Precision Tillage: Online variation of tillage depth

Walther, S., T. Schüle and K. Köller

Universität Hohenheim
Institute for Agricultural Engineering (440d)
Garbenstr. 9 • 70599 Stuttgart-Hohenheim
Germany
Fax: +49-711-459-23298
steffen.walther@uni-hohenheim.de

Precision Farming, Precision Agriculture, site-specific, tillage

Summary
Precision Farming equipment is more and more common on modern, large scale farm enterprises. With basic equipment being available, an important condition for the use of site-specific approaches is given. Site-specific approaches may help to increase the efficiency of a farm enterprise, as well as may help to achieve certain, predefined goals. A site-specific tillage strategy focusing on soil conservation was developed and evaluated. Online inclination data and local available biomass, calculated from yield maps, was used to compute necessary working depth for each unit area of a site. A control-unit controlling an electronic valve for two hydraulic cylinders fitted with displacement transducers and an on-board computer system implemented the calculated working depth online. While working precision was excellent, the time span require to switch between two working depths can be optimized.

INTRODUCTION

Modern technologies in the frame of Precision Farming have led to the development of various site-specific approaches. While some of these approaches have been successfully established on the market, e.g. in fertilization [1; 2], other fields have yet to prove its advantages in large scale farming. Variable tillage intensities have been discussed in science and on manufacturer level as a promising strategy to reduce both, operational input and ecological impact [3; 4, 5].

Precision Farming equipment refers to a variety of tools available to the farmer, either as part of a proprietary solution, or not brand specific. In the latter category, we find both, suppliers of GPS and GIS technology offering solutions for the agricultural market, agricultural companies that develop non-proprietary solutions, and co-operations between GPS/GIS specialists and agricultural companies. In either case, this technology is well present especially on modern, large agricultural enterprises. The most common equipment includes [6]:

- GPS steering assistance or auto-guidance solutions.
- Guidance aids for harvesting machines.
- Yield mapping systems.
- Electronic dosage control (seeder / fertilizer spreader).
- Fertilizer demand sensors.
Especially the GPS system is crucial to most other operations, unless online sensors are used. However, even in this case documentation may be of interest and would require spatial orientation on the field. This is today nearly exclusively done via GPS. A highly accurate and durable GPS system for agricultural purpose is a major investment and only makes sense, if the system can be (and is!) used for as many applications as possible. Site-specific tillage is a promising approach, as tillage operations are generally considered to be carried out more efficient with guidance aids. Hence, site-specific solutions therefor are a consistent step to utilize synergisms.

Site-specific tillage has been found to have a potential to save time and utility-costs [7], while yield is not significantly reduced. Another important issue is soil protection, e.g. thru reducing the risk for soil erosion [4, 5]. Especially during high-water and flooding events, this issue is discussed vividly. Generally, it should be possible to define any goal, amongst these could be:

- Minimization of operational input.
- Reduction of erosion risks.
- Maximization of yield.
- Minimization of yield risks.
- Maximization of marginal income.
- Consideration of weed-level.
- Consideration of local melioration requirements (hard pan / moist pan).
- Consideration of phytosanitary requirements.
- Other.

However, farmers are frequently reluctant to change their approved systems towards less or even no tillage. Site-specific farming allows farmers to conduct a desired level of soil tillage in general, while defining zones where more or less intense tillage is required. This can lead to a better acceptance of reducing soil tillage intensities as a whole on farm level [5]. Soil tillage implements allowing the in-field variation of tillage depth are already available on the market [8; 9; 10]. If these are used as an online tillage solution, the functionality is however often limited, e.g. to only two depths. Additionally, intense offline pre-processing may be required. A decision support system does not exist. Manual depth control is possible, but cannot be considered to be an alternative for large scale tillage operations. For this reason, a solution of merging (available) offline and online data via appropriate algorithms was evaluated in the context of a field study in central Saxony, Germany.

MATERIAL AND METHOD

The chosen implement, an Amazone BBG Centaur 3002 (Figure 1), controls the working depth with hydraulic cylinders moving the tines, mounted on an own frame, up and down parallel to the implement frame [8]. Technical modifications on the implement include mounting an electronic valve to the hydraulic system, allowing full online access. Additionally, a potentiometric displacement transducer was fitted to the hydraulic cylinder, measuring the working depth. The entire system was controlled via a control unit that was connected to a mobile computer on the tractor. The computer merged the online sensor data, e.g. inclination, with mapped data, e.g. a yield map, calculating a set-value that was fed to the control-unit. The control-unit continuously compared set value and actual value, adjusting
accordingly. The decision-algorithm was developed prior to the tillage operations. An RTK-GPS system was mounted on the implement to be independent from the GPS system of the tractor.

In the study, the focus was put on reducing soil erosion risks. The study region in central Saxony is renowned for its fertile, but erosive loess-loam soils. Uphill and downhill stretches in combination with large field sizes and frequent heavy fall storms with intense rainfall increase this risk. Consequently, farmers and authorities are interested in technological approaches that sustain high yield levels without compromising sustainability. Large adjacent waters and rivers, e.g. the Elbe River, also suffer from translocated material. Policy-makers have to balance agricultural and public interests.

The parameters driving erosion are readily known [11]. For tillage operations, the two main criteria are inclination and soil surface coverage after tillage. Hereby, soil surface coverage is a function of available (residual) organic material (e.g. straw) and tillage intensity. The desirable soil surface coverage level was defined to depend on the local inclination, measured with the online sensor for the respective working width. Of course, subsequent operations, e.g. drilling technology, as well as phytosanitary aspects, and the crop being cultivated are key parameters to define the maximum level of surface coverage possible. These parameters are known and can be accounted for accordingly, allowing to create a unique decision matrix, as shown in Table 1 for e.g. subsequent mulch seeding of winter wheat with the preceding crop winter barley. For other crops this matrix has to be reconsidered, as some crops, e.g. rape, do not yield high enough amounts of residual material as required for the mentioned levels of desirable soil coverage.

Table 1: Inclination and soil coverage (example).

<table>
<thead>
<tr>
<th>Inclination class (%)</th>
<th>Desirable soil cover (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2,5</td>
<td>not relevant</td>
</tr>
<tr>
<td>2,5 - 5,0</td>
<td>15</td>
</tr>
<tr>
<td>5,0 - 7,5</td>
<td>25</td>
</tr>
<tr>
<td>&gt; 7,5</td>
<td>35</td>
</tr>
</tbody>
</table>
To be able to calculate the locally available amounts of residual biomass (straw), a combine-harvester with yield mapping is required during harvesting. The result can be converted into a raster map, e.g. showing deci-tons (dt) of organic material per unit area (ha). In-field orientation took place with an RTK-GPS system mounted on top of the implement. According to the inclination measured at the given position in field, and the local amount of residual material, the working depth was calculated and implemented online (Table 2). Below 2,5 % of inclination the default value, as common for the region, was used as a manual overwrite.

### Table 2: Amount of straw and computed working depth (example for two inclinations).

<table>
<thead>
<tr>
<th>Amount of straw (dt)</th>
<th>Working depth (cm) 2,5 % - 5,0 %</th>
<th>Working depth (cm) 5,0 % - 7,5 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 15</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>15 - 25</td>
<td>7,5</td>
<td>5</td>
</tr>
<tr>
<td>25 - 35</td>
<td>7,5</td>
<td>5</td>
</tr>
<tr>
<td>35 - 45</td>
<td>10</td>
<td>7,5</td>
</tr>
<tr>
<td>45 - 55</td>
<td>10</td>
<td>7,5</td>
</tr>
<tr>
<td>55 - 65</td>
<td>12,5</td>
<td>10</td>
</tr>
<tr>
<td>65 - 75</td>
<td>12,5</td>
<td>10</td>
</tr>
<tr>
<td>75 - 85</td>
<td>15</td>
<td>12,5</td>
</tr>
<tr>
<td>85 - 95</td>
<td>15</td>
<td>12,5</td>
</tr>
<tr>
<td>&gt; 95</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

**RESULTS AND DISCUSSION**

Draught force under stable soil conditions depends mainly on working depth, the choice of shares, and the presence or absence of preliminary work, e.g. stubble clearance. Draught force requirements for different pre-conditions and under consideration of desired results are shown in Figure 2. Stubble clearing, here with a disk harrow (SE, approx. 5 cm working depth), clearly reduces draught force requirements for comparable working depths. At the same time however, the working effect of a disk-harrow allows to achieve comparable results considering soil coverage with less working depth in the subsequent operation. For an acceptable result for seeding, the working depth without stubble clearance was about 7 cm with wing-shares (FS-OB 6,95). With stubble clearance, the same result could be reached with 5 cm working depth (wing-shares, FS-SE, 4,97). The different effect of the shares can be seen in the fact that, despite stubble clearance, the minimum working depth resulting in acceptable performances for twisted shares was 12 cm (WS-SE; 11,99). The columns with a working depth index (e.g. 6,95 cm) refer to tillage with fixed depths, while the columns coded with “0,00” are the result of variable depth tillage. A significant reduction of the required draught forces is a positive side-effect of variable tillage.
Figure 2: Draught force requirements.

An important point is the speed and accuracy a respective depth is reached. The transition zone, especially when switching between two extreme values, e.g. from 12.5 cm to 20 cm (Figure 2), should be minimized. The time required to reach the set value (20 cm) is 2.5 s. This equals to 8.3 m at a working speed of about 12 Km/h (3.33 m/s). Smaller changes in working depth are however more common. When changing from 12 cm to 17 cm, the time to reach the target value is little more than 1 s or about 3.5 m. It should be kept in mind that the tillage implement is already about 10 m in total length, not counting the tractor.

Figure 3: Transition zone between two working depths (fixed depth).

CONCLUSION

Draught force increases with working depth and decreases with preceding tillage operations. With soil conservation being a target goal, and using the presented algorithm, the efficiency gain increases with increasing amounts of inclined areas on a site and its dimension. Sensor data, used to measure inclination, is robust and practicable. This convenient tool can be considered to be easily adaptable for comparable systems. Yield maps are frequently available to farmers or can be obtained at low or no extra costs. They are a good and practicable aid to decision making in site-specific tillage, especially when soil-surface coverage is important. Improvements should be possible considering the speed the implement requires to reach the working depth. However, the classes and absolute values
have to be set by the responsible persons themselves – allowing full control over tillage operations. In general the presented system can be considered to be a good aid to an able farmer.

**REFERENCES**


