Precision Management and Technologies for Organic Field Crop Production

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INTRODUCTION

When we think of organic farming we do not often think about the latest technology in agriculture or precision farming. Some precision technologies have been developed specifically with organic farmers in mind, while others developed for conventional agricultural systems have the potential to be applied in organic systems. Let's first review some important terms in order to understand how precision management and associated technologies can be applied in organic production.

Precision

Precision refers to the degree of refinement with which an operation is performed; adapted for extremely accurate measurement or operation.

Technology

More broadly, 'technology' refers to the application of scientific knowledge to develop methods, systems, and devices being used for a practical purpose.

Precision Management

Precision management in agriculture refers to the use of technology to optimize the management of crops which may range from targeting individual plants for treatment to managing different soils across a field. Precision management relies on detailed information about the growing environment across the landscape and the expected response of a targeted crop or individual plant to a management practice.

Site-specific management could be based on information that has been previously gathered through mapping (e.g., slope position, fertility, yield, crop stress, moisture, salinity, soil type, travel pathways etc.). The information could also come from using sensors and computing systems that collect data in real time in the field.

Smart Agriculture

Smart agriculture involves the use of new technologies (e.g., digital sensing, communication, big data, internet of things, machine learning) to track, monitor, analyze and automate agricultural operations *(Fig. 1)*.

Ultimately, these technologies provide information so that a producer can be more proactive, productive and resource efficient through more informed management decisions and use of automated systems.

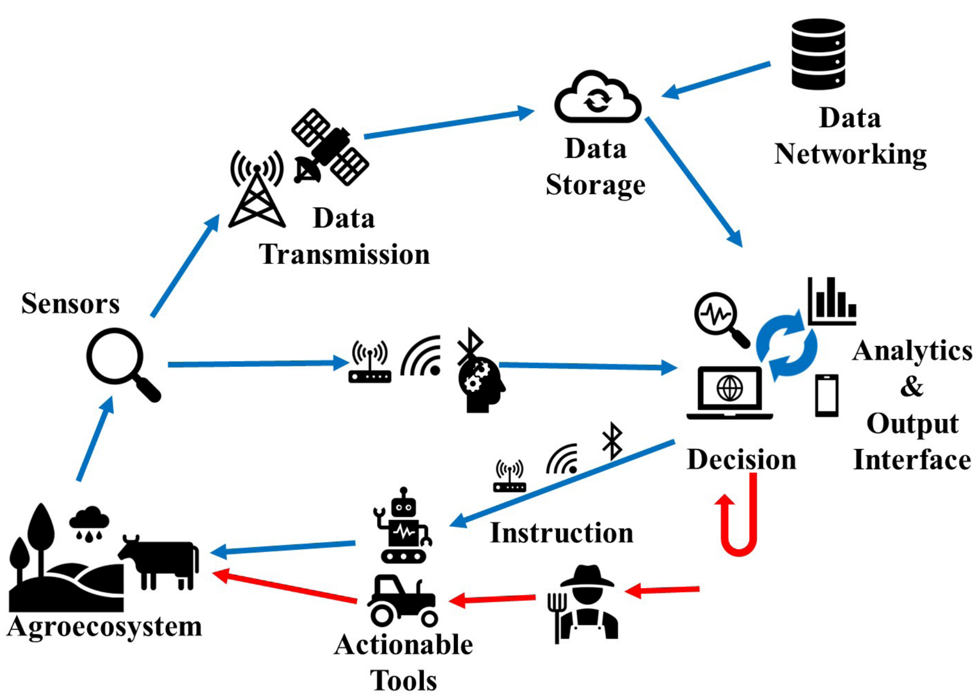

Fig. 1. Components of a smart agricultural system. Digital sensors gather information from a target such as a landscape and transfer data to a computing system that interprets the data and provides a recommendation to an automated system or to the farmer. Image: Andrew Hammermeister

TECHNOLOGY THAT COULD BE USED IN ORGANIC GRAIN FARMING

The most common production challenges in organic agriculture relate to maintaining soil fertility and controlling pests. Organic inputs are less available and more expensive than conventional counterparts. Thus, strategic and targeted use of these inputs can be economically advantageous.

Variable rate application

Organic inputs are expensive and may be limited in supply. Crop and cultivar performance can vary across the landscape depending on soil fertility, moisture, salinity, pH and possibly even weed competition. If soil type and slope features have been mapped, seeding plans and soil amendment application could be adjusted to be optimized for the growing environment. Using field level sensing and mapping technologies combined with a global positioning system can allow varying application of inputs across the landscape.

Variable rate input application requires: soil or landscape information + knowledge of crop response + prescription mapping + global positioning system + variable rate control on equipment.

Variable rate application and sectional control may not have much benefit on a uniform field but become much more useful in fields with irregularities such as knolls, slopes, and wetlands. The return on investment will also depend on the amount of inputs that are used, how many obstacles are in fields, the size of the farm, and the scale of equipment being used.

The most common use of variable rate practices is fertilizer application where granular or liquid fertilizer can be easily metered out at different rates, and potentially even with different blends. Of course, these inputs are not readily available for organic farmers.

Having seeding rates or cultivars targeted at different landscape positions could produce a more productive crop. For example, higher seeding rates would be more advantageous at lower slope positions where there is higher moisture and fertility, and potentially more weed competition. However, high seeding rates on hilltops may be less advantageous and may produce a lower economic return on costly seed. Unfortunately, there currently is insufficient information about crop/cultivar response to landscape position to allow such precise management.

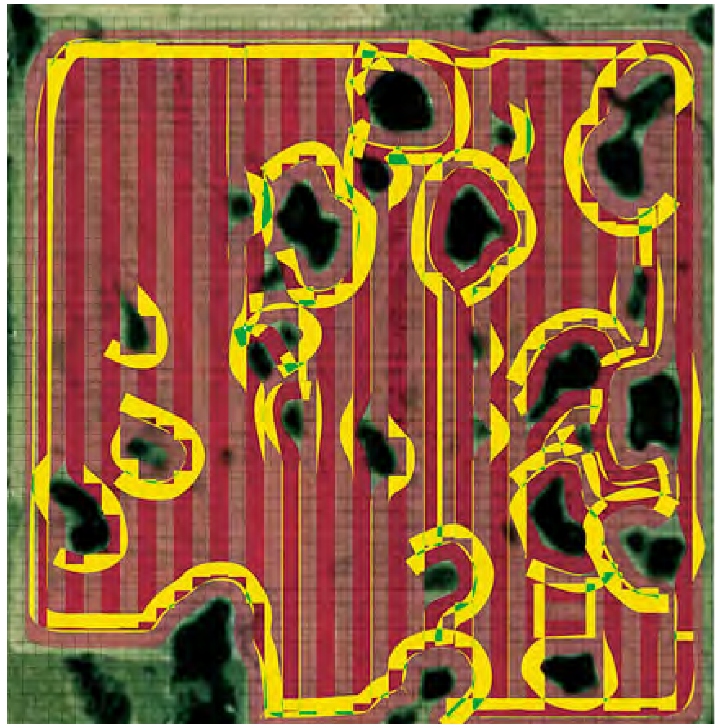

Fig. 2. Overlap areas that could be avoided with section control are highlighted in yellow. Image: Vaderstad.

Sectional control

Perimeter passes are usually required around field borders, depressions, and other obstacles in the field to allow turn-around space and to avoid misses in equipment operations. However, this typically results in overlapping of equipment passes that not only reduces efficiency but can also result in over application of inputs and thus higher input costs. This problem is worse in fields with many obstacles such as depressions and with wider equipment. A quarter section of land with many obstacles and wider equipment could have more than 15% overlap *(Fig. 2.).* Using sectional control on (air) seeders, sprayers and other input application equipment can significantly reduce input costs associated with overlap, especially in fields with many obstacles.

Camera-guided precision

Smart technologies are now allowing the identification of crop rows, and even individual plants species in real-time as equipment is moving through a field *(Fig. 3)***.** These systems can be trained to accurately distinguish a crop plant from weeds and bare ground. Computer software analyzes real-time images to identify crop rows, individual crop plants, or weeds as equipment is moving through the field. The computer then instantaneously sends a signal to the equipment to act on the information as is described below.

Fig. 3. Real-time detection of weeds in a crop allows spot application of a herbicide, or perhaps targeted mechanical control. Image: 3S Spot Spray System from Exxact Robotics.

Targeted spray application
Organic inputs can be very costly. Organic producers may use micronutrients, compost teas, or other biological treatments to support crop growth. Organically acceptable herbicides have been identified, however, they have not been widely adopted because either their efficacy depends on application rates that stress the crop or they may be too costly for field scale application. Spot application of such inputs has the potential to be effective and more economical. Sprayers equipped with independent nozzle control can target specific plants to receive treatment *(Fig. 4)*. While using traditional sprayer platforms is most common, drones are also now being developed to deliver spot treatments *(Fig. 5)*. Of course, the use of this technology is completely dependent on having organically acceptable liquid inputs available with recommended application rates.

Fig. 4. Camera technologies attached to equipment to either detect weeds or crop to allow precise application of treatments. Image: AgriFac

Fig. 5. Preparing the sprayer drones for testing and calibration. Image: Landview Drones.

Precise mechanical weeding
New camera-guided technology has allowed not only more precise cultivation in wide rows but has also enabled inter-row cultivation in crops with a narrow row spacing. This has been enabled by a camera detecting the crop row and using hydraulic side-shift technology to compensate for steering variability by making small adjustments from side to side to keep the cultivation equipment from hitting the crop *(Fig. 6)*.

Fig. 6. Interrow cultivation supported by camera guidance and side-shift technology. The camera detects the crop row and then uses side-shift technology to position the tillage equipment between rows and avoid hitting the crop. Image: Joanne Thiessen Martens.

This allows more aggressive cultivation to occur to remove larger weeds with minimal crop damage. However, researchers at both the Universities of Saskatchewan and Manitoba have found that camera-guided inter-row cultivation is most effective when used in combination with some form of in-row weed suppression such as higher seeding rate, rotary hoe, tine weeder, or in-row finger weeding attachment[1,2]. In other research at the University of Saskatchewan it was found that multiple inter-row cultivation passes in lentils and peas as the crop grows can result in yield reduction; limiting cultivation to a single early-season pass is recommended for these crops.[3]

Other Precision Weed Management

A simple tool developed in Sweden for selective weed control is called the ***CombCut*** *(Fig. 7)*. It has blades that are drawn through the cereal crops to selectively cut the rigid stems of weeds such as Canada thistle while leaving the more flexible cereal crop leaves unharmed. The ***Weed Zapper*** uses a tractor powered generator to electrify a contact bar or pad(s) at the front of the tractor which electrocutes plants that contact the bar/pad *(Fig. 8)*. This form of selective weed control is effective on weeds that are growing above the crop where contact can be made without touching the crop itself. Significant horsepower is needed to run the generator. This technology will kill weeds that it contacts without soil disturbance but misses lower growing weeds.

Fig. 7. CombCut weeder cuts the rigid stems of the thistle while having minimal damage to the flexible cereal crop. Image: Katherine Stanley.

Fig. 8. The Weed Zapper uses electricity to zap weeds growing above the crop canopy. Image: Crop Fertility Services.

We know that rhizomatous weeds, those with underground stems like Canada thistle and quackgrass, tend to initially grow in patches. Simple repeated mowing and/or shallow tilling of the patches will gradually deplete the energy reserves in the roots and set back these weeds. Doing this in combination with competitive cover crops like fall rye or alfalfa (in the case of thistle) can be even more effective. It can be hard to know where these patches are. This is where scouting fields with drones to produce maps of problem areas may be advantageous.

ADOPTION OF PRECISION MANAGEMENT IN ORGANIC SYSTEMS: BENEFITS AND BARRIERS

Benefits

While smart agriculture technologies are often associated with conventional systems of input application, these technologies can also be used to better understand the agroecosystem and thus could support approaches to improving management on organic farms also. Many of the diagnostic and mapping technologies can improve a producer's understanding of the crops and landscapes they are managing. Use of precision technologies can make the use of inputs more targeted, efficient, and cost-effective, providing that they are based on sound recommendations. In summary, the potential benefits of precision management include:

- better understanding of the variability of the landscape allowing identification and mapping of areas in the field with:
  - poor, average, or exceptional performance,
  - identification and mapping of areas with soil or weed problems,
- targeted application of management and inputs to best support the crop,
- reduced or optimized input use and associated economics, and
- information to support crop rotation planning.

Barriers

For these technologies to be adopted the benefits need to justify the (potentially high) costs. The usefulness of many of these technologies or management practices in organic farming systems has not been widely demonstrated. Despite the potential advantages of utilizing precision technologies, there are a number of barriers preventing organic farmers from adopting them including:

- initial cost of the precision technology,
- cost of adapting existing equipment to the technology,
- the technology use has not been proven or demonstrated in a way that is relevant to their farm,
- scale required to achieve a positive return on investment,
- knowledge required to use the technology,
- knowledge (or support) and time required to interpret data and make recommendations,
- lack of support networks for training and troubleshooting, and
- lack of organic inputs that can be used with precision management.

CONCLUSION

Smart technologies can be used to gather a wealth of information about the crop and soil across the landscape. This information has the potential to allow organic farmers to manage their crops and inputs more precisely for the benefit of the crop, environment, and pocketbook. While some tools are very simple and low-cost, others may require higher investment, knowledge, and training. Many of these barriers could be reduced by farmers cooperating to share equipment and knowledge while engaging the support of researchers and technology experts.

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