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MONITORING OF TYPICAL FIELD WORK IN DIFFERENT SOIL CONDITIONS USING REMOTE SENSING – A LITERATURE REVIEW AND SOME CONCEPTS FOR THE FUTURE

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ABSTRACT

The objective of the study was to analyse actual possibilities of monitoring and controling different field work such as cultivation, fertilization, harvesting with the use of remote sensing techniques. Moreover, the analysis covered utilization of different type of machinery using remote sensing systems, searching for and collection of data on soil structure in certain agricultural areas and adjusting conditions for development of digital maps. Obtaining data by the use of remote sensing methods is integrated with information concerning spatial variability of soil and plants, which comes from registered units which provide recorded changes of different parameters, having importance from the point of view application in precision agriculture. Precision agriculture guarantees not only obtaining very high and good quality yields but also limits pollution of the natural environment and reduction of production costs. Bands which cover these features can measure iron and other soil components. Thermal bands are used for determination of the stage of plants growth and also for prediction of expected yield. Some plants which are warm and the others which are cool show up difference in thermal bands. Development of precise agriculture contributes to the management of the system by controlling farm machinery during field work, monitoring biomass and crop yields, taking soil samples, dosing mineral fertilizers and pesticides, field crops measurement, monitoring animals, generation of field parcels identification, monitoring farm machinery work. Satellite systems enable obtaining information on the soil structure and different types of crops with feed plants as well.

Introduction

Agronomic practices 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 (Anderson et al., 1996) The philosophy involves matching resource application and agronomic practices with soil properties and crop requirements as they vary across a site. Precision agriculture involves the observation, impact assessment and timely strategic response to fine-scale variation in causative components of an agricultural production process (Earl at al., 1997). Therefore, precision agriculture may cover a range of agricultural enterprises, from dairy herd management through horticulture to field crop production. The philosophy can be also applied to pre- and post-production aspects of agricultural enterprises. With this definition in mind, present focuses are designated for applying precision agriculture in the field crop production systems (Ivanovs et al., 2011).

These actions are referred to as the "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 the crop production system (Pierce et al., 1997).

The objective of the study

The objective of the study 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 fertilizers and chemicals will be used and placed where needed. The benefits from this efficiency will be both economical and environmental.

Furthermore, the study aims at elaboration of precision digital maps using remote sensing concerning: fertilization (mineral fertilizer, liquid fertilizer, manure spreading), sowing, spraying, on the basis of field soil tests; in a similar way elaboration of digital maps of yield concerning different crops. Moreover, it is important to collect yield models from different farm machinery as corn and fodder harvesters of different models and companies. This can be utilized not only by farm machinery production enterprises, but also by farmers during field work preparation.

Methodology of study

It is significant to have data concerning the plots area, exclusion of the fields area, division into cultivation groups, plot localization regarding the registered plots. GPS with accuracy of position evaluation higher than 60 centimeters at 95 percent of working time of a measurement apparatus at frequency of 10 Hz can serve as an example (Colwell et al., 1997). It is possible to obtain a measurement accuracy lower than 2 percent in the range from 0.5 to 0.9 percent. Additionally, remote sensing can also contribute to the development of precision agriculture by controlling farm machinery during field work, monitoring biomass and crop yields, taking soil samples, dosing mineral fertilizers and pesticides, field crops measurement, monitoring animals, generating field parcels, monitoring farm machinery work. Precision agriculture guarantees not only obtaining very high and good quality yields but also reduces pollution of the natural environment and production costs.

Soil tests on the farm are recommended by Good Agriculture Practice and it can be utilized in practice.

Environmental costs are difficult to quantify in monetary terms. Reduction of soil and groundwater pollution resulting from farming activities has a desirable benefit for the farmer and the society. If maps of the spatial distribution of soil productivity potential (maps of the 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 hectare 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 a nutrient (Searcy et al., 1997).

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 the lack of year to year correlation. An alternative to mapping of actual crop yields would be the use of remote sensing to determine spatial distribution of plant status (health or efficiency) and the corollary expected yields.

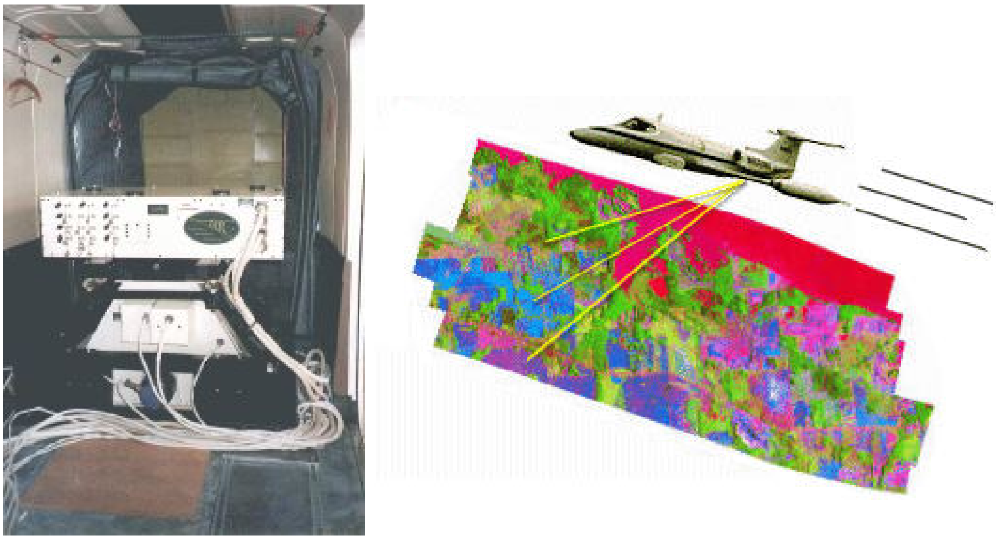
A major advantage of this approach is that remote sensing can provide a current assessment of the overall plant health of the crop rather than relying on past history of yields. Several different approaches exist for using remote sensing data for this purpose. Most of the commonly recognized techniques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

Typically, this involves some relationship comparing the reflectance of a visible band (such as red light) to the reflectance of a near-infrared band. Since green vegetation has a very sharp change in reflectivity across this range and other materials do not, virtually any technique will in fact detect it. The approach suffers from several defects (Searcy et al., 1997).

The thermodynamic efficiency of the crop have been examined. For example, it is a relative technique and can be significantly affected by soil conditions. A different path have been pursued in this research. The core of this approach depends on energy in the thermal-IR. This experiment relied on the investigation of the energy budget of the crops and on obtaining a relationship between multi-temporal thermal imagery and a crop yield (Steward, et al., 1998). The precision agriculture study utilizes the advanced thermal and land applications sensor ATLAS remote sensing instrument flown on the NASA Lear jet presented in figure 1.

The position of the aircraft, its orientation and the sensor orientation are all recorded at least once a second. The active calibration and record of a position mean enable accurate and reproducible measurement of the field plots while flying in a jet aircraft.

ATLAS is able to sense 15 multispectral radiation channels across the thermal – near infrared – visible spectrums. The sensor also incorporates onboard, activates calibration sources for all bands. Atlas is capable of approximately 2.0 meter resolution per pixel when flown in NASA's Lear jet and sees about a 30 degree swath width to each side of the aircraft.



Source: NASA Stennis Space Center, 2010

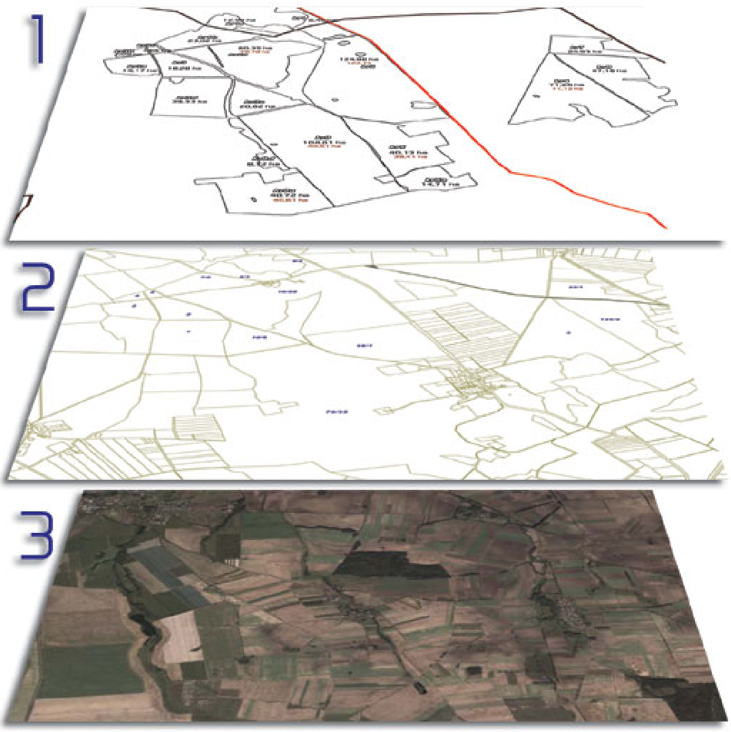
Figure 1. Aircraft NASA jet equipped in ATLAS scanner – left

Results of the study

A tremendous amount of data is collected on each flight, and must be processed by investigators prior to conducting research on the remote sensing imagery. The data must be corrected for geometric abnormalities due to flight path variations and must be radio metrically calibrated. These raw sensor scan lines are then reconstructed into a two dimensional image data set.

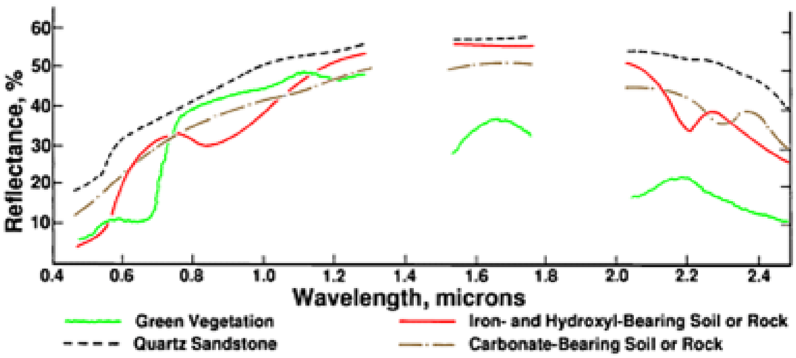
Knowing that the data is an image, the scientist is able to begin data inquiries. This is typically done by creating false colour images based on 3 spectral channels from the sensor. Dependent on whether vegetation health or soil characteristics are of concern, differing channels of the data will be combined. Data remote sensing from one channel is assigned to the shades of red, another to those of green and the third to the blues. At first point it is possible to elaborate general digital areas as agriculture cultivation sites, with information concerning soil structure and possibility of plants to be proper for these circumstances. Elaborated maps can contain a few layers as it is shown in figure 2.

Then these pictures visually reveal a tremendous amount of information to the investigator. Our remote sensing is driven by the biology and physics of the crop and the soil. We need visible and near infra red bands for several reasons. Vegetation has a very strong reflectance feature at 0.7 microns – see the plot of typical reflectance curves presented in figure 3.



Source: TPI Agrisystem, 2011

Figure 2. Elaboration of digital layer maps for different plants cultivation purposes as: sowing, fertilization, harvesting and yield evaluation



Source: NASA Geostat, 2010

Figure 3. Typical reflectance curves NASA/Geosat Test Case Project

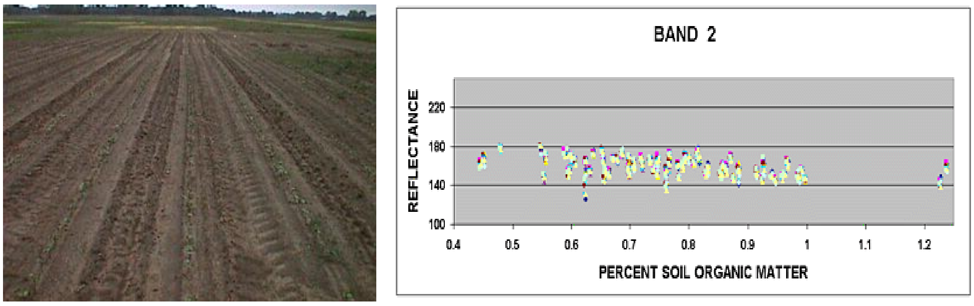
A pair of bands which bracket this can be used to determine the amount of green vegetation. Clay minerals have a strong absorption feature in the 2.2 micron region. Comparison of a 2.2 micron band with a 1.6 micron band is therefore sensitive to clay. Iron, as hydrated iron oxides, has a high reflectivity in the red portion near 0.7 microns of the spectrum and a reflectance depression near 0.8 microns. Bands which cover these features can measure iron content. Thermal bands are used for completely different reasons. Plants cool themselves by evaporating water. Some plants which are warm and the other ones which are cool show up differently in thermal bands.

A crop stage, spatial resolution, seasonal and daily weather conditions must be controlled. For example a spatial resolution in the 2-5 meter range was chosen, avoiding many complexities caused by aliasing crop row spacing at higher resolutions yet finer than the harvester's tightest recording rate. This dictates the use of an airborne system.

Use of an airborne remote sensing system also makes scheduling around weather much simpler than the use of satellite data. Active video calibration was recognized as essential if quantitative measures were ever to be obtained or reproduced. The remote sensing system would also need to have an onboard geometry recorded during data acquisition.

There is a limited number of sensor/aircraft combinations that provide the required features. A currently available system that meets all of these criteria and is called the Atlas scanner, flown out of NASA Stennis Space Centre is presented.

With remote sensing we can estimate many of the important properties of the soil. Clay, iron and other mineral contents can also be estimated. While nutrients are important for the plants' 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. Soil organic matter tests at Wiregrass Experiment Station of Auburn University is presented in figure 4.



Source: Auburn University, Headland, Alabama, USA , 2009

Figure 4. Soil organic matter tests at Wiregrass Experiment Station

The influence of soil organic matter percentage on the band reflectance is presented in figure 4. It is also connected with the soil water content, which is the lifeblood of the system. Heaving data, which can make characteristic of different band size responsible for percentage of its reflectance, we can elaborate special digital maps, which could be utilized later during farm machinery field work.

Without a sufficient moisture content of soil, photosynthesis is impossible. Perhaps a proper balance of available water is more important. Root systems of plants also require air in order to survive, with too much water, plants will literally drown. The most common source of electromagnetic radiation that we are familiar with is the sun and it can be utilized in remote sensing.

The electromagnetic spectrum range varies from very short wavelengths of less than ten trillionths of a meter known as gamma rays, to radio waves with very long wavelengths of several hundred meters.

A good example of utilization of the GPS system for machinery control on the field is corn spraying using a self-propelled Case spreader, which is equipped with multispectral radiation analytical channels combined with the GPS system, which can analyze data related to the crop condition for proper fertilizer distribution on the field – figure 5.

Source: Case Co. Information materials, 2012

Figure 5. Corn spraying using satellite system (multispectral radiation analytical channels combined with the GPS system) for application of fertilizer of Case Co.

Discussion and conclusions

– Lack of knowledge necessary to answer varied questions limits the development of the precision farming management decision support systems. Remote sensing collects data on energy reflected from the surface of plants and soil. The physics used in the remote sensing technology is very complicated. Farm operators will depend on professional engineers and precision farming consultants to process the raw image data into useable information for taking management decisions. There is a shortage of information on the reasons for plant condition variability and on the management solutions needed to manage variability in order to improve crop production.

– The concept of precision agriculture has developed over last years with the introduction of new electronic equipment which has allowed farmers to increase the efficiency of their operations and to develop new farming practices.
– Investment in the precision agriculture 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 which 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 on 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 time frame of the upgrade is around 10 years so may not influence purchasing decisions in the short term.
– 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 rather to complete task rather that one large agriculture machine.

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MONITORING TYPOWYCH PRAC POLOWYCH W RÓŻNYCH WARUNKACH GLEBOWYCH PRZY WYKORZYSTANIU TELEDETEKCJI – PRZEGLĄD LITERATURY I KONCEPCJE NA PRZYSZŁOŚĆ

Streszczenie. Celem opracowania była analiza aktualnych możliwości monitorowania oraz sterowania pracą maszyn podczas uprawy, nawożenia i zbioru przy wykorzystaniu teledetekcji. Poza tym istotnym jest również badanie i zbiór danych dotyczących struktury gleby na danym obszarze dla przygotowania map cyfrowych do ogólnego wykorzystania. Ważnym jest też odpowiedni dobór sprzętu rolniczego w zależności od polowych warunków uprawy, nawożenia i zbioru. Dane uzyskane przy wykorzystaniu metod teledetekcyjnych są zintegrowane z informacją o przestrzennej zmienności warunków glebowych oraz wymaganiami roślin uprawnych i mogą służyć pomocą w planowaniu działań w rolnictwie precyzyjnym w zakresie uprawy, nawożenia i zbioru roślin. Rolnictwo precyzyjne gwarantuje pozytywny wpływ na ochronę środowiska, wzrost plonów oraz obniżenie kosztów produkcji rolnej. Wykorzystanie systemu teledetekcji umożliwia sterowanie procesem pracy maszyn rolniczych, takie jak: regulowanie dawką nawożenia pól w zależności od jakości gleb, monitorowanie wydajności roślin uprawnych, monitorowanie stanu technicznego maszyn, monitorowanie stada zwierząt hodowlanych. Systemy satelitarne dzięki programom komputerowym umożliwiają opracowanie map z aktualną strukturą gleb na danym terenie i przewidywaniem odpowiednich upraw do zastosowania, aby uzyskać wysokie plony przy niskich kosztach produkcji rolnej. Zastosowanie analizy spektrum fal odbitych od roślin uprawnych umożliwia określenie fazy dojrzałości, wielkości plonu oraz uszkodzeń roślin spowodowanych warunkami atmosferycznymi lub działaniem owadów lub dzikich zwierząt. Dotyczy to także odbicia fal elektromagnetycznych od powierzchni gleby uprawnej o różnej klasie i różnym składzie fizyko-mechanicznym.

Słowa kluczowe: teledetekcja, GPS, mapy cyfrowe, uprawa gleby, nawożenie, zbiór