ECONOMIC EVALUATION OF A VARIABLE LIME APPLICATION STRATEGY BASED ON SOIL PH MAPS DERIVED FROM ON-THE-GO PH-MEASUREMENTS UNDER GERMAN CONDITIONS

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ABSTRACT

Spatial soil pH variability of more than 2 pH units can occur in a field even within short distances. To cover these in-field differences variable liming strategies are necessary but have not been used in Germany due to substantial costs for manual soil sampling and lab analysis so far. By using the on-the-go soil pH mapping system Veris MSP, this variability can be measured at high spatial resolution. However, the decision to use such an on-the-go pH sensing system to calculate variable lime application rates has to be based on reliable information on economic data for soil and cropping conditions in Germany.

A detailed survey based on test measurements for different fields (small, medium, and large scale) under practical farm conditions was conducted. Time requirements needed for all working steps (incl. preparatory phase, online pH-measurement in the field, collecting reference soil samples, data management and preparation of lime application maps) were measured and labor costs were calculated using typical wages for agricultural service providers. Furthermore investment costs for technical equipment and costs for tractor use were considered. On the other hand the profit for farmers due to variable lime application (i.e. savings in lime, increased yields due to optimal soil pH in each subunit of the field) were calculated based on results from field trials.

Depending on field size the time required per hectare for the complete process (i.e. from preparatory activities to lime application map) decreased from 38 min/ha for a 3 ha field down to 8 min/ha for a 100 ha field. Average annual costs for the equipment (including 500 € for repairing) sum up to 1.81 €/ha assuming that in one year 1500 ha can be scanned with the system. The final service fee an agricultural contractor has to charge for such an online pH-measurement is also drastically decreasing with field size: 69 €/ha for a 3 ha field vs. 8 €/ha for a 100 ha field. For small fields site-specific lime application is therefore not reasonable.

Keywords: in-field variability, service charge, soil pH mapping, Veris MSP

INTRODUCTION

Because under most farming conditions a decrease in soil pH over time occurs, application of lime is a standard farm practice to readjust soil pH. In general every 3 to 5 years one representative soil sample from the top soil layer is collected from a field and analyzed in the lab. Based on these results (taking also into account soil texture and organic carbon content) liming rates are calculated. Up to now on almost all farms in Germany liming is done uniformly for a given field, although it has to be expected that within a field variation concerning soil pH might exist. However, the cost-benefit ratio for site-specific liming appeared not promising due to high costs for manual soil sampling and pH analysis in the lab to assure the required density of pH-measurements (e.g. Adamchuk and Mulliken, 2005).

Recently, the Veris MSP sensor for high-resolution mapping of soil pH has been made commercially available in Germany and the technical performance of the system was evaluated under German soil, climate and farming conditions (e.g. Olfs et al., 2010; Schirrmann et al., 2011). Soil pH is measured using ion selective antimony electrodes on-the-go directly in soil samples taken by a sampling shoe from a depth of approximately 8 - 10 cm. Based on reference samples from each field online pH readings can be transformed into pH values that are equivalent to the German standard lab procedure to derive site-specific lime application maps. Although economic benefits of a such variable rate lime application strategy using on-the-go measured soil pH values has been demonstrated under US farming conditions (Adamchuk et al., 2004; Bongiovanni and Lowenberg-Deboer, 2000), introduction into farm practice in Germany needs a reliable economic evaluation for the contractors offering this kind of service to farmers as well as for the farmer.

MATERIALS AND METHODS

Economic calculations were based on costs related to operational hours, investment costs (including depreciation, interest on capital as well as maintenance and repair) and expected profit due to improved crop growth and reduced lime application.

Time recordings for all preparatory activities before Veris MSP pH-measurement can start (e.g. mounting of the Veris MSP to the tractor, filling of the water tank, installation and calibration of the electrodes, check-up of all pumps and filters) as well as post-processing tasks at field level (e.g. storage of all raw values, data export into Excel based software, data analysis, settling of 3 zones for reference sampling) were done with 3 replicates. On three arable fields with different size (3, 12, and 30 ha) online pH-measurements were conducted and gross times required were recorded (including all interruptions due to turning activities or malfunction of the sensor system). In addition the time necessary for collecting the reference samples as well as the time needed for the final data management including the generation of a lime application map have to be considered.

Assuming that a service contractor will replace the equipment every 10 years fixed costs per year were calculated. Purchase cost, costs for the adaptation to German farm technique (e.g. fitting to electrical power and hydraulic systems of the tractor), estimated value of the Veris MSP at the end of its utilization period, depreciation and interest were taking into account. Average costs for repairs were estimated making use of data from a 2-year usage of the Veris MSP in the framework of a R&D project.

The economic evaluation of site-specific lime application for the farmer is based on the following assumptions: (1) no difference in the total amount of lime applied per field due to the variable liming strategy, (2) increased costs for lime application (+ 5 €/ha) because a lime spreader with a device for online variation of the application rate has to be used, (3) suboptimal soil pH values on 25 % of the total area has to be corrected, (4) liming is done once in an oilseed rape – winter wheat – winter wheat – winter barley crop rotation. For such a crop rotation the average revenue calculated with market prices of 2011 in Germany was 1300 €/ha. Supposing yield increases of 2 % for winter wheat and 5 % for winter barley and taking into account that this increase is only realized on some parts of the whole field an average extra profit of 9.56 €/ha was calculated.

RESULTS AND DISCUSSION

Time required for preparatory as well as for post-processing tasks (including calculation of the site-specific lime application map) differ only marginal between field sizes from 3 to 100 ha (Fig. 1). For the collection of the reference samples between 30 minutes for a 3 ha field to about 1 hour for a 100 ha field have to be considered. As expected the total time spend for the online pH-measurement itself increased with field size (25 min for 3 ha to 400 min for 100 ha). Time demand for the total process per ha decreases from 38 min/ha for the 3 ha field to 8 min/ha for the 100 ha field.

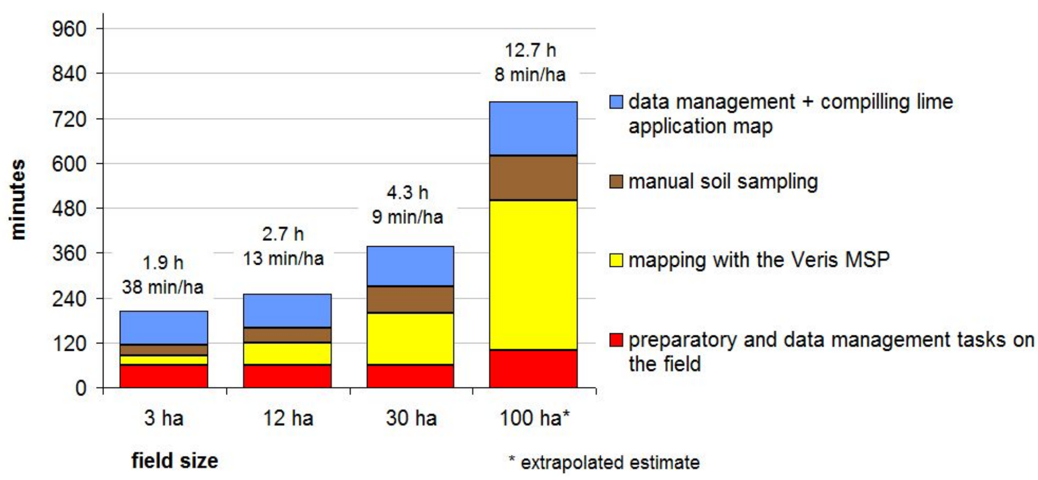

Figure 1. Time required for different tasks related to the use of the Veris MSP for online pH measurement depending on field size

Based on the data in Table 1 the overall annual fixed costs for purchasing the Veris MSP, technical adaptations, residual value after 10-years usage, depreciation and interest sums up to 2220 €. Furthermore 500 € per year have to be assessed for repairs and replacement/wearing parts. Assuming that the pH online measurement is realized on 1500 ha/year total costs per ha can be calculated as 1.81 €.

Table 1. Fixed costs for a Veris MSP online system (usage period 10 years)

Veris MSP sensor system	19600 €
Required technical adaptation	1200 €
Residual value (after 10-years usage)	7000 €
Annual depreciation	1380 €
Annual interest (interest rate 4 %)	840 €
Annual fixed costs	**2220 €**

For the final specification of the service fee the contactor has to charge to a farmer, the total costs for different field sizes need to be calculated (Fig. 2). For this calculation the costs for a mid-sized tractor (70 – 80 KW; 25 €/h), the wages for a skilled worker (responsible to carry out the online measurements including all preparatory/past-processing tasks as well as the reference sampling), lab costs for the pH measurements and finally the wages for an agricultural consultant (50 €/h) who is responsible for final data management and compiling the application maps for variable liming were derived from a specialized database with representative economical data for typical farms and farm services in Germany (KTBL 2010). The total costs ranged from 207 € for the 3 ha field to 814 € for the 100 ha field (Fig. 2). The costs per hectare decease drastically from 69 €/ha down to 8 €/ha. These calculations are based on the assumption that the Veris MSP system is used to scan 1500 hectare per year. Scenario calculations with an annual operational area of 1000 and 2000 hectare reveal that overall costs per ha change only marginal (data not shown).

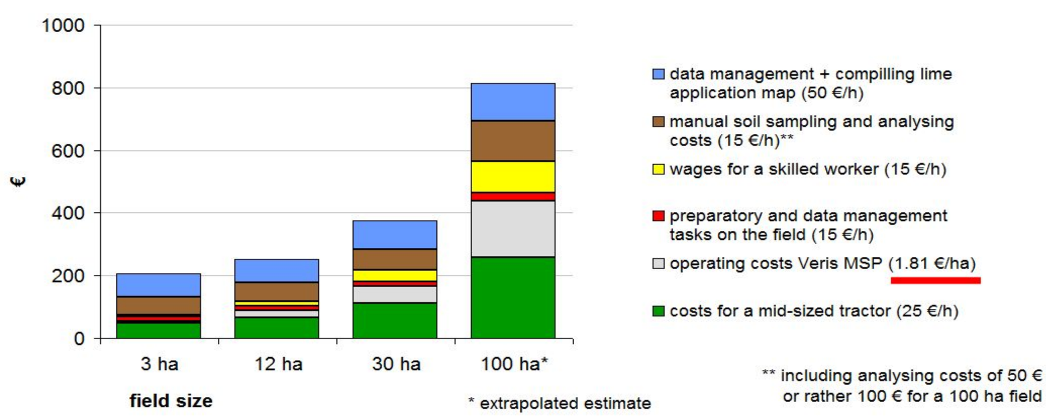

Figure 2. Calculated service charges for different field sizes assuming an annual scanned area of 1500 ha (based on time recordings, fixed costs and typical German labour costs depending on the qualification of the employees)

The economic evaluation reveals that for a farmer a site-specific lime application strategy is not reasonable for small fields (net loss 100 €/field; Tab. 2). This is mainly due to the fact that the costs for collecting the reference samples (including lab costs) as well as for data management and generation of a lime application map are more or less not depending on field size (see Fig. 2). Calculation of the extra profit due to variable lime application increased from 166 € for a 12 ha field to 2648 € (= 26 €/ha) for a 100 ha field.

Table 2. Cost-benefit calculation for farmers based on different field sizes

field size (ha)	3	12	30	100
mapping costs (€/ha)	69.03	21.12	12.48	8.14
mapping costs (€/field)	207	253	374	814
increased lime application costs (€/field)	15	60	150	500
savings due to redundant standard soil sampling (€/field)	7	21	42	140
additional costs (€/field)	**215**	**292**	**482**	**1.174**
average yield increase due to optimized soil pH (€/ha)	9.56	9.56	9.56	9.56
average yield increase due to optimized soil pH (€/field)	29	115	287	956
average yield increase due to optimized soil pH (€/field in crop rotation)	**115**	**459**	**1.147**	**3.823**
extra profit of site specific lime application (€)	**-100**	**166**	**664**	**2.648**

Adamchuk et al. (2005) developed a numerical model for quantitative assessment of the net return over cost of liming for different lime management strategies showing that the largest benefit (6.13 $/ha and year) was generated from using an on-the-go soil pH mapping approach.

CONCLUSION

Although considerable in-field variability of soil pH has been demonstrated for arable fields in north-western Germany using the Veris MSP system for on-the-go pH-measurements the usefulness of variable lime application depends strongly on field size. A precise liming strategy will result in a more homogeneous soil pH status compared with standard farm practice and finally improve crop growing conditions. However, break-even for the farmer depends above all if and to what extend crop growth is improved due to a more adequate soil pH (Adamchuk and Mulliken, 2005).

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