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Modelling fertilizer distribution: Obtaining 2D from 1D spread patterns

Two-dimensional (2D) spread patterns are required to simulate site-specific fertilizer application in precision agriculture. The question is how models of spread patterns can be obtained with minimum effort. Causal models of fertilizer distribution try to address as much factors as possible to understand the complete process. Thus, these models become relatively complex and parameter estimation is difficult [2]. Additionally, the laborious measurement of two-dimensional fertilizer distribution is rarely done. Instead, the quality of fertilizer spreaders is evaluated by the lateral fertilizer distribution which is just one-dimensional (1D) [3]. This paper introduces a method for deriving two-dimensional from one-dimensional spread patterns of two-disc centrifugal fertilizer distributors.

Keywords

Fertilizer spreader, simulation, spread pattern

Abstract

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2D spread patterns of centrifugal disc spreaders were modelled by a seven parameter function fitted to 1D lateral distribution

To keep to a minimum the number of parameters a phenomenological model is used which sufficiently reproduces the performance of a two-disc spreader without mimicking physical processes. The model was based on the decomposition of fertilizer distribution of each disk into tangential and centripetal components. Both components were described by log-normal frequency distributions. The algebraic expression of the 2D distribution consists of four functionals modelling the tangential and centripetal of the left and right disc, respectively (Figure 1, top): SB(s,dd,x,y) = ZVL(s,dd,x,y) • TVL(dd,x,y) + ZVR(s,dd,x,y) • TVR(dd,x,y) with s being the requested fertilizer rate, dd is the distance between these discs, x and y are the coordinates of the spread pattern.

The number of effective parameters was seven (Figure 1, bottom). They were estimated by minimizing the squared difference between the lateral distribution observed and the lateral distribution derived from the 2D model. While this optimization function was nonlinear and possessed a large number of local minima, sophisticated methods of global optimization were required. Methods implemented in MATLAB's (2006a) "Genetic Algorithm and Direct Search Toolbox" were not able to solve this problem. Instead, a modified Hooke-Jeeves algorithm implemented by the "Direct Optimizer" [1] was successful. The "Direct Optimizer" converged quite slowly to the global optimum, but results were stable.

Results

Modelling of a spread pattern is depicted in Figure 2. Empirical data were obtained from experiments carried out at the Danish Institute of Agricultural Sciences, Research Centre Bygholm by K. Persson and H. Skovsgaarden under the direction of C. Weltzien within the joint project "preagro" [3]. Effective working width was set to 18 m. The lateral spread pattern of this particular spreader has a "crown" shape leading to a systematic deviation from the optimum triangular shape. One can observe an overstepping of the requested rate (100%) in the centre of the lateral distribution and an undershooting at the margins. The main features of this authentic spread pattern were sufficiently reproduced by the model. Noticeable divergences between observed and modelled data occurred near the centre of the lateral spread pattern.

Summary

A method of modelling 2D spread patterns using empirical data from lateral distribution analysis is presented. This method is efficient because data from lateral distributions are readily available from conventional spreader tests and just seven parameters are needed for fitting the model. Parameter estimation has to be done by means of global nonlinear optimization. Accuracy of the 2D spread pattern model is sufficient for simulating site-specific fertilizer distribution in precision agriculture applications.

Literature

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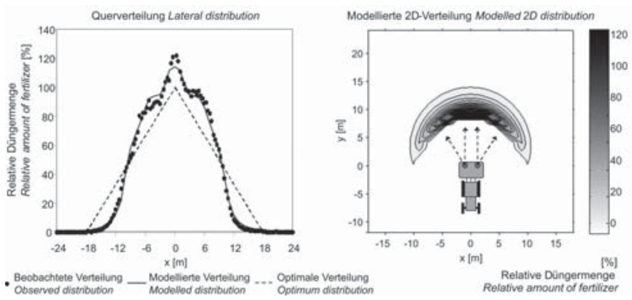
Fig. 1

Funktionale ***Functionals***	Linke Scheibe *Left disc*	Rechte Scheibe *Right disc*
Zentripetalverteilung *Centripetal distribution*	$ZV_L(s,dd,x,y) = a_Z \cdot \exp(-\ln(2) \cdot \ln(s + (w_L - b_Z) w (d_Z^2 - 1)/(d_Z \cdot c_Z))^2 \ln(d_Z)^2)$	$ZV_R(s,dd,x,y) = a_Z \cdot \exp(-\ln(2) \cdot \ln(s + (w_R - b_Z)(d_Z^2 - 1)/(d_Z \cdot c_Z))^2 \ln(d_Z)^2)$
Tangentialverteilung *Tangential distribution*	$TV_L(dd,x,y) = \exp(-\ln(2) \cdot \ln(1 + (\alpha_L - b_T)(d_T^2 - 1)/(d_T \cdot c_T))^2 \ln(d_T)^2)$	$TV_R(dd,x,y) = \exp(-\ln(2) \cdot \ln(1 + (\alpha_R - b_T)(d_T^2 - 1)/(d_T \cdot c_T))^2 \ln(d_T)^2)$
Wurfweite *Spreading range*	$w_L = \sqrt{x_L^2 + y^2}$	$w_R = \sqrt{x_R^2 + y^2}$
Wurfrichtung *Spreading direction*	$\alpha_L = \arctan(y/x_L)$	$\alpha_R = \arctan(y/x_R)$
X-Koordinate der Streuscheibe *X-coordinate of the spreader disc*	$x_L = -x - 0.5 \cdot dd$	$x_R = x - 0.5 \cdot dd$

Parameter ***Parameters***	Wurfweite *Spreading range*	Wurfrichtung *Spreading direction*
Maximale Häufigkeit *Maximum frequency*	a_Z	
Zentralwert *Central value*	b_Z	b_T
Streuung *Variation*	c_Z	c_T
Schiefe der Verteilung *Distribution skewness*	d_z	d_T

Model of the 2D distribution pattern of a spinner disc spreader

Fig. 2



Example of deriving a 2D distribution pattern from a 1D lateral distribution