar.

There are several ways of defining the spatial areas for the mapping approach. Thus from yield maps, relief maps, soil samplings and aerial photographs the borders of the spatial areas can be established by classifying a summarisation of characteristics [4]. Labour input is high, so this approach is used only when there are as few as possible large spatial areas to be drawn in for uniform treatment.

In the case of sensor-controlled Nr. application with a broadcaster, size of spatial area is according to the working width (typically 24 m). For defining spatial area in driving direction, definition within a meter is possible, but not practical because while heterogeneity can be recorded within this unit the smallest width is 24 m. Investigated within the following report is whether the smallest possible spatial area size of 24 m • 24 m can represent an area of heterogeneity in the standing crop.

TTable 1: Characteristics from the different regions interpreted through analysis from sensor values $REIP_{mittel}$: mean of sensor value of whole field; $REIP_{std}$ its standard deviation; MCD minimal spatial area length (mean correlated distance); WR: winter rape, WW winter wheat, WG: winter barley

Region	Crop, Field, Date	REIP $_{mittel}$ [mem]	REIP $_{std}$ [mem]	MCD [m]
östliches Hügelland	WR, Achterkoppel 16. 4. 99	722.2	0.6	75
	WW, Achterkoppel			
	23. 3. 00	721.4	1.2	33.5
	27. 4. 00	727.7	0.7	28.4
	31. 5. 00	729.7	0.5	13.2
	WG, Achterkoppel			
	4. 4. 01	718.7	0.9	5.9
	23. 4. 01	719.8	1.2	32.8
	30. 5. 01	723.9	0.8	34.1
	WG, Kronskoppel			
	26. 4. 00	725.8	0.7	11.8
	11. 5. 00	728.2	0.5	14.7
	WW, Viehkoppel			
	27. 4. 99	723.2	0.9	8.6
	26. 5. 99	727.5	1	12
	WG, Niedeel			
	16. 4. 99	722.6	0.8	17
	26. 5. 99	729.5	0.8	99.1
	WW, Niedeel			
	4. 4. 01	718.8	0.7	13.4
	17. 4. 01	720	0.8	7.2
	7. 5. 01	725.5	1.1	7.5
	30. 5. 01	732.6	0.8	7.4
	13. 6. 01	732.4	0.7	32.9
Geest	WG, Olenhöbek			
	23. 4. 99	721.3	0.7	29.4
	19. 5. 99	724.7	0.5	33.7
	WR, Olenhöbek			
	11. 4. 00	720.1	0.4	18
	WW,Olenhöbek			
	8. 5. 01	724.4	1.3	46.9
	7. 6. 01	728.5	1.1	27.3
Fehmarn	WW, Ostenfeld			
	6. 5. 01	724.9	0.6	116.1
	4. 6. 01	732.1	0.6	139
	WG, Hohlblöcken			
	6. 5. 01	728.1	0.8	28.6
	4. 6. 01	728.9	0.7	32

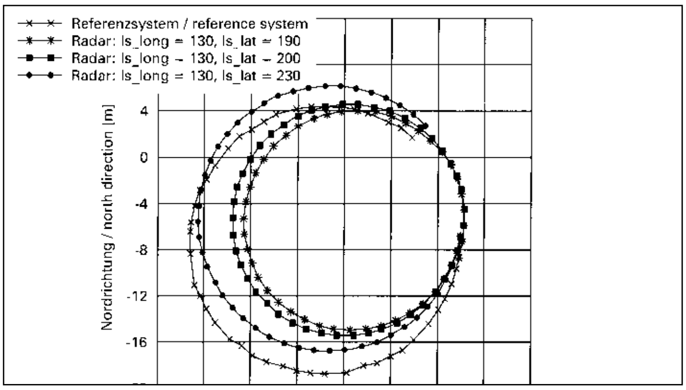

Fig. 1: Sensor values along a tramline in winter wheat at the date for the third nitrogen application

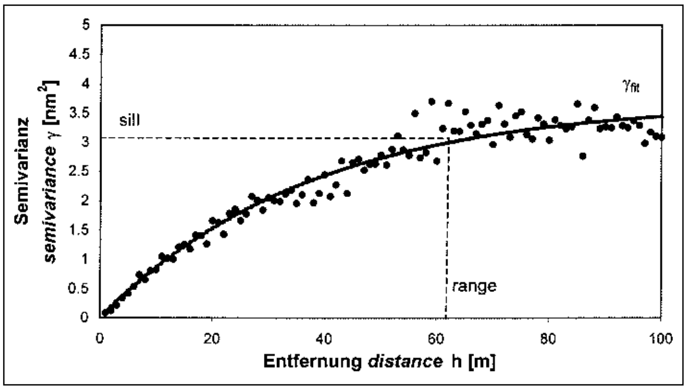

Fig. 2: Semivariogram of the data taken from figure 1. The straight line is also the adjusted function γ_{fit} used for estimation of s and h_{max}

Method

At the dates for Nr. application, reflection measurements of winter cereals and oilseed rape were made in the uniformly fertilised tramlines. Typical north German regions were selected: the strongly heterogeneous „östliche Hügelland" with changeable relief features, the predominantly sandy Geest region and the homogenous fields on flat-lying Fehmarn. The vehicle mounted sensor system used is described in [5]. Sensor values were positioned via GPS data and recording of land covered during passes.

Data evaluation

Data collected during passes served for determination of minimum spatial area size, i.e. the area wherein Nr. required could be regarded as uniform and also for determining crop variability over the whole field. As basis for Nr. requirement sensor values were used (turning point position) in that these indicate the extent to which the crop altered with distance.

In *figure 1* one sees that within the sensor values of a tramline within 20 m, there is not a lot of alteration in most sections. However, so that this important factor is not subjectively used from just a few short field sections, a geostatistical analysis of the whole length was carried out.

A semivariogramme of selected areas was completed recording the deviations between sensor values, their variance 2γ from one another against their distance h. The n sensor values z naturally depend on the location x_i (I = 1...n) on the field and so give the semivariance γ in:

((Formel einsetzen)) (1)

In *figure 2* this semivariance is shown as an example of the data from figure 1. This type of semivariogramme indicates a few characteristics: from a certain distance the „range" h_{max}, shows the characteristic z of the location x_i, a maximum semivariance, the „sill" s. This means that with such a distance the characteristics have become independent from one another. Calculated as a minimum spatial area length was the „mean correlated distance" MCD [6]:

((Gleichung einsetzen)) (2)

A minimum spatial area length of 26 m was produced from figure 2 with a sill of 3.3 nm^2 and a range of 60 m. It must be hereby stressed that this concerns an average calculated via analysis. In Nr. application there are naturally a few locations showing small area heterogeneity and which, e.g. must be treated with a smaller working width. But for the most part this large acceptance is justified.

Spatial area size and heterogeneity

The spatial area sizes of measured fields are shown in *table 1*. Additionally, the variability of the sensor values expressed over the average $REIP_{mittel}$ and the standard deviation $REIP_{std}$ are given for the whole field.

Finally, a result can be produced as to whether spatially specific fertiliser application is practical or whether the crop is so homogenous that a uniform Nr. application suffices. In the first place the size of these spatial areas is decisive.

It is noticeable in the case of the average sensor values that these increase during the vegetation period. This is naturally through the biomass increase of the growing crop. From March to April the cereal plants tiller and begin to shoot by the end of April with the increase greater with winter wheat and lasting longer (into June) compared with winter barley.

From table 1 one notes that the „östliche Hügelland" fields are characterised by a larger standard deviation of sensor values and a smaller minimum spatial area length compared with Geest and Fehmarn. The standard deviation in the „östliche Hügelland" was an average 0.82 nm, in Geest 0.8 nm and on Fehmarn 0.68 nm. Minimum spatial area length in the „östliche Hügelland" was on average around 25.2 m, in Geest around 31 m and on Fehmarn even 79 m. This is to be expected in that the fields on Fehmarn feature a homogenous soil. However the fact that even here a clear difference between the spatial areas emerged – characterised by the clear different deviations from 0 – made a spatially-specific fertilising appear practical.

Most fields showed a reduction in variability as vegetation period progressed as if the crops grew more uniform towards the summer. The MCD varied strongly between the application dates.

The MCD characterised the spatial area size in such a way that it gave the length upon which the sensor value could be taken as approximately constant. Thus they represented a lower threshold for the spatial area length which may be treated uniformly with safety. This is an important factor for the working width and division of the of spatial area sizes in spatially-specific Nr. fertilising: the heterogeneities should be recorded instead of working with roughly divided areas where uniform dunging through working width and area definition can be difficult to manage precisely. While the MCD, especially in the „östliche Hügelland" lay under 10 m with some application dates, (over the working width on average, however), the fertiliser application with a typical broadcaster width of 24 m is seen as sufficient for coping with the heterogeneities in the crop.

Literature

[1] *Heege, H.J. und S. Reusch*: Sensor for on the go control of site specific nitrogen top dressing. Annual International Meeting of the ASAE, July 14.-18., 1996, Phoenix, Arizona. Paper No. 961018

[2] *Ehlert, D.*: Pflanzenmasseerfassung mit mechanischen Sensoren. Tagungsband der Tagung Landtechnik 2000, S. 289-294, VDI-Verlag, Düsseldorf, 2000

[3] MiniVeg Nr. Sensor.: http://www.dlr.de/imf/miniveg.html, 2000

[4] *Franzen, D.W. and N. R. Kitchen*: Developing management zones to target nitrogen applications. Site-specific Management Guidelines http://www.ppi-far.org/ssmg, 2000

[5] *Thiessen, E.*: Sensorgesteuerte Stickstoffdüngung. Landtechnik 55 (2000), H. 2, S. 144-145

[6] *Han, S., J. W. Hummel, C. E. Goehring and M. D. Cahn*: Cell size selection for site-specific crop management. Transaction of the ASAE, 37 (1994), no. 1, pp. 19-26