Perspectives For Site Specific Application Of Soil Herbicides In Arable Farming

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Abstract

The use of soil herbicides will become more sustainable when the dosage is adjusted to local soil condition. This so called Variable Rate Application (VRA) is the core of Precision Farming.

With increasing advances in sensing and spray technology, and the development of Decision Support Rules (DSR), the shift to VRA application is likely to occur soon. Soil applied herbicides are sprayed around crop-emergence and kill germinating weed seeds in the top few cm of the soil. The activity of a herbicide in the soil is influenced by physico-chemical characteristics of the herbicide, and weather and soil conditions. For the VRA application of soil herbicides, the relation between herbicide efficacy and relevant soil properties needs to be known, and has to be described with a DSR or more complex model. Today, at least three types of soil sensors can be used to scan soils on soil properties such as organic material or clay content. DSR can be obtained by greenhouse experiments, on-farm trails, bioassays, literature reviews, modelling, or a combination of these methods. A soil map with data on the spatial variation of the relevant soil properties is required. Soil maps can be obtained by soil scanning in combination with soil sampling plus analysis and interpolation. Combining soil maps with DSR provides recommended dosage maps. The farmer or farm advisor then adjusts these dosage maps in his Farm Management System (FMS), taking into account routing and settings and properties of his spray equipment, providing task maps.

The first steps to implement VRA of soil herbicides have been taken on innovative farms in the Netherlands within the R&D of two precision farming programs. Results of the R&D are summarized in this manuscript. Perspective of VRA of soil herbicides is discussed.

Introduction

Pre emergence herbicides are applied to the bare soil after sowing and generally before emergence of the crop. They kill germinating weeds in the top soil layer. The amount of herbicide available for effectively controlling weeds is strongly depended on the degree of sorption of the herbicide to soil particles. Less herbicide is available for uptake if it is sorbed by clay or soil organic content of the soil. The efficacy of a specific herbicide is thus determined by soil factors such as organic matter and clay content (Peter & Weber, 1985; Blumhorst et al., 1990; Williams et al., 2001). Besides attributes of the agro environment (e.g. pH), physico-chemical characteristics of herbicides affect behaviour of the herbicide after application (Carter, 2000).

Arable fields show within-field variation of soil properties such as texture and organic matter content (see a.o. Cambardela et al., 1994 and Heijting et al., 2011). The practice of precision farming takes this variation into account when applying crop management activities such as fertilization and spraying. When adjusting input of soil applied herbicides to local needs, the financial and environmental spillage is minimized, while still ensuring good control of weeds. An increasing amount of data on within-field soil variation becomes available. To adjust herbicide dosage to local circumstances, not only data on field variability are needed but also knowledge and insight in processes affecting the herbicide efficacy.

A successful pesticide VRA system for soil herbicides consists of (1) a sensing unit for detection of site-specific variation in soil conditions, (2) a decision making unit that translates sensor readings into need and a minimum effective dose, and (3) an actuator or implement unit that applies the herbicide in a site specific dose (Kempenaar et al., 2012). VRA can be applied at levels of irregular patches, regular raster or grids, or individual plants (Christensen et al., 2009). In this paper, we describe the progress in the development of a VRA system for site-specific application of soil herbicides at grids of ca. 50 m^2. Soil scanning was done with gamma radiation, electromagnetic resonance or near infrared (NIR) sensor technology (e.g. ECPA, 2013). R&D results are presented and perspectives are discussed.

Materials & Methods

This section contains a short description of the hardware (sensors and sprayers) we used to develop a VRA system for soil herbicides, and the lab and desk studies we did to develop DSR. For details we refer to study reports.

Sensors, soil maps and sprayers

We worked with soil maps based on sensing with at least three technologies: gamma radiation, electromagnetic magnetic (EM) resonance and NIR (see Figure 1). The Veris sensor combines NIR with other technologies. All technologies require soil analyses for calibration of the sensor(s). For details, we refer to websites of the technologies, or ECPA (2013) and Kempenaar et al. (2012).

Figure 1. Overview of soil scan technologies used in the R&D program.

One type of variable rate application (VRA) was studied in the on farm experiments: task map spraying using organic matter or clay content soil maps and concept DSR. Task maps were made with software of Farm works or Akkerweb. Most experiments were done with a CHD arable field sprayers (see Figure 2) in combination with a Müller terminal for sprayer control. The experiments were done on commercial farms in e.g. Biddinghuizen, Dronten and Vierhuizen in The Netherlands. Soil types on the farms were marine clay, with a lutum generally between 20 and 40 %. The task maps were made for sprayers with spray booms between 27 and 45 m wide. Dose optimization is then done at a scale of 25 – 100 m^2.

Figure 2. Overview of field test with VRA task map spraying in sugar beet.

Experiments

We carried out several dose-response experiments with different types of soil, herbicides and plant species. Clay, sand and peat soils were collected from arable fields. Mixtures of these soils were made to have soils differing in lutum fraction (2 - 50%) or organic matter (o.m.) content (1 - 30%). Soils with the desired clay or o.m. content were put in 0.5 - 1 L pots. Seeds of plant species of interest were added to the soils. We tested a.o. the following soil herbicides: prosulfocarb, linuron, dimethenamid-P and isoxaflutole. The herbicides dosages were applied with an air-pressurized laboratory track sprayer delivering 400 L ha^{-1} (Birchmeier 1.2 mm cone nozzles, 300 kPa, and medium fine droplets). The pots were placed in a greenhouse for observations on emergence of plants and level of control. E.g., ED_{90} (the dose that gives 90% reduction of aboveground biomass compared to untreated at 3-4 weeks after treatment) were calculated. Water and nutrients were adequately supplied. Day temperature was set at 18 °C, night temperature at 12 °C and relative humidity at 70%. Photoperiod and light intensity were influenced by season. For details, see Dobma (2008) and Tielen (2010).

DSR and task maps were tested in on farm experiments. Farmers were asked to test VRA task maps on one or more of their fields. They were asked to spray at least one spray strip (27 – 45 m wide) with the VRA task map. The other part of the field was sprayed according to a common practice fixed rate. Crop and weed growth was evaluated by visual assessments. For details, see Heijting et al., 2013. The validation of the DSR is ongoing until 2015.

Results & Discussion

This section contains information on how we came to a dosing model for VRA of soil herbicides plus an example of the task maps we tested. We end the section with conclusions and outlook. Figure 3 is a typical example of soils maps we had access to.

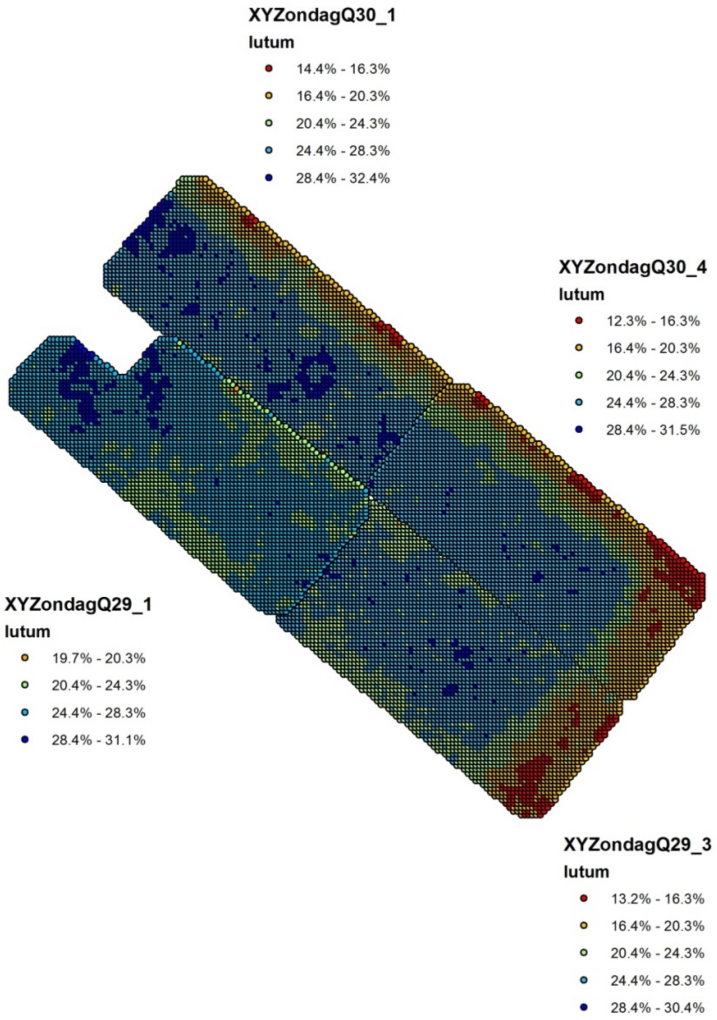


Figure 3. Soil lutum map of four fields of an arable farm in Biddinghuizen made by Medusa Company (2011) and visualized in ArcGis. The map is based on gamma radiation sensing. Fields have sizes of ca 500 by 200 m. Field Q29_1 comes back in Figure 6 as well.

Dosing model

Figure 4 shows typical results we obtained in dose-response experiments in the greenhouse. Significant effects of species and soil organic matter (o.m.) or clay content on herbicide efficacy were observed. ED_{90} were higher when the o.m. or clay content was higher. The slope of the regression line differed between species and herbicide.

We then searched for a way to summarize the information from the greenhouse experiments in a basic model for VRA of soil herbicides. The simplest model we made was a linear relation between soil parameter and dose, in combination with a minimum and maximum dose based on expert judgement or legal conditions. For the example we show in Figure 6, VRA of Boxer (a.i. is prosulfocarb), the parameters are given in Table 1. The model covers weeds that are normally sensitive to the herbicide. If less sensitive weeds are expected, other herbicides or DSR should be used.

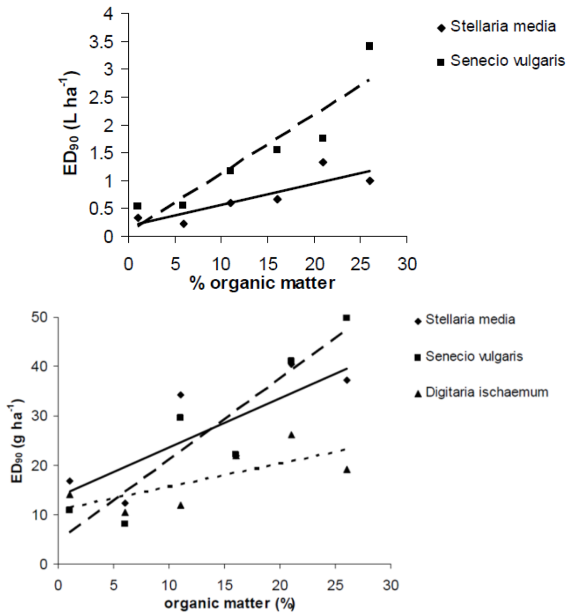


Figure 4. Herbicide efficacy of dimethenamid-P and isoxaflutole in pot experiments (Tielen, 2010).

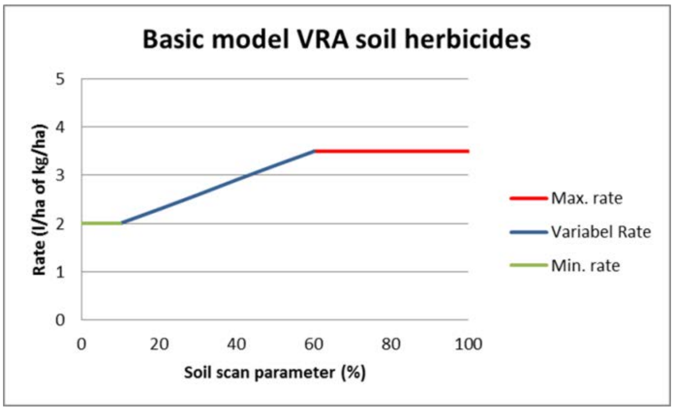


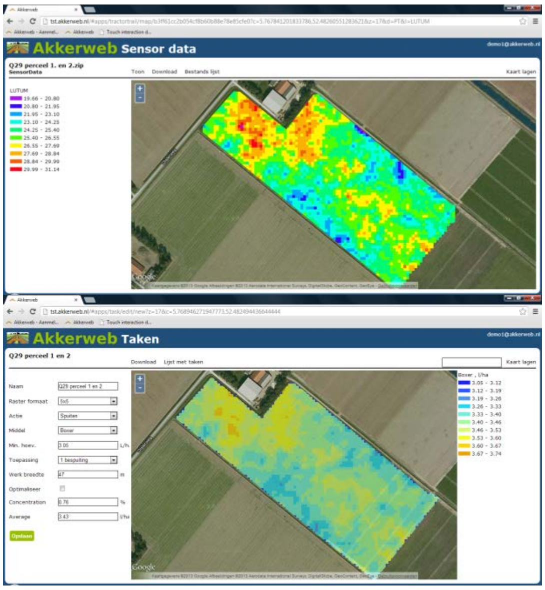
Figure 5. A basic model that translates soil scan parameters into dose rates.

Table 1. Parameters for the DSR that translates lutum fraction into minimum effective dose of Boxer herbicide.

				Function	y=ax+b
Herbicide	A.i., content	Min. dose	Max. dose	a (r.c.)	b (intercept)
-	-	[l prod./ha]	[l prod./ha]	[-]	[-]
Boxer	Prosulfocarb, 800 g/l	2.5	4.5	0.048	2.4

On farm experiments

The first on farm experiments started in 2011. In the first years, we had problems getting task maps sprayed by the field sprayers of the farmers. We were able to make task maps, but the task maps were not read by the sprayer control terminals or data were not stored. In 2013 we had solved some of the start-up problems, and we applied our first VRA soil herbicide task maps on commercial fields. The farmer involved was satisfied with the result. We had good level of control, fewer effects on the crops on parts of the field with low clay content, and a reduction in herbicide use. The on farm studies are continued in 2014 and 2015. In Figure 6 we show the four steps in the making of a VRA task map of Boxer. This VRA map resulted in a herbicide use reduction of ca 15 % compared to the fixed rate the farmer normally would apply.



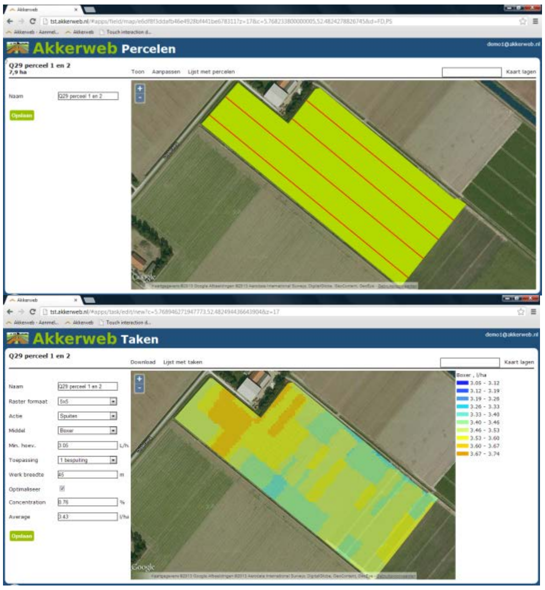


Figure 6. A grid raster of lutum content of an arable field in Biddinghuizen (top row left), the corresponding VRA dose map based on the translation of the lutum map into boxer dose with the DSR parameters shown in Table 1 (top row right), tramlines of the sprayer on the field (bottom row left), and task map with grids for a 45 m wide spray boom (bottom row right).

With the further technological development, VRA of soil herbicides will soon became a Good Agricultural Practice (GAP) on arable farms. It will contribute to a more sustainable use of pesticides. The spatial variation within the field, the DSR, settings and properties of the sprayer, and the route planning within the field together determine the possible reduction in the applied herbicide. First results of on farm research show that with such a VRA system, level of weed control remains good while herbicide side effects on the crop are minimized. And herbicide use will be reduced. It is a challenge for the stakeholders involved to come to system where farmers have access to validated DSR.

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