1 Spatial Optimization of Fertilizer Application by a Centrifugal Spreader

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Abstract

Fertilization practice using centrifugal spreaders generally consists in the mass flow rate regulation thanks to the simple mathematical relation D=Q.L.V/600 where Q is the prescribed fertilization rate, L the working width and V the tractor speed. Modern machines equipped with DPAE device can thereby continuously control the mass flow rate with respect to the working width that is in most cases considered as constant during spreading. When computing the previous equation, one reasons as if fertilizer was homogeneously distributed by the machine onto a rectangular area which length is equal to the wished working width. This practice gives satisfying results with regularly spaced parallel travel direction but is very inefficient when geometrical singularities are met in the field (pointed end of field, irregularly spaced parallel travel path, bends, start and end of spreading) and then can produce some local application errors. Indeed, the broadcasted amount of fertilizer is often higher than the local crop requirements. In some cases, it can be lower and then results in smaller crop productions. Thus, spreading process is more and more considered as a source of pollution of groundwater and watercourses.

The difference existing between the fertilizer demands in the field and the actually applied fertilizer can be explained by an inappropriate fertilization strategy only based on the best transverse distribution adjustment and not on the overlapping of spatially heterogeneous distribution patterns. These can be modelled as the product of two Gaussians, one depending on the medium radius R_{med}, corresponding to the distance between the spinning disc centre and the distribution pattern centre, and the other depending on the medium angle θ_{med}, corresponding to the angle between the travel direction and a straight line that passes by the distribution pattern centre and the rotating disc centre [1]. In order to improve fertilization application accuracy, optimal paths were investigated [2], but this strategy is unsuitable for field crop area where paths are fixed by sowing. Therefore, it is important to know how best arrange the shape and the placement of distribution patterns during spreading with respect to the field geometrical characteristics. This adjustment should be continuously performed by changing several settings of the spreader.

An approach for optimization of fertilizer application by computing the optimal distribution pattern characteristics values, that is to say the mass flow rate D, the medium radius R_{med} and the medium angle θ_{med}, is presented. Constant rate fertilization, straight and parallel travels are considered. The target field is gridded with 1 m $\times$ 1 m cells where densities must get closer to the desired rate fertilization. After modelling spreading process and considering simplifying assumptions, a nonlinear cost function is proposed in order to minimize the application errors. Constraint bounds on decision parameters and time derivatives are formulated so that machine mechanical limits are taken into account. The prohibitive computational cost for the minimization function and gradient evaluations lead to implement an Augmented Lagrangian algorithm with BFGS limited memory [3]. Faced with a large scale optimization problem subjected to numerous constraints, one divided the initial problem into sub-problems. Thereby a sliding window is defined to reduce the number of parameters. It

denotes a rectangular surface that scans the field and on which the optimization algorithm is executed. Two methods are proposed :

- The first deals with juxtaposed sliding window. Thanks to this method, the scanning time of the field is rapid. However, it results in overdoses located at upper window limits.
- The second relies on overlapping of sliding windows. This strategy permits to eliminate the previous overdoses but takes long time. Nevertheless, if the treated field features geometrical similarities in some place, the computational time can be reduced.

The second method gives better results than first and application errors can be reduced to a value inferior to 15%. This optimization of distribution patterns parameters can be used on the one hand to decrease the global application error because it takes account of parcel geometry and on the other hand to locally limit spreading defects by adjusting distribution patterns. Thus, the featured technique should offer new possibilities about the error minimization when non parallel and curved paths are met.

References

1. Colin, A., *Etude du procédé d'épandage centrifuge d'engrais minéraux*. 1997, Phd. Thesis, Université Technologique de Compiègne. 207 pages.
2. Dillon, C.R., S. Shearer, J. Fulton, and M. Kanakasabai, *Optimal path nutrient application using variable rate technology.* Precision Agriculture. Eds. Stafford J., and A. Werner. Wageningen Academic Publishers., 2003. p. 171-176.
3. Byrd, R.H., J. Nocedal, and R. B. Schnabel, *Representations of Quasi-Newton matrices and their use in limited memory methods.* Mathematical Programming, 1994. **Vol. 63**: p. 129-156.