Jan BARWICKI PhD.* , Kinga BOREK MSc. Eng.*

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* Institute of Technology and Life Sciences in Falenty, Warsaw Branch
Corresponding author: Jan Barwicki; e-mail: jbarwicki@.gmail.com

Jan Barwicki ORCID: 0000-0002-5437-5284

Kinga Borek ORCID: 0000-0002-0171-7498, ResearcherID: B-7982-2019

REMOTE SENSING IN FARM MACHINERY DESIGN - AS FUNDAMENTAL IMPROVEMENT OF DEVELOPMENT - OF PRECISION AGRICULTURE PHENOMENON

ROZWÓJ PROJEKTOWANIA MASZYN ROLNICZYCH W ASPEKCIE ZDALNEGO STEROWANIA PROCESAMI ROLNICZYMI MAJĄC NA UWADZE ROLNICTWO PRECYZYJNE

***Summary**: When using remote sensing we can achieve not only high and good quality yields but also lower pollution of natural environment and substantial reduction of production costs. Some satellite systems make possible obtaining information about soil structure and different types of crops with plants designated for feeding purposes as well. Besides that it can contribute to the development of precision agriculture by steering of farm machinery during field work, providing monitoring of biomass and crop yields, taking soil samples, dosing of mineral fertilizers and pesticides, field crops' level measurement, monitoring of animals and monitoring of farm machinery work.*

***Keywords**: remote sensing, agricultural engineering, ecology, cultivation, control, satellite systems, GPS, monitoring, fertilization, harvesting, progress*

***Streszczenie**: Dzięki zastosowaniu teledetekcji możemy osiągnąć nie tylko wysokie i dobre plony, ale także mniejsze zanieczyszczenie środowiska naturalnego i znaczne obniżenie kosztów produkcji. Niektóre systemy satelitarne umożliwiają uzyskanie informacji o strukturze gleby i różnych rodzajach upraw, a także roślinach przeznaczonych do celów żywieniowych. Poza tym może przyczynić się do rozwoju rolnictwa precyzyjnego poprzez sterowanie maszynami rolniczymi podczas prac polowych, monitorowanie biomasy i plonów, pobieranie próbek gleby, dozowanie nawozów mineralnych i pestycydów, pomiar wielkości upraw polowych, monitorowanie zwierząt, monitorowanie gospodarstwa oraz pracy maszyn.*

***Słowa kluczowe**: teledetekcja, technika rolnicza, ekologia, uprawa, kontrola, systemy satelitarne, GPS, monitorowanie, nawożenie, zbiory, postęp*

Introduction

The technological tools often include the global positioning system, geographical information system, yield monitor, variable rate technology and remote sensing. Literature review shows that there are quite a lot of problems to be solved by utilization of remote control. By use of remote control we may be utilize crop management owing to which the areas of crop within a given field may be managed with different levels of input depending upon the yield potential of the crop in that particular area of land. The benefits of such operations are as follows: cost of producing the crop in that area can be reduced and the risk of environmental pollution from agrochemicals applied at levels higher than those required by the crop can be reduced, as well.

The global positioning system GPS is a network of satellites developed in U.S.A. The GPS constellation of 24 satellites, orbiting the earth transmits precise satellite time and location information to ground receivers. The ground receiving units are able to receive this location information from several satellites at a time for use in calculating a triangulation fix thus determining the exact location of the receiver.

Formerly, agronomic practices and management recommendations have been developed for implementation on a field basis. This generally results in the uniform application of tillage, fertilizer, sowing and pest control treatments at a field scale. Farm fields, however, display considerable spatial variation in crop yield, at the field scale. Such uniform treatment of a field ignores the natural and induced variation in soil properties, and may result in areas being under- or over-treated, giving rise to economic and environmental problems.

The more substantial of these problems being: economically significant yield losses, excessive chemical costs, gaseous or percolator release of chemical components, unacceptable long-term retention of chemical components and a less than optimal crop growing environment.

A geographical information system GIS consists of a computer software data base system used to input, store, retrieve, analyze, and display.

It is important "differential" treatment of field variation as opposed to the "uniform" treatment underlying traditional management systems. The result is an improvement in the efficiency and environmental impact of crop production systems. Elaboration of precision digital maps concerning fertilization (mineral fertilizer, liquid fertilizer, manure spreading), sowing, spraying, on the basis of field soil tests is very important for yield concerning different crops. Also, it is important to collect yield models from different farm machinery such as corn and fodder harvesters of different models and companies.

The goal of remote sensing is to gather and analyze information about the variability of soil and crop conditions in order to maximize the efficiency of crop inputs within small areas of the farm field. To meet this efficiency goal the variability within the field must be controllable. Efficiency in the use of crop inputs means that fewer crop inputs such as fertilizer and chemicals will be used and placed where needed The benefits from this efficiency will be both economical and environmental.

Environment protection development

Environmental costs are difficult to quantify in monetary terms. The reduction of soil and groundwater pollution from farming activities has

a desirable benefit to the farmer and to society. If maps of the spatial distribution of soil productivity potential (maps of expected yield) and maps of the spatial distribution of plant nutrients available from the soil are developed for a field, fertilizers and organic wastes can be applied in amounts per acre that are directly proportional to the soil's expected yield and adjusted for the soil's fertility at any location in the field. Such

a procedure would optimize the economic potential of a field, yet minimize the leaching of nutrients.

The above protocol depends on having a good map of the spatial variation of the expected yields for crop fields. Maps of past crop yields for a field could be used for this purpose. However, multiple years of spatial yield data would be needed to overcome variations caused by year to year differences in weather, especially rainfall, and there remain multiple factors which result in lack of year to year correlation.

A major advantage of this approach is that remote sensing can provide a current assessment of the overall plant health of the crop rather than relying on the past history of yields. Several different approaches exist for using remote sensing data for this purpose. Most of the commonly recognized techniques depend on measuring the greenness of the field.

For example, it is a relative technique and can be significantly affected by soil conditions. It have been pursued a different path in this research. It have been examined the thermodynamic efficiency of the crop.

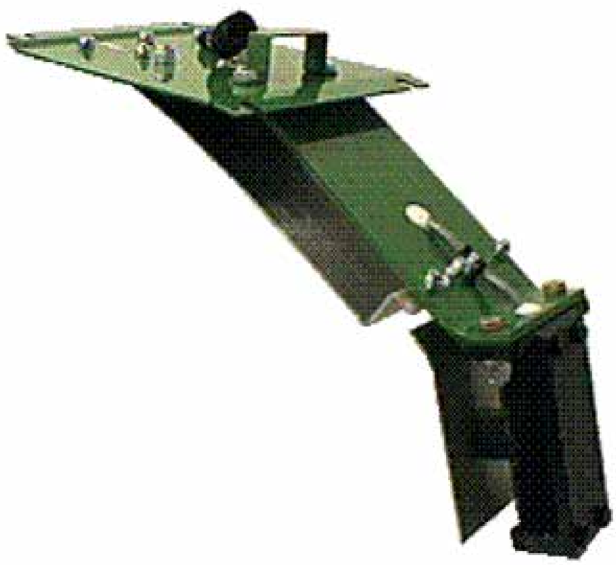
With remote sensing we can estimate many of the important properties of the soil. The organic carbon content can be estimated from albedo. Clay, iron and other mineral contents can also be estimated. While nutrients are important to plant growth, more critical to their vitality is plant available moisture. Water is essential for the transport of nutrients to and from the plant. This transport occurs laterally within the soil, and vertically within the plant.

Remote sensing in farm machinery systems

Remote sensing refers to the process of gathering information about an object, at a distance, without touching the object itself. The most common remote sensing method that comes to most people's minds is the photographic image of an object taken with a camera. Remote sensing has evolved into much more than looking at objects with our eyes - figures 1 and 2.

Fig. 1. Combine yield monitor
Source: John Deere Green star Precision Farming Equipment [2010]

Fig. 2. Combine grain tank flow sensor
Source: John Deere Green star Precision Farming Equipment [2010]



The term remote sensing is restricted to the methods that employ electromagnetic energy as the means of detecting and measuring target characteristics. Remote sensing is the information obtaining from a distance about objects or phenomena without being in physical contact with them. The science of remote sensing provides the instruments and theory to understand how the objects and phenomena can be detected.

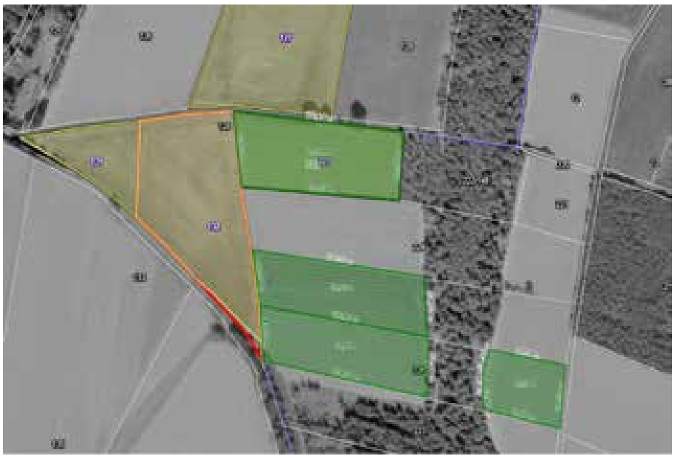
Variable rate technology ("VRT") consists of farm field equipment with the ability to precisely control the rate of application of crop inputs and tillage operations shown on figure 3.

A goal of many publicly funded research institutions is to promote technology transfer from government agencies to the private sector. Soil

Fig. 3. VRT Spreader
Source: [Amesremote, USA, 2009]

Fig. 5. Fertilizer spreader Case Co. equipped in remote control system
Source: Case Co. products [2011]

Fig. 4. Orthophotomaps can help in evaluation of crop development
Source: [Barwicki, 2011]



maps are also sometimes used to determine management zones. Soil maps are becoming a part of the Geographical Information

Systems (GIS) database. The grid sampling technique takes separate soil samples from uniform sized grids laid out over the field.

A problem with this type of sampling is the variability that can exist in soil types within each grid.

This variability makes it much more difficult to determine soil characteristics within the grid for crop input management purposes. To minimize this problem smaller grids are required what then requires many more soil samples to be collected for a larger number of grids. Soil samples can become a major cost of the socalled precision agriculture. An alternative to grid sampling is targeted or zone sampling.

The soil samples are located in homogeneous management zones instead of uniformly spaced grids. The zones are laid out using

a process similar to computer based unsupervised image classification. Images obtained from multispectral remote sensors are taken of the vegetated areas of the field.

One goal of remote sensing is to cut crop production inputs, which result in cost and environmental savings. Conventional farming methods apply herbicides to the entire field.

Site-specific variable-rate application puts the herbicide where the weeds are found. Aerial remote sensing has not yet proved to be very useful in monitoring and locating dispersed weed populations. Some difficulties encountered are that weeds often will be dispersed throughout a crop that is spectrally similar, and very large-scale high resolution images will be needed for detection and identification as shown on figure 4.

The United States and Russia are planning updates to their remote control systems, while the European Union and China are planning to launch their own systems. This will significantly improve the accuracy and robustness of satellite navigation but will require new receivers to be purchased, however, the timeframe of the upgrade is around 10 years so may not influence purchasing decisions in the short term.

The use of machine vision technology systems to detect and identify weeds places remote sensors directly on the sprayer equipment. Being close to the crop allows for very high spatial resolutions.

Machine vision systems have the ability to be used in the field with the real-time capabilities that are necessary to control sprayer equipment as above shown in Case fertilizer sprayer.

Management decision support systems

Remote sensing is just one component of a much larger integrated technology in farm machinery design. The increase in net profits from precision farming come from a combination of revenue increases from higher yields and decreased input use and their associated costs.

Global Navigation Satellite Systems (GNSS), are commonly used in agriculture for:

- crop and soil testing;
- crop yield and quality monitoring;
- remote and proximal soil and crop sensing;
- terrain modelling;
- variable-rate application of inputs;
- vehicle navigation systems - guidance and auto steering.

Many sensors and monitors already exist for in-situ and on-the-go measurement for a variety of crop, soil, landscape and environmental variables. Technological development continues to increase the range of cropping attributes measured in real-time and at high spatial densities. Such sensors are commercially available for :

- yield and quality;
- crop reflectance for biomass, vigour and stress;
- soil apparent electrical conductivity, natural gamma radiation emission,
- reflectance and pH;
- elevation.

Discussion and conclusions

Remote sensing collect data on energy reflected from the surface of plants and soil. The physics used in remote sensing technology is very complicated. Farm operators will be dependent upon professional engineers and precision farming consultants to process the raw image data into useable information for making management decisions. There is an abundance of remote sensing technology available to measure variability in plants and soils. Also, there is a shortage of information about the causes of plant condition variability and the management solutions needed manage variability to improve crop production. The lack of knowledge needed to answer these variability questions is restricting the development of precision farming management decision support systems.

The concept of remote sensing has emerged over the past 15 years with the introduction of new electronic equipment which has allowed farmers to increase the efficiency of their operations and develop new farming practices. However, the investment in remote sensing equipment represents a significant financial outlay and as with all 'high-tech' equipment it can become superseded relatively quickly and therefore does not tend to hold its capital value. When deciding what equipment to purchase farmers need to understand the capabilities of currently available equipment as well as the likely evolution of the technology in order to 'future proof' their investment.

Most precision agriculture equipment is based around the Global Navigation Satellite System (GNSS). The United States and Russia are planning updates to their systems, while the European Union and China are planning to launch their own systems. This will significantly improve the accuracy and robustness of satellite navigation but will require new receivers to be purchased, however, the timeframe of the upgrade is around 10 years so may not influence purchasing decisions in the short term.

There is a major push from farmers and equipment manufacturers for standardisation between different remote sensing equipment and the associated data. It has led to the development of the ISOBUS 11783 standard which outlines both the hardware requirements in terms of plugs and wiring as well as the communication protocols so that equipment from different manufacturers can interact. Manufacturers are well down the path of meeting the standard with a lot of commercially available equipment already compliant. It is recommended that farmers should now look to purchase only ISOBUS compatible equipment to ensure maximum functionality into the future.

Electronic monitors and controllers have long been utilised with boom sprayers, from simple running totals to today's automatic boom section controllers. Research is being conducted into further advancing application control across the boom, driven by increasing boom widths and wider travel speeds. A lot of this work is centred on controlling the application rate and spray pattern of individual nozzles Another line of research is based around further advancing the concept of weed identification and automatic spot spraying. The systems are being developed that can identify and even differentiate plant species. This research is also closely tied to 'Micro Spray' research whereby several different systems are being developed to target and control weeds on a finer scale or individual basis. Given that an increasing proportion of cropping system is converting to minimum and no-till with the associate heavy reliance on bigger boom sprayers, it should be considered actively contributing to this major research effort.

Advances in digital technology and sensor systems over the past decade have resulted in a great deal of research and development of more intelligent agricultural vehicles capable of automation tasks with minimal operator input. The ultimate aim is to remove the human operator all together and have tasks completed autonomously. While most of the hardware and control systems are already a reality, issues of machine interaction with an essentially unpredictable environment still need to be addressed. It is generally accepted that autonomous operations will need to be conducted by a number of small machines which interact to complete a task rather that one large machine. This not only improves the safety aspects but also offers greater flexibility in terms of scalability. It should also be a part of this research effort as there are many operations in our farming systems which could greatly benefit from this technology.

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