The International Society of Precision Agriculture
presents the

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Hyatt Regency • Sacramento, California USA

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PRECISION AGRICULTURE, FOOD SECURITY AND GEOSTATISTICS

Dr. Margaret Oliver

Deputy Editor of the European Journal of Soil Soil Science (2011–present).

The talk will comprise two sections, the first is a general section linking precision agriculture (PA) with food security issues and the second is more specific, involving the place of geostatistics in PA. Food security is a major issue globally because of the projected growth in population to about nine billion by 2050 and continuing and relentless soil and land degradation. Degradation of land through soil erosion, salinization, sodification, desertification, compaction and so on results in huge losses of agricultural land at a time when the pressures on food security are increasing. Precision agriculture focuses on managing soil nutrient status, soil moisture, organic matter content, pests and diseases, crop status and so on, should also play an increasing role in mitigating the effects of degradation. In the developing nations, the poor quality of land (both innate and because of degradation) and low yields lead to protein-calorie malnutrition and under-nutrition because of the lack of certain micronutrients. The latter also applies to large numbers of people in developed nations where there is increasing nutrient malnutrition especially in relation to iron, selenium and zinc. Fertilizers can be fortified with micronutrients and they might require more precise management than are required for the macronutrients.

Precision agriculture and geostatistics are dynamic and complimentary subjects that have spatial variation at their core. The strong relation between them is likely to increase as more information on soil and crops becomes available from sensors and on-the-go technology. There is a variety of geostatistical techniques that can be applied to a range of issues in PA such as sampling, prediction, mapping, decision-making, variable-rate applications, economics and so on. The two core techniques of geostatistics (variography and kriging) are described with examples. Knowledge of the spatial scale of variation is important to ensure that sampling is adequate and the resulting predictions accurate. Both traditional geostatistical and 'state-of-the-art' approaches for guiding and optimizing sampling will be considered.

Many environmental variables that are relevant to precision agriculture vary in both time and space. Space-time geostatistics is a useful extension to spatial geostatistics for precision agriculture. Many field properties can be expensive to measure, whereas ancillary information such as that from electromagnetic induction scans (ECa), aerial photographs, imagery, yield and so on is relatively cheap to obtain. Geostatistical methods can use ancillary information to guide sampling and to improve the accuracy of prediction by incorporating it into kriging where soil or crop attributes are sparse. The methods include cokriging, the multivariate extension of ordinary kriging, kriging with external drift and simple kriging with local means. To manage fields site-specifically for nutrients and water requires detailed and accurate maps of crop nutrients and soil moisture content. If such detail is unavailable an interim solution is to use geostatistics to identify site-specific management units (SSMUs) to resolve the spatial variation. Recent and exciting developments in the application of geostatistics to PA show that management-class and local-response experiments can be analysed geostatistically. Geostatistical simulation is relatively novel in PA, but it provides a means to mimic the spatial and or temporal variation of relevant processes. Simulation incorporates uncertainty into modelling to obtain a more realistic impression of the variation. Case studies will be used to demonstrate the above geostatistical applications to PA.

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PLANT SPECIFIC AGRICULTURE, ENGINEERING TECHNOLOGIES FOR CROP MAPPING, PROXIMAL SENSING, AND MANAGEMENT AT THE CENTIMETER SCALE

Dr. David Slaughter

Professor in the Biological and Agricultural Engineering Department and director of the Biological and Agricultural Engineering Sensors and Instrumentation Laboratory (BAESIL) at the University of California, Davis.

Dr. Slaughter is a strong proponent of the nexus between information and energy in agricultural mechanization and the importance of taking a systems approach in engineering design to solving complex problems. The efficiency of implementing new precision farming technology depends upon our ability to use information to guide and coordinate the application of resources. Using traditional manual methods of weed control as an example, Dr. Slaughter will demonstrate how an information-for-energy exchange can be achieved if the GPS position of the planter, at the time each crop plant is placed into the soil, is recorded on the fly when planting to create an as-planted crop location map. The individual crop plant map can then be utilized throughout the subsequent growing season to deliver precision individualized plant care on a plant-by-plant basis. By knowing the exact location of each crop plant, a robotic system for automatic within-row weed control can remove a higher percentage of the weeds with a minimal increase in energy use and the added energy input to precisely position these tools automatically would be greatly offset by the reduction in manual labor required to remove weeds by hand hoeing. Dr. Slaughter will describe recent advances in proximal sensing of crop location and identity and the application to automating plant care tasks at the 1-centimeter scale and will demonstrate and discuss the performance of prototype systems developed in California.

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TOWARDS AUTOMATED PNEUMATIC THINNING OF FLORAL BUDS ON PEAR TREES

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Thinning of pome and stone fruit is an important horticultural practice that is used to enhance fruit set and quality by removing excess floral buds. As it is still mostly conducted through manual labor, thinning comprises a large part of a grower's production costs. Various thinning machines developed in recent years have clearly demonstrated that mechanization of this technique is both feasible and cost effective. Generally, these machines still lack sufficient selectivity to take into account the specific fruit bearing capacity of each tree. Furthermore, the current devices often cause damage to shoots, leaves and fruitlets which makes the trees more susceptible to dangerous diseases such as fire blight (Erwinia amylovora) and cankers.

To address these issues, we investigated a new non-contact way of thinning using pulses of compressed air in combination with a sensor capable of detecting the floral bud distribution. This way, the thinning efficiency can be improved by providing real time information of the floral bud distribution. We focused on the early phenological stages (until bloom) of the pear cultivar Conference, for which there are few chemical thinning alternatives.
The forces required to remove a floral bud were measured in a laboratory test bench. These required forces change as a function of bud development. A pneumatic setup was built and tested during a two-year trial in an orchard to determine the effects of air pressure, nozzle type, distance and phenology on the attainable removal efficiency. Hereafter, a performance model was built using stepwise logistic regression modeling. Thinning grades as high as 93.13 % and 74.52 % could be achieved for, respectively, a dry and a wet season. Furthermore, pneumatic thinning was observed to reduce tree damage to a minimum since floral buds were removed at their natural breaking point, i.e. the pedicel abscission layer.
Besides this, we developed a multispectral vision sensor capable of detecting floral pear buds during the phenological stages before bloom. During two flowering seasons, scenes were captured in the orchard at six distinct optical wavebands in the visible and near infrared region of the spectrum. Measurements were conducted under controlled illumination. Using canonical correlation analysis, a spectral discrimination model was built that recognizes pixels originating from floral buds. Hereafter, an image analysis technique was developed to translate the pixel classification to object recognition. This algorithm was able to recognize more than 80 % of the floral buds that were captured under proper illumination. Therefore, the multispectral sensor can be used to increase the efficiency of pneumatic thinning or other thinning machines. Furthermore, it can as well be used independently for early-season yield estimation.

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AUTONOMOUS SERVICE ROBOTS FOR ORCHARDS AND VINEYARDS: 3D SIMULATION ENVIRONMENT OF MULTI SENSOR-BASED NAVIGATION AND APPLICATIONS

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In order to fulfill economical as well as ecological boundary conditions information technologies and sensor are increasingly gaining importance in horticulture. In combination with the reduced availability of human workers automation technologies thus play a key role in the international competition in vinicultures and orchards and have the potential to reduce the costs as well as environmental impacts.

The authors are working in the fields of unmanned or remote controlled autonomous field robots, navigation, image-based sensor fusion as well as agricultural applications. In particular field robots have been applied for a few years in outdoor agricultural field applications. Within an interdisciplinary research group these technologies are transferred to robot applications in vineyards and orchards. The goal is the availability of an autonomous service robot, whereas first applications are site-specific plant protection (e.g. precise spraying), mulching and picking up fruit boxes. A first version of the robot with electrical drives and precise sprayers has already been developed. The applications, however, show a large range of field conditions which have to be considered for the vehicle application design. Thus the authors have developed a 3D simulation environment which allows the virtual test of the robot platform prior to its application. Moreover, the software algorithms can be directly transferred to the robot and thus allow iterative optimizations of the development process. The generation and first applications of the 3D simulation environment of multi sensor-based navigation and applications in vinicultures and orchard is the focus of this work.

Robot Operating System (ROS) has been chosen as software framework for integrating the autonomous vehicle, the sensors and the environment for navigation and application processes. ROS supplies the 3D simulation environment Gazebo using physical engines (e.g. ODE – Open Dynamic Engine) in order to simulate the robots behavior as close as possible to reality. Moreover, the software tool Rviz is used for visualization of the sensor data (as for example) for optimization of navigation algorithms. Since the navigation in vine and fruit rows, the various applications as well as safety issues require sensor based solutions. The navigation itself is performed by image based sensors, since GPS based systems do not fulfill the requested functionality. In order to compensate for varying selectivities of different sensors, concepts of sensor fusion are applied. Sensor data in ROS is exchanged by so called messages, which can easily be logged to a database. For processing this data ROS integrated tools like NumPy (matrices and mathematical function) or OpenCV (image processing) are used. An interface from the database to MATLAB is also a powerful tool for evaluating the sensor data offline and testing first algorithms.

In practice color cameras (for documentation purposes), 3D cameras, laser range finders as well as ultrasonic multi reflectance sensors are used. In addition a priori data (such as maps or row distances) or GPS sensor information can be included and thereby increase the robustness of the navigation or the safety level. Within ROS plugins for different sensors have been generated (color camera, 2D laser scanner Sick LMS511; 3D laser scanner Nippon FX-8; ToF camera Mesa SR4500). Together with environmental data of crop plants (or obstacles) the robot behavior with respect to the navigation and the application can be evaluated prior to field tests. As for example the leaf wall area for controlling precise sprayer can be virtually measured and the reduction of chemicals can be evaluated. ROS enables the usage of the same control software for the simulation and the hardware (robot, actuators), thereby strongly reducing the development times.

As a result the simulation environment has been developed and the results of first reactive row navigation algorithms are evaluated and compared to dynamic tests with real robots.

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POST-HARVEST QUALITY EVALUATION SYSTEM ON CONVEYOR BELT FOR MECHANICALLY HARVESTED CITRUS

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Recently, a machine vision technology has shown its popularity for automating visual inspection. Many studies proved that the machine vision system can successfully estimate external qualities of fruit as good as manual inspection. However, introducing mechanical harvesters to citrus industry caused the following year's yield loss due to the loss of immature young citrus. In this study, a machine vision system on a conveyor belt was developed to inspect mechanically harvested citrus fruit. Object based classification was conducted on RGB images acquired on the conveyor belt. Three ensemble learning classifiers AdaBoost, bagging and random forest, a relatively new method in machine learning, were trained with 74 features including color histogram features, textures and histogram intersection with immature and mature citrus color model. Overall performances of the three classifiers showed good classification ability for mature citrus (minimum 97% accuracy). Among them, the bagging trees showed the highest accuracy, 91.5, 89.1, 97.4, and 85.2% for green immature, intermediate, mature and diseased citrus, respectively.

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PRECISION THINNING OF FRUIT CROPS

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Thinning is a pre-requisite in the majority of fruit crops worldwide in order to overcome or prevent alternate bearing (change of years with large and low yields) and to provide regular yields of high quality fruit in terms of size, taste, colour and constituents, as required by the market. The widely-used chemical thinning often uses compounds, commonly referred to as hormones, temperature-dependent and critised by the consumer.

Hence, a new device was developed to achieve a wide variety of three-dimensional thinning motions in such biosystems, which consists of three variable horizontal rotors with rotating tines. The objective was to remove individual flowers out of the 5 flowers in a cluster; otherwise the large number of fruitlets within a cluster develops into small, hard, green and unripe fruit. Six- year-old apple cv. 'Pinova' trees on M9 rootstock 3.5 m x 1.5 m spacing near Bonn, Germany were mechanically blossomed-thinned in the periphery.

Overall, the success of the selective thinning depended on the interaction between branch angle and singlet portion. Branches facing (45°) the thinning device were more severely thinned. Selective thinning led to removal of individual flowers out of a flower cluster (rather than removing complete clusters) and increased the portion of the desired singlets from , i.e. flower bunches with one single flower with less fruit to fruit competition for photo-assimilates and subsequently better fruit quality.

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A DUAL MOTOR ACTUATOR USED TO DETACH FRUIT BY SHAKING LIMBS OF FRUIT TREES

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Mechanizing the fruit removal operation during fresh-market apple harvesting will result in considerable cost savings for fruit growers. This study introduces a mechanical fruit removal technique that uses a unique limb shaking mechanism called a Dual Motor Actuator (DMA). The DMA was developed as an infinitely variable end-effector that applies rhythmic motions to a fruiting limb to remove fruit. The novelty of the DMA design is the use of two eccentrics mounted to electric motors that are pinned together to form a triangle with an adjustable base. In this paper, the development of the mechanism and a field study using two varieties of fruit ('Fuji' and 'Granny Smith') is reported. The fruit removed was classified based on three removal conditions (stem-intact, stempull, and spurpull) commonly used in the fresh-market apple industry. Stem-intact is the preferred classification whereas a limited percentage of spurpull will also be acceptable. Stem-intact fruit removal rates with the DMA were excellent for 'Fuji' (90 % avg) and moderate for 'Granny Smith' (50 % avg). The DMA end-effector provides an alternative mechanism to apply a controllable shaking pattern and rhythm. This precise limb acceleration method shows great potential for removing apples from a limb while maintaining fresh-market stem-intact quality fruit.

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SUSTAINABLE USE OF IRRIGATION WATER

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The water footprint of irrigation systems can be reduced significantly by combining data from Electromagnetic (EM) soil survey with variable rate technology on irrigators. Variable Rate Irrigation (VRI) is providing annual irrigation water savings of between 25 -50% on farms throughout New Zealand. Flow-on benefits include reduced pumping costs, improved crop yields and soil health along with reduced nutrients leaching to groundwater.

The greatest water savings are on the shoulders of the irrigation season. At this time, with the use of VRI, the farmer is able to mine the soil moisture from high water-holding capacity zones, as identified by an EM soil survey, applying irrigation to the lighter soils as they start to come under stress. In this instance irrigators fitted with VRI are often only operating with 20% of the machine applying water. With VRI the farmer is able to control irrigation application by each individual nozzle along the length of the irrigator. This allows the farmer to manage each soil zone separately as well as avoiding areas like water ways, laneways and water troughs.

The placement of soil moisture probes in zones determined by EM soil surveying means that it is possible to accurately monitor and maintain optimal soil moisture levels. Irrigation water is applied to match the water holding capacity of each specific zone and match the use of the crops that are being grown in the individual zones. When soil moisture levels are maintained at a level between the crop stress point and the soil full point it allows the farmer to capture every rainfall event throughout the growing season. If the farmer can do this without soils reaching the full point they will eliminate any possible drainage.

Improved water quality is an immediate benefit of VRI. Through accurate irrigation water placement the farmer is able to maintain nutrients within the root zone of the plants giving optimal nutrient uptake while avoiding any leaching into the groundwater. When the use of multiple EM survey information layers including data on slope, aspect and drainage is combined with the use of VRI application systems runoff of nutrients, such as Phosphate, into waterways is also able to be avoided

The benefits of VRI are not limited to the environment. There are also significant potential savings in the amount of energy required to irrigate a field or farm. In times of low or restricted availability of irrigation water the use of VRI means that the crops or pastures requirements are more likely to be met resulting in the most profitable outcome for the farmer.

Water is the biggest issue that will effect food production throughout the world both from a productive and environmental perspective. Agriculture uses 70 % of the world's fresh water. With a growing population and need for increased food production the demand for water will only increase. Agriculture needs to get smarter about the way it uses water. This is now happening with the use of EM soil surveys and VRI.

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INTRODUCING AN INTEGRATED FRAMEWORK TO OPTIMZE COTTON VARIABLE RATE IRRIGATION IN HUMID REGIONS

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The need to avoid yield loss from drought stress along with increased commodity prices have caused a significant conversion of rainfed to irrigated production in humid regions. Management of cotton supplemental irrigation in humid regions is challenging due to significant spatial variation of the soil physical characteristics as well as temporal changes in rainfall patterns. This study aimed to introduce a practical framework to optimize cotton supplemental variable rate irrigation in humid regions.

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EVALUATION OF A SENSOR-BASED PRECISION IRRIGATION SYSTEM FOR EFFICIENCY AND TO MONITOR AND CONTROL GROUNDWATER OVER-PUMPING IN OMAN

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Oman is a country with a total area of 309,500 km2. However, cultivable land in Oman is estimated to be less than 2%, which amounts to about 6100 km2. More than 50 percent of the arable lands located in the northern coastal belt of Al Batinah region. The country with average annual rainfall around 100 mm, has limited natural fresh water resources and has been facing the serious problem of sea water intrusion into the scarce groundwater reserves due to undisciplined excessive pumping of groundwater for irrigation. Accomplishing this task, intelligent Energy & Water Meters were installed in selected farms to monitor and allocate groundwater quota and ensure sustainability of farming through controlled irrigation.

In order to implement this, it was decided to control/monitor groundwater pumping, while monitoring several field parameters such as soil moisture, EC and temperature. Since the farmlands are spread over the whole Batinah region of near 200 km stretch, it was decided to install the monitoring system in selected 40 farms with varying levels of control. This required remote monitoring of data, transmission of data and control commands to and from the remote stations to a central server computer, in order to make near real-time decisions based on the data and crop water requirement models to ensure safe pumping of ground water. It was also decided to implement sensor-based irrigation control instead of ET-based control systems for more precision.

The irrigation control system was designed around the PIC-182455 microcontroller and short range radio links based on Zigbee communication protocol. Each field module was planned to consist of a microcontroller programmed to access the sensors and acquire data, which will be transmitted to a central module that acts as the coordinator or the main node for the particular farm. The main node will transmit data to the server computer encapsulated as an SMS, over the cellular network. In order to achieve better reliability in operations, the database part of the project was made independent of the real time decisions taken to control the actuators by utilizing part of the intelligence of the microcontrollers. It was decided to program them to handle day to day measurements and take on-farm decisions based on the measured values and the model predicted values. In order to achieve this, it was necessary to derive model predicted values for the particular crop pattern in a particular farm and convert them to a look up table that can be fed to the on-board memory of the microcontroller device. The data collection environment was designed to be in MS Excel, while a GUI will be developed in MS Visual Basic to handle the communication and data transfer between the coordinator modules and the main server.

The developed prototype system could monitor at least five crops in a farm and could operate multiple solenoid valves in sequencing manner compensating with the capacity of the main pump. Data file indicated the instantaneous irrigation status at any lateral in the farm and the same could be monitored through any mobile devices by accessing through relevant web link. In contrary to the commercially available systems, the develop system could be arranged for small and medium farms in Oman under site-specific manner.

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RAPID SENSING FOR WATER STRESS DETECTION IN FOXTAIL MILLET (SETARIA ITALICA)

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Water stress in plants reduces photosynthetic rate, resulting in decreased crop productivity. Timely detection of water stress could help in maintaining optimal plant water status for improved crop growth and productivity. This study evaluates the application of rapid sensing techniques based on thermal imaging and visual-near infrared spectroscopy for water stress detection in foxtail millet (Setaria italica). The visible-near infrared spectral data were collected from healthy and water stressed plants at regular intervals, along with other physiological parameters. Quadratic discriminant analysis (QDA) and Naïve-Bayes (NB) classifier were trained and tested to assess their performance in classifying well-watered and stressed plants. Significant difference in average leaf temperature as measured using a thermal camera was detected between well-watered plants and stressed plants. In addition, the classification using QDA and NB models resulted in classification accuracies of up to 83% and 91%, respectively.

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A METHOD TO ESTIMATE IRRIGATION EFFICIENCY WITH EVAPOTRANSPIRATION DATA

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Irrigation efficiency is defined as the ratio of irrigation water consumed by the crops to the water diverted (Wg) from a river or reservoir or wells. This terminology serves for better irrigation systems designation and irrigation management practices improvement. But it is hard or high cost with labor intensity to estimate irrigation efficiency from field measurement. This paper proposes an estimating method of irrigation efficiency at the scale of irrigation district based on ET from remote sensing with ETWatch, a system to monitoring ET with multi-source remote sensing data, and data on water diversion: (1) ET monitoring: ET is actual water consumption of crops in the field. Irrigation water can be divided into evapotranspiration of crops and leakage to groundwater or return flow to surface water. To acquire high accuracy ET dataset is the key step for calculating the value of irrigation efficiency. Once ET data is available, it is not necessary to acquire leakage data or return flow. ETWatch with annual deviations 3.8% at sub-basin scale has been used to monitor ET; (2) Irrigation area estimation: actual irrigated areas vary with rainfall, considering rainfall is the only available water for non-irrigated field so that ET from those fields should less than irrigation area given same crop type and phenology. Irrigation area can be retrieved by using ET (ET large than rainfall) with field verification; (3) Crop classification: due to the difference of phenology, crops would show different NDVI profile, so that crop types could be distinguish through constructing NDVI time series dataset, which further divided into non-irrigated and irrigated crops. (4) Ration of ET contributed by irrigation water: Farm process model is applied to estimate transpiration ration (Tirri) from irrigation water, taking account of precipitation, soil types, irrigation water and crop phenology; (5) irrigation efficiency estimation: the summary of ETirri of different crops is water effective consumed of irrigation water, so irrigation efficiency of irrigation district could be calculate as following formulation IE=Tirri/Wg.

Shijin irrigation area is located at Ziya river basin of Hebei province, China, where groundwater is over-draft. Proposed method is applied Shijin irrigation area for year 2010-2012. Irrigation efficiency is estimated for this area in comparison with 0.574 recorded by irrigation administrator

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DETECTION OF NITROGEN DEFICIENCY IN POTATOES USING SMALL UNMANNED AIRCRAFT SYSTEMS

E.R. Hunt Jr., D.A. Horneck, P.B. Hamm, D.J. Gadler, A.E. Bruce, R.W. Turner, C.B. Spinelli, J.J. Brungardt

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Small Unmanned Aircraft Systems (sUAS) are recognized as potentially important remote-sensing platforms for precision agriculture. A nitrogen rate experiment was established in 2013 with 'Ranger Russet' potatoes by applying four rates of nitrogen fertilizer (112, 224, 337, and 449 kg N/ha) in a randomized block design with 3 replicates. A Tetracam Hawkeye sUAS and Agricultural Digital Camera Lite sensor were used to collect imagery with near-infrared (NIR), red and green bands with pixel sizes from 1 to 4 cm. Colored tarps were set out for each flight for an empirical calibration of digital numbers to spectral reflectances; however, the camera footprint was too small to have the tarps in each image. Two spectral indices were calculated from the color-infrared imagery, the normalized difference vegetation index (NDVI) and the green normalized difference vegetation index (GNDVI). NDVI and GNDVI from the tarp digital numbers were correlated to NDVI and GNDVI calculated from tarp spectral reflectances. The slopes and intercepts of the calibration equations varied with the exposure time, which was set by the sensor. For images without the tarps, the exposure time was used to determine which calibration equation was used. Variation of NDVI and GNDVI over the growing season followed changes of leaf area index or plant cover. Comparison of GNDVI with NDVI was expected to enhance sensitivity to differences of leaf chlorophyll content; but only plots with the low N treatment were detectable. The value of sUAS for precision agriculture is information and its relevance to management. A first law of precision agriculture is proposed, "it's the sensor, not the platform."

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SUAVS TECHNOLOGY FOR BETTER MONITORING CROP STATUS FOR WINTER CANOLA

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The small-unmanned aircraft vehicles (sUAVS) are currently gaining more popularity in agriculture with uses including identification of weeds and crop production issues, diagnosing nutrient deficiencies, detection of chemical drift, scouting for pests, identification of biotic or abiotic stresses, and prediction of biomass and yield. Research information on the use of sUAVS have been published and conducted in crops such as rice, wheat, and corn, but the development of support tools associated with this technology is still under progress. One main example on the use of the sUAVS technology is portrayed herein for winter canola. Research studies were performed in Manhattan, Kansas at the Kansas State University –Department of Agronomy-, in a joint effort pursued by the Crop Production and Ecology and Agriculture Spatial Analysis Laboratory groups. Winter canola acres are gradually rising in the southern Great Plains region. Optimum nutrient management, specifically related to the right rate of nutrient to be applied, should be pursued to maximize crop production. The main issue faced by the scientific community is that the lack of information about nutrient management for canola. This study has as a main objective to: 1) determine biomass and nutrient accumulation for winter canola; 2) establish correlations between these parameters and blue NDVI and canopy temperature; and 3) determine the predictable value of blue NDVI and canopy temperature in assessing crop production issues and final canola yield. At flowering, blue NDVI presented a high correlation in predicting the whole-plant biomass under diverse mass levels. As expected, the canopy temperature map collected via sUAVS showed a trade-off relationship with whole-plant biomass, suggesting an optimum plant temperature value for maximizing solar radiation capture and efficiency in conversion (measured as final biomass). Both blue NDVI and canopy temperature, determined by the use of the sUAVS, predicted very well biomass status on canola. This information might help guide future nutrient prescriptions at the site-specific level. For the future, preparation of support decision tools are needed in order to quantify the "real" contribution of this technology in assisting key stake-holders for facilitating the decision-making process.

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UNNAMED AERIAL SYSTEM TO DETERMINE NITROGEN STATUS IN MAIZE

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Maize field production shows spatial variability during vegetative crop growth that could be used to prescribe nitrogen variable rates. The use of portable sensors mounted on high-clearance applicators is well documented, however new UAS vehicle equipped with high resolution digital cameras could be used to determine crop spatial variability with the advantage of survey extensive field areas. To our knowledge, comparisons between vegetation indices obtained by a modified digital camera and GreenSeeker or hyperspectral measurements are unknown. The aims of this study were to compare vegetation indices (VI) obtained with a modified digital camera versus SPAD, VI obtained with a GreenSeeker and a hyperspectral sensor, and to study the relationship of VI with crop variables related to N status in maize. Selected treatments, ranged from 0 and 276 kgN ha-1, were used to determine biomass, SPAD and sensors readings with a GreenSeeker and Ocean Optics USB 4000. The UAS was equipped with a digital camera modified by the extraction of the internal near-infrared blocking filter and the inclusion of a visible light-blocking filter. Crop measurements were made at V6 and V10 growth stages and photograph were obtained with two ground spatial resolution. Crop variables at V10 were related with VI determined with commercial sensors and with aerial photograph. The highest sensitivity to detect biomass and LAI changes was observed for VI calculated from an uncorrected high spatial resolution aerial photograph obtained with a modified RGB camera.

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A COMPARISON OF PERFORMANCE BETWEEN UAV AND SATELITE IMAGERY FOR N STATUS ASSESSMENT IN CORN

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For the sensing of crop conditions, a number of platforms, varying from proximal (tractor-mounted) ones to satellites orbiting the Earth, are available. Access to unmanned aerial vehicles (UAVs), or drones, that are able to carry sensors payloads providing data at a very high spatial resolution has recently aroused a great deal of interest. This study compares performance between UAV imagery acquired in a corn nitrogen (N) response trial set-up. The nitrogen (N) response trial consisted of two fields (one loamy, one clayey) sowed on two different dates at Agriculture and Agri -Food Canada's L'Acadie Experimental Farm, in the Montérégie region of Quebec, Canada. Eight unreplicated N treatment rates (from 0 to 200 kg N ha-1) were applied, with or without irrigation, to create a gradient of crop development stages and N status at the time of imagery acquisition. Multispectral imagery from the Pléiades-1B satellite was acquired on 8 July 2013. Then, 4 d later, a multispectral image was acquired with a UAV responder. On the day of UAV imagery acquisition, a ground-truthing campaign was performed. Leaf area index (LAI), chlorophyllmeter (with a SPAD chlorophyll meter), and destructive biomass data were measured at 96 points. The Soil-Adjusted Vegetation Index (SAVI) was calculated for both the Pléiades-1B and the UAV images and was matched to the ground-truthing database to perform the statistical comparisons. Relationships were established between the SAVI and the LAI, SPAD chlorophyll and biomass biophysical descriptors measured on the ground for both the satellite and the UAV imagery. The SAVI acquired from a UAV was better correlated than imagery from a satellite to fresh biomass (R2 = 0.93 for the UAV vs 0.88 for the satellite) and to LAI (R2 = 0.91 for the UAV vs 0.74 for the satellite). Image segmentation on the UAV imagery improved R2 by only 0.02 to 0.03 points. The accurate remote estimation of chlorophyll status from a corn crop at an early growth stage remains a challenge, even with pure leaf endmembers resulting from image segmentation, because of relatively low and more variable LAI values at that stage than at a later ones. The finer spatial resolution provided by the UAV allowed the observation of drainage effects on the vegetation, which were not clearly visible in the satellite image.

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VALUE OF CONNECTIVITY IN RURAL AREAS: CASE OF PRECISION AGRICULTURE DATA

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Practitioners of precision agricultural technology have overcome many obstacles over last two decades. The next gap in the adoption continuum of profitable precision agricultural technologies is data and data use, the so-called Big Data. A pertinent barrier to successful use of precision agriculture data is the connectivity with respect to transferring data from machine to the cloud computing and vice versa, and can be thought of as access to broadband internet. We have addressed this issue in a conceptual framework by proposing two methods; a partial budget approach and a non-parametric data envelopment analysis. Both methods are useful to estimate the foregone value absent broadband connectivity. In addition to constraining the profitability of agricultural firms; lack of broadband connectivity limits the adoption of precision agricultural technologies that make use of or relies upon near real time connectivity.

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PRECISION AGRICULTURE AS BRICOLAGE: UNDERSTANDING THE SITE SPECIFIC FARMER

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There is an immediate paradox apparent in precision farming because it applies all of it 's precision and recognition of variability to the land, yet operates under the assumption of idealism and normative notions when it comes to considering the farmer. Precision Agriculture (PA) systems have often considered the farmer as an optimiser of profit, or maximiser of efficiency, and therefore replaceable with mathematical constructs, so that although at the centre of decision making they are effectively made to disappear. However if the farmer disappears then so does the farm in terms of individualism and it simply becomes a patch work of zones and problem setting strategy generates the traditional approach to linear extension models. However practicing farmers do not think or act in the same way as the model specifies they should, the models might be more idealistic rather than realistic.

This paper explores the idea that "bricolage" could make a useful contribution to explain the slow rates of adoption achieved in PA, or put another way, the lack of apparent appeal of PA even though it would appear to offer many benefits through optimisation. Even the social science that has been applied to PA would appear to be enamoured with achieving greater precision by removing the individual farmer by breaking them down into generalised categories and sub sets to explain their behaviour.

The French anthropologist Leví Struass introduced the concept of bricolage in the nineteen sixties to counter "the supposed ineptitude of 'primitive people' for abstract thought", in contrast to the highly engineered solutions driven by modern science. In essence bricolage is a cobbling together of what is at hand, (local or particular knowledge and available enabling technologies). Essentially this process is driven by on-going curiosity and an iterative trial and error development of partial solutions rather than a linear march where curiosity has been replaced by "so-called" certainty. The idea of bricolage has gone on to be developed in a number of fields relevant to PA, such as information systems development, artificial intelligence and entrepreneurial activity, but to date it has not been applied to PA.

Case study evidence of very early adopters and the most advanced or leading edge farmers indicate that they are individuals with individual interests, skills and knowledge. What they tend to do is target their areas of improvement and build solutions based on their particular knowledge and the enabling technologies at their disposal. Essentially a bricolage, which is driven by the individual farmers on-going curiosity and producing workable precision at the individual farm level.

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SUSTAINABLE GRAIN PRODUCTION WITH CONTINUOUS IMPROVEMENTS AND LEAN PRODUCTION

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When improvements in agricultural production processes are being sought, the focus is generally on biological and agronomic aspects. However, an equal focus on farm-level management and organization is needed. Lean production (Lean) comprises a set of management practices for implementing improvements and has proven successful in other industries. This study investigated Lean in an agricultural application, grain production, where labor and most processes proceed in an annual cycle.

A method was developed to facilitate the introduction of Lean into Swedish grain production and to gain an increased understanding of how farm-level work performance relates to environmental impact in a life cycle perspective. The study was conducted on three large grain farms practicing precision agriculture, which were given opportunities to start working towards improved productivity and resource efficiency through three coaching sessions and their own independent work. By the end of the project, all three farms were working with daily visual control and an initial visual aid system for continuous improvements. Work on preventive maintenance had been facilitated by orderliness and visual planning.

The farms are just beginning a new way of working and more time is needed for them to save time. The future rewards of the work will hopefully meet the expectations of farmers and researchers – reduced environmental impact, increased productivity, higher profitability, and ultimately greater competiveness.

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ECONOMICS OF SITE SPECIFIC LIMING - COMPARISON OF ON-THE-GO AND GRID-BASED SOIL SAMPLING TO DETERMINE THE SOIL PH

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An important basis for adequate liming is the recording of the soil pH. Several studies indicated a large heterogeneity of soil pH within fields. Recent technological improvements facilitate an on-the-go determination of the soil pH in a much higher sampling density compared to the conventional, time-consuming and costly laboratory method. The Veris Soil pH Sensor allows georeferenced on-the-go mapping of the soil pH. However, the Veris Soil pH Sensor and the widely accepted laboratory method differ in their measuring principles. Hence, it is necessary to adjust the results of the pH sensor to the results of the laboratory method.

The economic potential of high resolution soil sampling strategies compared to the conventional soil sampling strategies is determined by four effects: the costs of applying the technology, the cost savings resulting from the reduction of over-fertilisation, the improved exploitation of phosphate (which will become plant-available due to small scale pH management) and the expected increase in yield (and thus revenues) resulting from a better lime distribution. To quantify the four effects, on-farm experiments were carried out, and the results of which are presented. In the on-farm field trials four different soil sampling approaches were compared: (1) one-ha fixed grid, (2) five-ha fixed grid, (3) "intelligent" apparent electrical conductivity homogenous sampling zones, (4) high resolution soil sampling. The impact of the four approaches on profitability was calculated for a six-year crop rotation. The costs of the technology, the cost savings resulting from the reduction of over-fertilisation and the improved exploitation of phosphate occur only once within the six years. The expected yield effects, however, must be taken into consideration six times within the crop rotation.

The analysis of the field trials shows that sampling density is crucial for the reduction of oversupplied and undersupplied zones. According to the conventional sampling method (5-ha fixed grid), approx. 32 % of the area was over-fertilized and approx. 38 % under-fertilized. The "intelligent" soil sampling showed similar results. The reduction of over-fertilisation was equal to a value of approx. 20 € ha-1, which can be saved or better distributed. An improved lime distribution resulting from high resolution soil sampling increases the amount of plant-available phosphate and leads to an increase in yield. Corresponding savings amount to approx. 32 € ha-1 for the phosphate which must not be applied. The increase in yield generates increased revenues of approx. 15 € ha-1 (annually). The costs for applying technology add up to 20 € ha-1 for the pH sensor, whilst the conventional procedures (fixed grids) cause costs between 2 and 13 € ha-1. In short, the field trials indicate an annual economic advantage of 15 – 30 € ha-1 of the high-resolution soil sampling compared to conventional soil sampling.

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USE OF ACTIVE RADIOMETERS TO ESTIMATE BIOMASS, LEAF AREA INDEX, AND PLANT HEIGHT IN COTTON

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Active radiometers have been tested extensively as tools to assess in-season nitrogen (N) status of crops like wheat (Triticum aestivum), corn (Zea mays), and cotton (Gossypium hirsutum). Fewer studies target in-season plant growth parameters such as biomass, plant height or leaf area index (LAI). Uses of this plant data include simulation modeling, total N uptake measurements, evapotranspiration (ET) estimates and irrigation recommendations. Our objective in this study was to examine relations between canopy reflectance and biomass, LAI and plant height in irrigated cotton. Canopy reflectance was measured at 1 m height above the tallest plants in field using two, three-band Crop Circle ACS-470 radiometers in a 2.5-ha irrigated nitrogen (N) fertilizer management study in cotton in central Arizona. Cotton was planted in May in 1 m rows. There were 18 plots that were 170 m long. Interference filters were centered on 800, 780, 730, 670, 590, and 530 nm. Wavelength widths were 20 nm for 800 and 780 nm and 10 nm for the rest. Plant height was estimated with a Honeywell 943 ultrasonic distance sensor. Canopy reflectance and plant height were sensed every 7 to 14 days during the season with one pass per plot at 0.5 m/sec, and data were acquired at 5 Hz. Leaf area index was measured five times per season at 24 to 72 DGPS-referenced points using a Li-Cor LAI-2000 Plant Canopy Analyzer. Manual plant heights were taken at the 72 points as well. Biomass (1 m2) samples were cut at ground level two times during the season. Variation in plant parameters were due to N fertilizer treatments and to sandy areas of the field with reduced water holding capacity. Several vegetative indices (VIs) were calculated and correlated with biomass, LAI, and plant height. Correlations were strongest with VIs and LAI or plant height and weakest with biomass. The normalized vegetative index (NDVI) using red as the visible band correlated with LAI, biomass, and lint yield better than using green or amber. NDVI amber correlated with N rate slightly better than NDVI-red. Correlations were weaker from using VIs that used reflectance in the red edge such as normalized difference red edge (NDRE) or the DATT index. In summary, NDVI calculated with and active sensor and plant height from an ultrasonic sensor appear to have potential to guide N fertilizer management, plant growth regulators and or harvest aid applications in irrigated cotton in the southwest USA.

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HAND-HELD SENSOR FOR MEASURING CROP REFLECTANCE AND ASSESSING CROP BIOPHYSICAL CHARACTERISTICS

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Crop vigor is difficult enough to define, let alone characterize and conveniently quantify. The human eye is particularly sensitive to green light, but quantifying subtle differences in plant greenness is subjective and therefore problematic in terms of making definitive management decisions. Plant greenness is one component of crop vigor and leaf area index or the relative ability of the crop to capture solar energy is another. It is well documented that reflectance of red light is a good way to quantify plant chlorophyll content until the canopy approaches closure. Once the canopy closes, red light reflectance remains very low and thus is no long responsive to changes in plant chlorophyll content. Reflectance in the red-edge region of the spectrum has been shown to be quite sensitive to canopy chlorophyll content over a wide range of biomass conditions. Canopy biomass is best quantified by measuring near infrared (NIR) reflectance. In a practical sense, NIR reflectance quantifies the size of the photosynthetic factory while red and red-edge reflectance collectively characterize how fast the factory can operate. The three-band (red, red-edge, and NIR) hand-held RapidSCAN CS-45 crop canopy sensor was developed to address these needs. The basic optical design was brought forward from the active three-band Holland Scientific Crop Circle ACS-430 sensor. The hand-held version provides a long-life lithium battery, internal GPS, large display and data storage capacity, and convenient data transfer into Microsoft Excel. Additionally, the versatility and autonomy of the RapidSCAN sensor has extended its usefulness to other applications such as unmanned aerial vehicles (UAV). Internally, the software calculates red, red-edge and NIR reflectance, NDVI and NDRE vegetation indices and various statistical values for scanned plant canopies as well as calculating plant biophysical properties or computing nutrient rates based on mathematical models. In practice, the sensor makes it possible for producers and consultants to scan crops to make fertilizer N recommendations, assess forage biomass, estimate yield, estimate crop leaf area and geospatially map agricultural landscapes.

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DETECTION OF FRUIT TREE WATER STATUS IN ORCHARDS FROM REMOTE SENSING THERMAL IMAGERY

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Remotely sensed crop water stress index (CWSI) can be used to depict fruit tree water status. The aim of this study was: i) to develop an empirical approach for assessing the CWSI of peach trees throughout a growing season and validate it with ground-based leaf water potential (Ψleaf) measurements, and ii) to detect the spatial variability of fruit tree water status in a 2-ha peach orchard and throughout a complete growing season based on remotely estimates of leaf water potential (Ψrem) from airborne thermal imagery. Ψrem was estimated from the seasonal relationships with CWSI. This study was carried out during 2012 and 2013 growing seasons. CWSI and Ψleaf were significantly correlated both years indicating a similar tendency between years, but differences between phenological stages. Differences in the spatial variability of peach tree water status were successfully remotely detected, demonstrating that remote estimates of leaf water potential can be used for precise irrigation purposes.

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AN INEXPENSIVE AERIAL PLATFORM FOR PRECISE REMOTE SENSING OF ALMOND AND WALNUT CANOPY TEMPERATURE

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Monitoring water stress in specialty crops to increase water use efficiency (WUE) is becoming more necessary when faced with the reality of depleting water resources. Leaf temperature (TL) of almond [prunus dulcis] and walnut [juglans regia] trees has been shown to be closely linked to stem water potential, a sensitive indicator of stress in woody plants.

This study was conducted to explore the feasibility of remotely measuring canopy temperature (Tcan) of walnut and almond trees with a small, inexpensive unmanned aerial vehicle (UAV). An infrared (IR) point sensor was installed with a lightweight camera on the underside of a multi-rotor UAV. The UAV was flown over a targeted tree canopy recording temperature and images. Image classification was used to identify the ground contents of each temperature measurement, and a linear system of equations utilizing the image/temperature records pertaining to a targeted tree canopy was established to approximate the temperature of the sunlit and shaded portions of that canopy.

Analyses of three flights over almond tree canopies approximated the temperatures of the sunlit and shaded portions of the canopies within an average of 2.2oC of their respective ground truths for both portions, and analyses of four flights over walnut canopies approximated the sunlit and shaded portions within 1.0 and 1.3oC of their respective ground truths, the average difference for all temperature approximations between the seven trees being 1.5oC. With canopy temperatures ranging from 16 to 40oC, the approximations fit a linear trend with a coefficient of determination (r2 value) of 0.96.

The use of an IR sensor coupled with a camera to establish a linear system of equations for individual trees showed promising ability to approximate a tree's canopy temperature. This method also has the advantage of distinguishing between the sunlit and shaded portions of the canopy.

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NIRS SENSOR CONTROLLED TOTAL-MIXED-RATION FOR NUTRIENT OPTIMIZED FEEDING OF DAIRY CATTLE

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Feed mixer are used to feed grass and maize silage together with other components in one ration. It can be used in combination with a transponder system for concentrated feed as well as for feeding of a total mixed ration. The implementation of a measurement system based on NIR-spectrometric sensors to measure DM-content and other nutrients (XP, XL, and XF) should result in a more precise nutrient adjustment of the ration.
To calibrate the measurement system spectra of many different silage samples are taken offline and analysed by wet chemistry. The goal is a good calibration model which can be used in the online measurement system. The NIR sensor and the spectrometer have been integrated in the mass flow of the self-propelled feed mixer. The calibration model is the start point for the online measurement at the feed mixer. The calibration models were validated in online and offline measurement. The tests have been completed and the validation shows good results.

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THE PERFORMANCE OF MOBILE DEVICES? INERTIAL MEASUREMENT UNIT FOR THE DETECTION OF CATTLE'S BEHAVIORS ON PASTURE

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Over the past decade, the Precision Livestock Farming (PLF) concept has taken a considerable place in the development of accurate methods for a better management of farm animals, as Precision Agriculture has done for crop production. Mass consumption mobile devices have nowadays the possibility to record accurately user movements with their Inertial Measurement Unit (IMU). We used iPhone 4S to detect accurately cattle behaviors such as grazing and ruminating with the aim of performing a precision grazing management on the near future. Results showed accuracies ranging between 84% and 100% when detecting these two major behaviors by analyzing recorded raw signals in the time-domain. Ongoing research tries to link these behaviors to different pasture characteristics and performs a refined signal processing analysis for a better monitoring of some possible behavioral changes.

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CAPTURING, DEMONSTRATING AND DELIVERING VALUE FROM INTEGRATING REAL-TIME ON-FARM SENSING WITH EXTERNAL INFORMATION FLOWS

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The need for significant productivity gains in the Australian agricultural sector is undeniable - sustainable industries must be capable of consistently producing a margin above the base costs of production. Viable and resilient farm businesses will need to make sense of what they know as they come to know it, and then make fine-grain, accurate and timely decisions. Timely, accurate and objective measurement of resources across the farm business, coupled with sound interpretation and understanding, will enable more accurate, timely and efficient management outcomes.

On an extensive beef grazing farm in the tropical region of northern Australia, a 'Digital Homestead' was established implementing sensor and related technologies to provide information to simple and usable cloud-based decision support systems for farmers and agriculture advisers. A sensor network collects data streams from a range of sensors such as weather stations and walk-over-weighing platforms to collect individual animal liveweight data. The data are uploaded to a central server and can be viewed in real time via a dynamic web interface, or 'dashboard'.

The design and functionality of the dashboard was shaped by ongoing engagement with industry stakeholders. Information flowed in real-time from both the on-farm sensors and off-farm sources such as market information and climate forecasts. Information was presented as a series of 'widgets' to allow customizing to individual preferences, and interrogation of information from a simple overview to detailed data.

For the future viability and resilience of farm businesses the use of these technologies offers a significant opportunity to drive outcomes in profit, productivity and sustainability if data can be linked and translated into insight These new technologies may also form the backbone of emerging agri-environmental services businesses.

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SPATIAL VARIABILITY OF SOIL PROPERTIES AND YIELD OF AN ALFALFA PASTURE UNDER GRAZING IN BRAZIL

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Alfalfa is extremely demanding in fertility, and an adequate supply of nutrients is important for forage production and is essential to maintain high forage quality and profitable yields. Tropical acid soils are naturally poor in plant nutrients, therefore, soil liming and balanced nutrient supply essential to ensure high yields and high alfalfa forage quality. The knowledge of soil properties spatial variability and forage yield is useful for the rational use of inputs, as in the variable rate application of lime and fertilizers. Precision agriculture requires methods to indicate the spatial variability of soil and plant parameters. The objective of this research was to map and evaluate the spatial variability of soil properties, yield, liming and fertilizer need and economical return of an alfalfa pasture. The study was conducted in a 5.3-ha-area of irrigated alfalfa pasture, directly grazed, intensive managed in a rotational system with 270 paddocks in Sao Carlos, SP, Brazil. Alfalfa shoot dry matter yield was evaluated when the crop has 10% of flowering and before the dairy cattle grazing. Soil samples were collected at 0-0.2m depth and each one represented a group of 5 paddocks. The values of soil pH, P, K, CEC and basis saturation were analyzed by traditional soil testing. Apparent soil electrical conductivity (ECa) was measured with a contact sensor. Data of liming and fertilizer needs were used to estimate the 1-ha-alfalfa cost of production and the total cost of production dairy system. Results of alfalfa dry matter yield were used to simulate pasture stocking rate, milk yield, gross revenue and net profit. The entire variable used at the estimation was based on a Brazilian intensive dairy cattle production systems based on grazing. Spatial variability soil properties and site specific liming and fertilizer need were modeled using semivariograms with Vesper software, and the soil fertility information and economic return were obtained by SPRING software. Results showed that the geostatistics and GIS use were decisive tools to show soil and pasture spatial variability and support management strategies. Soil nutrient were used to classify the soil spatial distribution map in order to design site-specific lime and fertilizer application maps. Spatial variation of forage and estimative of stocking and milk yield are adequate pasture management tools. Spatial variation of issue needs, forage availability and economic return are management tools to avoid economic and potential environmental problems form unbalanced nutrient supplying and over- or under-grazing pressure.

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ESTIMATING SPATIAL VARIATION IN ANNUAL PASTURE YIELD

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Yield mapping is a potentially valuable tool for precision management of pastures. However it is difficult to map annual yields of grazed pastures, which are harvested many times through the year, usually by grazing animals rather than by machine. Although pasture herbage mass can be mapped using tools such as the C-Dax Pasture Meter, this involves mapping the entire paddock repeatedly to measure annual pasture yields, a significant additional workload. For yield mapping to contribute to decision making, techniques are needed to allow selected strategic mapping events to be used to estimate the within-paddock variability of annual pasture yields.

Pasture herbage mass in kg DM/ha was mapped using the C-Dax Pasture Meter, pre- and post-grazing associated with most grazings, for 12 months on a rotationally grazed, irrigated ryegrass and white clover dairy pasture in Canterbury, New Zealand. Post-grazing pasture cover maps were subtracted from pre-grazing cover maps to obtain maps of pasture intake by cows for each grazing. The intake maps at each grazing event were added together to obtain a map of total pasture intake for the year. The yield variation present in individual pre-grazing maps was compared with the total annual variation in intake by cows, to identify individual maps that give a good estimate of the total annual yield variation.

On this property (an irrigated dairy farm in Canterbury, New Zealand), the variation in total annual pasture intake could be estimated by collecting a single map of pre-grazing pasture cover between December and early April, or ideally January – March. This timing is expected to be appropriate for other similar farms in the same climatic zone. Further work is ongoing to validate this timing with data from a second year of measurements.

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EXPLOITING THE VARIABILITY IN PASTURE PRODUCTION ON NEW ZEALAND HILL COUNTRY

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New Zealand has about four million hectares in medium to steep hill country pasture to which granular solid fertiliser is applied by airplane. On most New Zealand hill country properties where cultivation is not possible the only means of influencing pasture production yield is through the addition of fertilizers and paddock subdivision to control grazing and pasture growth rates. Pasture response to fertilizer varies in production zones within the farm which can be modelled using decision mining trees.

New Zealand pastoral farmers target production of a blend of perennial rye grass (Lolium perennecv) and white clover (Trifolium repens cv). Concentrations of these desired species reduce as pasture fertility reduces and topography becomes steeper, being replaced by wild grasses and weed species. As a result there are often significant differences in pasture quality, expressed as Crude Protein, (CP) Metabolisable Energy, (ME) and in-vitro Organic Matter Digestibility, (OMD). Traditionally these have not been measured as the process is extremely time consuming, expensive and there is often a long delay between sampling and the farmer receiving the results, which is inconvenient for decision making. This results in a lack of information around pasture productivity and differences in pasture quality not being fully recognised.

These differences in quality have been measured in the field using a hyperspectral sensor (ASD FieldSpec Pro), which allowed the full range of pasture quality within one large station to be observed and measured in-situ. In one farm case study completed, the sites examined had a range of pasture quality results, ME (7.2 to 11 MJ kg-1), CP (7.8 to 22%) and OMD (45 to 75%) which would significantly impact animal production. Results were compared to wet chemistry in order to calibrate and validate the methods. The results indicate that this method can give useful results with a high level of explanation of the data, providing a reliable means to determine pasture quality parameters from non-destructive field measurement.

Pasture production is considerably effected by variations in slope, aspect, seasonal rainfall and soil type, factors which in some cases do not change and other variables which do change but are outside the control of the farmer. In this variable environment the traditional method of soil testing a monitor paddock, assuming it represents the whole farm and planning a blanket application of fertiliser makes little sense as there is significant variation in production on different hill country zones reflected in the decision mining tree. Many of the factors affecting productivity can be represented in a GIS, which allows production zones and fertiliser response to be mapped once the farm plan is overlaid over an accurate digital terrain map.

In order to gain this benefit from such a decision mining tree the fertiliser application system must be accurate in terms of achieving the desired application rate from an aircraft. A computer controlled delivery system fitted to the topdressing aircraft has been developed which has significantly improved the coefficient of variation c.v. of spread. Trials have a reduction in the in-field coefficient of variation (CV) in spread from around 70% to about 40%, which is the level achieved on flat dairy pasture by spreading trucks using differential global positioning system (DGPS). This has enabled more complex fertiliser application plans to be carried out.

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FIRST RESULTS OF DEVELOPMENT OF A SMART FARM IN THE NETHERLANDS

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Global Positioning systems (GPS, GNSS) have been introduced on about 20 % of the Dutch arable farms in The Netherlands today. Use of sensor technology is also slowly but gradually being adopted by farmers, yielding making available large amounts of spatial data on soil, crop and climate conditions. Typical spatial data are soil organic matter, crop biomass, crop yield, and presence of pests and diseases. We still have to make major steps to use all this data in a way that agriculture becomes more sustainable.

In 2012 we took up the objective to transform a Dutch farm of ca. 180 ha into a Smart Farm. The farm combines arable (winter wheat, potatoes, sugar beet and onion crops) and dairy farming (cows plus grassland and maize crops). Smart Farm means that spatial information on cow condition, feeding, soil, crop, pests, diseases, and yield data are available and used in strategic and operational decisions.

Scanning more than 70 ha obtained soil maps on variation in soil organic matter and clay in 2013. Variation in biomass of crops was determined with satellite, airplane, Unmanned Aerial Systems (UAS) and tractor mounted sensors. Yield monitoring was done in the cereal crops and on grassland. We studied correlations between soil, crop and yield maps. In 2013, we also started with experiments on variable planting density of potato, variable rate application (VRA) of soil herbicides, VRA of N-fertilizers and VRA of potato haulm killing herbicides.
First results of the data collection and analysis are presented. The outlook of smart farming is discussed.

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FACTORS RELATED TO ADOPTION OF PRECISION AGRICULTURE TECHNOLOGIES IN SOUTHERN BRAZIL

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Brazil plays an important role as a supplier of agricultural products. The adoption of technologies as precision agriculture (PA) is a requirement to increase food production with improving quality and to reduce environmental footprints. Therefore, more detailed information about the dynamics of PA adoption process in Brazil is required. The objective of this study was to investigate the adoption of different PA tools by farmers in Rio Grande do Sul State (southern Brazil) and the factors involved in adoption decision. Here we analyzed the attributes of PA technology using adoption theory, characterize the users and document some of our personal observations in interacting with farmers, service providers, and researchers working on precision agriculture. An online survey was sent to 715 farmers from August to October 2011. The main motivations for adopting precision agriculture were the increase of crop productivity and the reduction of cost production. On the other hand, equipment high price and lack of staff skills/training were the most frequent limitations reported. The gateway to adopted PA by grain-producing farmers in southern Brazil was based on grid soil sampling. Outsourcing services in PA play a key role in diffusion of this technology. Yield map and variable rate seeding are the preferable tools among current adopters in order to expand the use of PA technologies. PA adopters frequently cultivate large areas; have an innovative profile and a high education level. Engagement with PA is 4.3 years on average. Technological factors explained 48% of farmer's satisfaction with PA technologies. Furthermore, impact of PA did not meet farmer's expectation at the time of adoption. In this sense, rate of PA adoption should increase as more benefits of this technology are proven.

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INTRODUCING PRECISION AGRICULTURE TO HIGH SCHOOL STUDENTS IN AUSTRALIA

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With a growing population and land available for agricultural production declining, there is a need to produce more food with less. The use of precision agriculture technologies at a selective high school student conference, Generation2050: Project Feed the World was held at UNE in December 2013. From all Australian States and the Australian Capital Territory, 101 students were chosen to attend from 161 applications based on a short written essay and the subjects they were studying at school. Over the four day event students were exposed to numerous agriculturally based activities in science laboratories and in the field. One of the student nominated highlights was the precision agriculture sessions.

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PRECISION AGRICULTURE USE IN SELECTED AGRICULTURAL REGIONS IN BRAZIL

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Investment in technology brought Brazil to the position among the top agricultural producers in the world. Brazilian agricultural production has increased drastically as a result of productivity growth instead expansion in area. In this scenario the use of Precision Agriculture (PA) in the farm management, considering the spatial variability for maximizing economic return and minimizing the risk of damage to the environment can be decisive. However, the adoption of PA by Brazilian producers iss occurring at a slower rate than the production increasing. Understanding the factors that influence the adoption of PA can be decisive to devise strategies that will enable it dissemination by Brazilian agribusiness. This paper provides a brief overview of selected agricultural regions in Brazil and the main features of the farms surveyed, summarizing the main results of the survey and examining particular features of the precision agriculture adoption and use in Brazil. The survey was conducted through applying a questionnaire to 301 land owners and managers in the Brazilian localities of traditional agriculture region as: Cascavel,PR; Não me Toque, RS, Patos de Minas, MG e Rio Verde, GO and the latest agriculture frontier as Balsas, MA; Bom Jesus, PI; Campo Verde, MT; Luís Eduardo Magalhães, BA; Maracaju, MS. The results indicated that the profile of the owners and property managers who adopt the PA is young, educated, more likely to use technology and informatics and cultivate large land areas. The average time of PA technologies use is 4 years. The properties in which the PA is being used tend to be higher than the traditional ones, indicating that the larger production scales favor the adoption of PA technologies. The main agricultural products cultivated with PA tools are soybeans and corn, followed by wheat and beans. The properties that use PA have equipment, but are underused. The most common equipment in the farms is the navigation systems like light bar and auto guidance, and variable rate for both fertilizer and seed. The main activities in which PA is use are in the supplying of soil amendments/fertilizer and harvest. Most of the PA activity is performed by a third party using farmer's or rental equipment. The soil sampling grid used ranges from one samples for each 3 to 5 ha. The main sources of information producers have been consultants, courses and training programs, and agricultural fairs and exhibitions. There is a perception that the PA adoption can increase productivity, economic returns, and product quality and reduce the negative environmental impact.

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EVALUATING DIFFERENT NITROGEN MANAGEMENT STRATEGIES FOR THE INTENSIVE WHEAT-MAIZE SYSTEM IN NORTH CHINA PLAIN

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The sustainable agricultural development involves both environmental challenges and production goals to meet growing food demand. However, excessive nitrogen (N) applications are threatening the sustainability of intensive agriculture in the North China Plain (NCP). Improved N management should result in greater N use efficiency (NUE) and producer profit while reducing the risk of environmental contamination. Therefore, developing and disseminating feasible N management strategies that will achieve both high yields and high NUE are crucial. Many recently developed N management strategies have been successful in improving NUE and reducing N losses while achieving similar grain yield as farmer's practice. The objective of this study was to evaluate different N management strategies for the intensive wheat-maize double cropping system in NCP. Field experiments were conducted from 2008 to 2012 at Quzhou Experiment Station of China Agricultural University in Hebei Province. The six N management strategies evaluated were (i) no N fertilizer as control (N0), (ii) soil mineral N (Nmin) test-based in-season root-zoon N management strategy (IRNM-soil Nmin), (iii) GreenSeeker-based precision N management strategy (PNM-GS), (iv) green window-based in-season N management strategy (INM-GW), (v) regional optimum N management strategy (RONM), (vi) farmer's N practice (FNP). The N fertilizer rate determined with IRNM-soil Nmin, PNM-GS, INM-GW and RONM were significantly reduced by 45%, 62%, 46% and 40% compared to the FNP, respectively, without significant changes in grain yield. As a result, the IRNM-soil Nmin, PNM-GS, INM-GW and RONM increased N use efficiency. Future studies are needed to integrate this strategy into high yield crop management system to achieve both high yield and high NUE simultaneously for food security and sustainable development.

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PRECISION NUTRIENT MANAGEMENT IN COTTON AT DIFFERENT YIELD TARGETS IN NORTHERN TRANSITIONAL ZONE OF KARNATAKA

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Nutrient management in cotton is complex due to the simultaneous production of vegetative and reproductive structures during the active growth phase. Lot of spatial variation in soil available nutrients is observed under similar management situation. In view of this an experiment was conducted to study the precision nutrient management by assessing status of soil nutrients in cotton growing area for precision application of nutrients. Bisanahalli cotton belt is selected for this study. The study area is a centre place of cotton growing belt in Haveri district of northern Karnataka consisting of both red soils (Alfisols), deep black soils (Vertisols) and mixed red and black soil. Totally, 178 soil samples were collected from 55.84 hectare cotton growing area at 60 m grid. The location of the sample was recorded using GPS. The samples were processed and analyzed for available nutrients status. Results show that, spatial variability observed with respect to all chemical properties between soil types and within each class of soil. The soil pH varied from 5.66 to 7.32, and 6.12 to 8.6, EC varied from of 0.07 - 0.84 and 0.08 to 0.24 dS/m, organic carbon from 0.74 and 0.68 % in red and black soil, respectively. Major nutrient status shows that, 60 per cent of the soil samples were low and 40 per cent samples were medium in available N status. With respect to P, 4 per cent samples were low and 96 per cent samples were medium in available status. Available K status was medium (86%) to high (14%). Available Fe and Zn status were deficient to the extent of 38 and 4 percent as against higher levels in 60 and 36 percent in alfisols and vertisols, respectively. Available Cu ranged from 0.66 to 3.6 ppm with higher levels in all grids. Available Mn was in the range of 0.26 to 20.6 ppm. Based on this soil fertility status, a field experiment on precision farming in cotton was carried out on an area of 55.84 ha by planning target yields of 20 and 25 q/ha for alfisols and 25 and 30 q/ha for vertisols. The soil fertility maps for different nutrients are generated using Arc GIS. Total area was delineated in to 4 management zone (MMM, LMM, MMH and LMH (low, Medium and High for N, P& K, resp.,) in red soil and MMM, LMM, MHM and LMH in black soil) based on available nutrient status and near neighbor wood classification. The required soil nutrient maps were generated based on site specific nutrient management (SSNM) concept by considering soil available status, crop uptake/ ton of seed cotton yield, and the target yield. As such, variable rate applicators (VRA) are not available at Indian conditions. Hence, variable rate of nutrients were applied manually according to the management zone. The results revealed that, the seed cotton yield target of 20 and 25 q/ha was achieved in alfisols and vertisols, respectively at all the nutrients status. However, we could able to achieve only 88 percent of the higher targets fixed (25 and 30 q/ha seed cotton yield, in alfisols and vertisols, respectively) due to prolonged dry spell during peak boll development stage and soil moisture constraints.

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THE TOAS PROJECT: UAV TECHNOLOGY FOR OPTIMIZING HERBICIDE APPLICATIONS IN WEED-CROP SYSTEMS

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Site-specific weed management refers to the application of customised control treatments, mainly herbicide, only where weeds are located within the crop-field. In this context, the TOAS project is being developed under the financial support of the European Commission with the main objective of generating georeferenced weed infestation maps of certain herbaceous (corn and sunflower) and permanent woody crops (poplar and olive orchards) by using aerial images collected by an unmanned aerial vehicle (UAV). This article introduces TOAS project and describes the whole research process developed and the main results attained to date. The main tasks are focused on: 1) configuration and use of the UAV and sensors for image acquisition, 2) evaluation of the specifications (sensor type, imagery characteristics, crop-weed phenological stage) required for each type of crop, and 3) development of automatic and robust image analysis procedures for weed mapping and crop assessment by using the captured remote images in order to optimize herbicide applications or other crop-weed management operations. Advances of the TOAS project are regularly updated in http://toasproject.wordpress.com.

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VERIFY THE EFFECTIVENESS OF UAS-MOUNTED SENSORS IN FIELD CROP AND LIVESTOCK PRODUCTION MANAGEMENT ISSUES

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Project Justification

There is interest by individuals and companies to use unmanned aircraft systems (UAS) as management tools in production agriculture, however there is little proof that sensors mounted on UAS can effectively identify crop development differences and anomalies.

This project is a "proof-of-concept" demonstrating specific UAS applications in production agriculture. Project personnel used UAS-mounted sensors to collect data of ongoing crop and livestock research projects during the 2014 crop season at the North Dakota State University Carrington Research Extension Center (CREC). Project personnel collaborated with NDSU research scientists conducting research at the CREC, and used UAS-mounted sensors to monitor research fields at specific times as identified by the individual researchers. The primary goal of the project to demonstrate proof-of-concept of the usefulness and effectiveness of UAS in crop and livestock management in North Dakota. Project personnel demonstrated UAS applications in crop and livestock management, and instances where UAS were not effective. Project personnel developed data processing methods and tools to convert image data to information that farmers, ranchers and consultants can use in their farming and consulting businesses.

UAS operations for this project began in May 2014, and are ongoing at the date of publication of this paper. All UAS remote sensing data is being correlated to data collected on the ground by the project investigators. All UAS applications for this project will be completed during 2014.

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THE USE OF A MULTIROTOR AND HIGH-RESOLUTION IMAGING FOR PRECISION HORTICULTURE IN CHILE: AN INDUSTRY PERSPECTIVE

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As part of the prototype development of a yield forecasting and precision agriculture service for Chilean horticulture, we evaluated the use of an eight-rotor Mikrokopter for high-resolution aerial imaging to support ground-based surveys. Specific considerations for UAV and communications performance under Chilean conditions are windy conditions, limited space for take-off and landing in orchards, tree height and plantation density, and the presence of high metal contents in soils. We discuss our experiences with this hobby-grade UAV after two seasons of flights. We also compared several free and commercial image stitching and orthomosaicing programs, including in-house software for pre- and post-processing. Criteria for comparisons were based on our requirements for application in the field, in particular, ease of use by non-specialists and rapid processing times on a laptop. Other considerations included value (features vs cost), technical support and hardware requirements. Mosaics were evaluated for their suitability for decision making in terms of accuracy of global and local features. Results for the different software are presented in terms of number of images, GPS accuracy, and processing times.

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WEED SEEDLINGS DETECTION IN WINTER CEREALS FOR SITE-SPECIFIC CONTROL: USE OF UAV IMAGERY TO OVERCOME THE CHALLENGE

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Weed management is an important part of the investments in crop production. Cost of herbicides accounts for approximately 40% of the cost of all the chemicals applied to agricultural land in Europe. Although weeds are distributed in patches, herbicide treatments are usually broadcast over the entire field and there is potential for overapplication. The development of site-specific weed management strategies based on weed maps in which herbicides are only applied to the crop zones were weeds spread could remedy this situation. Moreover, most of these strategies should be implemented in early season, just when post-emergence herbicide treatments are applied. Until now, obtaining weed infestation maps in early season has been a great challenge due to the reduced size of the weed and crop seedlings, and the spectral and morphological similarities between weeds and crop. This article describes the complete workflow developed to achieve the weed patch mapping in wheat fields, as paradigm of winter cereals. The workflow can be divided in three main steps: 1) configuration of the UAV and design of the flight route to acquire a set of overlapped images of the wheat field, 2) mosaicking of these images to create a georeferenced ortho-image of the whole crop field, and 3) automatic object based image analysis (OBIA) procedure developed for generating weed patch maps and herbicide prescription maps accordingly. The described workflow was applied in two wheat crop parcels, and the prescription maps and herbicide savings are showed and discussed.

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APPLYING CONVENTIONAL VEGETATION VIGOR INDICES TO UAS-DERIVED ORTHOMOSAICS: ISSUES AND CONSIDERATIONS

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In recent years, unmanned airborne systems (UAS) have gained a lot of interest for their potential use in precision agriculture. While the imagery from color infrared (CIR)-enabled commercial off-the-shelf cameras onboard UAS is appealing to facilitate crop scouting, the application of quantitative spectral analyses is influenced by a range of confounding factors. In contrast to satellite (and conventional airborne) imagery, typical UAS datasets are (1) subject to unknown and highly varying irradiance due to the ability to fly in all weather conditions at all times of the day, (2) using uncalibrated sensors and compressed and distorted digital numbers, preventing conversion to reflectance factors in an efficient and broadly applicable way, and (3) characterized by a very high spatial resolution causing a significant amount of soil and shadow noise to be visible at the sub-canopy level. When directly applying vegetation vigor indices (such as the NDVI) that have been historically designed to work using reflectance factors derived from satellite imagery at the canopy level and at a much coarser resolution than UAS imagery, these characteristics may compromise the validity of the resulting maps. While it is clear that calibrated algorithms are needed to produce maps that need a high level of confidence for decision making and prescription mapping, we recognize the need for simple crop scouting strategies based on automated and out-of-the-box data gathering practices to identify problem areas in a field, prior to more in-depth analytical approaches, which can be applied later after crop scouting has been done using the simpler approach. Here, we visualize the effects described above on a realistic scenario, and quantify the influences of soil and shadow noise on relative, uncalibrated vegetation vigor indices, using a Trimble UX5 UAS equipped with different filters. The multiple band combinations obtained in this way allow the calculation of several vegetation vigor index maps, which are then evaluated against handheld Trimble GreenSeeker NDVI measurements. Our goal is to describe potential pitfalls in using only a relative NDVI based on default UAS-based imagery for crop scouting, and to suggest ways to increase our understanding of UAS-based imagery for crop scouting.

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3-DIMENSION RECONSTRUCION OF CACTAS USING MULI¬TISPECTRAL IMAGES

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Using 3D reconstruction result to investigate plant morphology has been a focus of virtual plant. And multispectral imaging has proved to carried biological information in quite a lot work. This paper present a idea to investigate chlorophyll spatial variability of cactus using a bunch of multispectral images. 46 multispectral images are taken at equally distributed angles surrounding the tree and have over 80% overlap. Structure from motion approach has been used for dense point cloud generation mesh building and texture filling.

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DEVELOPMENT OF VARIABLE RATE SYSTEM FOR SOIL DISINFECTION BASED ON INJECTION TECHNIQUE

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A variable soil pesticide injection system was developed for control of soil pesticide amount by PWM. The paper analyzed a algorithmic model of control system, and designed hardware, algorithm and control of soil pesticide, mainly software flow and a feedback control way. In the paper, the variable-rate control system was consisted of infrared sensor, speed sensor, PWM valve, and pump motor. According to the amount of soil pesticide information, controller can automatically control flow amount by adjusting solid solenoid valve and PWM valve based on working speed, which changes the pulse duty cycle to achieve the variable work. Injection experiments of soil pesticide was pre-set different dosage, the results shown that pesticide amount was precise in fact, and the errors was less than 3.2%. The system could achieve variable rate injection of liquid pesticide into deep soil based on infrared sensor. Fitting equation of flow amount by adjusting PWM valve based on working speed could draw the R2 value of 0.935.

The chip can calculate the output PWM duty cycle according to the pre-set injection of soil pesticide amount after collected the speed of tractor. The feedback control is to regulate the PWM signal duty cycle according the real liquid flow obtained by the microcontroller chip which collected the output signal of liquid sensor which fixed on pesticide pipeline.

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WEED IDENTIFICATION FROM SEEDLING CABBAGES USING VISIBLE AND NEAR-INFRARED SPECTRUM ANALYSIS

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Target identification is one of the main research content and also a key point in precision crop protection. The main purpose of the study is to choose the characteristic wavelengths (CW for short) to classify the cabbages and the weeds at their seedling stage using different data analysis methods. Using a handheld full-spectrum FieldSpec-FR, the canopies of the seedling plants, cabbage '8398, cabbage 'zhonggan', Barnyard grass, green foxtail, goosegrass, crabgrass, and small quinoa,, at three- & four-week growth were measured in the range of wavelength 350 ~ 2500nm. In Unscrambler Data Analysis software system, the Principal Component Analysis (PCA) was applied respectively to extract CWs. Then plants were classified by means of Bayes discriminant analysis method with the chosen CWs as variable. The results showed that (1) According to the load factors and its changing rate of PCs corresponding to the spectral wavelengths, the CWs which were sensitive to plant identification were extracted respectively as 567, 667, 715, 1345, 1402, 1725, 1925, and 2015 nm for the first stage and 567, 667, 745, 1345, 1402, 1545, 1725, and 1925nm for the second stage. among the each 8 CWs of two stages, just two of the CWs were different, which indicated that the changes of spectral characteristics at different growth stages of cabbages have little influence on identification of cabbages and weeds. (2) The corresponding spectral data of the 8 CWs extracted from the data at the first stage were taken as the input variables of the model which was built up using Bayes discriminant analysis to classify two varieties of cabbages and five kinds of weeds. The correct classification rates for the training and testing sets were respectively 90.7% and 84.3%. When the two varieties of cabbages were regarded as the same category, using the analysis method the correct classification rates of the training and testing sets were respectively 95% and 100%, which indicated that different varieties of cabbages owned similar the spectral features.

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PERSPECTIVES FOR SITE SPECIFIC APPLICATION OF SOIL HERBICIDES IN ARABLE FARMING

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The use of soil herbicides will become more sustainable when the dosage is adjusted to local soil condition. This so called Variable Rate Application (VRA) is the core of Precision Farming.

With increasing advances in sensing and spray technology, and the development of Decision Support Rules (DSR), the shift to VRA application is likely to occur soon. Soil applied herbicides are sprayed around crop-emergence and kill germinating weed seeds in the top few cm of the soil. The activity of a herbicide in the soil is influenced by physico-chemical characteristics of the herbicide, and weather and soil conditions. For the VRA application of soil herbicides, the relation between herbicide efficacy and relevant soil properties needs to be known, and has to be described with a DSR or more complex model. Today, at least three types of soil sensors can be used to scan soils on soil properties such as organic material or clay content. DSR can be obtained by greenhouse experiments, on-farm trails, bioassays, literature reviews, modelling, or a combination of these methods. A soil map with data on the spatial variation of the relevant soil properties is required. Soil maps can be obtained by soil scanning in combination with soil sampling plus analysis and interpolation. Combining soil maps with DSR provides recommended dosage maps. The farsmer or farm advisor then adjusts these dosage maps in his Farm Management System (FMS), taking into account routing and settings and properties of his spray equipment, providing task maps.

The first steps to implement VRA of soil herbicides have been taken on innovative farms in the Netherlands within the R&D of two precision farming programs. Results of the R&D are summarized in this manuscript. Perspective of VRA of soil herbicides is discussed.

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USE OF VEGETATION INDICES IN VARIABLE RATE APPLICATION OF POTATO HAULM KILLING HERBICIDES

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Variable rate application (VRA) of pesticides based on measured spatial variation in crop biomass is possible with currently available crop reflection sensors (remote and proximal), GNSS technology and modern field sprayers. VRA has the potential to contribute to a more sustainable use of pesticide. Dose rates are optimized based on local needs at a scale of about 5-50 m2, leading to less adverse side effects, less costs and higher yields. In the long run, individual plant treatment (optimization at a scale < 1m2) will become practical too.

WUR-PRI has developed with some partners VRA systems for leaf desiccants (potato haulm killing herbicides) in potato. The basis of the system is a decision support system (DSS) that relates biomass parameters (WDVIg, or derived parameter) to minimum effective doses of the desiccants, such as the a.i. diquat-dibromide, glufosinate, carfentrazone-ethyl. Proximal and remote sensors were used. A first prototype of a proximal sensor (N-Sensor) and injection type sprayer in combination with the DSS was successfully tested in ware potatoes in 2006. In next years, other types of sprayers in combination with other types of proximal (e.g. Greenseeker) and remote (satellite and UAS mounted) sensors systems were tested. This R&D yielded several options for farmers to acquire data on spatial variation of crop biomass on their fields. With the Dutch satellite images database, which became available in 2012, farmers have access to spatial biomass data on a scale of less than 10 m2. If data are obtained from UAS mounted cameras, the resolution is even higher up to less than 1 m2.

The different sensor – sprayer VRA systems have been tested in practice in commercially grown potato crops over eight years in The Netherlands, Germany, UK and Denmark. These validation studies showed good efficacy while potato haulm killing herbicide use was 30 to 40 % less compared to farmers' practices. The actual reduction was determined by e.g. resolution of sensor, patchyness of the field and width of (the section) of the spray boom. Following up on the success of the VRA potato haulm killing system, new biomass dependent VRA systems for fungicides in e.g. potatoes, strawberries and orchards are being developed.

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EFFECT OF TIME OF APPLICATION ON SPRAY COVERAGE USING SOLID SET CANOPY DELIVERY SYSTEM

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Permanent or solid set canopy delivery system (SSCDS) can be used for foliar application in tree fruit orchards. The emitters are placed along the tree rows and are very close to tree canopy. During spray application, droplets quickly get deposited on tree canopy and good coverage could be achieved. However concerns still exist regarding critical time required to achieve target coverage using SSCDS. This knowledge of selecting an appropriate application time could help growers achieve target coverage while potentially reducing chemical usage, off-canopy application and harmful environmental impacts. This study was conducted to study the effect of duration of spray application on spray coverage in super spindle apple trees in high-density orchards planting system. SSCDS was setup in a commercial orchard. Three emitters were selected for this study. Emitters were fixed in two different designs, one with to emitters mounted side by side at two (2x2 design) and second with s ame configuration emitters (2x3 design) mounted at three canopy height levels located in the middle of each tree along the tree rows. Spray system was calibrated and set to spray at three operating pressures of 35, 55 and 75 psi. Three locations were selected to locate Water sensitive cards to observe and record spray coverage development over time. To record coverage over time, a high-speed camera with 75 mm focusable lens. The camera was set to capture 10 frames per second with 200 ms and record images using HiSpec Control software. Images were then analyzed using ImageJ software to calculate percent coverage and plot percent coverage over time. The results indicated that spray drop deposited in less than 2 s to provide 100% spray coverage using 2x3 design at 75 psi. Therefore, for lower spray coverage lesser application times can be used. It was also interesting to note that any spray application greater than this time would result in chemical being loss to off-canopy target. Overall, a short spray time of less than 2 s can be selected to achieve desired coverage and reduce application cost.

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RECOGNITION AND CLASSIFICATION OF WEEDS IN SUGARCANE USING THE TECHNIQUE OF THE BAG OF WORDS

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The production of sugar and ethanol in Brazil is very prominent economically and the reducing costs and improving the production system being necessary. The management crops operations of sugarcane and the control of weed is one of the processes that cause the greatest increase in production costs; because the competition that exists between cane plants and weed, for water, nutrients and sunlight is big, contribute to the loss of up to 20% of the useful cane. The use of image processing techniques has proven to be a tool to aid the decision, reducing production costs, because through the early recognition of infestation, it is possible to make the localized application of herbicides, reducing the impact on losses during cutting and harvesting of cane. Applying bag of words technique for recognizing weeds plants is proposed. The method is divided into three stages: vocabulary of visual words, training and classification. Were defined six varieties of weeds that have significant occurrence in cane fields infestation in the São Paulo State, which is the largest producer of sugar and ethanol in the country. The varieties of harmful plants chosen were: Panicum maximum, Euphorbia heterophylla; Brachiaria decumbens; Brachiaria plantaginea; Quamoclit Ipomoea; Ipomoea hederifolia. As main class was defined sugarcane (Saccharum officinalis). Digital images were obtained weekly between September and November 2013, using a digital camera (Nikkon Coolpix P510). The recognition of the images was developed in MATLAB R2012a. On classification stage was used the Support Vector Machine (SVM), which is a non-probabilistic binary classifier, being the methodology tested with a set of 105 images of seven kinds of plants (six weeds plants and sugarcane). The proposed method gotten average accuracy of 90.68% in the recognition, showing is more sensible in identification of plants Brachiaria plantaginea and Ipomoea hederifolia.

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RAPID DATA ACQUISITION FOR IN-FIELD PLANT PHENOMICS

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High throughput sensing is necessary for the rapid acquisition of plant canopy physical and physiological parameters on field scales. Simultaneous measures of these descriptive parameters will provide a clearer picture of plant response to biotic and abiotic stressors. Information obtained can assist in early identification of desired genetic traits and the degree to which they are expressed. Identifying these traits and their expression can provide higher efficiency in genetic selection for breeding programs and define better management practices for genetics currently on the market. To meet this sensing need, a new multi-parameter sensor system was developed, and accordingly, represents a new integrated approach for measuring radiative transfer and physiological characteristics of plant canopies. The phenomics system was developed and provided by Holland Scientific (Lincoln, NE, USA) and was field tested on winter wheat during the spring growing season of 2013. The system is a combination of active and passive sensors consisting of a three-band active optical sensor (AOS), a multi-parameter data acquisition sensor and geospatial data logger (Holland Scientific GeoSCOUT GLS-400). The AOS (Holland Scientific Crop Circle ACS-430P) provides measurements for red, red-edge (RE) and near infrared (NIR) reflectance, red and red-edge normalized difference vegetation indices (NDVI and NDRE) and estimation models for leaf area index (LAI), plant canopy chlorophyll content (CCC) and optical sensor-to-plant distance. The multi-parameter sensor (Holland Scientific Crop Circle DAS43X) provides measurements for passive upwelling and downwelling photosynthetic active radiation (PAR), passive temperature for both canopy and ambient air, humidity and atmospheric pressure. The Crop Circle DAS43X also includes two 24-bit differential voltage channels with the option of configuring one of the channels as a pulse counter. Canopy data was collected at a rate of 5 samples per second and geo-referenced using a Trimble RTK GPS receiver. From this dual sensor data we were able to derive CCC, LAI, canopy height, canopy temperature departure (ΔT), and fractionally absorbed PAR (fAPAR). Data was collected at three dates on a yield trial study that includes thirteen public varieties adapted for the Great Plains and grown in Eastern Nebraska. We were able to characterize the highest yielding variety as a shorter plant with high LAI, CCC and fAPAR. Potentially, a variety with a higher light use efficiency (LUE) throughout the canopy, most likely a result of an erectophyle structure of the leaves. This particular variety had the highest ΔT in the presence of acute heat stress, indicating increased rates of transpiration as a strategy of heat tolerance. The system has demonstrated that significant discrimination can be obtained for a variety of plant canopy physical and physiological parameters in a high throughput manner using the set of measurements provided by the sensor suite.

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USING PRECISION AGRICULTURE AND REMOTE SENSING TECHNIQUES TO IMPROVE GENOTYPE SELECTION IN A BREEDING PROGRAM

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Precision Agriculture (PA) and Remote Sensing (RS) technologies are increasingly being used as tools to assess crop and soil properties by breeders and physiologists. These technologies are showing potential to improve genotype selections over their traditional field measurements, by providing quick access to crop properties throughout the crop cycle and yield estimation. The objective of this work was to use vegetation indices (VIs) and soil apparent electrical conductivity (ECa) as predictor variables of yield. This information was obtained from a durum wheat yield trial, aiming to estimate yield of different genotypes under full and reduced irrigation. This work was carried out at CIMMYT's experiment station at Ciudad Obregón/Sonora, Mexico, during 2013 wheat crop cycle. There were four yield trials, two with reduced irrigation (RID) and two with full irrigation (FIG), which tested 112 different genotypes in a completely randomized design with three replications. A flight campaign took place, with six flights, once per week from March to April 2013, using a 6-channel multispectral camera with 10 nm FWHM filters onboard an airplane flying 300 m above ground yielding 0.3 m resolution. The ECa data was collected just before sowing using an EM38 device in each plot. Twenty three different VIs ranging from chlorophyll, structural, red edge ratios and RGB indices were calculated using the multispectral images. A Pearson's correlation was done using the yield of the check genotypes of each experiment with the VIs of each image and ECa, aiming to explore the potential of each variable on predicting yield. This approach was followed by a subset multiple regression method, using as predictive variables the VIs coefficients fitted to each genotype considering a quadratic effect plus ECa, to fit the yield of each genotype in a training dataset, and then applied into a Bootstrap method in the cross validation dataset. The significant correlations among yield from the check genotypes and VIs from all images, plus ECa, ranged from -0.82 to 0.73 in the RID and from -0.70 to 0.60 in the FIG experiment. The correlation coefficients between measured versus predicted yield by the models got mean values of 0.51 (RID) and 0.68 (FIG) using the cross validation dataset, being 0.27 (RID) and 0.47 (FIG) of r-squared, indicating that the use of different VIs together may improve the yield prediction of breeding experiments.

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AIRBORNE ACTIVE OPTICAL SENSORS (AOS) FOR PHOTOSYNTHETICALLY-ACTIVE BIOMASS SENSING: CURRENT STATUS AND FUTURE OPPORTUNITIES

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The first published deployment of an active optical reflectance sensor (AOS) in a low-flying aircraft in 2009 catalyzed numerous developments in both sensor development and sensor platform integration. Integral to these sensors is a modulated light source composed of high power LED technology that emits high radiance polychromatic light. The sensor easily mounts to agricultural aircraft and can sense agricultural landscapes at altitudes from a few meters to altitudes exceeding 40 meters while traveling at velocities of more than 270 km/h. The rather large sensor-to-canopy measurement range allows the sensor to accurately measure ratio-based spectral reflectance indices such as the NDVI over fields with rolling terrain. Two versions of the sensor have since been developed and tested. A key advantage of airborne AOS is that they provide ratio-based index values unaffected by path radiance. This alone offers a viable, large scale sensing technique for researchers interested in plant and soil moisture investigations using the 'reflectance index-temperature' space concept or for the large scale, yet location specific conversion of 'top-of-atmosphere' vegetation indices, as derived from satellite imagery to the 'top- of-canopy' values.

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APPLICATION OF SEMANTIC SENSOR WEB IN AGRICULTURE

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In July 2013, heavy rainstorms across the Midwestern region of the US caused many rivers to breach their banks. Residents of Valley Park, a small town along the Meramec River, Missouri, had to decide whether to rely on a newly constructed levee or abandon their homes for higher ground. Although the levee held, many chose the latter option and fled their homes; it was a chaotic situation that might have been avoided through access to better situational knowledge regarding the current water pressure and the levee's structural integrity. Had pressure sensors been embedded in the levee, they might have provided accurate real-time information that let residents make informed decisions about the safety of the levee, their homes, and themselves. This scenario demonstrates the increasingly critical role of sensors that collect and distribute observations of our world in our everyday lives. In recent years, sensors have been increasingly adopted by a diverse array of disciplines, such as environmental monitoring for growth of crops ,meteorology for weather forecasting and wildfire detection, civic planning for traffic management, satellite imaging for earth and space observation, medical sciences for patient care using biometric sensors, and homeland security for radiation and biochemical detection at ports. Sensors are thus distributed across the globe, leading to an avalanche of data about our environment. The rapid development and deployment of sensor technology involves many different types of sensors, both remote and in situ, with diverse capabilities such as range, modality, and maneuverability. Today, it's possible to use sensor networks to detect and identify a multitude of observations, from simple phenomena to complex events and situations. The lack of integration and communication between these networks, however, often isolates important data streams and intensifies the existing problem of too much data and not enough knowledge.

With a view to addressing this problem, we discuss a semantic sensor web in which sensor data is annotated with semantic metadata to increase interoperability as well as provide contextual information essential for situational knowledge. In particular, this involves annotating sensor data with spatial, temporal, and thematic semantic metadata.

The semantic sensor web is a framework for providing enhanced meaning for sensor observations so as to enable situation awareness. It enhances meaning by adding semantic annotations to existing standard sensor languages of the SWE. These annotations provide more meaningful descriptions and enhanced access to sensor data than SWE alone, and they act as a linking mechanism to bridge the gap between the primarily syntactic XML-based metadata standards of the SWE and the RDF/OWL-based metadata standards of the semantic web. In association with semantic annotation, ontologies and rules play an important role in semantic sensor web for interoperability, analysis, and reasoning over heterogeneous multimodal sensor data.
In this paper, we mainly discuss the application of semantic sensor web in agriculture. This paper combined agriculture actual characteristic, summarized the research status of semantic sensor web in agriculture and key technologies involved, finally analyzed semantic sensor web application prospect in agriculture. All these would help widen ideas for the application of semantic sensor web in agriculture.

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FIELD-BASED HIGH-THROUGHPUT PHENOTYPING APPROACH FOR SOYBEAN PLANT IMPROVEMENT

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The continued development of new, high yielding cultivars needed to meet the world's growing food demands will be aided by improving the technology to rapidly phenotype potential cultivars. High-throughput phenotyping (HTP) is essential to maximize the greatest value of genetics analysis and to better understand the plant biology and physiology in view of a "Feed the World in 2050" theme. Field-based high-throughput phenotyping platform including a LiDAR-based proximal sensing field scout and its data processing system were developed and applied for near-real-time remote sensing of soybean 3D canopy structure variation and plant growth condition among different plant and plot scale in this paper.

The proximal sensing field scout consists of an extremely accurate distance measurement sensor, called the SICK LiDAR (Light Detection And Ranging) scanner, with distance measurements over a 180 degree area up to 8 meters away among canopy. The GPS sensor and a 6 DOF (Six Degrees of Freedom) Inertia Measurement Unit were mounted on the tractor. The scanning frequency is 1Hz and the resolution will be 10mm. The canopy height and density will be calculated after the canopy 3D structure is reconstructed. The resolution is 0.16m / pixel, which is much smaller than the individual soybean plant size of 0.762m. The ground reference data of each plot, such as canopy height information, were collected during the growing season, and the yield harvested at the end of the season was measured. These ground-based agronomic traits data will be correlated with the ground proximal sensing data. 4 rows of the soybean were proximal sensed and scouted by LiDAR considering the traveling speed and the sensor resolution. The average maximum height of the plant and the canopy coverage were derived, and the plant canopy volume was calculated based on the canopy 3D reconstruction algorithm. Therefore, a novel canopy volume model algorithm was developed to correlate with the yield considering the canopy height and canopy coverage information based on the entire field and each soybean family evaluated. The results shows that the canopy height by proximal sensing of LiDAR has a good correlation with that of field measurement (R2=78.51%) and the canopy volume value has a correlation of 69.34% (R2=69.34%) with soybean yield harvested in 2013. Additionally, some of the families has a positive correlation between the yield harvested and the soybean canopy volume across the whole field and the proposed canopy volume model has better stability and robustness than that of the field height only. It is indicated that proposed proximal sensing system is high efficiency and effective to conduct the field-based high-throughput phenotyping and which could be helpful to better understand the plant biology and growth condition for plant improvement. Commercial pre-harvest yield prediction would likely to be made during the early season based on the proximal sensing data. Moreover, the proximal sensing approach for high-throughput phenotyping could be applied in QTL and association mapping with crop genetics in the future.

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TRIALS OF PRECISION RESTORING AGRICULTURE IN JAPAN

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The objective of the paper is to describe a tentative scheme of precision restoring in Japan in a view of agricultural engineering. On March 11th in 2011 the northeast Japan was attacked by the tri-disaster; a M 9.0 super earthquake, more than 10-m–high huge Tsunami, and explosions of Fukushima nuclear power station. Tremendous damage has been confirmed across the cities and rural communities, including agriculture and industry. In three weeks after the catastrophe, the author organized a project team in the Society of Agricultural Machinery to investigate the damages and to look for avenues on not only community-based reconstruction but also removal of radioactive contamination from the farm land. Two actions were made for immediate requests. The one was to develop machines to remove the top thin layer of agricultural land with highly dense radioactive contaminations. The second one was to look over the farm land damaged by the Tsunami and to find avenues for recovery. These actions have made linkage with many related activities and policies, and have still continued.

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STRATEGIES FOR SCIENTIFIC COMMUNICATION OF PRECISION AGRICULTURE IN BRAZIL

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Scientific knowledge popularization is the way to the society access technical scientific advances. The challenge is to increase the means, channels and processes of information and relationship with society and decode scientific issues into a format that makes knowledge accessible. The Embrapa Precision Agriculture Network has been used scientific communication strategies at the traditional and new media, as a way of approach with various stakeholders, contributing to the construction of a critical conscience of Brazilian society. The aim of this research is to present and evaluate the results of these strategies in scientific communication of the PA Network. For an efficient scientific communication is essential that the information have been transmitted in clear, simple, direct and easy to understand in a way to become it accessible to the public. Since the launched of the PA network in 2009 the strategies for scientific communication of PA as a website, educational videos and media reports have been adopted. The website (http://www.embrapa.br/agriculturadeprecisao) contains information about the project, activities, results and publications releases. Based on the reports generated by Google Analytics the website received more than 58,000 accesses, with around 190,000 page views and more than 42,000 visitors, with about 27% of return to the site. Social media can help to make science a closer experience of the public and the YouTube videos are an efficient tool. Internet videos were created and are available at the YouTube (http://www.youtube.com/redeapvideos#p/u) to disseminate the results and concepts of PA. The access to the videos focusing PA themes has been increasing and reached around 15,000 views. This access to the short videos format (with 2-3 min) has been an indicative of the public preference. Scientific journalism plays an important role in decoding the scientific subjects for an accessible language to the public. So, the publication of articles in the media (newspapers, radio, magazines, television, internet) has been stimulated. Around 400 reports were published about PA Network activities and results indicating the increasing interest of the public on PA subject. The release of research results has been an efficient way of the project team approach to the society by showing the generation of PA knowledge in Brazil made by Embrapa and partners. It can also contribute to the strengthening and promotion of the concept of PA as a management tool for producers and service providers. It is also a form of accountability to society, indicating the destination of the financial resources.

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ECONOMICALLY OPTIMIZED SITE SPECIFIC NITROGEN APPLICATION USING DATA MINING TOOLS

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Future economic and environmental demands on agricultural production require a more efficient use of resources. Excessive use of nutrients may cause leaching, whereas deficits could lead to impediments in tapping full yield potential. As part of an ongoing research project, we investigated the ability to increase nitrogen efficiency for winter wheat fertilization using Artificial Neural Networks (ANN) and Support-Vector-Machines (SVM). Based on a high-resolution yield prediction, a site-specific economic optimal nitrogen amount was determined according to the maximum Nitrogen Cost-free Revenue. Results showed an increase in nitrogen efficiency of about 30 % (ANN) and 10 % (SVM) compared to uniform treatment (UT). However, a decrease in yield level of about 0.6 t ha-1 occurred using the ANN-based strategy.

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EVALUATING DECISION SYSTEMS FOR USING VARIABLE RATES IN PLANTING SOYBEAN

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Increased interest in managing seeding rates within soybean fields is being driven by advances in technologies and the need to increase productivity and economic returns. A wealth of previous research was focused on studying how different seeding rates affect soybean yields at small-plot scales. However, little is known about different site-specific factors influence the responsiveness of soybean to higher or lower plant population densities at field levels, especially across geographic areas with similar soils, weather, and management conditions. In addition, there is no system that farmers can use to evaluate various recommendations for variable rate seeding. The objective of this study was to use on-farm observations to identify major factors that affect yield response of soybean to seeding rates that are slightly above or below the planting rates currently used by farmers. Between 2009 and 2011, farmers conducted 83 field-scale replicated strip trials across Iowa with two soybean seeding rates, high, about 395 K seed ha-1 and the low, about 340 K seed ha-1. The two seeding rates were replicated at least four times in each trial. Yield responses to the higher seeding rates were estimated at 30-m grid patterns within each field. Hierarchical modeling and Bayesian analysis were used to identify field and within field-level factors that had significant effect on yield response to the higher seeding rate. For the field-level factors, we considered soybean row spacing, soybean planting dates, monthly and cumulative growing season rainfall. For the within field-level variables, we used relative elevation, slope, soil drainage class, crop suitability rating index, and soil organic matter levels. The Bayesian analyses helped to quantify the uncertainty in the parameters of observed yield response distributions and make predictions for potential yield responses to higher or lower seeding rates at field and within-field areas not studied but assumed to have similar crop management and weather conditions. Based on estimated predictive posterior probabilities of profitable yield response (a yield increase above the marginal cost for the seeds) to higher soybean seeding rates, a decision management system was developed that would help farmers and agronomists make economic decisions regarding where to increase or decrease soybean seeding rates within and across fields.

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OPTIMIZING SITE-SPECIFIC ADAPTIVE MANAGEMENT USING A PROBABILISTIC FRAMEWORK: EVALUATING MODEL PERFORMANCE USING HISTORIC DATA

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Agricultural producers are tasked with managing crop yield responses to nitrogen (N) within systems that have high levels of spatial (biophysical), climatic, and price uncertainty. To date, the outcome of most variable rate application (VRA) research has focused on the spatial dimension, proposing optimal fertilizer prescription maps that can be applied year after year. However, temporally static prescriptions can result in suboptimal outcomes, particularly if they do not consider the impact and likelihood of alternative weather or price regimes that can drastically alter crop responses and net returns. Furthermore, most optimizations are built on the assumption of linear crop responses when non-linearity may be more biologically appropriate and could result in altered N prescriptions.

In this presentation, we outline our methodology to address these uncertainties using a non-linear spatiotemporal Bayesian updating framework. This strategy continually improves N optimizations, increases net returns and reduces uncertainty in the parameter estimates. The framework is able to quantify the probabilities of different net return outcomes, allowing the producer to choose their N management based on their particular level of risk adversity. It also enables the producer or researcher to assess the impacts of future scenarios such as prolonged drought or price fluctuations.

This methodology was tested within a simulation to assess the number of years required for model convergence and enhanced net returns. It was then applied to the years 1980 – 1992 to hindcast the impact of extended drought in Montana during 1987-1991. Simulated crop responses incorporated realistic levels of residual variability based on ten years of observations from a dryland wheat farm located near Great Falls, Montana. For simplicity, the crop was assumed to respond non-linearly to variation in soil apparent electrical conductivity (ECa), applied nitrogen (N), and precipitation. Historical wheat price data from this region also informed the model and served as an additional source of variability that impacted the net returns.

Parameter convergence and net returns higher than those of uniform fertilization were achieved after six to eight years, resulting in a spatial net return benefit of $23-25/hectare. After year six, the spatial random effects in the model
effectively eliminated the confounding influence of spatial autocorrelation on the crop response coefficients. Small experimental N rate treatments (0, 60, 120, 180 kg/ha) were randomly applied each year as a part of this framework to ensure that crop responses to N were explored under the full space of possible soil and precipitation conditions. These strip experiments reduced the time required for convergence of the parameter estimates.

During the late 1980s, the severe drought in Montana reduced hypothetical savings from a level of $450,000 in 1983 to below zero as early as 1988. The impacts on savings are mirrored in governmental data on farm bankruptcies during this period. Substantial variability remained around the estimates for the different fertilization scenarios; however the optimized fertilizer prescriptions consistently outperformed the uniform prescriptions on a field-wide basis. With a nominal level of governmental price support, producers spatially optimizing their N inputs would have survived the drought. Producers applying uniform levels of fertilizer would have increased levels of debt, especially under low and high input levels.

This simulation study demonstrated a useful decision aid framework that can empower agricultural producers with site-specific management that accounts for the range of possible uncertainties producers must face. Decision support tools must be applicable across years rather than being optimal under only one set of climatic conditions. Decision support tools must use crop response functions that are biologically appropriate yet statistically tractable. Finally, the decision aid must acknowledge the variability not only in crop responses, but also the variability in crop prices that has a strong impact on net returns and management strategies. With the uncertainty associated with future climates, an approach for monitoring system agronomic and economic performance is crucial for maintaining resilient agro ecosystems. The framework developed here meets all of these requirements and can be easily adapted to incorporate additional driving variables or alternative crop response functions. By providing a flexible platform for progressively refining system parameters and optimizing spatial N prescriptions, this research provides a baseline tool that may be useful to producers across a wide range of crops and growing conditions.

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EVALUATING LEAF FLUORESCENCE SENSOR DUALEX 4 FOR ESTIMATING RICE NITROGEN STATUS IN NORTHEAST CHINA

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Chlorophyll meter (CM) has been commonly used to non-destructively estimate crop leaf chlorophyll concentration, and indirectly estimate crop N status. Dualex 4 is a newly developed leaf fluorescence sensor that can estimate both leaf chlorophyll concentration and polyphenolics, especially flavonoids. The ratio of chlorophyll and flavonoid concentration, which is termed N balance index (NBI), has been reported to more sensitive to crop N status than SPAD meter readings. The objective of this study was to compare the accuracy of Dualex 4 sensor and chlorophyll meter SPAD-502 for estimating the N nutritional status of rice in Northeast China. A field experiment involving five N application rates (0, 70, 100, 130, 160 kg N ha-1), two cultivars (Longjing 21 and Kongyu 131) and three replications was conducted in Jiansanjiang, Heilongjiang Province, China in 2013. The preliminary results indicated that both instruments could explain over 80% of variation of leaf chlorophyll concentration. The new index NBI (Chlorophyll/Flavonoid) did not significantly improve the accuracy of estimating leaf N concentration as compared with SPAD meter. More studies are needed to further evaluate the Dualex 4 leaf fluorescence sensor for estimating rice N status and determine its potential benefits over SPAD meter.

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SELECTION OF FLUORESCENCE INDICES FOR THE PROXIMAL SENSING OF SINGLE AND MULTIPLE STRESSES IN SUGAR BEET

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In our studies, we evaluated the suitability of fluorescence-based signals to detect and differentiate the occurrence of single and multiple stresses in sugar beet leaves. In the scope of greenhouse and field experiments we evaluated the impact of nitrogen supply, drought, and occurrence of pathogens on the characteristic fluorescence signature of selected sugar beet cultivars. Here, we present major outcomes using a commercial hand-held multiparametric sensor. In particular, we focus on the fluorescence indices 'Blue-to-Far Red fluorescence ratio' and 'Nitrogen Balance Index'. The advantages and limitations of these and other fluorescence signals and fluorescence indices are discussed.

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SPADE: AN AGGATEWAY PROJECT FOR INTEROPERABILITY IN PRECISION AGRICULTURE

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AgGateway Precision Ag Council

Interoperability among different hardware and software components is a major challenge in precision agriculture. In this paper we describe the ongoing efforts of AgGateway's Precision Ag Council to facilitate the implementation of data exchange standards through the SPADE family of projects.

AgGateway is a consortium of about 200, mostly North American, private sector companies. It is organized into several councils, each corresponding to a different segment of the ag industry. Councils within AgGateway include Seed, Crop Nutrition, Crop Protection, Ag Retail, Grain, Feed, Allied Providers, Ornamental Horticulture, and Precision Agriculture. AgGateway began with a primarily B2B (business-to-business) focus, working to enable exchange of electronic messages such as purchase orders and price lists among manufacturers and distributors of seed, crop protection, and crop nutrition products. Over time, and as a result of continuing success, its scope has widened to include agricultural retail and precision agriculture stakeholders.

AgGateway's Precision Ag Council, started in 2010, currently has two active projects: SPADE2, focused on field operations such as seeding, harvest, crop protection and crop nutrition; and PAIL, its irrigation-oriented counterpart.

The SPADE2 project is the second phase of a project started in 2012. In the first phase, the group captured a series of use cases and defined standard, albeit flexible, documents that describe how farming, particularly the seeding use case, is documented: Plan, Recommendation, Work order, and Work record. This was followed by gap-checking the ISO 11783 ISOXML format against these requirements, collecting the additional needs into a document, and submitting them to AEF / ISO for review. In particular, great emphasis was placed on expanding the ISOXML format's ability to associate globally-unique identifiers to its own locally-scoped identifiers.

An additional main point of interest in SPADE was reference data. On one hand, it is necessary to define the data that needs to be shared across the whole system that different stakeholders who may have access to a document (for example, a grower that creates a work order for a seeding operation, and the service provider that is contracted to carry it out) may need to access. Examples of reference data include geometric offsets for different pieces of machinery; seed variety names, manufacturers, unique identifiers and traits; crop protection product names, manufacturers, unique IDs and active ingredients, and so forth. On the other, an infrastructure needs to be built so the reference data can be provided. The first phase of SPADE produced two proof-of-concept reference data application programming interfaces (APIs), for machinery and seed, to use as a starting point for further work. The group also created a proof-of-concept index API to provide one-stop access to the distributed system of multiple data sources (albeit all using the standard APIs) that could be hosted by various manufacturers and/or third-party reference data providers upon implementation.

In SPADE2 the group is expanding scope to include harvest and crop protection operations. It is also building additional infrastructure for different companies to source reference data. Finally, it is also developing a proof-of-concept conversion toolbox to facilitate the adoption of the proposed expanded ISOXML format by Farm Management Information System (FMIS) and equipment manufacturers.

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CANOPEN IMPLEMENTATION TO WIRELESS SENSOR NETWORK

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Field buses are widely applied in the control of mobile machines. They enable us to build embedded control systems, where the sensors and actuators are connected to each other by the bus. ISOBUS is the most commonly used bus standard for Control Area Network (CAN) between tractors and implements in agriculture and forestry. Once the number of sensors and actuators increases in the implement side, a combination of ISOBUS and CANopen can be applied. CANopen is a communication protocol and device profile specification for embedded systems used in automation. In addition to agricultural applications, it is used in mobile machinery, in mines and forestry, in power systems such as substation automation and wind turbines, and in many other kinds of industrial systems, which require embedded automation to be able to operate. However, there are always places which are not reachable by cables. These parts can be mobile, or the mechanical conditions can otherwise be too harsh for the cables. A wireless extension of CANopen enables us to connect these parts to the CAN-based control system. It will also enable us to connect several mobile machines to the same control network.

In this paper we present the implementation of CANopen protocol to wireless sensor platform called the UWASA Node. The UWASA Node is a modular and stackable wireless sensor node, which is designed to fill the requirements of wireless automation. There are enough memory and computation power to run some computation required by the control applications in the node. The modular hardware architecture and the protocol software architecture enable a relatively easy integration of different kinds of industrial sensors depending on the measurement needs. On the other hand, the UWASA Node can operate just as a low energy consuming router in a mesh type of network, if such architectural solution is preferred. The CANopen implementation to UWASA Node is done by using the open source stack CanFestival. It is tested by a set of standard CANopen functionality tests in cooperation with TK-Engineering Ltd. and CANopen competence center C3 Vaasa. Certain errors and operational shortages are detected and fixed based on the test results. Finally, the hybrid control system consisting of CANopen fieldbus and the wireless sensor network is tested and its performance in terms of capability and reliability is evaluated based on the test results. In the conclusions we also evaluate the feasibility and possible limitations of CanFestival compared to some other CANopen protocol stacks.

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DESIGN, ERROR CHARACTERIZATION AND TESTING OF A SYSTEM TO MEASURE LOCATIONS OF FRUITS IN TREE CANOPIES

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This paper presents the design, error characterization and testing of a mobile system which utilizes radio waves and trilateration to measure the locations of fruits inside tree canopies. The system achieves accuracy better than 20 cm, 95% of the time (mean error is 11 cm) within a large digitizing volume of 15 m3, and a fruit position digitization rate of approximately 1 fruit per second. The system was tested successfully in commercial orchards; its high digitizing rate makes it practical to map the variability of fruit properties within tree canopies, for large numbers of trees.

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DETECTION OF FRUIT IN CANOPY NIGHT-TIME IMAGES: TWO CASE STUDIES WITH APPLE AND MANGO

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Reliable estimation of the expected yield remains a major challenge in orchards. In a recent work we reported the development of an algorithm for estimating the number of fruits in images of apple trees acquired in natural daylight conditions. In the present work we tested this approach with nighttime images of similar apple trees and further adapted this approach to nighttime images of mango trees.

Working with the apple images required only minimal re-parameterization of the algorithm and did not require changes of the algorithm itself. Twenty images were used to calibrate the algorithm, and after re-parameterization the number of objects detected by the algorithm corresponded to 79.9% of the number of apples visible in the images. The procedure was tested with 144 images containing close to 7000 apples and the number of objects detected by the algorithm corresponded to 80.2% of the number of apples visible in the images.

The analysis of the mango images was more challenging and some modifications of the algorithm were required, mostly to handle the elliptical shape of mangoes and avoid false positive detection on trunks. Twenty images were used to perform these changes and thus calibrate the procedure, which was then tested on three datasets containing 164 images with over 6000 fruit. The number of objects detected by the algorithm in the calibration set corresponded to 72% of the number of fruit counted by visual inspection. In the validation sets the number of objects detected ranged from 66% to 69% of the number of fruit identified by visual inspection.

Considering the differences between the two datasets in terms of shape and size of the fruit and leaves, these results are very encouraging and show that, after site-specific calibration using a small number of images, the proposed approach could provide good yield estimates.

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EFFECT OF STARCH ACCUMULATION IN HUANGLONGBING SYMPTOMATIC LEAVES ON REFLECTING POLARIZED LIGHT

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Huanglongbing (HLB) or citrus greening disease is an extremely dangerous infection which has severely influenced the citrus industry in Florida. It was also recently found in California and Texas. There is no effective cure for this disease reported yet. The infected trees should be identified and removed immediately to prevent the disease from being spread to other trees. The visual leaf symptoms of this disease are green islands, yellow veins, or vein corking; however, starch accumulates on infected leaf and causes some blotchy mottle which is the finest diagnostic leaf symptom. Still it is not easy to decide the blotchy mottle is the results of starch accumulation or nutrient deficiency. Starch can rotate the polarization planar of light at a specific waveband. In this study, a vision sensor was developed based on this property of starch to detect the blotchy mottle on HLB infected citrus leaf and differentiate it from similar symptoms caused by nutrient deficiencies. A highly sensitive monochrome camera and 10 high power narrow band LEDs at 591 nm were used in this sensor. Also a polarizing film and a polarizing filter were mounted in perpendicular directions in front of the LED panel and the camera lens correspondingly. Therefore, the camera receives the minimum reflection. Since starch rotates the polarization planar of light, the sensor is able to highlight the accumulation of starch on the leaf. The narrow band polarized illumination condition was compared to non-polarized natural white light for leaf samples in healthy, HLB symptomatic, and nutrient (zinc) deficient conditions. The result showed that the developed vision sensor increasingly highlighted the HLB symptomatic areas on the leaf which contained more starch. Additionally, the separability among four different citrus leaf classes were compared before and after being ground, to investigate if the starch in ground infected leaves can be identified as good as unground leaves. The results showed that the freeze-dried ground leaves had more uniform brightness; but the starch accumulation could be identified more clearly.

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CONDITIONING FACTORS FOR DECISION-MAKING REGARDING PRECISION AGRICULTURE TECHNIQUES USAGE

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The present study sought to list and analyze the main responsible factors for defining whether an area will succeed or not in the use of precision agriculture. The method used for this analysis was to estimate revenue and cost of production by the use of an agricultural production function and consider the different conditions we find in the field if inputs are applied to fixed and varied rates. The results showed that the factor to influence most the gain in producer profitability, considering the use of precision agriculture tools in relation to uniform input application, was the sampling method performed for uniform application. Corroborating other studies, the results also indicated that the use of precision agriculture for varied application of fertilizers is economically more advantageous if applied over large areas. However, unlike it is described in other studies, we cannot affirm that precision agriculture reduces input or increases crop productivity. One or both cases would occur depending on the area's condition and the sampling that is taken for uniform application of inputs. Therefore, it is concluded that there is no sense in scientific papers that analyze the economic impact of applying techniques of precision agriculture, since this impact must be analyzed individually for each area.

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A METHOD FOR SAMPLING SCAB SPOTS ON APPLE LEAVES IN THE ORCHARD USING MACHINE VISION

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One of the largest threats in apple orchards is scab. Current procedures involve models based on weather data that predict the likelihood of scab attacks. Previous work in laboratory conditions suggests that it is possible to see scab in NIR and SWIR before the naked eye. This study investigated and demonstrated methods for sampling leaves on the trees in the field. It was found that it was possible to detect scab spots after 4 days of inspection, which is too late for curative spraying, but a mapping perspective is suggested, and the proposed spot detection algorithm may be useful for other pests and other crops.

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BASIC TESTS OF PH AND EC PROBES FOR AUTOMATIC REAL TIME NUTRIENT CONTROL IN PROTECTED CROP PRODUCTION

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Research on greenhouse and plant factory has been actively conducting to provide a stable growth environment. In plant factory, EC concentration (EC) and acidity (pH) of nutrient have a significant impact on physiological and morphological of plant. Therefore, EC and pH are important element for automatic control of nutrient solution. In this study, performance pH and EC sensors was evaluated for the responsiveness, accuracy and displacement. This study includes development of environmental monitoring system using pH and EC sensors which connected with computer and the pH and EC data was displayed in computer screen. PH buffer solutions were used in the experiments of seven kinds such as 4, 5, 6, 7, 8, 9, 10 res. EC of each standard solution in distilled water (0 μS / cm) were used in the experiments of seven kinds such as 100, 1000, 2070, 2764, 3900, 5000 μs / cm respectively. The experimental environment was kept in 25?? and 50% humidity to control error. For evaluating the performance, measurement program was designed by control and instrumentation program (Labview 2010, National instrument Inc., Texas, USA) and data processing program carry out on data operation, storage, and display. Data was saved every 10 seconds. To evaluate the performance of the sensor, 1second interval and 10second intervals were used for 5minutes and 60minutes respectively for measuring accuracy. Also, for investigating whether nutrient or performance changes, cleaning sensors were compared to non-cleaning sensors. The error ranges were showed that pH was less than 2% and EC was 0 and 0.1 dS/m. From this study, these sensors are confirmed the appropriate sensors to measure the pH and EC of nutrient solution. For proposing sensor calibration and cleaning time, compared two statuses during 14 days in difference frequency for sensors correction and cleaning. One sensor was always in the nutrient and another one was corrected and cleaned in every 24 hours. Result showed the error of pH sensor was more than 5% after 6 days. Correction and cleaning of sensors are required within 6 days.

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MEASURING AND MAPPING SUGARCANE GAPS

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Sugarcane is an important semi perennial crop in tropical regions of the world as the principal source of sugar and bioenergy. A sugarcane important parameter is the gaps caused by problems during planting and harvesting. Distances above 0.5 m between two stalks along the sugarcane row are considered gaps and it is usually defined manually by a team measuring gaps in field samples, and expressing results as a percentage of gaps in relationship with the total sugarcane row distance. We developed a technique to measure and locate gaps in the field by using a photoelectric sensor horizontally positioned underneath a vehicle. This sensor was connected to an encoder and a GNSS receiver to compute gaps measure and the distance between these gaps. Initial tests were run under controlled conditions and field tests were conducted on newly planted and first ratoon areas. Sample plots were established to compare manual and sensors readings. Statistical tests showed no statistical difference between manual and sensor measuring methods and the correlation were 0.80 on a planted field and 0.66 to the first ratoon comparison. With this method it is possible to georeference the measurements allowing the generation of maps representing the spatial distribution of gaps, giving to the user an information about gaps occurrences and their locations.

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TOMATO DEVELOPMENT MONITORING IN AN OPEN FIELD, USING A TWO-CAMERA ACQUISITION SYSTEM

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Monitoring the growth of crops and estimating their yield allows the farmer to better manage the resources after the harvest. The existing methods for monitoring the growth of crops depend on remote sensing data or soil and weather information, which are prone to error due to adverse climatic conditions or insufficient information.

Here we present an alternative approach, where the growth of the crop (tomato) is monitored from images captured in an open field. For this, the tomatoes are identified in the image using a segmentation procedure and their size is measured. This is a challenging task because of severe occlusions and poor contrast in the images. In order to increase the robustness of the segmentation procedure (based on active contours) and simplify the size estimation, we approximate the tomatoes as spheres in the 3D space, hence as ellipses in the image space. This model enables us to integrate a priori information about the shape of the object to be segmented and to avoid a complete reconstruction of the 3D scene. The automatic segmentation was evaluated by comparing the results with manual segmentation. For the cases with a reasonable amount of occlusion (less than 30%), good results were obtained, with an average relative error of 6.46% (expressed as a percentage of the tomato size). The metric reconstruction has also been evaluated. It was observed that the error on the estimated tomato radius was less than 5% for 91% of the cases. Finally, the complete system was tested. The size of the tomatoes was correctly estimated in 80% of the cases. In addition, preliminary studies have showed that the actual volume of tomatoes can be estimated from the calculated sphere radius, using a correction factor

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ADVANCES IN AUTOMATING INDIVIDUAL PLANT CARE OF VEGETABLE CROPS

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This work describes the recent effort conducted at UC Davis to couple multi-row synchronized precision planting in a grid planting pattern with automated, synchronized precision intra-row mechanical weed removal in a systems approach to automated weed control in vegetable crop production in California. Selecting tomato as the target vegetable crop, a three-row synchronized intra-row weed control system was developed that utilized a co-robot design approach to automation of intra-row hoeing mechanism. In this design, a set of three co-robot actuators automatically positioned three pairs of miniature hoes into the intra-row zone between crop plants in three adjacent rows. Co-robot hoe actuation was controlled using a priori knowledge of the crop planting pattern and real-time odometry data as the control input for hoe positioning. All three co-robot systems acted synchronously; simultaneously moving their pairs of hoes in and out of the intra-row zone in sync with the multi-row grid planting pattern and the forward travel of the weeding platform. Low-frequency drift in the odometry control points relative to the actual plant locations was corrected occasionally as needed in real-time by the co-robot's human supervisor who was monitoring system performance.

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ASSESSING IMPACT OF PRECISION ON AGRICULTURAL ENERGY REQUIREMENTS: WEED CONTROL CASE STUDY

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The anticipated world population increase demands growth in sustainable food production. The current trend is to use more efficient agricultural processes in order to increase food production. Precision agriculture (PA) technology provides the means to increase equipment productivity and field and input efficiency. The concept of small modular and scalable intelligent machines tries to address the challenge of more productivity with the goal of reduced cost and power. In addition, power system technologies with potential application to agricultural machines are evolving quickly and issues of renewability and sustainability are becoming common priorities, with demands for standardization and certification. At present, most of the energy used directly in agriculture of developed countries comes from fossil fuels, and agricultural machinery systems are typically powered with diesel engines because of their reliability, efficiency and durability. With the emergence of precision technologies enabling intra-row and plant scale cultural practices, agricultural machines could be smaller in size and powered by electrical energy. This evolution of agricultural machinery systems could move agricultural production to a new level of sustainability. However, there are challenges making this transition from conventional agricultural machines to smaller, electrically powered agricultural machines. Currently, in the area of weed control, there are several strategies for controlling weed infestations in crop production, such as chemical control, mechanical cultivation, and thermal treatment among others. All of these strategies have different power and energy requirements, and sustainability could be improved from each of these strategies. In a case study, a prototype robotic mechanical weed control system powered by electrical power was analyzed using performance metrics such as work rate and energy requirements per area across different operational speeds. Several different weed control technologies were compared on an energy per area basis to determine how agricultural precision information can be used to reduce energy requirements. The comparison showed that the energy of the prototype represents less than 20% of that associated with conventional cultivation and chemical weed control.

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DESIGN AND CONSTRUCTION OF AN ULTRASONIC CUTTING WIDTH SENSOR FOR FULL-FEED TYPE MID-SIZED MULTI-PURPOSE COMBINES

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Precision agriculture analyzes the spatial variability according to the characteristics of an optimum setting of agricultural materials. To raise the profitability of agriculture and to reduce the environmental impact, technological research and development of precision agriculture has been conducted. In Asian countries such as Japan and Korea, yield monitoring system and crop growth sensors for rice and dry-land crops have been studied. Market for full feed type combine harvesters is recently growing in many countries including Republic of Korea. Yield monitoring system is one of the recent trends of the combines, and the major components consist of a positioning system, grain flow and water content sensors, ground speed and cutting width sensors. Objective of the paper was to design and construct an ultrasonic cutting width sensor for full-feed type mid-sized multi-purpose combines, as a part of a yield monitoring system, targeting row-planted and broadcasted rice, barley, wheat, soybean, and rapeseed. The target combine harvester was 55-kW full feed types for various crops with about 20% of the grain water content. Cutting width was about 200 cm, a maximum working speed of 1.7 m/s, and the turning radius of 1.5 m, and overall loss of 1.5% or less. First, an experimental device with paired ultrasonic sensors was designed and constructed. Two ultrasonic sensors (UDS-10A) were mounted on a frame, shaped of a combine header, connected to a computer through an USB port, and the data were obtained with customized software. Then, calibration tests were conducted in various conditions. Basic performance of the ultrasonic unit was validated by confirming distances to the wall. The tests were conducted from 50 to 200 cm with a 10-cm interval, and the results proved the accuracy, showing that the coefficient of determination of the linear regression was 0.99. Average and maximum errors of the tests were 1.7021 cm and 0.9686 cm, respectively. The experimental unit was also tested for field conditions. Distances from the crop were varied from 0 to the full cutting width (i.e., 210 cm), and the signal was collected for 1 minutes at stationary condition with 3 replications. Average and maximum errors were 2.5195 cm and 4.8021 cm, respectively. Next, in order to know the possibility of the measurement of actual combine width with the above experiment method, the distance with the crop has been moved (around 1.7m/s) for the measurement. Average and maximum errors were 2.2934 cm and 5.4763 cm, respectively. However, the value was not adequate for the measurement of cutting width, which was minimum 82.3% which must have used all the data. Results of the study showed a good potential of the fabricated cutting width sensor. Future study would include dynamic tests, combine installation and field tests during harvesting season, and optimization with other components of the yield monitoring system. Also, future study will develop a data process algorithm for the precise real time measurement of cutting width.

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SPATIAL VARIATION AND CORRELATION BETWEEN ELECTRIC CONDUCTIVITY (EM38), PENETRATION RESISTANCE AND CO2 EMISSIONS FROM A CULTIVATED PEAT SOIL

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An EM38 was used to collect conductivity values (ECa) from a cultivated peat soil in Sweden. These values were compared to CO2 emission, penetration resistance and water content sampled at 30 points with 10 m spacing. The result showed correlation between penetration resistance and water content, ECa and CO2 emission. The structure of the spatial variation of ECa was visible as easily identified zones that could be used to design the measurement scheme for soil physical parameters.

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WATER AND NITROGEN USE EFFICIENCY OF CORN AND SWITCHGRASS ON CLAYPAN SOIL LANDSCAPES

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The Renewable Fuel Standard (RFS) mandated that 36 billion gallons of fuel must originate from renewable sources by 2022 with only 15 billion gallons originating from corn (Zea mays L.) grain. Therefore other sources must be investigated. This research was conducted at the University of Missouri, South Farm Research Center Soil Productivity Assessment for Renewable Energy and Conservation (SPARC) research site from 2009-2013. The soil depth to the claypan horizon treatment was classified into erosion classes as severely eroded (< 5 cm), moderately eroded (5-20 cm), slightly eroded (20-30 cm), or depositional (>30 cm). This investigation included corn and switchgrass (Panicum virgatum L.) with four replications per soil erosion class. Yearly simulations, using an original water-balance model, were run for the number of days of water stress, water used, runoff and Water Use Efficiency (WUE) based on recorded weather data from the research site and previously-derived relationships of water storage on variable claypan soil landscapes. Nitrogen content was measured for corn grain and switchgrass biomass to determine Agronomic Nitrogen Use Efficiency (NUEa). The biomass and grain yield for each plot was used for WUE and NUEa calculations. Results of the simulated model indicate that switchgrass results in more days of water stress, but also less runoff and better WUE. In dry years, increased depth to claypan led to an increased WUE of 1.17-1.25 kg m-3 for the severely eroded soils and 2.19-2.77 kg m-3 for depositional soils for switchgrass compared to corn. Switchgrass NUEa was 14-18% more efficient than corn on severely eroded soils and 50-55% more efficient on depositional soils in dry years. This research indicates that when considering water and N use efficiency, switchgrass for biofuels is a viable option when grown on claypan soils, with better drought tolerance and low environmental impact when compared to corn.

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NEW INNOVATION APPROACHES IN PRECISION FARMING – THE EXAMPLE OF THE BASE FERTILIZATION PROCESS

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Recent years have shown tremendous precision farming innovations. However, these innovations are currently limited to new equipment (hardware) and software. What is missing is the link between these two innovation dimensions, especially in service driven approaches: process management. In this paper, we present a holistic approach for supporting efficient and effective precision farming processes. It is based on an improved soil sampling device and an appropriate tool called IPS. The approach is evaluated based on the use case base fertilization.

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MULTILAYER AND MULTIYEAR DATA ANALYSIS IN PRECISION YIELD PLANNING

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This work covers two separate field experiments. In the first one, the results of 1-ha grid soil analysis for soil organic matter (OM), pH, cation exchange capacity (CEC), nitrate N, P, K, S, Ca, Mg and soluble salts were compared with the results of yield mapping, biomass index from optical on-the-go sensors, as well as multispectral imagery analysis for the last 30 years. As a result, it was found that none of the analyzed soil characteristics was predominant for determining yield. Correlation between the soil properties and yield of spring wheat was -0.24 for soil pH, -0.15 for phosphorus, -0.13 for nitrate nitrogen, -0.06 for potassium, 0.12 for soil OM, and 0.01 for soil electrical conductivity. At the same time, correlation between one-year normalize difference vegetation index (NDVI) and grain yield was 0.51, and multi-year NDVI resulted in r=0.65. In the second experiment, we analyzed spatial variability of vegetation in the field using 22 layers of NDVI collected between 1984 and 2013, and compared these 22 years of data with one-year yield dataset to estimate the accuracy of management zones. Soil electrical conductivity (EC) measurement was also compared with the yield data. Correlation coefficients between one-year NDVI and yield data fluctuated between 0.3 and 0.75 depending on the year, and for soil EC the value of this coefficient was -0.34 for EC deep and -0.37 for EC shallow. Management zones delineated from soil EC data gave good separation for different soil types, but poorly separated areas with different yield potential. Field analysis of yield potential is contrast EC zones three weeks prior to harvesting revealed almost identical yield potential, whereas in the zones delineated from vegetation indices and yield data, the difference between high and low productive areas exceeded 200%. Based on our results, we concluded that yield is an integrated result of many different factors, including various soil characteristics, relief, PAR, air moisture etc., and it is very difficult to create an accurate model for yield planning based just on soil characteristics. The main goal of spatial analysis and delineation of management zones should be aimed to determine main yield limiting factors in the field. Yield data or vegetation indices obtained from multispectral satellite imagery give better results for delineation of management zones in the field than soil EC, and the accuracy of multi-year mapping is better than utilization of one-year data. Also, analysis of yield data or spatial variability of green biomass through various vegetation indices gives more predictable results for accurate yield goal planning than analysis of soil variability using grid sampling or soil EC measurement.

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THERMAL SENSING OF ROSES AFFECTED BY DOWNY MILDEW

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Downy mildew caused by the oomycete Peronospora sparsa affects roses and is a serious problem in nurseries and cut roses in commercial greenhouses, especially in those without heating systems. The disease, which affects the quality and the yield of roses, develops fast under suitable environmental conditions. Currently it is controlled mainly by the application of foliar fungicides and removal of symptomatic plant material due to the limited availability of resistant cultivars of high commercial value. Though downy mildew is a destructive disease and its control increases production costs, few alternatives have been explored to detect the disease at early stages. In greenhouses epidemics begin usually in localized areas of the crop. Therefore, non-invasive systems for early detection of the disease may become an alternative in a future framework of more sustainable crop management. Hence, this study evaluated the visualization of rose downy mildew in adult plants by infrared thermography for presymptomatic detection of the disease. Roses of the cultivar Elle® susceptible to P. sparsa were inoculated, incubated and the presence and development of the disease was followed visually and thermographically. Mock inoculated plants were kept under the same conditions. Thermal assessments were conducted using a VARIOSCAN 3201 ST camera (Jenoptic Laser, Jena, Germany) with 0.03 K thermal resolution. Initial symptoms were detected visually five days post inoculation (dpi), while presence of the disease was visualized by thermal imaging one or two days before. Results showed that leaf temperature of plants was affected after the inoculation and its dynamics changed over time depending on the phase of the disease. Infection of P. sparsa in early stages of pathogenesis was detected as an increase of leaf temperature compared to healthy tissue, which indicated a decrease in leaf transpiration. The technique allowed the recognition of infected leaflets in the leaf, affected leaves in the plant and to discriminate between healthy and diseased plants. In contrast to other host-downy mildew interactions the response of roses to leaf colonization by P. sparsa was clearly associated with an increased leaf temperature throughout the pathogen development. The use of thermography for the detection of primary foci of diseased plants at the commercial level seems to be suitable because of this unambiguous host plant response. The technology may be applied in automated monitoring systems from above the crop canopy or from the side of plant rows, even on different scales. IR thermography proved to have a high potential as a non-invasive method for the detection of the disease and has become a promising tool to be used in risk assessment programs of rose crops in commercial production systems.

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BIOLOGICAL SOIL MAPPING - INFESTTION BY PLASMODIOPHORA BRASSICAE AND SOIL CHARACTERISTICS

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Clubroot, Plasmodiophora brassicae, is a soil-borne pathogen that causes severe yield losses in many Brassica crops. The longevity of the spores makes them difficult to eradicate. The only practical way available to control clubroot development in oilseed rape rotations is to reduce the frequency of sensitive cultivars. Infection by the pathogen is favoured by edaphic environments such as acidic pH, low calcium content, poor soil structure, impeded drainage and high soil temperature. These environmental conditions vary within many arable fields, indicating that the prevalence of the pathogen may be patchy. A possible patchy presence in combination with great longevity makes it worthwhile mapping soil infection by P. brassicae. This study sampled 22 fields on commercial farms and analysed the soil for the presence of P. brassicae DNA using the qPCR technique. The level of infection varied considerably between and within fields in a patchy distribution and showed a low correlation with soil chemical characteristics. Mapping of P. brassicae using qPCR can be a useful management tool on farms with a history of intensive Brassica production and strong ambitions to avoid growing susceptible crops in areas of fields with a high risk of clubroot infection.

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USING AIRBORNE IMAGERY TO MONITOR COTTON ROOT ROT INFECTION BEFORE AND AFTER FUNGICIDE TREATMENT

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Cotton root rot is a severe soilborne disease that has affected cotton production for over a century. Recent research has shown that a commercial fungicide, flutriafol, has potential for the control of this disease. To effectively and economically control this disease, it is necessary to identify infected areas within the field so that variable rate technology can be used to apply fungicide only to the infected areas. The objective of this study was to use airborne imagery to monitor cotton root rot infection in cotton before and after fungicide treatment to the soil. A 105-ha irrigated cotton field with a historically consistent spatial pattern of infection was selected for this study. Airborne multispectral imagery with visible and near-infrared wavebands was taken from the field in 2001 and 2011 under natural root rot infection and again in 2013 with uniform flutriafol treatment at planting. The imagery was rectified and then classified into infected and noninfected zones using unsupervised classification. The classification results showed that the fungicide treatment reduced root rot infection from approximately 17% in both 2001 and 2011 to less than 2% in 2013. Although overall spatial patterns of infection between 2001 and 2011 were similar, there were slight changes in the locations of infected areas. A change detection analysis showed that 9.0% of the field was infected in both years, while 8.0% of the field was infected only in 2001 and 8.5% only in 2011. Thus a total of 25.5% of the field was infected in either 2001 or 2011. Change detection also showed that the infection in 2013 occurred within the infected areas in either 2001 or 2011, indicating a higher rate of fungicide may be needed to more effectively control the fungus with the season. Results from this study demonstrate that airborne multispectral imagery in conjunction with image classification techniques can be a useful tool not only for detecting and mapping cotton root rot infection, but also for assessing the efficacy of fungicide treatments and for optimizing site-specific treatment plans.

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FUNGIPRECISE - A GERMAN PROJECT FOR PRECISE REAL-TIME FUNGICIDE APPLICATION IN WINTER WHEAT

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A joint research project funded by the German Federal Office for Agriculture and Food (support code: 2814704511) was started in fall 2012 to develop real-time application technologies using non-contact sensors for precise fungicide spraying in winter wheat.

The joint research project consists of three subprojects:

1. Precision Farming Module “Fungicide” (proPlant Co.)
2. Ultrasonic-controlled field sprayer (Agri Con Co.)
3. Camera-controlled field sprayer and coordination of the project (ATB).

The decision support system proPlant expert.classic or the internet-version proPlant expert.com (proPlant Co.) resp. suggest the appropriate fungicides and their dosages for a certain infection scenario of eight important leaf and ear diseases of winter wheat. The Precision Farming Module “Fungicide”, which will run on the onboard terminal in the tractor`s cabin, controls the spraying process. The module defines the local target application amount while spraying by using the local sensor value as input parameter.

First results from regression analyses, performed on the data from one year experiments in 2013, showed that there is a dependency between the parameters Leave Area Index (LAI) as well as plant biomass and the sensor value which is important for the dosage algorithm in precise real-time fungicide application.

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DIAGNOSIS OF SCLEROTINIA INFECTED OILSEED RAPE (BRASSICA NAPUS L) USING HYPERSPECTRAL IMAGING AND CHEMOMTRICS

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Brassica napus L leaf diseases could cause seriously reduction in crop yield and quality. Early diagnosis of Brassica napus L leaf diseases plays a vital role in Brassica napus L growth. To explore an effective methodology for diagnosis of Sclerotinia infected Brassica napus L plants, healthy Brassica napus L leaves and Brassica napus L leaves infected by Sclerotinia were prepared in a controlled circumstance. A visible/short-wave near infrared hyperspectral imaging system covering the spectral range 380-1030 nm was set up to identify healthy and infected Brassica napus L leaves. The clear and non-deformable hyperspectral images were captured and the spectral information was exacted from the hyperspectral images according to the predefined region of interest (ROI). The spectral ranges of 380-439 nm and 951-1030 nm which contained obvious noises were removed. Moving average was used as the pretreatment method for spectra to remove noises. Chemometric methods were applied to build classification models for healthy and infected Brassica napus L leaves identification, including Principal Component Analysis (PCA), Partial Least Squares Discriminant Analysis (PLS-DA) and Support Vector Machine (SVM) models. Weighted regression coefficient (Bw) was applied to select sensitive wavelengths, and PLS-DA model and SVM model were also built on the basis of the sensitive wavelengths for healthy and infected leaves identification. For the infected leaves, the healthy part, the infected part and the joint part of the healthy part and the disease part were analyzed separately to investigate which part was most efficient for disease identification by PLS-DA, and the results showed that the infected part obtained better identification results than the other parts. For both full spectra and the sensitive wavelengths, PLS models and SVM models showed good performances with identification rate over 85%, and PLS models using the spectra extracted from the infected part obtained the identification rate over 90%. The classification models using sensitive wavelengths showed similar or better performances compared with the classification models using full spectra, indicating that selected sensitive wavelengths could be used for Brassica napus L disease diagnosis with fewer input variables. The overall results indicated that Brassica napus L leaf diseases could be early diagnosed by hyperspectral imaging and multivariate techniques effectively, which would be helpful for the prevention and treatment of Brassica napus L diseases. The results were gained in laboratory, and to obtain more accurate and practical results, the hyperspectral imaging system for field application should be developed, and more experiments should be conducted to select more accurate and stable sensitive wavelengths and build more robust identification models.

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USE OF QUALITY AND QUANTITY INFORMATION TOWARDS EVALUATING THE IMPORTANCE OF INDEPENDENT VARIABLES IN YIELD PREDICTION

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Yield predictions based on remotely sensed data are not always accurate. Adding meteorological and other data can help, but may also result in over-fitting. Working with American Crystal Sugar, we were able to demonstrate that the relevance of independent variables can be tested much more reliably when not only yield but also quality attributes are known, such as the sugar content and the sugar lost to molasses for sugarbeets. The problem of potentially over-fitting the data, when working with a large number of independent variables, is known as the curse of dimensionality. We show that the over-fitting problem in selecting variables can be effectively countered by increasing the number of dependent variables. An increased dimensionality on the side of dependent variables avoids that an independent variable may be considered relevant because similar values accidentally result in similar values of the dependent variable. We show that such reasoning can be very effectively applied to the problem of how to preprocess massively available data such as rainfall. Using rainfall data with a finer granularity than the aggregate over the full year can clearly hold benefits. In the absence of quantitative techniques, researchers and crop consultants have to decide how to preprocess rainfall data based on educated guessing alone. We provide a computational approach to answering such questions quantitatively.

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MULTITEMPORAL SATELLITE IMAGING TO SUPPORT NEAR REAL-TIME PRECISION FARMING

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This paper presents a 2014 update on the DMC constellation of optical satellite sensors and how they are exploited for various types of agricultural monitoring. Thousands of farmers around the world are exploiting this powerful data source for the management of crops, enabled by specialist service providers which convert the imagery into meaningful biophysical measurements and spatially variable nitrogen/irrigation recommendations. The paper also looks ahead to future DMC satellite missions which will further enhance the availability of timely imagery for precision agriculture.

DMC is an international programme of satellite ownership and ground stations, with joint campaigns being coordinated centrally by DMC International Imaging (DMCii). All sensors in the constellation are rigorously calibrated to enable them to be used interchangeably throughout the season, and to enable quantitative biophysical information to be estimated from the data.

The DMC satellites are built in the UK by Surrey Satellite Technology Ltd and each carries a very wide swath (650km) optical sensor which makes them collectively capable of capturing fresh imagery the world's agricultural regions on a regular basis. The first generation satellites had 32m resolution sensors, but now the second generation satellites generate 22m resolution imagery which is suitable for a great many precision farming applications on broad acre crops. But it is the rapid revisit and timeliness of data acquisition that is the primary advantage of the DMC constellation. For example, since the 2011 season the Deimos-1 and UK-DMC2 satellites have been covering the whole of the mainland USA every 15 days, 90% cloud-free on average. This dataset is used by USDA for their annual crop classification and by other organisations for precision agriculture services.
The DMC constellation currently provides an imaging opportunity several times per week anywhere in the world at 22m resolution and with three visible/NIR spectral bands. The capability to cover huge areas of land on a regular basis enables a different approach a number of remote sensing applications that are either difficult or impossible with other data sources, with precision agriculture being a prime example. The DMC user community for precision agriculture includes service providers in more than 10 countries in Europe, North America, South America and Asia. These service providers are delivering guidance to many thousands of farmers based on timely satellite imagery, coupled with other ground-based information layers and models. Examples of these systems will be presented, along with a look ahead to satellite missions planned for the near future which will ensure data continuity for many years and further enhance the reliable availability of timely imagery for precision agriculture.

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DEVELOPMENT OF AN INDEX-BASED INSURANCE PRODUCT: VALIDATION OF A FORAGE PRODUCTION INDEX DERIVED FROM MEDIUM SPATIAL RESOLUTION FCOVER TIME SERIES

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An index-based insurance solution is being developed by Pacifica Crédit Agricole Assurances and Airbus Defence & Space to estimate and monitor forage production in France in near real-time. It is based on an indicator called Forage Production Index (FPI). FPI is derived from the Fraction of green Vegetation Cover (fCover) integral and used as a surrogate of forage production. fCover is a biophysical parameter obtained from Medium spatial Resolution (MR) MODIS/MERIS time series. Because one MR pixel may contain different types of land cover, a spectral unmixing model based on a statistical approach is applied to determine fCover time series for grassland. Consequently, FPI is calculated at an elementary unit (EU) scale of 3600 ha. In the insurance product, payouts are indexed on the ratio between the annual FPI and the Olympic average of FPI of the last 5 years. In the framework of FPI development, a scientific validation is implemented and this paper presents the first step of it. Local ground measurements of biomass production are compared with FPI values obtained from High Resolution (HR) space-based images provided by different sensors, in particular, SPOT4 (Take5). This paper describes the grassland parcels, the field protocol established to collect biomass production data, the method used to get the fCover biophysical variable. The analysis consists in studying the relationship between biomass ground measurements and grassland production estimated by fCover. Discrepancies between the two variables are quantified by the coefficient of determination, the mean square error (systematic bias) and the root mean square error. First, fCover values derived from the four sensors are coherent. It demonstrates the ability of the algorithm used in this study to provide a consistent way of calculating the biophysical variable. Then, for the whole dataset, the scatter plot between FPI and biomass shows an acceptable correlation (R^2=0.72; $\alpha < 0{,}0001$) with a correct systematic bias. However, there remains dispersion as highlighted by the RMSE value. If we only take into account data recorded up until the production maximum, the results are improved (R2= 0.81; $\alpha < 0.0001$ and RMSE decreases of 25%). Finally, the analysis carried out on the scale of the parcels, grass species, period of mowing or climatic conditions reveals variability on the regression coefficients. It indicates that, in addition to the fCover, other explanatory variables should be integrated to better compute the FPI. In the framework of the research activities developed to create the index-based insurance product, all these different results are discussed to make recommendations for improving the FPI index.

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USING IMAGERY AS A PROXY YIELD MAP AND SCOUTING TOOL

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Combine yield maps represent a post-mortem quantification of the spatial variability in crop vigor that occurred during the growing season. The spatial resolution of yield maps is defined by the width of the combine header but the length of the cell depends on the ground-speed of the implement and how long it takes for the grain to reach the mass-flow sensor that quantifies yield. Grain collected from the center of the combine header naturally reaches the mass-flow sensor before the grain that enters from the outer ends of the header. In contrast, aircraft imagery and some satellite images can be used to generate field maps with much higher spatial resolution than combine yield maps. Images collected during the growing season have been shown to illustrate some of the same patterns as presented in combine yield maps. Crop canopy sensor data collected during the growing season can also be used to generate maps that characterize crop vigor and spatial patterns. Timely assessments of crop vigor (color and biomass) with either imagery or crop canopy sensors make it possible to identify and investigate areas within fields that are likely to have reduced yields. Spatial information obtained by producers and consultants from selected areas will help to plan remedial action (nutrients, irrigation, pesticide applications) or determine if cultural practices, weather, or insect damage contributed to reduced crop vigor. Processing imagery and sensor data into useable maps that illustrate spatial patterns can be as simple as using NIR reflectance data or one of several vegetation indices. Images and sensor maps generated closer to harvest are more highly correlated with yield because less time is available for weather to impact yield. Normalizing in-season data is one way to redistribute the total amount of grain from a field on a spatial basis to generate a proxy yield map. Proxy yield maps based on aircraft imagery will be used to illustrate greater resolution of spatial patterns than a combine yield map because of complex grain processing operations. Thermal images of in-season vegetation will illustrate specific information regarding crop water status that is likely related to soil properties or irrigation water distribution problems.

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EVALUATING SOIL NUTRITION STATUS WITH REMOTE SENSING DERIVED LAND PRODUCTIVITY

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Available nitrogen is the amount of this nutrient available to plants in the soil and the amount of nitrogen provided by fertilizers. Compared to total nitrogen, nitrogen availability is a more useful tool for determining how much fertilizer you need and when to apply it. Determining the level of nitrogen available in field soil is also a useful method to increase the efficiency of fertilizer. Most soil properties are time-consuming and costly to measure, and also change over time. Fast and accurate prediction of soil properties is a necessary to overcome the lack of measured soil property information. Satellite imagery provides contiguous spatial coverage of a field and can be used as a surrogate to measure soil attributes. In the past three decades, considerable progress has been made which prove the capacity and potential of remote sensing in soil science. The spectral characteristics of a number of nutrition content in soil have been studied and huge number of field nutrition mapping were implemented successfully.

Yet there still three major obstacles that prevent the wide application of remote sensing derived soil nutrition status map in precision farming, they are: 1) common remote sensing means cannot detect the entire soil body ("pedon") that extends from the surface to the parent material, not mention that the thin, upper layer sensed by optical sensors may easily be affected by many factors such as dust, rust, crop residue, plowing and particle size distribution; 2) in most studies that mapping soil nutrition status based on its spectral characteristics, high spectral resolution data are required, yet ever since the failure of EO-1 Hyperion in 2009, there has been a period of more than 4 years that has no satellite-mounted hyper-spectral images at the resolution higher than 30 m. The acquisition of hyper-spectral satellite image cannot be guaranteed. 3) crop coverage in crop growing season make it difficult to obtain soil radiometric property directly, the short period of soil explosion between crop seasons make it difficult to obtain satisfactory satellite images.

To deal with these three obstacles in mapping field soil nutrition status with satellite images, a new method was put forward and tested in mapping available nitrogen content. The basic concept of the method put forward by this research is that soil nutrition deficiency is the primary limitation on crop yield when other conditions are favorable (water, temperature and radiation). Firstly we map the crop yield of three major crops (wheat, soybean and maize) in last 4 years with a light use efficiency (LUE) model –CASA, which can integrate remote sensing indicators and meteorological data to describe crop growth. Secondly, yields of different crops (wheat, soybean and maize) were normalized to make them comparable, a value (normalized yield index, NYI) between 0 and 1 were assigned to each pixel based on its place in the yield range of the crop type. Thirdly, the maximum NYI in the last 4 years was calculated for each pixel to represent the NYI in favorable crop growing conditions. At last the relationship between maximum NYI and observed soil available nitrogen content was identified through regression analysis, and then a map of field soil available nitrogen were produced.

In this study, taking HJ-1 CCD image as major data source and a farm in Northeast China as study area, the method proposed by the author was tested. The technical procedure, application and validation of this method were introduced in detail. After explore the potential of mapping field nutrition status with remote sensing derived crop yield, this paper provides some ideas on how to propel this technology forward to enable its widespread adoption in precision farming.

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DESIGN, DEVELOPMENT AND APPLICATION OF A SATELLITE-BASED FIELD MONITORING SYSTEM TO SUPPORT PRECISION FARMING

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The factual base of precision agriculture (PA) - the spatial and temporal variability of soil and crop factors within or between different fields has been recognized for centuries. Field information on seeding suitability, soil & crop nutrition status and crop mature date is needed to optimize field management. How to acquire the spatially and temporally varied field parameters accurately, efficiently and at affordable cost has always been the focus of the researches in the field. Satellite remote sensing has held out much promise for within & between-field monitoring, along with the promising development regarding spatial, temporal and spectral resolution in the last decade. Scientists from all over the world have provided a great deal of fundamental information relating spectral reflectance and thermal emittance properties of soils and crops to their agronomic and biophysical characteristics. This knowledge has facilitated the development and use of various remote sensing methods to detect spatially and temporally varied environmental stresses which limit crop productivity. This can make significant contribution in optimizing crop management as sowing, irrigation, fertilization and harvest.

However, gathering, accessing, and processing of remote sensing images from different satellites require high technical skills, not mention the time consumed in processing large amount of images. The lack of comprehensive software platforms to extract useful spatially and temporally varied information from satellite image hindered the wide application of satellite image to support PF. With this back ground, an integrated satellite-based field monitoring system was designed and developed with .Net and IDL (Interactive Data Language). The system consists of 4 primary functional models: 1) satellite image pre-processing model; 2) field seeding suitability evaluating model; 3) soil & crop nutrition status monitoring model and 4) crop mature date predicting model. In the first model, remote sensing images from different sensors can be pre-processed with format conversion, radiation calibration, atmospheric correction and geometric correction. BRDF correction was also provided for images with wide swath. Fusion of images from different sensors can also be implemented in this model to provide images with both high spatial and high temporal resolutions. In the second model, soil moisture and surface temperature will be acquired from satellite images. Together with the information on needs of different crops in seeding, seeding suitability of different fields can be evaluated. In the third model, the soil and crop nutrition status (nitrogen and chlorophyll concentration for crop; available nitrogen and organic matter content for soil) will be mapped with satellite image, and then been transferred to field/pixel scale fertilization prescriptions. In the fourth model, crop canopy/leaf water and chlorophyll content will be quantitatively mapped, along with the digital expression of crop water and chlorophyll content variation at maturing stage, crop mature date will be predicted 20days before the harvest, and will updated with the approaching of crop maturity.

The structure, methods and the development of the system are introduced in detail in this paper. A case application of the system in ShuangShan Farm in Northeast China will also be presented as result of the system.

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AUTONOMOUS SERVICE ROBOTS FOR ORCHARDS AND VINEYARDS: 3D SIMULATION ENVIRONMENT OF MULTI SENSOR-BASED NAVIGATION AND APPLICATIONS

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In order to fulfill economical as well as ecological boundary conditions information technologies and sensor are increasingly gaining importance in horticulture. In combination with the reduced availability of human workers automation technologies thus play a key role in the international competition in vinicultures and orchards and have the potential to reduce the costs as well as environmental impacts.
The authors are working in the fields of unmanned or remote controlled autonomous field robots, navigation, image-based sensor fusion as well as agricultural applications. In particular field robots have been applied for a few years in outdoor agricultural field applications. Within an interdisciplinary research group these technologies are transferred to robot applications in vineyards and orchards. The goal is the availability of an autonomous service robot, whereas first applications are site-specific plant protection (e.g. precise spraying), mulching and picking up fruit boxes. A first version of the robot with electrical drives and precise sprayers has already been developed. The applications, however, show a large range of field conditions which have to be considered for the vehicle application design. Thus the authors have developed a 3D simulation environment which allows the virtual test of the robot platform prior to its application. Moreover, the software algorithms can be directly transferred to the robot and thus allow iterative optimizations of the development process. The generation and first applications of the 3D simulation environment of multi sensor-based navigation and applications in vinicultures and orchard is the focus of this work.

Robot Operating System (ROS) has been chosen as software framework for integrating the autonomous vehicle, the sensors and the environment for navigation and application processes. ROS supplies the 3D simulation environment Gazebo using physical engines (e.g. ODE – Open Dynamic Engine) in order to simulate the robots behavior as close as possible to reality. Moreover, the software tool Rviz is used for visualization of the sensor data (as for example) for optimization of navigation algorithms. Since the navigation in vine and fruit rows, the various applications as well as safety issues require sensor based solutions. The navigation itself is performed by image based sensors, since GPS based systems do not fulfill the requested functionality. In order to compensate for varying selectivities of different sensors, concepts of sensor fusion are applied. Sensor data in ROS is exchanged by so called messages, which can easily be logged to a database. For processing this data ROS integrated tools like NumPy (matrices and mathematical function) or OpenCV (image processing) are used. An interface from the database to MATLAB is also a powerful tool for evaluating the sensor data offline and testing first algorithms.
In practice color cameras (for documentation purposes), 3D cameras, laser range finders as well as ultrasonic multi reflectance sensors are used. In addition a priori data (such as maps or row distances) or GPS sensor information can be included and thereby increase the robustness of the navigation or the safety level.

Within ROS plugins for different sensors have been generated (color camera, 2D laser scanner Sick LMS511; 3D laser scanner Nippon FX-8; ToF camera Mesa SR4500). Together with environmental data of crop plants (or obstacles) the robot behavior with respect to the navigation and the application can be evaluated prior to field tests. As for example the leaf wall area for controlling precise sprayer can be virtually measured and the reduction of chemicals can be evaluated. ROS enables the usage of the same control software for the simulation and the hardware (robot, actuators), thereby strongly reducing the development times.
As a result the simulation environment has been developed and the results of first reactive row navigation algorithms are evaluated and compared to dynamic tests with real robots.

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EVALUATION OF THE TEMPORAL AND OPERATIONAL STABILITY OF APPARENT SOIL ELECTRICAL CONDUCTIVITY MEASUREMENTS

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Measuring apparent soil electrical conductivity (ECa), using galvanic contact resistivity (GCR) and electromagnetic induction (EMI) techniques is frequently used to implement site-specific crop management. Various research projects have demonstrated the possibilities for significant changes in the measured quantities over time with relatively stable spatial structure representations. The objective of this study was to quantify the effects of temporal drift and operational noise for three popular ECa mapping instruments. The sensors were placed in stationary positions approximately 5 m apart in an area with relatively low ECa. Temporal drift was assessed using a series of 4.5-h data logs recorded under different weather conditions (from extremely hot to near freezing temperatures). Both EMI instruments were also used to quantify the effect of minor changes in the height, pitch and roll of the sensor with respect to the ground. These operation noise tests were replicated over several days. GCR measurements of ECa, along with perpendicular coplanar (PRP) EMI measurements, have shown relatively strong stability over time. Each operational effect introduced measurement uncertainties comparable to the impact of a change in temperature and soil water content.

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GNSS POSITIONING TECHNIQUES FOR AGRICULTURE

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Broadacre, row crop and high value crops each have different positioning needs. Within these agricultural groups, individual practices such as mapping, guidance and machine control for tillage, application and harvest each have their own Global Navigation Satellite Systems (GNSS) needs for an optimal price/performance and value equation. New research and algorithm development by NovAtel has resulted in a significant simplification of positioning methodology with increased reliability and performance worldwide.

There are typically two fundamental measurements that are made from GNSS satellites: the pseudorange and the carrier phase. Many different kinds of algorithms have been developed to convert these measurements into positions that can then be used by agricultural applications. This presentation will illustrate how pseudorange and carrier phase measurements made from the same rover antenna can be processed with very different techniques to produce position solutions with radically different performance characteristics as well as price points.

This presentation will describe the various error sources that contribute to position errors, as well as techniques to mitigate or eliminate these errors. NovAtel CORRECT™ positioning technology was released in early 2014. NovAtel CORRECT optimally combines data from multiple GNSS satellite constellations with corrections from a variety of sources, to deliver the best position solution possible. NovAtel CORRECT provides systems integrators with the opportunity to choose pricing and subscription options that best match their OEM business objectives. With NovAtel in control of the entire positioning solution, future innovation including seamless integration with all positioning modes and correction types is assured.

Additionally, this presentation will compare and contrast several positioning approaches commonly used by agricultural application. Advantages and disadvantages of each approach will be discussed, as well as quantification of the accuracy and robustness of the computed position. The various positioning approaches will include NovAtel's GLIDE technique (with a comparison of single-frequency and dual-frequency approaches), Precise Point Positioning (PPP), as well as Real-Time Kinematic (RTK). These three approaches allow for positions ranging from sub-meter (GLIDE), decimeter (PPP) to centimeter (RTK).

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PESTICIDE APPLICATION MANAGER (PAM) - DECISION SUPPORT IN CROP PROTECTION BASED ON TERRAIN-, MACHINE-, BUSINESS- AND PUBLIC DATA

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Pesticide Application Manager (PAM) is a project co-funded by the German Federal Ministry of Food and Agriculture (BMEL) that aims to develop solutions for automating important processes in crop protection by using ICT. PAM is implemented by a consortium of public and private organizations under the lead of the Central Institute for Decision Support Systems in Crop Protection (German acronym: ZEPP).

One of the focal points of the project is the development of a Decision Support System (DSS) that automates pesticide application and the protection of adjacent natural and aquatic ecosystems by using GIS-created, machine readable application maps, that include legal buffer zones where spraying is prohibited.

In the first year of the project the focus has been put on identifying data and methods that can be integrated into the DSS. Geodata play important roles in this process. To be able to create machine readable application maps information about the location of fields as well as water bodies and terrestric structures like hedges are necessary. These are the base for identifying and creating the legal buffer zones.

To avoid unnecessary survey work for farmers, the first approach was to check if geodata in adequate quality and quantity is publicly available or if not, easy to create via digitizing from areal views. A baseline survey was conducted on pilot farms. The main result was that geodata available for farmers in Germany does not meet the requirements in accuracy or completeness necessary to be useful for the purposes of the PAM-Project. This means that in most cases a separate survey done by the farmer is necessary. A technical procedure how to conduct such surveys is being developed using a GNSS-RTK based approach.

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NUTRIENT EXPERT SOFTWARE FOR NUTRIENT MANAGEMENT IN CEREAL CROPS

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International Plant Nutrition Institute

Many countries in Asia have started replacing blanket fertilizer recommendations for vast areas of rice, maize, or wheat with more site-specific guidelines adapted to local needs. This process has been accompanied with a shift from traditional on-station research to on-farm development and evaluation of novel practices. A key challenge faced by the local extension agencies remains the complex nature of factors influencing nutrient requirements. To aid in this process, the International Plant Nutrition Institute has developed Nutrient Expert (NE), a nutrient decision support software, which uses the principles of site-specific nutrient management (SSNM). NE enables crop advisors to develop fertilizer recommendations that are tailored to a specific field or growing environment. NE takes into account important factors affecting nutrient management recommendations and uses a systematic approach of capturing information to develop location-specific recommendations. Nutrient Expert does not require a lot of data nor very detailed information as in the case of many sophisticated nutrient decision support tools, which can overwhelm the user. Nutrient Expert allows the users to draw the required information from their own experience, the farmers' knowledge of the local region, and the farmers' practices. NE can use experimental data, but it can also estimate the required SSNM parameters using existing site information.

NE provides fertilizer recommendations that are based on the relationship between the balanced uptake of nutrients at harvest and grain yield, called internal nutrient efficiency, which are predicted using the quantitative evaluation of the fertility of tropical soils (QUEFTS) model. The fertilizer requirement for a field or location is estimated from the expected yield response to each fertilizer nutrient, which is the difference between the attainable yield and the nutrient-limited yield. These parameters are determined from nutrient omission trials in farmers' fields, while attainable yield is the yield for typical year at a location using best management practices without nutrient limitation. Nutrient-limited yield is that when only the nutrient of interest is omitted. The amount of nutrients taken up by a crop is directly related to its yield so that the attainable yield indicates the total nutrient requirement and the nutrient-limited yield indicates the indigenous nutrient supply. The yield response indicates the nutrient deficit, which must be supplied by fertilizers.

As a computer-based decision support tool, NE combines all the steps and guidelines in SSNM into simple software tailored for crop advisors especially the not-so-technical users such as the extension agents in developing countries. In such countries, many crop advisors from both public and private companies do not have the data nor facilities needed to run sophisticated models. The parameters needed in SSNM are usually measured in nutrient omission trials installed in farmers' fields, which require at least one crop season. With NE, parameters can be estimated using proxy information, which allows crop advisors to develop fertilizer guidelines for a location without data from field trials.

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HEAVY METAL PB2+ POLLUTION DETECTION IN SOIL USING TERAHERTZ TIME-DOMAIN SPECTROSCOPY FOR PRECISION AGRICULTURE

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Soil is an important natural resource for human beings. With the rapid development of modern industry, heavy metals pollution in soil has made prominent influences on farmland environment. As a result, the crop yield shall be greatly cut down; and the heavy metals do great harms to human body by food chain. Pb2+ is kind of typical heavy metals and its pollution is serious at present. The typical existing detection methods are not suitable for agricultural applications. Development of an advanced, safe, efficient and portable detection method for heavy metals content in soil is in an urgent need. This study presents a feasible study of heavy metal Pb2+detection method based on Terahertz Time-domain Spectroscopy (THz-TDS), which is rapid and maybe portable and low cost for future in-field applications. THz is a brand new and safe technology with many unique features. It showed some feasibility for heavy metal detections in soil according to former experiments. A series of experiment were carried out in this study. Soil samples with predefined concentration levels of heavy metal ions Pb2+ were carefully prepared. Pressed-slice method was used for the spectra measurement and sample making parameters were determined. The absorption spectra were collected with a THz spectroscopic system in Capital Normal University. Multivariate statistical methods were studied and used to analyze the collected data and establish predication model for Pb2+concentrations. Calibration and prediction models were established based on partial linear regression (PLR) and interval-partial linear regression (i-PLR) methods using the full THz spectrum and the selected THz wavebands respectively. The results showed that the optimized models were able to predict soil heavy metal Pb2+ content with a correlation coefficient of 0.81. The method of using THz technology for soil heavy metal Pb2+ detection is feasible. However, more investigation on measurement principles and a large amount of sample tests are still needed. With the detection results, it can be found the heavy metal Pb2+ pollution spatial distribution information of the soil in-field and get the “pollution map”. Specific measures shall be taken based on the “pollution map” to manage the soil to improve the farmland productivity. This study will provide a reference for heavy metals pollution detection solutions for precision agriculture and sustainable agriculture development.

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VISIBLE AND NEAR-INFRARED SPECTROSCOPY FOR MONITORING POTENTIALLY TOXIC ELEMENTS IN RECLAIMED DUMPSITE SOILS OF THE CZECH REPUBLIC

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Due to rapid economic development, high levels of potentially harmful elements and heavy metals are continuously being released into the brown coal mining dumpsites of the Czech Republic. Elevated metal contents in soils not only dramatically impact the soil quality, but also due to their persistent nature and long biological half-lives, contaminant elements can accumulate in the food chain and can eventually endanger human health. Conventional methods for investigating potentially harmful element contamination of soil based on raster sampling and chemical analysis are time consuming and relatively expensive. Visible and Near-Infrared (Vis-NIR) diffuse reflectance spectroscopy provides a rapid and inexpensive tool to simultaneously and accurately predict various soil properties. In this study concentrations of Manganese (Mn), Copper (Cu), Cadmium (Cd), Zinc (Zn), Iron (Fe), Lead (Pb) and Arsenic (As) in soil samples from fields near the brow coal mining dumpsites in the Czech Republic were chemically analyzed and the suitability of Vis-NIR diffuse reflectance spectroscopy for predicting their occurrence was evaluated. Soil spectral reflectance was measured with an ASD FieldSpec 3 spectroradiometer (Analytical Spectral Devices, Inc., USA) under laboratory conditions and the correlations between seven toxic elements and soil diffuse reflectance spectra were studied. Partial Least Square Regression (PLSR) and Support Vector Machine Regression (SVMR) models were constructed to relate soil contaminants data to the reflectance spectral data by applying first and second derivatives preprocessing strategies. Then, the performance of Vis-NIR calibration models was evaluated by Residual Prediction Deviation (RPD) and coefficients of determination (R2). Based on the correlation patterns with reflectance spectra, the seven studied potentially toxic elements were categorized into two or three groups. Moreover, according to the criteria of minimal RPD and maximal R2, the first derivative and SVMR models provided more accurate prediction models for soil contaminants than PLSR models which were more feasible to predict the toxic metal levels in agricultural soils. Overall, this study indicated that the Vis-NIR reflectance spectroscopy technique combined with a continuously enriched soil spectral library as well as a suitable chemometric indicator could be a nondestructive alternative for monitoring of the soil environment. Because soil properties in contaminated areas generally show strong variation, a comparatively large number of calibrating samples, which are variable enough and uniformly distributed, are necessary to create more accurate and robust Vis-NIR reflectance spectroscopy calibration models. Future studies with real-time remote sensing data and field measurements are also strongly recommended.

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CROP CIRCLE SENSOR-BASED PRECISION NITROGEN MANAGEMENT STRATEGY FOR RICE IN NORTHEAST CHINA

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GreenSeeker (GS) sensor-based precision N management strategy for rice has been developed, significantly improved N fertilizer use efficiency. Crop Circle ACS-470 (CC) active sensor is a new user configurable sensor, with a choice of 6 possible bands. The objectives of this study were to identify important vegetation indices obtained from CC sensor for estimating rice yield potential and rice responsiveness to topdressing N application and evaluate their potential improvements over GS normalized difference vegetation index (NDVI) and ration vegetation index (RVI). Two site-years of field N rate experiments were conducted from 2012 to 2013 to evaluate the in-season N requirement prediction developed by Oklahoma State University in Jiansanjiang Experiment Station of China Agricultural University. The GS and CC active canopy sensor with green, red edge and near infrared bands was used to collect rice canopy reflectance data at stem elongation stages. The results indicated that the CC active multispectral canopy sensor had a better performance than GS for estimating rice yield potential and responsiveness to topdressing N application at stem elongation stage. More studies are needed to further evaluate CC sensor-based precision N management strategy as compared with GS active sensor-based precision N management strategy under diverse on-farm conditions.

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RAPIDSCAN AND CROPCIRCLE RADIOMETERS: OPPORTUNITIES AND LIMITATION IN ASSESSING WHEAT BIOMASS AND NITROGEN

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Remote sensing is a promising technology that provides information about the crop's physiological and phenological status. This information is based on the spectral absorption and scattering features of the plants. Many different vegetation indices (VI) have been developed, and are in use to estimate quantitatively the relationship between multi and hyper-spectral reflectance and effective crop physiological parameters, i.e. nitrogen (N) content, biomass, leaf area index (LAI). The CropCircle and the RapidScan, the simple radiometers, offer an option retrieving red (R), red edge (RE) and near infrared (NIR) plant reflectance enabling calculate the VI such as NDVI, NDRE, and other based on the important RE region. The objectives of this study were: (i) to test relationships between wheat biophysical characteristics such as biomass and nitrogen and remote sensing data; (ii) to evaluate accuracy of remote sensing biomass and nitrogen estimation; (iii) to explore the potential and limitations of using active remote sensing techniques. The study was carried out during the growing seasons of 2012–2013 on 16 commercial spring wheat fields of kibbutz Saad and 8 experiment fields at the Gilat Research Center, located in the Northern Negev region of Israel. Data have been collected by CropCircle (mounted on a car) in both seasons by passing over fields, while RapidScan data have been collected by hand in 2013. The data set includes fields at different growth stages, from 3 leaves (Zadoks 13) till stem elongation (Zadoks 35), reflecting large differences in canopy height (10 through 50 cm) and vegetation cover. The variation in wheat samples represents biomass of 1 to 880 g m-2, N concentration 9.7 to 54 g kg, and canopy N content 65 to 16500 mg N m-2. High correlations have been found between the different VI, as they were calculated from the same 2 or 3 bands. Very close relationships have been found between many VI and wheat biomass. For CropCircle, indices have been calculated by the closest point and by an average of the area near the sampling point. Most VI had similar correlation with wheat parameters independent of the representing area. Canopy nitrogen concentration estimation was problematic and most indices exhibit very low correlation, the best VI was MSRre that reached r = 0.47 (mREP 0.57 for RapidScan). Despite that low correlation, for most indices the correlation with canopy nitrogen content reached higher or similar correlation as with biomass. The best VI were WDRVI, MSR and WICI2 (r = 0.90) while the correlation with biomass was a little bit lower (r = 0.88). The NDVI and NDRE had lower correlations, of 0.41, 0.40; 0.86, 0.87; 0.84, 0.85 for N concentration, canopy N content and biomass, respectively, with little NDRE advantage. The RE band data can improve correlation, when it is included in newer VI. However, correlation accuracy must be regarded with caution as there was low repeatability in different data bases. The difference between CropCircle and RapidScan relationships as well as variation between fields accounted for the correlation much more than the within field variation. The potential and limitations of using active remote sensing as a tool for growers and/or scientists are discussed.

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EVALUATION OF IN-FIELD SENSORS TO MONITOR NITROGEN STATUS IN SOYBEAN

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In recent years, active optical crop sensors have been gaining importance to determine in-season nitrogen (N) fertilization requirements for on-the-go variable rate application. Although most of these active in-field crop sensors have been evaluated in corn and wheat crops, they have not yet been evaluated in soybean production systems in North Dakota. Recent research from both South Dakota and North Dakota indicate that in-season N application in soybean can increase soybean yield under certain conditions. This study was conducted to evaluate the use of Ag leader OptRx sensor in soybean production to determine the N need. The data for this research were collected from North Dakota State University, NDSU NW22 plots in Fargo in 2013. A field plot experiment was conducted with 2 drainage treatments, 4 varieties, 6 N treatments and 4 replications. Two OptRx sensors, mounted on a small tractor were used to collect the Vegetation Index (VI) values over the study area on 5 different dates throughout the growing season. Each plot (7.6m x 1.5m) consisted of 4 rows. The sensor data were collected from the middle two rows to eliminate the edge effects. The VI data were exported to ArcGIS to calculate the mean VI for each plot. For the last date (87 Days After Planting [DAP]) of data collection in the growing season, data were also collected with a SPAD meter, hand-held Greenseeker, and Greenindex+ app. The OptRx reading didn't show any significant differences between the N treatments and varieties during early and mid-season (48 and 53 DAP). But later in the growing season (87 DAP), the treatments such as 84 kg/ha at emergence, 28 kg/ha at emergence plus 28 kg/ha at R2-3, and 56 kg/ha at emergence ESN (Environmentally smart nitrogen) exhibited significantly higher VI compared to other N treatments. Also the varieties 6088 and 12R06 showed significantly higher VI than other varieties. For the last date (87 DAP) of data collection, none of the other sensors except OptRx showed any significant difference between the treatments and varieties. Collecting subsequent years of data will be necessary to confirm the response of OptRx sensor to N application in different varieties of soybeans.

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APPLICATIONS OF SMALL UAV SYSTEMS FOR TREE AND NURSERY INVENTORY MANAGEMENT

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Unmanned aerial vehicles (UAV) systems could provide an 'as needed' solution for small-to-medium scale farmers who want to monitor their fields at a low altitude with high accuracy frequently. This paper highlights the application of UAV systems in container counting and tree counting, which is vital to predict the tree density and yield. The main challenge of plant counting comes from the severe overlap of adjacent plants. In this paper, two types of crops were discussed. One crop is with uniform canopy area (e.g. container plants and citrus trees) and another is with non-uniform canopy area (e.g. Christmas trees). For the first type, aerial images of container-grown plants with green and yellow foliage were acquired with a stable, ground-based boom truck and UAV system. Two different index sets, (2*G-R-B) and (R-G)/(R+G) were used to extract the green and yellow container plants from background, respectively. A counting algorithm based on average canopy area was developed to estimate plant count. The effects of shoot height and adjacent plant distance on the accuracy of the algorithm are discussed. Further, the algorithm was successfully applied on the panorama images created from video file using Microsoft ® ICE software. In this realistic case, there are about 22,000 plants in the image and the applied algorithm accurately predicted the 22,000 plants within ±5%. This also indicates that the algorithm was successful when applied to low-resolution images. In addition, a second algorithm was employed which counted plants based on the local maximum value at or near the center of coniferous tree. A 3-D intensity distribution of the images showed that local maximum of intensity of (R-G) matched well with tree centers. Also, minimum distance filter (MDF) and thresholds generated from color component histograms were successfully used to remove the falsely identified tree locations.

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MANAGEMENT ZONES DELINEATION IN BRAZILIAN CITRUS ORCHARDS

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Precision agriculture (AP) has been recently introduced in orange production in Brazil. Early research that evaluated variable rate fertilization based on soil grid sampling and yield maps showed good results regarding fertilizer use efficiency. But, areas that present distinguished soil characteristics might not be suited for standardized spatial investigation and prescription and might benefit from different PA strategies like management zones (MZ). Cluster analysis and rich data over soil and yield maps is considered trustful methods for MZ delineation. But often electrical conductivity or grid soil sampling are expensive and not available for citrus growers. At the same time, if dedicated MZ software is not available, the statistical steps of clustering might be limiting for PA practitioners. Gathering data for yield mapping is an inexpensive task for citrus growers and might provide enough data for MZ delineation. Simple procedures for classifying yield points can be used for MZ delineation using easier software kits. The objective of this study is to compare two MZ delineation methods: one based on soil (texture, organic matter, and electrical conductivity) and yield data, using principal component analysis (PCA) and cluster analysis; and the other, based only on normalized yield data and simple classification procedure. Two 25.7 ha orange fields located in São Paulo, Brazil, were used. Both methods resulted similarly in one of the fields. This field presented clear spatial patterns of soil texture and yield. In the second field, the method based on soil and yield data and cluster analyses performed better. This field presents a small area with drainage problems that was successfully detected on EC maps. Also PCA allowed different weights for data that present greater variability. The simpler method might be used when clear patterns are viewed on available yield maps. Otherwise, soil data and more intelligent clustering methods should be applied.

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EFFECT OF A VARIABLE RATE IRRIGATION STRATEGY ON THE VARIABILITY OF CROP PRODUCTION IN WINE GRAPES IN CALIFORNIA

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Pruning and irrigation are the cultural practices with the highest potential impact on yield and quality in wine grapes. In particular, irrigation start date, rates and frequency can be synchronized with crop development stages to control canopy growth and, in turn, positively influence light microclimate, berry size and fruit quality. In addition, canopy management practices can be implemented in vineyards with large canopies to ensure fruit zone microclimate is optimized for producing high quality fruit.

Spatial variability in soil properties such as water holding capacity causes variability in fruit yield and quality. Ideally, irrigation should be applied differentially throughout the vineyard in order to compensate for soil variation and optimize both fruit yield and quality. We report on the first-season effect of a variable rate irrigation (VRI) prototype on canopy development and yield. The prototype system was implemented in early 2013 in a 4.05-hectare quadrant inside a drip-irrigated mature Cabernet Sauvignon vineyard measuring 12.5 total hectares. The VRI quadrant contained the full range of lowest to highest yields present in the vineyard (14.4 to 28.1 tons/ha), based on the 2012 yield map. The VRI quadrant was split into one hundred and forty 15 x 15-meter irrigation zones which were watered independently by drip irrigation with weekly schedules calculated using an energy balance approach based on the Mapping Evapotranspiration at High Resolution with Internalized Calibration (METRIC) model. The 2012 yield map was used to split all irrigation zones among low, medium and high yield classes. Irrigation during the 2013 growing season was initiated in both the low and medium 2012 yield classes at a time when the soil was still saturated (i.e. earlier than standard practice), while watering in the high 2012 yield class was withheld until vines had used a significant amount of the soil water holding capacity (i.e. standard practice). Low yielding zones received up to 17% more irrigation water than the high yielding ones during the 2013 growing season. For both 2012 and 2013, normalized difference vegetation index (NDVI) was calculated and mapped from airborne images captured in mid-August and yield was mapped from yield monitor data collected at harvest.

VRI affected spatial and non-spatial vineyard variability parameters. Non-spatial variability of both yield and NDVI, measured either as percent coefficient of variation or as percent spread (the range as percent of the median), decreased significantly from 2012 to 2013 in the VRI section compared with an adjacent 4.05-hectare section of conventionally irrigated vineyard. Compared to conventional irrigation (CI), VRI also decreased spatial dependency and structure as indicated by the mean correlation distance (MCD) and the Cambardella index (CmbI). This is the first of three seasons planned for the testing of this system that includes many soil, vine, fruit and wine attributes.

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A NOVEL PORTABLE SYSTEM FOR IMPROVING ACCURACY OF REIMBURSEMENT FOR FRUIT PICKING

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In this paper, a portable Labor Management System (LMS) for paying fruit pickers individually and accurately is presented. This system utilizes a digital hanging-weight scale (S-type load cell) and a computational unit (CU). The CU consists of: (i) a microcontroller (arduino mega), (ii) a RFID reader; (iii) a thermal printer; (iv) a GPS module; (v) a wireless transceiver (Xbee pro); (vi) a display unit (LCD); (vii) real-time clock (RTC); and (viii) a memory card (sd card). Low-cost passive RFID wristbands, which contain unique ID numbers, are worn by pickers. A hanging-weight system was developed in order to be self-levelling, an important factor for open field environments (e.g. sloped orchards). Each picker places their bucket(s) on the suspended platform and initiates the weighing system with their RFID-wristband by passing it before the reader. The LMS immediately calculates the weight of fruit, associates it with the picker ID, and prints a receipt that outlines the picker's ID, date, time, bucket(s) weight, and accumulated weight (total weight). Additionally, all data are stored locally to an sd card and transmitted wirelessly to the cloud.

This portable LMS was field-tested for accuracy and reliability during commercial harvest of sweet cherries (Prunus avium L.) and blueberries (Vaccinium corymbosum) in the Pacific Northwest, USA. Using the LMS the overall accuracy of payroll was improved, by providing the ability to reimburse pickers individually, based on the actual weight of fruit they harvested. The economic benefits of paying for actual weight of harvested fruit will be discussed as well as the potential for this system to generate accurate yield maps and provide "in-field" traceability.

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DEVELOPMENT OF ONLINE SOIL PROFILE SENSOR FOR VARIABLE DEPTH TILLAGE

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Compaction is great concern to farmers and soil scientist since it limits crop growth and yield. There are two types of soil compaction; natural one and the one that is the result of management practice in agricultural production. Sub soiling is a way of minimizing negative effects caused by compaction. Conventional management practice is to use chisel at a certain depth. Field traffic and variation of soil properties through field brings about variation on soil compaction degree and depth. Instead of taking variation into account, sub soiling at a certain depth can cause excessive energy consumption. For sustainable agricultural production, therefore depth variation of chisel is required.

For determination of compaction, soil strength is one of the main indicators which depend on several soil physical and biological properties such as dry bulk density, organic matter content. The objective of this study was to develop an online sensor based on measuring soil strength at multiple depths in order to interpret the depth of compacted soil layer so that the working depth could be adjusted on the go. Mechanical part of the sensor was developed using 3D CAD Design Software Solidworks. Manufacturing and assembling process followed design works. Data acquisition and control system were based on PLC. The acquisition script was developed in Phoenix Contact PC WORX software so that it records the data flowing from load cells and alters the depth of chisel. Laboratory tests were conducted in order to calibrate the load cell and compensate the measurement variation among load cells by modifying script. After all, on the go sensor was developed. Future tests were planned for the assessment of practical usage in situ.

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DEVELOPMENT OF AN ON-THE-SPOT ANALYZER FOR MEASURING SOIL CHEMICAL PROPERTIES

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The goal of this research is to develop an on-the-spot soil analyzer (OSA) capable of simultaneously deploying several different sensors to measure soil properties at a predefined depth. The mechanism developed is able to rapidly remove topsoil, condition the soil surface and bring the designated sensors into direct contact with the soil. After the measurements are obtained and the geographical coordinates are recorded, the analyzer is converted into transportation mode and is then ready for the next set of measurements. Unlike other systems, this mechanism allows for the deployment of multiple sensors at a given measurement depth and in a completely automated mode of operation. This technology should provide an opportunity to extend the suite of deployable sensors and to automate the process, thus allowing for advanced sensor fusion algorithms and integrated data acquisition practices.

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PREDICTION OF CATION EXCHANGE CAPACITY USING VISIBLE AND NEAR INFRARED SPECTROSCOPY

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Visible and near infrared (vis-NIR) spectroscopy holds large potential for the measurement of physico-chemical properties of different natural resources including soils. This study was conducted to investigate the potential of the vis-NIR spectroscopy for the measurement of cation exchange capacity (CEC) in laboratory and on-line field conditions. The diffuse reflectance spectra of 294 fresh soil samples collected from two fields (F1 and F2) in Turkey were measured using a fibre-type vis-NIR spectrophotometer. Partial least squares (PLS) regression analyses with full cross-validation were performed to establish prediction models for CEC. Laboratory measured, laboratory vis-NIR predicted and on-line vis-NIR predicted maps using the prediction set of samples were produced and statistically compared with kappa value. Results showed that the laboratory prediction performance of CEC in the prediction set was successful for both fields, with average R2 values of 0.92 (F1) and 0.74 (F2), average root mean square error of prediction (RMSEP) of 1.89 % (F1) and 1.58 % (F2) and average residual prediction deviation (RPD) of 3.69 (F1) and 1.84 (F2). On-line field measurement was also successfully predicted with average R2 values of 0.75 (F1) and 0.73 (F2), average RMSEP of 4.79 % and 1.58 % (F2) and RPD of 1.45 (F1) and 1.36 (F2). The output of the Kappa statistics test comparing between laboratory measured CEC and laboratory vis-NIR predicted ($\varkappa$ = 68.5) CEC maps for F1 indicated substantial agreement whereas moderate agreement for F2 was observed. This study proves that soil CEC can be successfully measured with vis-NIR spectroscopy under laboratory and on-line scanning.

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USING A POTABLE SPECTRORADIOMETER FOR IN-SITU MEASUREMENT OF SOIL PROPERTIES IN A SLOPE CITRUS FIELD

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This study is aiming at the capability of VNIR-SWIR reflectance spectroscopy to predict soil properties and develop 3-D soil maps that are useful for site-specific soil management in precision agriculture. In the study, field experiment was carried out in a slope citrus field in Ehime prefecture, Japan. A potable spectrophotometer FieldSpec4 (ASD Inc.) was used to collect spectra data on the field based on fresh soil samples. To develop calibration models, 100 soil samples with 24 properties were collected and analyzed. A Global Positioning System (GPS) (Hipper, Topcon) was used to determine the location information (Longitude, Latitude, and Elevation) of the sampling points. The partial least squares regression (PLSR) analysis with full cross-validation was used to establish the relationship between soil reflectance spectra and the soil properties. The ArcGIS 10 (ESRI) was used to create the 3-D soil maps. As a result, 9 calibration models; moisture content (MC), pH, soil organic matter (SOM), electrical conductivity (EC), total nitrogen (N-t), hot water extractable nitrogen (N-h), available phosphorus (P-a), cation exchange capacity (CEC), Boron (B) were developed with coefficient of determination (R2) range from 0.47 to 0.85, followed by residual prediction deviation (RPD) from 1.4 to 2.7. The 3-D soil property maps were developed using the spectroscopic models and the 100 soil samples analysis results.

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COMPARISON OF CALIBRATION MODELS DEVELOPED FOR A VISIBLE-NEAR INFRARED REAL-TIME SOIL SENSOR

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The visible-near infrared (Vis-NIR) based real-time soil sensor (RTSS) is found to be a great tool for determining distribution of various soil properties for precision agriculture purposes. However, the developed calibration models applied on the collected spectra for prediction of soil properties were site-specific (local). This is found to be less practical since the RTSS needs to be calibrated separately for every field. General calibration approach is expected to minimize this limitation. This paper describes the feasibility of general calibration model developed from two types of paddy field and to compare the performance of the calibration models. For this purpose, Vis-NIR reflectance spectra of fresh soil were acquired at two fields (organic and inorganic paddy fields). Fresh soil samples were also collected from these two fields for analysis of moisture content (MC), organic matter (OM), total carbon (TC) and total nitrogen (TN) in the laboratory. Three calibration models were then developed for each soil properties using partial least square regression (PLSR) technique coupled with full cross-validation. The first model (CM1) was developed using dataset from organic field, second model (CM2) was from inorganic field and the third model (general model – CM3) was developed from combination of dataset from both fields. The performance of the three calibration models were compared based on the determination of coefficient (Rval2), root mean square error of validation (RMSEval) and residual prediction deviation (RPD). Results showed for MC and OM, CM3 produced highest prediction accuracy with Rval2 of 0.90 and 0.95. For TC and TN, CM1 produced the highest accuracy. CM2 produced the lowest accuracy for all the soil properties. This result could be used as a step towards establishment a robust general calibration model for agriculture soil.

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NITROGEN FERTILISATION RECOMMENDATIONS : COULD THEY BE IMPROVED USING STOCHASTICALLY GENERATED CLIMATES IN CONJUNCTION WITH CROP MODELS ?

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Accurate determination of optimal Nitrogen (N) recommendations which ensure maximization of farmer's revenue while minimizing the environmental constraint is maybe among the major challenges in agriculture. Crop models have the potential to deal with such aspects and could thus be used to develop decision support systems. However unknown future weather conditions remains the key point of accurate yield forecast. This paper presents the results of a preliminary study that aims to supply the unknown future with stochastically generated climatic conditions. Coupling the methodology with appropriate decision rules led to a generic decision support system able to guide the N management practices.

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COMPARISON OF THE VARIABLE POTASSIUM FERTILIZATION ON THE LIGHT AND HEAVY SOILS

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The present study aimed to characterize the effect of the annual potassium variable rates fertilization (VRF) on the content of the soluble K, with this being investigated in both light and heavy soils. The study was performed between 2007 and 2013 in two separate areas differentiating in the soil texture classes. The initial levels of potassium determined in both experimental areas were classified as very high. The data obtained confirmed positive effect of the variable fertilization techniques on the equalization of the K contents in the experimental fields, as determined by the decrease in the variance, standard deviation, and range of the elements content in both types of the soils studied. As assumed, the controlled withholding of fertilization applied in the early stages of the experiment resulted in decrease of K contents toward the preferred, medium to optimal, levels. In addition, we found that the progressive initiation of the potassium VRF on the experimental areas, to prevent an excessive decreases, resulted in earlier equalization of K contents in the light soils in contrast to the heavy ones, with the final spatial equalization being better in the latter, however.

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BEYOND THE 4-RS OF NUTRIENT MANAGEMENT IN CONJUNCTION WITH A MAJOR REDUCTION IN TILLAGE

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Agribusiness and government agencies have embraced the 4-R concept (right form, rate, time, and place) to improve nutrient management and environmental quality. This concept could potentially apply to individual plants in a field, but in reality most current technologies and cultural practices limit application of the concept to management zones. Data and information to make finer-scale decisions are lacking or too expensive to acquire. The assumption is frequently made that the delivery across the width of a fertilizer applicator is uniform, which may not be the case. Further, the concept assumes that the algorithm used to make nutrient recommendations is properly calibrated to promote optimum plant performance. To be valid, the soils ability to supply nutrients must be accurately assessed so that crop needs can be properly supplemented with fertilizers. At some point, trying to spatially balance the various nutrients to meet crop needs becomes over-whelmed with uncertainties or costs. At some point, the absence of reliable soil data and recommendation algorithms makes it reasonable to supply nutrients proportional to crop needs. The Ortho ratio of 27-12-0-7 for N, P, K, and S has been proposed as the appropriate formulation to meet crop needs for reproductive growth stages. Seven N fertilizer rates using the Ortho ratio were applied using an Exactrix applicator to continuous corn in replicated field strips in 2008 and 2009 in Hugoton, Kansas, U.S.A. Yield and profitability were optimized with 158 kg N/ha and a yield of 12.51 Mg/ha. Using the Ortho fertilizer approach adds confidence when establishing the optimum N rate because the other major nutrients are supplied in approximately the correct ratio.

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SOIL COMPACTION: IMPACT OF TRACTOR AND EQUIPMENT ON CORN GROWTH, DEVELOPMENT AND YIELD

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Past research indicates that soil compaction affects crop growth and grain yield. As the size and weight of agricultural equipment have increased significantly in the past few decades, the severity and depth of compacted zone may have increased proportionately. Very few studies have been conducted in North Dakota to understand soil compaction under the current machinery, and its effect on crop growth and yield. The research described here was conducted on a no-till corn field at Jamestown in North Dakota in 2013. Five transects were identified on study area representing the five different soil types. The study area was divided into three strips along the row to replicate data collection so as to account for field variability. Field data were collected from the most trafficked and least trafficked rows within each 5 transect× 3 replication combination based on machine traffic pattern. Data collected included soil compaction, soil bulk density, soil moisture content, plant emergence, plant height and grain yield. The early plant emergence data showed significant difference between the trafficked and non- trafficked rows. This might be due to the fact that moderate surface compaction favoured the seed to be in better contact with the soil particles and aided in better germination.The plant height measured didn't show any significant difference between the transects. The yield data showed significant difference between the transects and no difference was observed between trafficked and non- trafficked rows . It is important to note that the study field was a no-till field for more than 10 years. Collecting subsequent years of data will help to know the effects of soil compaction on crop, and impact of weather cycle on soil compaction. Future plan involves analyzing the effect of winter freeze-thaw cycle on soil compaction as well as studying soil compaction in conventionally tilled and no-till fields.

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GIS MAPPING OF SOIL COMPACTION AND MOISTURE DISTRIBUTION FOR PRECISION TILLAGE AND IRRIGATION MANAGEMENT

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Soil compaction is one of the forms of physical change of soil structure which has positive and negative effects, in agriculture considered to make soil degradation. The undisciplined use of heavy load traffic or machinery in modern agriculture causes substantial soil compaction, counteracted by soil tillage that loosens the soil. Higher soil bulk densities affect resistance to root penetration, soil pore volume and permeability to air, and thus, finally the pore space habitable for soil organisms. In contrarily for some soils, controlled soil compaction can improve the water holding capacity. Through a combination of these factors, soil compaction will affect crop growth. Soil compaction reduces total pore space of a soil and makes water and air flow through soil more difficult. Low soil oxygen levels caused by soil compaction are the primary factor limiting plant growth. Rectifying compacted soil is very costly process and involves again the use of machinery. Precision agriculture is a farming management concept based on observing and responding to intra-field variations. Precision agriculture is proven to be successful and very cost effective in fertilizer and planting/seeding application rates and, another promising area could be in the primary tillage operations leading to irrigation management.

In this research conducted under arid-zone crop cultivation in Oman, a penetrologger was used to measure soil penetration resistance and moisture contents in a selected farm field plots grown with Rhoades Grass and Sweet Corn. The main objective of this study was to investigate the effects of soil compaction level due to vehicle traffic indicated in the cone penetration resistance and irrigation patterns on the growth of grass and corn grown. The selected field plot area was approximately 1.8 ha. Based on the layout of the sprinkle irrigation system used, the field was subdivided into 84 subplots (each 12×12 m). One control condition and six compaction treatments were given to filed strips (24×12 m) having three replications from each arranged under randomized block design. The penetrologger device utilized in the experiments recorded GPS and moisture content readings simultaneously. The experiments were conducted for more than two years, completing three corn crops and seven grass crops. The results were analyzed and used for planning irrigation applications and tillage management.
The mapping of soil compaction levels and moisture status were successfully done through integrating data obtained into GIS maps. Result indicated that there was a trend for significant reduction in the growth of Rhoades grass in areas of higher soil compaction level due to traffic. In part of the field a hard pan (penetration resistance higher than 5 MPa) was clearly visible at 6-10 cm depth soil layer. Water logging observed on the fields was correlated with high soil compaction at the soil surface layer (1-5 cm deep). However, significant correlation could not be obtained for corn due to the fact that deeper root zone, soil type and other climatic factors specific to the country. Based on the result of this study, operational costs, schedules for tillage management practices could be optimized.

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DEVELOPMENT OF AN HYDRAULIC PENETROMETER DATA ACQUISITION SOFTWARE

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Currently, in addition to increased production, the costs reduction are focused in order to increase efficiency in production, so the modern agriculture intent to find planting methods which extract the maximum possible data about the used area for making possible to do this preparation in the most appropriate manner, considering the shortcomings of evaluating these data. This method is contained in the concepts of an agricultural practice that has been steadily growing, the "Precision Agriculture", which covers, among many other factors, soil preparation. The soil penetration resistance is a feature that can show the condition of compression and hence allow to evaluate the soil as this will promote the development of the growing. Considering that the development of the root system is strongly related to a better efficiency in production and also is directly linked to the resistance that the soil offers to its development, it was considered reasonable to create , through this work, a simple and accessible tool for obtaining this information. The objective was to create a software for data acquisition which can be adapted to any penetrometer that represents the magnitudes "strength" and "position" in the form of analog voltage signals. The software was tested on UMAS - Mobile Unit Sampling Soil, belonging to NEMPA – Agroforestry Machinery and Tires Test Center, located at FCA - College of Agricultural Sciences - UNESP Botucatu. UMAS is a trailer equipped with an hydraulic valve that controls an hydraulic double way actuator, controlled manually and having at its end a spindle on which a load cell is trapped and positioned between the actuator and a rod with a conical tip with standardized dimensions, thus constituting an hydraulic penetrometer. The displacement of this rod is measured by a multiturn potentiometer that is installed as a voltage divider and thus provides a position as an analog signal. The applied force is measured by a load cell with a maximum load measurement of 2000Kgf giving an output signal of 2mV / V. The software was created in "LabView", a "G" language development environment. The hardware used was the "USB6009" data acquisition device that communicates with a laptop computer by USB port. After the software development, the system was tested in a soil with deep tillage and controlled traffic. The software proved to be easily managed and represented in a coherent and satisfactory way the soil compression characteristics.

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PENETRATION RESISTANCE AND YIELD VARIATION AT FIELD SCALE

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The characterization of soil variability at field or subfield scale using conventional methods is a labor intensive, very expensive, and time-consuming procedure, particularly when high-resolution data is required. One property that can be measured fairly easy is soil penetration resistance. Since the mechanical properties of the soil around the penetrating cone are complicated and depend on several factors, the result from a penetrometer can be difficult to interpret. The low specificity should however not be seen as a disadvantage rather as a way to detect any change in soil physical conditions

To measure the penetration resistance across entire fields efficiently a tractor pulled penetrometer was used. The horizontal penetrometer shows values that are in the same range as a standard vertical penetrometer.
Four different fields in Sweden were used in this study. Yield was compared with penetration resistance as well as EM38-measurements at field scale. Penetration resistance varies considerably across all fields. There are however strong indications that penetration resistance can be used to find areas where the physical state of the soil has limited yield.

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AUTOMATIC SOIL PENETROMETER MEASUREMENTS AND GIS-BASED DOCUMENTATION WITH THE AUTONOMOUS FIELD ROBOT PLATFORM BONIROB

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For a sustainable agriculture, reliable measurements of soil properties and its interpretation are of highest relevance. Until today most of the measurements are carried out manually. Moreover, the number and density of measurement points is always an important aspect with respect to the statistical significance of the results. In this paper, a fully automatic measurement system has been developed and applied for the first time with free selectable measurement points.

As first measurement examples – in particular for soil compaction interpretations – a penetrometer module has been designed, where the penetration can be measured up to 80 cm below ground level. If the resistance (as for example caused by a stone) measured with a pressure sensor at the probe exceeds a certain level the measurement is automatically stopped via the vertical linear actuator control. New trials can be performed close to these measurements by programming the implemented horizontal linear motor for positioning the measuring rod perpendicular to the driving direction (within a range of 60 cm). Moreover, surface moisture and temperature are measured in parallel. The complete measurement module is attached to a multi-purpose field robot platform ("BoniRob"), which can navigate autonomously or via remote control on the field. The module can be considered as an application module ("App") of the robot with defined mechanical, energetic and digital interfaces.

A RTK-DGPS attached to the robot allows a precise positioning and GIS-based documentation of the measurement data. By combining the GPS navigation with the option of the horizontal linear positioning actuator, user-defined positioning and statistics can be predefined. For the communication between the application module and the field robot, the Robot Operating System (ROS) has been chosen as the open framework software. For validating the system, the measurement data has been compared to the data of a commercial penetrologger. The results match within the standard deviation of the data. At first the system has been tested independent of the robot. Afterwards field measurements have been performed by using the robot in two modes: a "manual mode", where the user controls the system via a remote control panel, and an "automatic mode" where the robot acts completely automatic, however, safety is assigned to the user. As a result, GIS maps of sensor data have been generated as a basis for further interpretation and agricultural processing. The field robot-based soil sensor system has a high potential for further applications, e.g. by including additional sensors.

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SPECTRAL HIGH-THROUGHPUT ASSESSMENTS OF PHENOTYPIC DIFFERENCES IN SPIKE DEVELOPMENT, BIOMASS AND NITROGEN PARTITIONING DURING GRAIN FILLING OF WHEAT UNDER HIGH YIELDING WESTERN EUROPEAN CONDITIONS

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Single plant traits such as green biomass, spike dry weight, biomass and nitrogen (N) transfer to grains are important traits for final grain yield. However, methods to assess these traits are laborious and expensive. Spectral reflectance measurements allow researchers to assess cultivar differences of yield-related plant traits and translocation parameters that are affected by different genetic material and varying amounts of available N. In a field experiment, six high-yielding wheat cultivars were grown with N supplies of 0, 100, 160 and 220 kg N ha-1. Wheat canopies were observed spectrally throughout the grain-filling period and three spectral parameters were calculated. To describe the development of the vegetative plant parts (leaves+culms) and the spikes, plants were sampled four times during grain filling. Dry weights and the relative dry matter content were recorded for leaves+culms and spikes. The N status of the plants was assessed by measuring the total N concentration and by calculating the above-ground N uptake. In case of an equal and sufficient N supply of 160 kg ha-1, the final grain dry matter was best assessed by spectral indices offering information about physiological maturity. Observing effects of various N supply, good correlations were found between spectral indices and single plant traits throughout grain filling but varied with N supply and development stage. The normalized difference vegetation index, NDVI, was strongly affected by the saturation effects of increased N concentration. The red edge inflection point, REIP, predicted plant traits with r2 values up to 0.98. However, in plants with advanced senescence, the REIP was less efficient in describing plant traits. The NIR-based index R760/R730 was closely related to yield-related plant traits at early grain filling. Compared to the REIP, the R760/R730 index was resistant to strong chlorophyll decays being able to predict plant traits at late grain filling, with r2 values of up to 0.92. Spectral reflectance measurements may represent a promising tool to assess phenotypic differences in yield-related plant traits during grain filling.

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PREDICTING WINTER WHEAT BIOMASS AND GRAIN PROTEIN CONTENT

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This paper addresses the problem of predicting biomass and grain protein content using improved particle filtering (IPF). First, we propose to use the IPF for improving nonlinear and non-Gaussian crop model predictions. In case of standard particle filtering (PF), the latest observation is not considered for the evaluation of the weights of the particles as the importance function is taken to be equal to the prior density function. Unlike the PF which depends on the choice of sampling distribution used to estimate the posterior distribution, the IPF yields an optimum choice of the sampling distribution based on minimizing Kullback-Leibler divergence, which also accounts for the observed data. Second, we apply the state estimation techniques PF and IPF for predicting biomass and grain protein content. In a first step, we present an application of the IPF to a simple dynamic crop model with the aim to predict a single state variable, namely winter wheat biomass. In a second step, we apply the IPF for updating predictions of complex nonlinear crop models in order to predict protein grain content. The performance of the estimation techniques is evaluated on a synthetic example in terms of estimation accuracy and root mean square error.

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NDVI 'DEPRESSION' IN PASTURES FOLLOWING GRAZING

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Pasture biomass estimation from normalized difference vegetation index (NDVI) using ground, air or space borne sensors is becoming more widely used in precision agriculture. Proximal active optical sensors (AOS) have the potential to eliminate the confounding effects of path radiance and target illumination conditions typically encountered using passive sensors. Any algorithm that infers the green fraction of pasture from NDVI must factor in plant morphology and live/dead plant ratio, irrespective of the senor used. Moreover, livestock grazing affects the morphology of pastures so the veracity of instrument calibration procedures applied under 'protected plot' conditions is questionable if the sensor is subsequently deploy as a 'calibrated sensor' into grazed fields. In this research we have simulated pasture grazing on establish plots of Tall fescue (Festuca arundinacea) in a heavy clay (vertosol) soil and examined the effect of such grazing on the temporal NDVI values as derived using a Crop CircleTM sensor. Five plots with different soil moisture condition were maintained in the study period. Time domain reflectometer (TDR) was used to monitor volumetric soil moisture content (%) and NDVI measurements were taken on a daily basis. Following a grazing event (facilitated by uniformly mowing the grass to a height of 6 cm), biomass samples were collected on 3rd, 4th and 5th day along with coincident measures of the NDVI. For those plots with low soil moisture level (< ~37% of the full profile), the NDVI progressively decreased up to 2 or 3 days following the 'grazing' event, despite the plot biomass increasing due to regrowth. The NDVI values did not 'recover' until approximately 4 days after the 'grazing' event. However, for those plots of moderate to high soil moisture (>~37%) the NDVI-time curves monotonically increased with biomass re-growth immediately following 'grazing'. This has important ramifications for those intending to use NDVI as the basis for pasture assessment, particularly in situations involving short-term grazing rotation

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ESTIMATION OF VEGETATIVE BIOMASS USING ON-THE-GO MOBILE SENSORS

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Non-destructive methods for estimation of vegetative biomass have been developed using several remote sensing strategies as well as physical measurement techniques. An effective method for estimating biomass must be at least as accurate as the accepted standard for destructive removal measurement techniques such as a forage harvester or quad harvest strategies. In large part vegetative biomass is considered a function of canopy or plant height. Subsequently, a method or piece of equipment which can estimate a height component is typically implemented for collecting measurements and from those measurements a relationship is created between height and mass. A number of sensing technologies have been examined for such applications. This study examined several types of ground-based sensing strategies for use in estimation of in-field forage biomass. A forage production trial consisting of multiple fertilizer treatments and mixed as well as monoculture species treatments was employed as an evaluation platform for the performance of the sensor estimation as compared to physical removal harvests. Predictive models were constructed and comparisons of sensor based estimates made to physically measured biomass harvested by hand from quad harvests as well as machine harvests using a forage harvester. Statistical analysis for both methods of harvest and sensor estimated harvests were performed as would normally be done according to treatment structure. Mean estimates were examined for evaluation of differences between biomass evaluation methods for each treatment. This strategy was employed in order to evaluate the difference if any on the overall research implications for data which was generated from physical collection techniques as well as sensor estimated data. Ultimately differences were minimal and did not contribute to disparity in implications for research aspects of the trial. Additionally, statistical analysis was performed on a subset of the data for repeatability. Paired identical plots were compared using Limits of agreement analysis to evaluate the repeatability of each technique. This analysis produced more narrow error bands for the sensing data as compared to the harvested data which suggests the sensing data is at least as stable as the physically harvested data. Subsequently, using ground-based mobile sensing for data collection which are incorporated into a biomass estimation model could prove to be effective in rapid accurate in field biomass estimation.

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NEAR-REAL-TIME REMOTE SENSING AND YIELD MONITORING OF BIOMASS CROPS

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The demand for bioenergy crops production has increased tremendously by the biofuel industry for substitution of traditional fuels due to the economic availability and environmental benefits. Pre-Harvest monitoring of biomass production is necessary to develop optimized instrumentation and data processing systems for crop growth, health and stress monitoring; and to develop algorithms for field operation scheduling. To cope with the problems of missing critical timing of field crop conditions in the traditional remote sensing process (e.g., satellite or aerial imaging systems), an experimental near-real-time remote sensing platform with high spectral resolution, spatial resolution and temporal resolution was proposed, designed and developed for a biomass production field pre-harvesting crop monitoring. The crop monitoring system can scan the crop field within 15 minutes. 91 images are captured daily to cover a 35-acre crop field. The multi-spectral imaginary of a bioenergy crop with spatial resolution of 100 mm/pixel was automatically collected and an intelligent control algorithm, e.g., camera movement such as zoom, focus and robust real-time multi-spectral camera parameters adjustment such as gain and exposure time under varying natural lighting conditions in the field, were developed to automatically capture high quality daily images through the growing season. The Normalized Difference Vegetation Index (NDVI) was calculated for understanding of the temporal vegetation response variations in the crop growth cycle over the growing seasons after imaginary geometrical corrections and geo-referencing. Special algorithms were developed to compile the high-resolution images to form an entire field crop index map. The image processing results from the proposed near-real-time remote sensing system were then compared to the biomass yield data in this paper. With the crop index map as a field condition-monitoring tool, the accurately geo-referenced biomass yield data points (1m x 1m) were generated through manually harvested, dried and weighed Miscanthus plants during the growing season.

A novel “daily canopy reflectance accumulation” algorithm was developed to match the field yield data. To increase data processing accuracy, both GPS readings and (manually identified) image patterns were used to locate the manually harvested data points. Preliminary analysis results show that the crop monitoring system can generate a high-resolution yield map that can explain 84.96% of the daily (distributed) biomass gain during the growing season. Moreover, the in-field growth variation and the plant growth pattern of the Miscanthus were derived and recognized. The biomass yield was predicted during an earlier growing season and provided decision support for the optimum harvest scheduling and site-specific crop management for the biofuel industry.

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PRODUCTION AND CONSERVATION RESULTS FROM A DECADE-LONG FIELD-SCALE PRECISION AGRICULTURE SYSTEM

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Research is needed that simultaneously evaluates production and conservation outcomes of precision agriculture practices. From over a decade (1993-2003) of yield and soil mapping and water quality assessment, a multi-faceted, "precision agriculture system" (PAS) was developed and initiated in 2004 on a 36-ha field in Central Missouri. The PAS assessment was accomplished by comparing it to the previous decade of conventional, whole-field corn-soybean mulch-tillage management. The employed PAS plan takes advantage of targeted management that addresses crop production and environmental issues. The PAS plan included no-till, cover crops, growing wheat instead of corn for field areas where depth to the argillic horizon was shallow, site-specific N for wheat and corn using canopy reflectance sensing, variable-rate P, K, and lime using intensively grid sampled data, and targeting of herbicides based on weed pressure. Yield slightly improved for corn (5%) and soybean (9%) with PAS over pre-PAS management. Risk as measured by grid cell year-to-year yield coefficient of variation decreased 57% when comparing where wheat replaced corn with PAS, but has remained unchanged for soybeans. Removing corn from the northern portion of the field for the PAS years resulted in within-year corn CV of 16.6%. Using soil quality measurements on research plots adjacent to PAS, we can estimate that PAS soil quality has increased at the rate of one point per year on a 0-100 scaled index. Surface runoff has not been found to be significantly different between PAS and pre-PAS. Sediment loss with PAS has been reduced 80% compared to pre-PAS years.

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PRECISION DESIGN OF VEGETATIVE BUFFERS

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Precision agriculture techniques can be applied at field margins to improve performance of water quality protection practices. Effectiveness of vegetative buffers, conventionally designed to have uniform width along field margins, is limited by spatially non-uniform runoff from fields. Effectiveness can be improved by placing relatively wider buffer at locations where loads are greater. A GIS tool, AgBufferBuilder, was developed that accounts for non-uniform flow and produces more-effective, variable-width, designs. The design model was developed by simulation modeling using the Vegetative Filter Strip Modeling System (VFSMOD-W) to produce relationships between pollutant trapping efficiency and buffer area ratio. To apply them, one relationship is selected that best describes a given field situation based on slope, soil texture, field cover management, and pollutant type. That equation is used to determine the buffer area ratio that would produce a desired level of trapping efficiency and it would be applied to the contributing area to each segment of field margin. The equation also can be used in reverse to estimate the performance of existing or hypothetical buffers. The design model was, then, adapted for use in a GIS. The GIS tool employs an aerial photo to define the field margin and a DEM grid to segment the field margin and determine contributing areas and slopes to each one. The photo is used again to map the resulting buffer design on the ground. Results using the GIS tool on case study fields suggest that pollutant trapping performance per unit area of buffer can be increased substantially over conventional designs by using a precision variable-width approach.

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CLIMATE CHANGE AND SUSTAINABLE PRECISION CROP PRODUCTION WITH REGARD TO MAIZE (ZEA MAYS L.)

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The paper is based on the European Regional Climate Models of Ensemble project and DSSAT – Ceres-Maize crop simulation model. The main goal of our paper was to predict maize (Zea mays L.) yield based on various climate models at management zones level and county level until 2100.
Another application was the use of crop simulation model in order to find responses to the climate change challenges. However, the change of yield in the next decades of the 21st century is predicted differently by the various climate change scenarios. Consequently, the responses should also be different: change of genotypes, and technologies (site-specific soil tillage, planting, nitrogen replenishment, variable rate irrigation) etc.
This study brings together the expected effect of climate change and fulfilling the requirements of sustainable crop production based on management zone and county level approach.

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A FIVE YEAR STUDY OF VARIABLE RATE FERTILIZATION IN CITRUS

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Citrus is a major crop in Brazil, especially in the São Paulo State, which is the main citrus production region in the world. Yet, site specific technology is still in early stages of adoption. Variable rate application of inputs is the most important tool in a Precision Agriculture system, however its effect on citrus agronomical aspects are still unknown, especially during long periods of observation. Thus, variable rate fertilizer application has been tested in citrus orchards in Brazil in a long term study. The goal is to evaluate the effects of this technology on input consumption, soil fertility and on fruit yield. Two 25.7 ha commercial orange fields were divided into variable and fixed rate fertilizer strip treatments. Data of soil electrical conductivity, elevation and soil texture were used to assess the variability of these fields. Variable rate prescriptions (lime, N, P and K) were based on soil and leaf grid sampling and yield data. Fixed rate applications followed standard prescriptions based on soil sampling and yield expectation. Results presented here are from five yield data (2008 until 2012) and four variable rate fertilizations (2008 until 2011). Field 1 showed more variability than field 2 regarding soil texture, EC and elevation. Site specific applications provided significant reduction on input consumption, mainly for nitrogen (37 and 51% less on field 1 and 2, respectively) and potassium fertilizers (41 and 18% less on field 1 and 2, respectively). In field 1, better fertility levels were found on the variable rate treatment. Along the years of evaluation, it reduced regions with excess of nutrients and enlarged areas of adequate levels of potassium and base saturation. Yield gains up to 13.1% occurred in this field. In the second field, loss on soil fertility and yield was found in the site-specific management in two years of evaluations. This field presented lower natural nutrient fertility and the variable rate prescriptions used were considered not suited for this soil condition. Overall results were better for the field with higher variability. This study showed the potential of variable rate technology to increase yield and improve soil fertility management.

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MULTIVARIATE GEOSTATISTICS AS A TOOL TO ESTIMATE PHYSICAL AND CHEMICAL SOIL PROPERTIES WITH REDUCED SAMPLING IN AREA PLANTED WITH SUGARCANE

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Precision Agriculture (PA) can be described as a set of tools and techniques applied to agriculture in order to enable localized production management, considering the spatial and temporal variability of crop fields. Among the numerous existing tools, one of the most important ones is the use of geostatistics, whose main objective is the description of spatial patterns and estimation data in non-sampled places. Nowadays, one of the most limiting factors to the use of PA is the number of samples required to represent the spatial soil attributes. Within this context, multivariate geostatistics emerges as a promising technique for mapping and quantification of soil attributes. One of the techniques, which minimize the number of samples needed, is the use of maps obtained by soil sensors equipment to identify points for sampling. The objective of this study was to map the spatial variability of chemical and physical soil properties, using a reduced number of samples, and applying kriging with external drift (KED) based on maps of apparent soil electrical conductivity (ECa). Samples were taken on a regular grid georeferenced at two depths. ECa soil readings in the whole area were made by means of a direct contact sensor. The results indicate that it is possible to obtain maps with acceptable precision in the spatial distribution of chemical (CEC, BS, SEB, K and pH) and physical attributes (clay) of soil from of 20 sampling points (0.4 samples ha-1) determined based on the ECa. The methodology used to obtain the maps of spatial variability of chemical and physical soil properties indicate that it is possible to predict, with acceptable accuracy, maps that can be used for fertilizer recommendation at variable rate. This approach opens new possibilities for other important agronomical attributes that can be estimated over large areas from a small number of samples, assisting farmers in crop management.

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UNMANNED AERIAL SYSTEM APPLICATIONS IN WASHINGTON STATE AGRICULTURE

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Three applications of unmanned aerial systems (UAS) based imaging were explored in row, field, and horticultural crops grown in Washington State. The applications were: to evaluate the necrosis rate in potato field crop rotation trials, to quantify the emergence rates of three winter wheat advanced yield trials, and detecting canker disease-infection and spread in pear orchards. The UAS equipped with green-NDVI imaging was used to acquire field aerial images. In the first application, one and two year crop rotation fields were imaged to evaluate the necrosis rates of 64 plots. The GNDVI data showed strong relationship with ground-truth necrosis measurements (R2 = 0.911).

Winter wheat seeds planted in the 6 to 12 inch annual rainfall zones of Washington are normally sown deeper than usual (10 to 15 cm) for better availability of water to the germinating seed. Precipitation up to seven days after planting may result in formation of hard top-soil layers reducing seed emergence rates. Therefore, the second application evaluated applicability of aerial imaging to quantify the germination rates of the new winter wheat cultivars being developed by WSU wheat breeders. The aerial imagery data showed good correlation to the ground scouting data with correlation of 0.78, 0.79 and 0.86 for soft white common, hard, and soft club wheat trials, respectively.

The pear orchards in the Pacific Northwest are usually very old and characterized by large and vigorous tree canopies. Such trees when irrigated by under the canopy system results in very humid microclimate that triggers the development of fungi. Many of these fungi are responsible for the formation of cankers in the bark growing inside the phloem and are difficult to control. If the trunk is infected, the tree health declines slowly with eventual death. Therefore, understanding the canker spread pattern is important to trigger appropriate management decisions. Therefore, UAS based imaging was successfully used in this study to identify the canker infection areas in Red Anjou pear variety. Overall, results suggest that the UAS based high resolution imagining is a versatile and complementary technique useful to both the researchers and growers in field trails quantification and scouting for crop diseases and management.

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DEVELOPMENT OF AN ENTERPRISE LEVEL PRECISION AGRICULTURE SYSTEM

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We present the ground work for the development of an Enterprise Level system for implementation of Precision Agriculture (PA). Population growth, ongoing draught, loss of arable land and diminishing water and nutrients require the development of a farm management methodology and tools at the enterprise level. The spatial and temporal complexities of farm management require a Big Data approach. Development and implementation of suitable navigation and control systems for unmanned air and ground vehicles is discussed. Mobile and in field sensor platforms are discussed. Data flow in the enterprise is presented along with a five year timeline for the development of the system. The threshold object of the system under development is the management of a specified crops production at a minimum of two (2) meters square. The target objective is the management of a specified crop at the plant level.

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SITE-SPECIFIC VARIABILITY OF GRAPE COMPOSITION AND WINE QUALITY

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Precision Viticulture (PV) is the application of site-specific tools to delineate management zones in vineyards for either targeting inputs or harvesting blocks according to grape maturity status. The majority of PV studies in winegrapes have focused on the relation of soil and vine-related spatial data with grape composition at harvest. However, the inclusion of site-specific wine quality data are very rare in literature, even though grape quality is ultimately judged upon wine properties. The aim of this study was to investigate the effect of the variability in soil and vine properties on both grape composition and wine quality. The study was conducted in a commercial vineyard in the Nemea area, Southern Greece, during the 2013 vintage. An elevation and an apparent electrical conductivity (ECa) map were created to assess soil variability. The vineyard was sectioned in a regular grid of 18 cells, sized 400-550 m2. Berries from each cell were sampled three times until harvest and were analyzed for total soluble solids, pH, titratable acidity, anthocyanins and total phenolic compounds. Grape harvesting was performed manually in September 2013 and grapes were destemmed, crushed and vinified separately for each vineyard cell, applying classic red winemaking procedures. The final wines were analyzed for alcohol content, pH, titratable acidity, colour density and hue and phenolic composition. Yield and berry weight showed a two-fold variation within the vineyard. Among berry compounds, anthocyanins and total phenols showed the highest within-filed variability (5-10 fold). Berry weight was the most sensitive among berry attributes to field variability with significant correlations with slope, elevation (negative) and ECa and yield (positive) throughout ripening. Berry weight also presented a consistent spatial pattern throughout ripening, linked to soil variability. On the contrary, berry composition parameters (brix, titratable acidity, anthocyanins and phenols) had no consistent spatial pattern and none of them was related to the variability of topography, soil or yield. Yield variations were not associated with any of grape and wine parameters except for a strong negative correlation with pH. Similarly, wine composition parameters spatial trend did not present any significant correlations with field characteristics. Moreover, no (or limited) connection between grape and wine composition spatial distribution was evident.

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TOWARD MORE PRECISE SUGAR BEET MANAGEMENT BASED ON GEOSTATISTICAL ANALYSIS OF SPATIAL VARIABILTY WITHIN FIELDS

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Sugar beet yields in England are expected to increase in the future, due to the advances in plant breeding and agronomic progress, but the intra-field variation in yield due to the variability in biotic and abiotic factors should not be ignored. This paper explores the spatial variation in the field in relation to sugar beet growth and yield. It also investigates the possibility of anticipating spatial variation in sugar beet yield based on early assessment of crop biomass. For this study 91 plots were placed in an irregular grid in a 9 ha sugar beet field located in the east of England. The results indicate significant spatial variation in final root yield from 36.5 to 89.5 t/ha across the field. The sampling protocol followed in this field was sufficient to describe the majority of the variation. Some of the observed variation related to the soil moisture and soil organic matter. The spatial variation in root yield at final harvest was correlated with the variation in Leaf Area Index (LAI) measured in July. Therefore variations in LAI observed early in the growing season were a good predictor of the final economic yield of sugar. In addition, preliminary results in two other fields also indicate a significant relationship between the yield map of sugar beet crop and the map of previous crop (winter wheat). These results indicate the feasibility of predicting the variation in sugar beet yield from the yield map of previous crop together with early LAI of the sugar beet crop.

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STUDY OF SPATIO-TEMPORAL VARIATION OF SOIL NUTRIENTS IN PADDY RICE PLANTING FARM

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It is significant to analysis the spatial and temporal variation of soil nutrients for precision agriculture especially in large-scale farms. For the data size of soil nutrients grows once after sampling which mostly by the frequency of one year or months, to discover the changing trends of exact nutrient would be instructive for the fertilization in the future. In this study, theories of GIS and geostatistics were used to characterize the spatial and temporal variability of soil nutrients in paddy rice fields in the Erdaohe farm of Heilongjiang Province, China, which located in the north of Daxing'an Mountains, has an area of nearly 36.1 million hectares for paddy rice planting. The soil samples, collected from 2009 to 2013 once a year, were sampled based on the spatial distribution of paddy rice fields, counting as 651 in 2009, 1488 in 2010, 954 in 2011, 483 in 2012, and 471 in 2013. These samples were analyzed for pH, soil organic matter (SOM), available nitrogen (AN), available phosphorus (AP), and available potassium (AK). In these measurement results, value of pH is not very variable among four years, ranging from 4.6 to 6.4 in 2009, 5.1 to 6.5 in 2010, 5.98 to 6.4 in 2011, 4.88 to 6.52 in 2012, and 4.94 to 6.21 in 2013, and the coefficient of variation (C.V. %) were 4.77, 3.73, 3.60, 4.42, 3.11 from 2009 to 2013, all of which had a weak spatial variability. Besides, the other four nutrients had a medium spatial variability, with the highest one of AK. On the other hand, for the general trend, spatial variation of soil organic matter (SOM) increased from 2009 to 2013, and decreased the rest AN, AP, AK. After calculating and comparing the spatial and temporal variation in whole farm area, variations between management regions is the second research point. To reach this aim, we chose interpolation method of kriging to generate grids for every soil test data. Among these five factors, only data of soil pH fit the normal distribution, the other four factors for several years need to be transformed for better results. Take the interpolation of AN as an example, Box-Cox transformation parameters were chosen as 0.1 in 2009, and Log transformation was used in 2012 and 2013, the temporal geographic maps revealed that in 2009, region I had the highest level of AN, and the next year most regions has the same level of AN, except for region VIII which is lower than the other six regions. In 2011, region II, IV, VI had a higher level than region I, III, V, VIII, while the next year kept the same except for region V becoming higher. Based on this study, conclusion acquired is that from 2009 to 2013, the spatio-temporal variations decreased in soil pH, AN, AP, AK, and increased in SOM. Moreover, according to the comparison of interpolation results, these five soil properties in Erdaohe farm remained not very stable in the past four years, which could implicate important significance in future research with consideration of fertilization, rice yield and other factors.

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AN EVALUATION OF HJ-CCD BROADBAND VEGTATION INDICES FOR LEAF CHLOROPHYLL CONTENT ESTIMATION

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Leaf chlorophyll content is one of the most important biochemical variables for crop physiological status assessment, crop biomass estimation and crop yield prediction in precision agriculture. Vegetation indices were considered effective for chlorophyll content estimation. Although hyperspectral reflectance is proven to be better than multispectral reflectance for leaf chlorophyll content retrieval, the scarcity of available data from satellite hyperspectral sensors limited its application. It is highly desirable to develop methods for leaf chlorophyll content estimation based on broadband satellite data. In this study, nine broad band vegetation indices were tested for their potential for leaf chlorophyll content estimation. The PROSAIL model was used for sensitivity analysis of the selected vegetation indices. The results of the sensitivity analysis showed that both the chlorophyll vegetation index (CVI) and the triangular greenness index (TGI) had better performance in leaf chlorophyll content estimation. Both CVI and TGI were less sensitive to leaf area index (LAI) and more sensitive to leaf chlorophyll content than the other vegetation indices. Validation based on field measurements showed that CVI ($R2=0.50$, $P<0.001$) and TGI ($R2=0.46$, $P<0.001$) were the most appropriate indices for leaf chlorophyll content estimation. These results demonstrate the possibilities for retrieving leaf chlorophyll content using broadband satellite data in precision agriculture. The preliminary results of this study also shed light on future improvement of vegetation indices for leaf chlorophyll content estimation.

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ESTIMATION OF NITROGEN AND CHLOROPHYLL CONTENT IN WHEAT CROP USING HAND HELD SENSORS

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A Field experiment was conducted to estimate crop nitrogen (N) and chlorophyll content in wheat crop by using chlorophyll content meter (Apogee's CCM-200) and N-Tester® (Make YARA International). The experiment was conducted on wheat variety viz. PBW 550 with 6 nitrogen levels i.e. 0, 30, 60, 90, 120 & 150 kg N/ha. It was found that at all stages like tillering, booting and ear emergence, when the nitrogen rates was increased from 0 to 150 kg ha-1, the correlation with both of the instruments i.e. CCM and NT for determination of plant nitrogen were better correlated having Pearson's coefficient 0.939, 0.863, 0.797 and 0.926, 0.827, 0.722 respectively. Also, at all the crop growth stages like tillering, booting and ear emergence, Lab N content in plant leaves was having strong linear relationship with CCI having coefficient of determination 0.88, 0.75 and 0.77 respectively. Coefficient of determination values for N tester and lab N-content also showed good linear relationship having values 0.85, 0.78 and 0.70 at tillering, booting and ear emergence stages respectively. The chlorophyll content measured in laboratory was having strong linear relationship with CCI at tillering, booting and ear emergence stage with coefficient of determination 0.84, 0.78 and 0.77, respectively. Coefficient of determination values between N tester and chlorophyll content showed linear relationship having values 0.82, 0.75 and 0.80 for tillering, booting and ear emergence stages respectively. There was a good correlation between plant N and chlorophyll content shown through Pearson's correlation coefficient values which were 0.890, 0.846 and 0.786 at tillering, booting and ear emergence stages respectively. This was also confirmed as there was a strong linear relationship between chlorophyll content and Lab N with coefficients of determination 0.798, 0.75 and 0.72 at tillering, booting and ear emergence stages respectively. It was concluded that both of the instruments i.e. NT and CCM are useful for the determination of N and chlorophyll in plant leaves especially at tillering stage.

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STUDY ON THE AUTOMATIC MONITORING TECHNOLOGY FOR FUJI FRUIT COLOR BASED ON MACHINE VISION

M. Chen, M. Li, J. Qian, W. Li, Y. Zhang, X. Yang, Y. Wang

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Fruit color is one of the important indicators of quality and commodities. Three kinds of the traditional methods are used to evaluate fruit color, including artificial visual identification, fruit standard color cards and color measurement instrument. These methods are needed to be conducted in the field by persons, which are time-consuming and labored, and also difficult to obtain the dynamic color information of the target fruits in the growth process. This study developed a practical technology for automatically monitoring the fruit color in the whole progress based on machine vision, the apple fruits were photographed by infrared camera, and the dynamic color change information were obtained through applying MATLAB software to process the image. Color change rule of the whole apple and fixed local position apple was analyzed. The results showed that the trend of the fixed local position R/G ratio was similar to that of the whole fruits. Therefore, the fixed local position color information was representative for whole apple in the corresponding period. The R/G ratio of apple was close to 1 when the bag was just removed, with the bag-removed days increased, the apple's color became more red, and R/G ratio was increased gradually, the R/G ratio was about 1.4 on October 25th, and the fruit was bright red. We can get dynamic color information of apple fruit through automatic monitoring technology based on machine visions. This technology can lay the foundation for analyzing the influence factors of apple color and building color model, and also providing an important reference for picking and presorting apple in suitable period.

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PRECISION NUTRIENT MANAGEMENT FOR ENHANCING THE YIELD OF GROUNDNUT IN PENINSULAR INDIA

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Groundnut is an important oil seed crop grown in an area of 8 lakh hectares in Karnataka state of India under rainfed conditions. In these situations farmers applied inadequate fertilizer without knowing the initial nutrient status of the soil which resulted in low nutrient use efficiency that intern lead to low productivity of groundnut in these areas. Soil fertility deterioration due to excess removal of fertilizers and manures is one of the major causes of fatigue in crop production. At present incidence and expansion of multinutrient deficiencies in Indian soils owing to inadequate and unbalanced nutrient input through fertilizers is considered one of the major reasons for decline factor productivity of crops. Therefore efforts were made during 2012 and 2013 to understand the situation and find solutions through Precision nutrient management with mechanisation in groundnut of the central dry zone of Karnataka state, in peninsular India. The study was conducted at University of Agricultural Sciences Bangalore in farmers fields with 50 x 50 m grids have been delineated using geospatial technology and also DGPS locations have been used for each grid to map the field variability. After grid making soil samples from 0-15cm were collected and analysed for different major and micro nutrients in all the selected 139 grids. Farm yard manure 5 t/ha was applied uniformly before sowing of the crop. Zinc sulphate @ 15 kg/ha was also applied at the time of sowing of the crop. To meet the sulphur need of the crop gypsum @ 500kg/ha was applied at 35 days after sowing. The available nitrogen status of soil revealed that 8, 80, 12 per cent was low, medium and high respectively, while the available phosphorus level remained lower for 96 per cent of samples and 84 per cent of the samples found to be medium available sulphur and zinc status remained lower. The crop was sown on 27.7.2012 and18.7.2013 and harvested during last week and third week of November 2012 and 2013 respectively. The project is in its second year of implementation, assessment, quantification of spatial variability of the field and the crop parameters like fertility status for major and minor nutrients, PH ,EC pest and yield are done through GIS mapping in order to supplement the right quantity of nutrients and pesticides on right time on right quantity and right method. The analysis of two years data showed that precision nutrient management with mechanized cultivation recorded 52.1 and 22.0 per cent higher pod yield of groundnut over farmer's method and by adopting university package of practices respectively. It was assessed for its variability spread in the field and insecticides were given as per variability by which we saved in the cost on pesticides.

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MODELING CANOPY LIGHT INTERCEPTION FOR ESTIMATING YIELD IN ALMOND AND WALNUT TREES

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A knowledge of spatio-temporal variability in potential yield is essential for site-specific nutrient management in crop production. The objectives of this project were to develop a model for photosynthetically active radiation (PAR) intercepted by almond and walnut trees based on data obtained from respective tree(s) and estimate potential crop yield in individual trees or in blocks of five trees. This project uses proximally sensed PAR interception data measured using a lightbar mounted on a mobile platform and a crop growth model to estimate potential yields of almond and walnut trees. An analytical model was developed to estimate PAR intercepted by the tree in which tree canopy was assumed to be spherical in shape. PAR intercepted by a tree was estimated taking into account the effect of row spacing, tree spacing within the row, latitude and longitude of the orchard, day of the year and row orientation. Scans were collected at solar noon in almond and walnut orchards during the 2012 and 2013 growing seasons. Diurnal scans were also collected during the 2012 season and were used to validate the model. Estimated versus measured data of PAR interception in almond and walnut trees had coefficient of determination of 0.86 and 0.94, respectively. The coefficient of determination for the relationship between actual yield and absolute midday PAR intercepted was 0.81 and 0.63 for almond and walnut trees, respectively. The coefficient of determination for the relationship between actual and potential yield was 0.80 and 0.59 for almond and walnut crops, respectively. Actual yield from those trees with lower values of midday PAR interception was found to be closer to their respective potential yield than those trees with higher values of midday PAR interception. The results suggest that there is a potential to use spatially variable PAR interception data to implement site-specific input management and enhance production.

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DEVELOPMENT AND EVALUATION OF A LEAF MONITORING SYSTEM FOR CONTINUOUS MEASUREMENT OF PLANT WATER STATUS IN ALMOND AND WALNUT CROPS

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Almond and walnut are two major crops grown in the Central Valley of California. With virtually no rainfall in this area during summer, these crops need to be irrigated throughout the season. There is a demand for using irrigation scheduling tools for effective use of very limited supply of water. Leaf temperature measurement using infrared thermometers has been used to predict plant water stress or to develop different indices to quantify plant water stress, but mostly on field crops. There have been very few studies conducted on tree crops. In this study, an inexpensive, easy to use sensing system called a 'leaf monitor' was developed and evaluated to continuously measure leaf temperature and relevant microclimatic variables in the vicinity of a leaf for prediction of plant water status for tree crops. The system was installed on almond and walnut trees to continuously monitor a selected leaf on each tree by logging leaf temperature, air temperature, relative humidity, wind speed and Photosynthetically Active Radiation (PAR). This study also proposed a method to develop a modified crop water stress index (MCWSI) in which a well-watered baseline was developed after every irrigation event for each tree for incorporating any temporal variability throughout the season. Additional parameters measured by leaf monitor also assists in controlling levels of disturbance variables like wind speed and light conditions. Leaf monitors were installed as a part of a wireless mesh network in field conditions. Data were obtained remotely over the web, and daily MCWSI values were calculated by assigning first day after irrigation as the reference day. MCWSI values were found to be correlated well with measured plant water stress, as measured by stem water potential (SWP). Sensing system has potential to be used as irrigation scheduling tool as it was able to provide a daily stress index value which follows a similar pattern as the actual plant water stress.

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APPLICATION OF HYPERSPECTRAL IMAGING FOR RAPID AND NON-INVASIVE QUANTIFICATION OF QUALITY OF MULBERRY FRUIT

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This study investigated the potential of using hyperspectral imaging working in near infrared region (850-1750 nm) for rapid and non-invasive determination of the total flavonoid in mulberry fruit. The spectra of samples were extracted according to the shape information of fruit contained in the hyperspectral images. Partial least-squares regression was used to calibrate the total flavonoid content of fruit samples with their corresponding spectral data. Results showed that a good correlation was obtained between the frozen days and spectral information. It indicates that it is possible for rapid and non-invasive quantification of quality of mulberry fruit with hyperspectral imaging technique.

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A NOVEL HYPERSPECTRAL FEATURE EXTRACTION ALGORITHM BASED ON WAVEFORM RESOLVING FOR RAISIN CLASSIFICATION

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Near infrared hyperspectral imaging technology was adopted in the paper to determine the variety of raisins produced in Xinjiang Uygur Autonomous Region, China. There are three varieties of raisins taking part in the research and the wavelengths of the hyperspectral images are from 921nm to 1680nm. A novel waveform resolving method was proposed in the paper to reduce the hyperspectral data and extract features. The waveform resolving method compresses the original hyperspectral data for one pixel into 5 Amplitudes, 5 frequencies and 5 phases, 15 feature values in all. Neural network was established to determine the variety of raisins. The accuracies of the model which are presented as sensitivity, precision and specificity which are higher than the accuracies of model of traditional PCA feature extracting method combined with neural network. The result indicates that the proposed waveform resolving feature extracting method combined with hyperspectral imaging technology is an efficient method to determine variety of raisin.

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DETECTION OF DRAINAGE FAILURE IN RECONSTRUCTED CRANBERRY SOILS USING TIME SERIES ANALYSIS

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A cranberry farm is often a semi-closed water system, where water is applied by means of irrigation and drained using an artificial drainage system. Sufficient drainage early in the season helps to improve rooting depth, which makes crops more resistant to drought and leads to higher cranberry yields. The key to maintaining an optimal water balance is timely irrigation and drainage, and therefore a proper understanding of the interaction between the two is required to increase production efficiency. Current diagnostic methods for identifying drainage failure on cranberry fields are based on outflow from tile drains; however these methods are time-consuming and expensive because the exact locations of tile drains are mostly unknown. In order to reduce the risk of crop disease related to waterlogging and optimize the cranberry production process, we here present an alternative diagnostic approach for detecting drainage failure based on the wavelet transform of hydrological time series obtained with soil column experiments. Wavelet transforms can be used to detect singularities in hydrological time series based on specific criteria, such as wavelet period, frequency, and change in the corresponding wavelet coefficient. Examples demonstrated in this paper are (i) wetting front instability characterized by variations in power response for short wavelets, (ii) long-term drifts that could point to specific characteristics of a laboratory experiment, or in the case of field data, weather conditions, and (iii) drainage failure characterized by a primary component in the CWT power response that shifts toward a longer wavelet period over the course of time.

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ASSESSING DEFINITION OF MANAGEMENT ZONES TROUGH YIELD MAPS

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The knowledge of the temporal stability of yield is very important in the decision making process, allowing to make more precise estimates of the risks associated with agricultural investments. Therefore, this study aims to check for yield stability in grain crops and define management zones using yield maps. Temporal inconsistencies lead to problems of yield scale, demanding a suitable data normalization, and small spatial inconsistencies pollute the data within a same range of comparison along years, demanding suitable filtering or majority rule within cells. In a first step of the work, for a historical sequence of yield datasets, two normalizations techniques were applied, three distinct filtering procedures were tested, and 11 within cell parameters were extracted for two distinct grids with two distinct cell-sizes (10m and 30m) cells upon the processed data). Pearson correlations along the data series showed higher values for global filtering procedure and 30m cell sizes; but the lower correlations values found for strength filtering procedures, cell classification by majority normalized value and smaller cell-size may suggest that the highest correlation obtained could be due to spatial data pollution which approximates values not spatially but also in time-series. In a second step of the work, yield maps were standardized and then submitted to principal component analysis to reduce the dimensionality of the data and determine the main causes of the variability in each field. The principal components with eigenvalues greater than one were kept and their scores were used to do a cluster analyses by the k-means method, delineating three management zones. The results yield maps of corn showed high temporal stability, suggesting that this crop has a great potential to delineate management zones. The proposed methods were efficient to delineate management zones identifying different yield potential zones an also given an estimate of each zone temporal stability.

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OPTIMIZATION OF MAIZE YIELD: RELATIONSHIP BETWEEN MANAGEMENT ZONES, HYBRIDS AND PLANT POPULATION

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Plant population per unit area is one of the most important aspects under farmer control that can influence maize grain yield. Adjusting plant population in crop fields is a strategy to manage spatial variability and optimize environmental resources that are not under farmer control like soil type and water availability. This study aims to evaluate the strategy of variable rate seeding (VRS) by management zones (MZ) in Brazil. In this study, ten hybrids and five plant populations ranging from 20 to 40% below, and 20 to 40% above the local planting density were analyzed. Three field experiments were conducted during 2012 and 2013 in two regions with distinct growing seasons, both under rain fed and non-tillage system. The attributes used to delineate MZ were apparent soil electrical conductivity (ECa), yield maps (YM) and elevation. The quality of seed rate (indicator of spacing between plants) was 88% to 95% accurate at all locations. The analyses of variance were significant ($P < 0.05$) for triple interaction between hybrids, plant population, and the MZ. The high MZ reached higher average yield compared to the low MZ and high populations reached higher yield regardless of MZ. Management zones influenced the maximum attainable yield. The optimum plant population varied across zones. However, there is no simple recommendation regarding the optimal plant population.

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DEVELOPING A HIGH-RESOLUTION LAND DATA ASSIMILATION AND FORECAST SYSTEM FOR AGRICULTURAL DECISION SUPPORT

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Despite technological improvements that increase crop yields, extreme weather events have caused significant yield reductions in some years. According to the United Nations Food and Agriculture Organization, 70% increase in agricultural productivity will be required by 2050 to meet the growing food demand. Climate Changes - rising temperature, increasing CO2 level, and altered precipitation patterns – have affected the water resources and agriculture productivity in U.S. and worldwide. The United Nations Framework Convention on Climate Change (Frankhauser et al. 2010) estimated that about US$14 billion will be needed annually by 2030 to cope with the adverse impacts of climate change, though this figure could be two or three times greater.

The National Center for Atmospheric Research, Research Applications Laboratory (NCAR/RAL) has been engaged with the research and end-user communities to develop numerous observing (see Fig. 1), modeling, and prediction capability for assessing interactions between weather, climate, crop growth, and hydrology, and for agricultural applications.

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PRECISION AGRICULTURE IN SUGARCANE PRODUCTION. A KEY TOOL TO UNDERSTAND ITS VARIABILITY

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Precision agriculture (PA) for sugarcane represents an important tool to manage local application of fertilizers, mainly because sugarcane is third in fertilizer consumption among Brazilian crops, after soybean and corn. Among the limiting factors detected for PA adoption in the sugarcane industry, one could mention the cropping system complexity, data handling costs, and lack of appropriate decision support systems. The objective of our research group has been to demonstrate to sugarcane growers and society PA economic advantages, environmental gains and yield/quality benefits in order to help boost its adoption. In this article we report an experiment that has been conducted since 2010 in a commercial site of 50 ha, using grid sampling (50 x 50 m – 204 points) and yield monitor. Results show that after two years of fertilizer application using variable rate technology, the amount of P available in the soil for plant nutrition was better distributed, stable and sufficient to supply crop needs. K requires replacing at different rates at each year, and its average availability for plant nutrition is been reduced. We could not find any pattern in soil K extraction, and it was certainly not related to yield. We also detected that on the first year (plant cane) the lowest part of the field presented the highest yield, but in the following year (first ratoon) the same area presented an abrupt reduction in yield. A deep investigation evidenced that this phenomenon could be explained by ratoon damage during the first harvest. This damage, which is almost impossible to repair and will impair the whole sugarcane cycle, could be detected by PA tools, thus demonstrating the usefulness of PA applied to sugarcane.

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AUTOMATIC DETECTION AND MAPPING OF IRRIGATION SYSTEM FAILURES USING REMOTELY SENSED CANOPY TEMPERATURE AND IMAGE PROCESSING

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Today there is no systematic way to identify and locate failures of irrigation systems mainly because of the labor costs associated with locating the failures. The general aim of this study was to develop an airborne thermal imaging system for semi - automatic monitoring and mapping of irrigation system failures, specifically, of leaks and clogs.

Initially, leaks and clogs were simulated by setting controlled trials in table grapes vineyards and olive groves. Airborne thermal images were acquired over the plots. The canopy temperature of the trees under the different treatments was compared to measured values of stem water potential (SWP). Initial results showed that it is possible to identify abnormalities of approximately 11 bars in olive groves and 3 bars in table grapes.
Consequently, detection of real faults was attempted: a preliminary algorithm was developed to identify suspicious areas (suspected faults) based on the distribution of canopy temperature. To examine the accuracy and reliability of the algorithm five sites were selected with olive groves (Gshur and Revivim), vines (Lachish), palm dates (Kalia and Almog) and almonds (Lavi). Assessing the accuracy and reliability of the algorithm, it was combined with the estimated potential savings in labor. The results indicated the following: 1. according to the map produced by the algorithm, 14-20% of the area has to be scanned, which corresponds to a 60% saving of the time needed to scan the whole area 2. The automatically detected suspicious areas contain 80% of the visible faults. 3. Most of the area that is detected for scan will not contain visible faults. However, it was found that in 70% of the locations suspected for leaks the trees indeed received excess water relative to their surroundings, and in 90% of the locations suspected for clogs the trees suffered from lack of water relative to their surroundings. That is, the map produced by the developed algorithm allows to save about 60% of the scan time, detects about 80% of the visible leaks, and detects leaks and clogs that are not visible with a reliability of 70% and 90% respectively.

Despite the benefits of the semi - automatic algorithm it requires input of four empirical parameters that can change its performance: minimum distance between pixels to create the histogram, size of pixels clusters associated with leaks and clogs, parameters associated with image enhancement (erosion) and allowed tolerance in estimating the location of the leak or clog. The algorithm has not yet been tested on palm dates and we intend to test it in the coming months.

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ARE THERMAL IMAGES ADEQUATE FOR IRRIGATION MANAGEMENT?

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Thermal crop sensing technologies have potential as tools for monitoring and mapping crop water status, improving water use efficiency and precisely managing irrigation. Leaf Water Potential (LWP) measurements by pressure bomb in the boll-filling stage of cotton is currently used as an effective tool for irrigation management. Nevertheless, these measurements do not express the variability in the field. Estimation of LWP from thermal images could address this problem. In previous studies, a regression model for assessing LWP in cotton plants based on crop water stress index calculated using ground and airborne thermal imagery was developed and validated. In this study we applied this model and compared between thermal-based irrigation management and today's common practice. The experimental results show that there is no significant differences between the methods and that cotton can be irrigate efficiently using LWP values that are derived from remotely sensed thermal images. The thermal-based method resulted to similar seasonal water application amounts as the commercial practice, and achieved yields that were slightly higher but with no statistically significant difference from commercial practice ($n=6$, $p=0.01$). For its assimilation the cost effectiveness of the thermal-based irrigation management should be examined in commercial scales. Future study should focus on the applicability of this approach for variable rate irrigation.

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RESPONSE OF RHODES GRASS (CHLORIS GAYANA KUNTH) TO VARIABLE RATE APPLICATION OF IRRIGATION WATER AND FERTILIZER NITROGEN

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Rhodes grass is cultivated extensively in Saudi Arabia under center pivot sprinkler irrigation system. The research work was carried out to optimize irrigation water and fertilizer nitrogen levels for the crop. The objectives of the study were: (1) to delineate the field into management zones, and (2) to study the effects of variable rate application (VRA) of irrigation water and fertilizer nitrogen on the yield of Rhodes grass. A field experiment was carried out from June to November 2012, on a 50 ha farmer's field irrigated by center pivot. The experimental field was divided into two management zones (MZ). Spilt-split plot design was employed with MZ as two main treatments. Sub-treatments were: irrigation at 100, 80, 60 and 40% crop evapotranspiration (ETc); and sub-sub treatments were nitrogen fertilizer levels of 240, 480, 720, 960 and 1200 kg/ha. The mean productivity across three cuts was higher in MZ 2 (8.16 t/ha/cut) than in MZ 1 (7.26 t/ha/cut). The effects of treatments were significant in the last two harvests but not in the first harvest. Significant differences between the management zones were observed only with respect to nitrogen levels but not with respect to irrigation levels. However, deficit irrigation was found to be beneficial in both zones. Across the zones, irrigation at 80 and 60% ETc resulted in higher hay yields in second and third harvests, respectively. By increasing the nitrogen level from 240 to 480 kg/ha, the hay yield increased from 7.58 to 8.46 t/ha/harvest, only in MZ 2, indicating the possible benefit of variable rate application of fertilizer nitrogen. Based on this study, the following conclusions can be drawn: (i) deficit irrigation can be adopted for Rhodes grass by irrigating the crop at 80% ETc for the first two harvests and at 60% ETc for the last/subsequent harvests. 2. Fertilizer nitrogen use can be optimized by adopting VRA technology.

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SITE SPECIFIC DRIP FERTIGATION

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Two test plots, one from high fertility zone and one from low fertility zone were identified and delineated with the help of GPS for raising the test crop. Soil samples were collected from the experimental sites one month before planting. The samples were analyzed for available N, P and K. Site specific nutrient recommendations were made using the Decision Support System for Integrated Fertilizer Recommendation (DSSIFER) software (Murugappan et al. 2004) for optimum yield. Field experiments were conducted to evaluate the effect of site specific drip fertigation in completely randomized design (CRD) with six treatments and four replications. Hybrid chilli (Hot line) was used as the test crop. Package of practices were carried out as per recommendations. Relevant observations on growth parameters at periodic intervals, root characteristics, yield and quality parameters of chilli were recorded and economics viz., gross return, net return and Benefit Cost Ratio (BCR) were calculated. Drip irrigation was scheduled daily (24 hrs) and once in two days (48 hrs) based on the treatments with the computed quantity of water. Phosphorous was applied as one basal dose and two top dressings in the form of super phosphate in three split doses (basal, 30 DAP and 60 DAP). Nitrogen and potassium were applied through fertigation system. Fertigation was done once in five days starting from 15 DAP up to 150 DAP.

The highest total green fruit yield was recorded under the treatment site specific drip fertigation with daily drip irrigation for low fertility area, whereas there was no significant difference between the total yield under the treatments site specific drip fertigation and recommended dose drip fertigation along with daily drip irrigation for high fertility area. The different yield parameters like fruit length, fruit girth, fruit weight and number of fruits per plant also varied in the same trend as that of total green fruit yield. In case of low fertility area, highest BCR was recorded with the treatment site specific drip fertigation and daily drip irrigation (2.42) followed by the treatment site specific drip fertigation and alternate day drip irrigation (2.25). The lowest BCR was recorded under the treatment with manual application of fertilizer and alternate day drip irrigation (1.91). In case of high fertility area, corresponding values of BCR were 2.47. 2.43 and 2. 17 respectively.

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CONTROL SYSTEM APPLIED TO NO-TILL SEEDING FOR HIGH-QUALITY OPERATION

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A high quality crop seeding operation should enable a rapid and uniform establishment of a desired plant population. Therefore, a no-till seeder must provide a seeding environment that allows the absorption of water by seeds and appropriate temperature and aeration conditions for germination and emergence processes. To stimulate these processes, the seed needs full contact with soil in order to accelerate the absorption of water and oxygen. Covering the furrow with straw is another important aspect, since it prevents soil water losses and surface crusting besides reducing soil thermal amplitude and seedlings stress. Soil contact no-till seeder components are responsible for the accomplishment of this overall function, which depends on correct setting of each individual component for residue cutting, furrow opening, distribution of fertilizer and seeds, furrow closing with soil and straw (grounding) and soil compaction laterally or over the seed. However, the setup and consequently the performance of these components is directly influenced by soil water content, compaction state and particle size of topsoil as well as the amount of straw over soil surface. These factors present a remarkable spatial variability and determine, for the same field, different operational conditions for grounding and compaction components of the seeder. Using of control systems at variable rates with electronic maps is not the best option to solve this problem because the required previous analysis of soil parameters is a time consuming and expensive activity and usually is physical and economically unfeasible. Thus, the quality of no-till seeding can be improved by the development of a real-time control system, operating on-the-go, and controlling the operational parameters of the grounding and compaction components based on information generated by a sensing system of soil conditions. The real-time control system discussed in this paper employs a set of transducers for measurement of soil and operational parameters and based on this information and on computational models estimates the main soil conditions and acts on the components of grounding and compaction in order to get a high seeding quality. The logic of the control system and its functional and non-functional specifications were defined from literature and analysis of field experiments at the Agricultural Research Institute of Paraná State (IAPAR), Brazil, between 2011 and 2012. The system will perform the control, in real time, of two no-till seeder components, i.e. the angle of a pair of grounding discs and the compression of a spring of compaction wheels. The control algorithm employs the autoregressive error function (AREF), a neural network and two arrays. The AREF and the neural network estimate soil moisture from time series of forces acting on a narrow tine and from operation speed. The soil moisture and depth of operation data are the inputs to an algorithm which determines the operational parameters of the grounding and compaction components using two arrays. The neural network with better performance was a Multi-Layer Perceptron type, 2-6-1, with sigmoid activation functions. The AREF uses the time series of forces on the narrow tine with a sample rate of 100 Hz, computing the last 3 m (118 in) readings from sampling position. The control system is under development and will consist of four sensors: a pair of load cells that measure horizontal and vertical forces acting on the tine; a radar that measures the tool operation speed and a laser distance sensor that measures the tool operation depth. The processing will be performed by an ARM microcontroller under a Linux operational platform. Two linear actuators with servo-motors will control the seeder components adjusting the working angle of a pair of grounding discs and the working pressure of the furrow compaction wheel.

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FUSION OF MULTI EXPOSURE STEREO IMAGES AND THERMOGRAPHY FOR OBSTACLE DETECTION ON AGRICULTURAL VEHICLES

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Autoguided vehicles have been successfully installed in indoor conditions such as hospitals and warehouses. The success can be contributed to the structured environment and LIDAR sensors stopping the vehicle for anything that it not the flat ground. This will not work in an agricultural context, where the vehicles have to move through tall crops. A fusion of sensors with different strengths and scales has to be used. The drawback of a classifier that merges all sensors to give results is timing, whereas a subset of the sensor suite may be given their own rights to make conclusions. This paper investigates a fusion of HDR stereo and thermography that can further be fused with other sensors but is powerful on its own. It is assumed that traversable paths are known and obstacles can be anything unpredictable. Consequently, a scheme that trains traversable paths, while everything else are obstacles is proposed. This way tall maize crops can be trained as traversable. It was found that water is difficult to handle with these sensors. It was often seen the same way as an abrupt decline that would then urge the vehicle to stop, even if it was just a large puddle.

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INSTRUMENTED BLADES WITH AUTOMATED CONTROL USED IN CHISEL PLOUGH ACTING IN VARIABLE DEPTHS

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Soil compaction is a problem that affects most of the tilled areas of Brazil, being caused by several factors, such as overloading and intense machine traffic, use of unsuitable tires for applied load and inflation pressures outside the recommendation, machines in the field with the water content of the soil not recommended and several other problems. There are available several models and systems of measuring soil compaction in Brazil; however, the sensors of the equipment require processing and interpretation of data. The objective of this work was to design and evaluate a prototype to identify compacted layers of agricultural soils in real time and in varying depths. The equipment was designed to be mounted on the front of the tractor with the vertical movement, for introduction in the soil, controlled by the tractor's central hydraulic system. The calibration of the equipment had been carried out in the area of the NEMPA Tests – test Core of machinery and Agricultural Tires, using compaction detector device calibrator, a penetrometer, in which the index values of cone (CI) have been entered in the data collector for comparison with an average of correlation r = 0,90. After calibration of the equipment has been carried out the test response time between the data obtained by the front sensor and times of ascent and descent of the tine. Then the comparative test between the usual systems with fixed depth of 0.35 m with regular equipment of instrumented stems, with variable depth, measured the parameters of time, fuel consumption, operating force in traction bar, average power, average speed, skating, effective field capacity of tractor and equipment response time. The results showed that, with equipment commanding the operation of chisel plough is used with variable depth, obtained a reduction of 26% operational fuel consumption (L ha-1) and there was an increase of 14% in effective field capacity (ha h-1). The reactions of the proposed equipment to change depth of scarification coincided with the locations and values obtained from soil mechanical resistance indicated by penetrometer, showing good data accuracy. The instrumented system produced maps that showed the spatial variability of soil mechanical resistance, with resolution, sampling density and higher operational capability when compared to surveys conducted with the cone penetrometer, indicating that there had been overestimation of compression by the equipment condition.

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ROW-CROP PLANTER REQUIREMENTS TO SUPPORT VARIABLE-RATE SEEDING OF MAIZE

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Current planting technology possesses the ability to increase crop productivity and improve field efficiency by precisely metering and placing crop seeds. Planter performance depends on using the correct planter and technology setup which consists of determining optimal settings for different planting variables such as seed depth, down pressure, and seed metering unit. The evolution of "Big Data" in agriculture today brings focus on the need for quality as-planted and yield mapping data. Therefore, an investigation was conducted to evaluate the performance of current planting technology for accurate placement of seeds while understanding the accuracy of as-planted data. Two studies consisting of 2 different setups on a 6-row, John Deere planter for seeding of maize (Zea mays L.) were conducted. The first study aimed at assessing planter performance at 2 depth settings (2.5 & 5.0 cm) and 4 different down pressure settings (varying from none to high) with planter setup to perform a uniform seeding rate (65185 seeds/ha) at a constant ground speed (7.0 km/hr). The second study focused on evaluating planter performance during variable-rate seeding with treatments consisting of 2 seed metering units (John Deere Standard and Precision Planting's eSet setups) with 5 different seeding rates (49383, 59259, 69136, 79012 & 88889 seeds/ha) and 4 ground speed treatments (6.0, 7.0, 8.2 & 9.4 km/hr). All treatments were randomized and replicated four times. A data acquisition system was developed for monitoring and logging real-time planting variables such as meter speed and row unit acceleration/vibration with this data tagged using a differential global positioning system (DGPS) receiver in order to create spatial maps. Field data collection for the down pressure study consisted of measuring plant emergence, plant population and seed depth whereas seed spacing, plant population after emergence along with distance and location for rate changes within the field were recorded for the variable-rate seeding study. As-planted data consisting of plant population, seed spacing and meter performance was also recorded using 2 commercially available displays for both studies and analyzed for comparing planter performance based on the actual field data. Crop yield was also measured to evaluate the effect of the different treatments on planter performance. Preliminary results indicated that down pressure impacted crop emergence. Measured seed depth was significantly different from the target depth even though time was spent adjusting the units to achieve the desired. For example, the mean depth for the 5-cm treatment was 3.8-cm in one field and 4.1-cm for another field. Seed depth results indicated variability at times based on field soil conditions which would explain the differences between the target and measured depths. Results from the variable-rate study indicated that seeding rate changes were accomplished within or less than a 1.9-m distance or a quick response time (< 1 sec) regardless of ground speed. This quick response over varying ground speed treatments indicates that current hydraulic drives minimize rate change errors. Row-unit acceleration or ride varied between individual units with one row-unit exhibiting lower ride quality compared to other units and the main toolbar. Planter field performance significantly varied for the two types of metering units. Seed metering unit setup and meter speed (dependent on ground speed and seeding rate) is critical to obtain expected performance of today's planting technology. The results showed that planter performance is dependent on meter speed, and field performance starts degrading at higher meter speeds (> 38 rpm) for both meter setups. Overall, the eSet meter performed better than Standard John Deere meter setup exhibiting more uniform seed spacing and higher crop yields. The study recommended that operators need to ensure the correct planter and display setups in order to achieve needed seed placement performance to support variable-rate seeding.

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AGRIBOT: DEVELOPMENT OF A MOBILE ROBOTIC PLATFORM TO SUPPORT AGRICULTURAL DATA COLLECTION

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Precision Agriculture and agricultural practices that take into account environment protection, leads to several research challenges. Sampling scale and the precision required by these new agricultural practices are often greater than those required by traditional agriculture, raising the costs of production. This whole process requests an expressive number of studies in developing automation instruments. Amongst them, the use of remote sensing techniques based on On-the-Go sensors technology stands out, coupled to a Geographic Information System (GIS) adapted and developed for agricultural use. Therefore, the application of Agricultural Mobile Robots is a strong tendency, mainly in the European Union, USA and Japan. In Brazil, studies are necessary for the development of robotics platforms, serving as basis for semi-autonomous and autonomous navigation systems, facilitating data acquisition in the field. The greatest difference in the agricultural practices between Brazil and other countries is that, at other countries the skilled labor is not an issue and often the farm owner or family members perform field operations. Consequently, tasks automation can provide more comfort and reduce working days. Moreover, as it is considered a strategic sector, the government provides subsidies to producers in order to ensure at least part of internal consumption. The access to technology is also a differential characteristic, due to its high price or even unavailability in Brazil. Thereby, in Brazil, autonomous systems are supposed to meet the needs of the scarceness of qualified professionals, in face of the rising demands; in addition to serve as a laboratory for the development of national technology. The aim of this study is to describe the project of a mobile robotic platform designed to be used for the development of control systems, navigation and data acquisition technologies for agriculture. The main application of the platform is to perform remote sensing of agronomic parameters in large areas, at the most important Brazilian crops. The platform does not require actions with high power, as in traditional agricultural operations, but has to move efficiently in this environment. The platform should enable the massive data acquisition required to study the spatial variability, through sensors and equipment that will be embedded in the platform. The proposal is based on a systematization of scientific work containing the main methodologies and technologies employed in agricultural vehicles and robots, which were used as a basis for constructing the presented model. Furthermore, a preliminary study of working conditions and the desired characteristics of the project were performed. The design of the mobile robotic platform has been developed entirely in a virtual environment by 3D CAD software. This allows checking for interference between components during operation and, if necessary, changes in the design can be done. Moreover, data from the computer model are used to create the kinematic and dynamic models. It was established that the structure would be rectangular in gantry shape, with 1.80 m between the ground and the base of the chassis. The propulsion and the steering system are 4WD and 4WS, respectively, with each wheel fully independent from each other. A turbo diesel engine was used as main power source and hydraulic systems with proportional valves were used for power transmission. The actuators control is performed by dedicated controllers that receive the control parameters by network, and perform the control of the actuators in a closed loop control system. The data transmission between controllers and an embedded computer, which contains other sub-routines (localization, navigation, data collection), is carried out by a CAN fieldbus. Finally, a wireless network with Ethernet standard is responsible for the communication between the mobile robot platform and the control station.

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IN-SEASON NITROGEN REQUIREMENT FOR MAIZE USING MODEL AND SENSOR-BASED RECOMMENDATION APPROACHES

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Nitrogen (N) management for corn (Zea mays L.) can be improved by applying a portion of the total required N in-season, allowing for adjustments which are responsive to actual field conditions. This study was conducted to evaluate two approaches for determining in-season N rates: Maize-N model and active crop canopy sensor. The effects of corn hybrid and planting population on recommendations with these two approaches were considered. In a 2-yr study, a total of twelve sites were evaluated over a 3-state region, including sites in Missouri, Nebraska, and North Dakota. Over all site-years combined, in-season N recommendations were generally lower when using the sensor-based approach than the model-based approach. This resulted in observed trends of higher partial factor productivity of N (PFPN) and agronomic efficiency (AE) for the sensor-based treatments than the model-based treatments. Overall, yield was better protected by using the model-based approach than the sensor-based approach. For two Nebraska sites in 2012 where high levels of N mineralization were present, the sensor approach appropriately reduced N application, resulting in no decrease in yield and increased profitability when compared with the non-N-limiting reference. This indicates that specific conditions will increase the environmental and economic benefit of the sensor-based approach. The optimal N rate (ONR) was also determined using a linear-plateau model, considering hybrid and population differences ($P \leq 0.05$) for both the linear and plateau parts of the model.

Compared to the ONR, the model-based approach more closely estimated ONR than the sensor-based approach when considering all sites collectively. Overall, the model-based approach erred by over-recommending N, while the sensor-based approach erred by under-recommending N.

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ACTIVE OPTICAL SENSOR ALGORITHMS FOR CORN YIELD PREDICTION AND IN-SEASON N APPLICATION IN NORTH DAKOTA

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A recent series of seventy seven field N rate experiments with corn (Zea mays, L.) in North Dakota was conducted. Multiple regression analysis of the characteristics of the data set indicated that segregating the data into those with high clay soils and those with medium textures increased the relationship between N rate and corn yield. However, the nearly linear positive slope relationship in high clay soils and coarser texture soils with lower yield productivity indicated that rate alone is not a good solution for N management in these soils. Split application of N would be necessary to increase N efficiency in N-loss challenged soils. In sixty of these data sets, the GreenSeeker™ and Holland Scientific Crop Circle™ sensors were used at V6 and V12 growth stages using the red-NDVI and red edge-NDVI optional light and detection filters. Manual canopy measurement was also conducted in these experiments at both growth stages. In 2013, an automatic acoustic height sensor was also tested the date of sensing at most sites. Yield and INSEY (in-season-estimate of yield/ instrument reading divided by growing degree days from planting to sensing) at V6 was generally better related using red-NDVI compared to V12. Red edge NDVI based INSEY was more strongly related to yield compared to red-NDVI based INSEY at V12. Crop height tended to increase the relationship with yield at V6 with red and red edge-NDVI based INSEY, but only the red-NDVI INSEY benefited from crop height at V12. Separate active-optical sensor algorithms are planned for use in residual soils west of the Missouri river. In eastern North Dakota, separate algorithms have been developed for fields in no-till more than six years, for conventional till fields on high clay soils with greater than 9.9 Mg ha-1 and less than 9.9 Mg ha-1, and for conventional tilled medium textured soils with greater than 9,9 Mg ha-1 and less than 9.9 Mg ha-1.

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OPTICAL SENSORS TO PREDICT NITROGEN DEMAND BY SUGARCANE

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The low effectiveness of nitrogen (N) from fertilizer is a substantial concern worldwide and has been threatening the sustainability of sugarcane production. The increment of nitrogen use efficiency (NUE) by sugarcane genotypes associated to the best practices of fertilizer management and nutritional diagnosis methods have a potential to reduce environment impacts of nitrogen fertilization. Due to the difficult to determine N status in soil test as well as there is no crop parameters to recommend N for sugarcane in Brazil, emerge the possibility to use optical sensor to monitor crop nutritional demand, such as those used to measure indirectly chlorophyll content as N status indicator. This technique is very common for scientific purposes, but for commercial fields it has few adoption. On the other hand, precision agriculture techniques may be one alternative to increase sustainability and crop production, and for localized management of fertilizers, mainly N-fertilizers, which will contribute to reduce N-fertilizer rate as well as decreasing environmental impacts. Therein it is evident that the application of N-fertilizer for sugarcane might not only be associated to the expected yield, methodology that has been applied by experts for recommendation of nitrogen fertilization. The diagnosis of nutritional status of N in sugarcane made by optical sensors "on-the -go" (real-time reading) seems to be one of the promising options to overcome this technological bottleneck. The aim of this work was to assess the nutritional diagnosis of sugarcane crop in N using active optical sensor, performing evaluation throughout the growth cycle of the crop. For this two experiments were established in sugarcane ratoon (2nd ratoon), which has been green harvesting. The N-fertilization has increased crop yield in one of the experiments, where the maximum stalks yield was obtained using 100 kg ha-1 of N. In this experimental area, the Pearson correlation showed that NDVI data obtained at 90 days after harvest (DAH) by the optical active sensor was able to predict sugarcane yield showing a strong correlation to N rates applied (>90%). The N content in leaves (L+1) has the best correlation to N rates at 120 DAH, and at this time both optical sensor were able to predict the differences among treatments having correlation to N content in leaves. The results from this work showed an interesting possibility of predict N demand, which has been encouraging our group to evaluating more areas in order to obtain a N fertilizer response functions that relate sensor readings to the amount of N fertilizer needed to overcome crop N stress.

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COTTON FIELD RELATIONS OF PLANT HEIGHT TO BIOMASS ACCUMULATION AND N-UPTAKE ON CONVENTIONAL AND NARROW ROW SYSTEMS

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Cotton field management remains a challenge for growers, especially due to spatial variability of soil conditions, which demands the use of variable rate application technology (VRT) for nitrogen and growth regulators. Canopy optical reflectance sensors are being studied as an option to detect infield variability but may have some limitations due to the known effect of signal saturation when used on very dense canopies. Based on that, two commercial fields located on the state of Goiás, middle west Brazil, one planted on conventional row system and other conducted on narrow rows system were investigated during the 2012/13 growing season. Each field was scanned with an optical reflectance canopy sensor three times during the season based on days after planting, followed by manual sampling for crop height, biomass and N content on 30 spots inside the area, guided by the field variability shown by the optical canopy sensor. The height of the cotton plant showed a high correlation with biomass and nitrogen uptake, and does not suffer saturation problems at late stages on both planting systems. This technology may be used as base for VRT nitrogen and growth regulator applications, or be combined with reflectance canopy sensors to improve accuracy at late split application, where canopy reflectance sensors are susceptible to lose accuracy.

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THE SPATIAL AND TEMPORAL VARIABILITY ANALYSIS OF WHEAT YIELD IN SUBURBAN OF BEIJING

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The yield map is the basis of the fertilization maps and plant maps. In order to diagnose the cause of variation accurately, not only the spatial variation of annual yield data, but also the successive annual yield data of temporal variability should be understood.The introduction of yield monitor system, global positioning system (GPS), and geographic information system have provided new methods to obtain wheat yield in precision agriculture. Although the description of the spatial and temporal variability could be finished more easily, little information was known about the spatial and temporal variability of wheat yield patterns, currently. One important application of yield map data was the study of the spatial and temporal properties of yield distribution. It was important information before implementing any site-specific management strategy. The objective of this study was to analyze the spatial and temporal yield variability of wheat grown in suburban of Beijing. Wheat yield data was collected from 2004 to 2013 and the location was N 40.175442°~40.179111°,E 116.439751°~116.442436°. Because of the equipment cause, only eight years' data was collected, the missing data was 2010 and 2011. The harvest combine was CASE 2366 equipped with AFS yield monitor system. The yield monitor system included wheat yield flow sensor, moisture and temperature sensor, ground speed sensor, elevator speed sensor, header height sensor and DGPS. According to the wheat yield data of one year, spatial variability was analyzed. According to the past eight years' data, temporal variability was analyzed. On the basis of spatial and temporal analysis, a new farmland classified management method was proposed. According to the coefficient of variation, the entire field was divided into four parts: high and stable yield area, middle and stable yield area, low and stable yield area and unstable yield area. Typically, high degree of variation place had the potential to increase yield. For the high and stable yield area, middle and stable yield area and low and stable yield area, the wheat yield potential is small, however, for the unstable yield area, more research should be needed from soil physical and chemical properties, as well as fertilization, planting, and so on. When the reasons were conducted from the data, management method could be carried out to improve the wheat yield in the future. The site-specific method could make low cost and improve the potential wheat yield.

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A COMPREHENSIVE MODEL FOR FARMLAND QUALITY EVALUATION WITH MULTI-SOURCE SPATIAL INFORMATION

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Farmland quality represents various properties, including two parts of natural influencing factors and social influencing factors. The natural factors and social factors are interrelated and interaction, which determine the developing direction of farmland system. In order to overcome the limitation of subjective factors and fuzzy incompatible information, a more scientific evaluation method of farmland quality should be developed to reflect the essential characteristic of farmland. The multi-information used to evaluate farmland quality could be not only derived from remote sensing data, but also derived from spatial data by GIS technology.

According to the existing standard of farmland classification and grading, the study adopted analytic hierarchy process (AHP) to screen variable factors of farmland quality, which could be mapped by spatial analysis technology. The natural influencing factors of farmland quality used in the study included soil organic matter, soil type, soil moisture, soil fertility, degree of land desertification, slope and soil PH. The social influencing factors included farmland use intensity, pollution of soil heavy metal, crop planting scale and location factors. All influencing factors were mapped by GIS or RS technology. Each influencing factors should be normalized to settle the lack of comparability with each other. The Delphi method was used to determine the weight of each influencing factors. The fully covered QuickBird images with high resolution were used to digitize the farmland parcels in the study area. Taking the farmland parcels as basic units, the comprehensive evaluation model for farmland quality was developed, through which the spatial patterns of farmland quality in Shunyi County in Beijing City was analyzed. The farmland quality in the study area was divided into five levels by the method of density slicing and the references of farmland gradation. The spatial distribution of farmland quality gradation in the Shunyi County was mapped. Results showed that the proportions of farmland quality in the study area were 7.73%, 25.23%, 32.89%, 18.48% and 15.66% respectively. The farmland quality level in the west of Chaobai River was lower than the other region, because of the decrease input of farmland nearby the city. The traditional agriculture dominated in the most villages and towns, of which the inputs of fertilizer were more than the west. The farmland with the first level of quality was loamy soil with rich nutriment, good irrigation and high road density. The farmland quality in the study area was mainly second and third levels, which was the main food grain region of Beijing city. The fourth and fifth level of farmland was easily influenced by urbanization and managed badly, which reduce the quality level of farmland. The spatial distribution of farmland with different quality levels derived from the developed model was basically consistent with the data of the department of Agriculture in the study area. It indicated that the comprehensive evaluation model with multi-source spatial information could map the farmland with different quality level effectively.

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PHYSIOLOGICAL REPSONSES OF CORN TO VARIABLE SEEDING RATES IN LANDSCAPE-SCALE STRIP TRIALS

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Yield improvements over the past few decades have been attributed to increasing optimum plant population and not the increase of grain produced per plant. A goal in precision agriculture is to identify seeding rates that optimize yield, but that also minimize intra-specific competition. Intra-specific competition occurs when plants of the same species compete for vital resources needed for plant growth and fruit development. Intra-specific competition can cause stress for multiple resources crucial to plant growth and performance.

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SPATIAL DEPENDENCE OF SOIL COMPACTION IN ANNUAL CYCLE OF DIFFERENT CULTURE OF CANE SUGAR FOR SANDY SOIL

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Mechanization currently practiced for the production of cane sugar involves a heavy traffic of machinery and equipment. Studying culture in your development environment generates a huge amount of information to fit the top managements and varieties for specific environments. The culture of cane sugar has a heavy traffic of machinery and equipment, where more than 20 operations per cycle , more intense during harvest , providing increased soil compaction and enhancing these effects when applied indiscriminately conditions the water content of the soil unsuitable. This work was carried out to evaluate the soil physical degradation in relation to the sequence of annual crop production of cane sugar, on a Typic Ferric with sandy texture and calculated the Soil Cone Index (SCI) in depth ranges: 0-0.10, 0.10-0.20, 0.20-0.30, 0.30-0.40 and 0.40-0.50 cm. Were evaluated during three subsequent seasons the productive area of cane sugar mill belonging to Barra Grande, the Zilor group located in the region of Paulista - SP. For soil sampling it was used the Mobile Soil Sampling Unit - UMAS – belonging to Agroforestry Machinary and tire Test Center - NEMPA, Department of Rural Engineering, College of Agricultural Sciences - FCA - UNESP, Botucatu - SP. Sampling points in the areas and in subsequent crop cycles (subsequent years), samples were taken with a sampling grid of 30 x 50 m, and every 30 meters between points following the line of planting sugar cane and every 50 meters between plant rows (in the line traffic) for resistance to penetration. Data were analyzed using geostatistical analysis. The models were adjusted by GS + 7.0 program. To analyze the degree of spatial dependence of the attributes under study, we used the classification Cambardella, which considers the strong spatial dependence semivariogram nugget that have a lower or equal to the threshold effect 0.25, moderate when between 0.25 and 0.75 and poor when it is greater than 0.75. There was a reduction in productivity in subsequent cycles, with the greatest reduction occurred in areas with sandy soils to the 3rd cycle of the crop. It was found that in areas with higher productivity reduction over the cycles, the values of cone index soil were higher than 3.5 MPa, the layers 0-0.30 m, in line with the culture of cane sugar.

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PROBABILITY DISTRIBUTIONS AND ALTERNATIVE TRANSFORMATIONS OF SOIL TEST NO3-N AND PO4-P, IMPLICATIONS FOR PRECISION AGRICULTURE

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Several alternative distribution functions and transformations of soil test N and P to normality are discussed.

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SOIL AND CROP SPATIAL VARIABILITY IN COTTON GROWN ON DEEP BLACK COTTON SOILS

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Cotton is an important commercial crop and forms principal raw material for a textile industry. Nutrient management in cotton is complex due to simultaneous production of vegetative and reproductive structures during the active growth phase. Bt. cotton retains relatively more number of bolls and synchronous boll development and hence it needs higher nutrients compared to Non Bt cotton. In view of this an experiment was conducted to study the spatial variability in soil with respect to soil properties and their effect on seed cotton yield.

The experimental site distributed from latitude: 15o 27.58'' to 15o 27.55 N and longitude 75o 2.82 to 75o 2.95 East. Totally, 73 soil samples were drawn up to 15 cm depth from 4 hectare area at 20 m grid. The location of the sample was recorded using GPS. The soil spatial variability for major, secondary and micro nutrients are assessed as per the criteria given by (Arora, 2002) by following standard analytical techniques (Jackson, 1973). Based on the soil fertility status, a field experiment on precision nutrient management was carried out by fixing 4 target yields (25, 30, 35 and 40 q/ha) by delineating 5 management zones based on major soil nutrient status (LLM, LMM, LMH, LLH and Soil test crop response (STCR) (Fig.1 and 2). The required soil nutrient maps were generated based on site specific nutrient management (SSNM) concept and the target yield. Variable rate of nutrients were applied to each grid manually.

Soil spatial variability observed with respect to all chemical properties within the 4 hectare of cotton growing soil. The soil pH varied from 7.36 to 8.82, EC varied from 0.06 - 0.28 dS/m, organic carbon from 0.19 and 1.44 %. Similarly, major nutrients also varied widely ranging from 100.8 to 756 kg N/ha, 0.81 to 52.2 kg P/ha and 102 to 1245 kg K/ha with an average value of 153.8, 7.63 and 218 kg available N, P and K /ha, respectively. Further, soil fertility status shows that, 98 and 2 per cent of the soil samples were low and high in available N. Nagaraj (2001) observed a similar trend of nutrient status in black soils of North Karnataka. With respect to P, 79 and 18 per cent of the samples were low and medium respectively. However, in majority of the grids, available K status was medium (81%) to high (19%).

Similar to N, 95 percent of the grids shown low in available S status as compared to medium (4%) and high level (1%). Micronutrient status was not different from major nutrients. Most of the soil samples were below the critical level in available Fe (100%), Mn (97%), and Zn (95%) status. However, only Cu status was above the critical limit .In black soils, low Fe content may be due to precipitation of Fe2+ by CaCO3. Since, the soils are alkaline and rich in CaCO3, zinc may be precipitated as hydroxides and carbonates under alkali pH range (Ravikumar et al., 2007). The observations on crop spatial variability revealed that, all the growth (plant height, Monopodium and Sympodial branches) and yield parameters (Number of squares and green bolls/plant) were higher with 40 quintal target yield grids in LMH management zone (Low in N, Medium in P and High in K) wherein it received maximum inputs. The crop was infested by flower bud maggot (Midge) in all the grids at peak square formation stage and creates hurdle in reaching the targeted yields. The seed cotton yield levels varied from 17.17 q/ha to 31.94 q/ha with an average yield of 25.80 q/ha. Higher seed cotton yield of 31.94 and 31.56 q/ha recorded with the application of nutrients required to achieve 35 quintal target yield in LLM management zone. However, the seed cotton yields were higher in LMH management zone at all targets. The seed cotton yield was higher with the application of nutrients required to achieve 40 q/ha target yield than 25 q/ha.

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SOIL CHARACTERIZATION AND MAPPING ACCORDING TO SHALLOW AND DEEP APPARENT ELECTRICAL CONDUCTIVITY

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Agriculture and Agri-Food Canada and Effigis Geo Solutions

In precision agriculture, knowledge of soil variability is essential to the optimal management of on-farm nitrogen applications to grain corn. Measuring the apparent electrical conductivity (ECa) of soils makes it possible to characterize and map specific soil properties such as soil texture and drainage. Our research into post-emergence application of nitrogenous (N) fertilizers to grain corn crops revealed that N dosages modulated by surface ECa classes take into account only part of the soil variability that must be considered. The purpose of this study is to confirm deep (granulometry of parent materials and soil drainage) and shallow ECa measurements in order to characterize and map maximum soil properties with a view to optimizing N in a variable rate application perspective. About 20 fields were mapped using a Veris 3100 EC (Veris Technologies Inc., Salina, KS). Hundreds of soil profiles in these fields were described and identified in soil series; some were sampled for horizons A, B and C to determine granulometry and texture. On several other sites in these fields, topsoil samples were taken to determine the granulometry, texture class and organic matter percentage of soils. The electrical conductivity data gathered with the Veris mapping machine were interpolated by kriging and mapped at a one-square-metre resolution with ArcGIS (ESRI, Redlands, CA). The databases were scrubbed of inconsistent data beforehand, and the spatial pattern was verified with the aid of semi-variogram modelling. Shallow (0-30 cm) and deep (0-90 cm) values were processed separately. Deep apparent electrical conductivity (ECa d) maps were sorted into six classes according to the granulometry of parent materials and drainage, ranging from 10 for well-drained skeletal materials to 60 for very fine clays with very-poor-to-poor drainage; shallow apparent electrical conductivity (ECa s) maps were separated into five classes according to the texture of topsoil, ranging from 1 for coarse to 5 for fine to very fine textures. Both maps were then combined to create a new map (ECa ds) with values ranging from 11 for skeletal materials with coarse surface texture to 65 for very fine clayey materials with a fine-to-very-fine surface texture. By studying the correlations between deep and shallow ECa values and the data for the granulometry of parent materials, topsoil and soil drainage, it was possible to determine specific ECa ds classes by soil type and surface texture (soil series and surface texture phases). It will thus be possible, using available soil maps for the Montérégie region of Quebec, to estimate ECa classes and adjust the doses of post-emergence applications of N fertilizers to grain corn crops to match the variability of soils.

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3D MAP IN THE DEPTH DIRECTION OF FIELD FOR PRECISION AGRICULTURE

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This study aims to establish an agricultural support system with advanced agricultural knowledge and technology that can support for any production area or varieties using IT. In this study, we investigated the availability of soil information collected using the soil moisture sensor to create the 3D map in the depth direction on citrus slope field. In addition, we developed a specification of the soil sensing system for slope field because there are many restrictions sensing of soil in the slope field. After this study, soil information in the direction on slope field can be represented in 3D map. Moreover, it is considered that the 3D map can be used as an index of the irrigation program.

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DESIGN AND IMPLEMENTATION OF AGRICULTURAL SENSOR DATA OF MULTIPLE AND HETEROGENEOUS ACCESS ARCHITECTURE

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For the moment, the Internet of things system oriented to the whole industry chain is gradually established in some fields of agriculture; At the same time, traditional management style of agricultural sensor data lack effective sharing mechanism, that can not meet the demand of agricultural network system for the multiple and heterogeneous sensor data. Especially with the growing the demand of agricultural products quality safety supervision system to the monitoring of agricultural products planting, production, transportation, sales process, that is requiring a large number of heterogeneous sensor data to support.

In the face of massive and heterogeneous sensing data, how to build an effective data access architecture,that is the first problem to solve the data sharing of agricultural sensor data. the paper is based on the existing sensor data access technology, combined with the cleaning technology and the buffer mechanism, explore the access mechanism of a multiple and heterogeneous agricultural sensor data for the multiple, heterogeneous and unstable characteristics of agricultural sensor data, and design the he access architecture is an agricultural sense data. it is consists of The Data Adapter Module, The Data Cleaning Module, The Data Buffer Module and The Thread Management Module. In The Data Adapter Module.Mainly studies the adapter resources dynamic allocation mechanism based on the Chukwa framework, using dynamic distribution principle of the Agent to realize the data adapter; And through the design of data buffer pool mechanism, solve data processing problem when large number of sensor data access in the short time; and add data thread management module, dynamically manage data access link thread, that realize concurrent mechanism of data access based on the above two; the other designed the data access port by using the Socket transport mechanism for non blocking communication mode. In addition, the distributed deployment mode which this architecture using increase the system load balance ability, and loose coupling, strong scalability, stability characteristics, can meet the demand of high concurrent processing of massive data.

In this paper, for the need of heterogeneous sensor data in agricultural products quality safety supervision system of the agricultural production, transportation, sales process. done the data access test. At present, the system has been successfully access the aquatic, logistics, field, facilities and other different types of agricultural sensor data, the test results show that multiple and heterogeneous agricultural sensor data access architecture can meet the need of access and processing for massive agricultural sensor data.

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X-RAY COMPUTED TOMOGRAPHY FOR STATE OF THE ART PLANT AND ROOT ANALYSIS

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During the last years, the formerly in medical applications established technique of X-ray computed tomography (CT) is used for non-destructive material analysis as well. Adapting this technique for the visualization and analysis of growth processes of plants above and underneath the soil enables new possibilities in the so called smart agriculture. Using State-of-the-art CT systems the computed 3D volume datasets allows the visualization and virtual analysis of hidden structures like roots or tubers in the substrate, or a detailed structural analysis of sprout features like caulis, leaves and branches. This is a completely renewed approach to phenotyping without the need of a huge amount of plants. Due to the non-destructive technique time resolved CT measurements can be conducted at the same plant.

CT is based on the generation of multiple X-ray projections of the specimen from different angles of view. The projection dataset is used for computing a three-dimensional CT volume dataset whereas the spatial resolution depends on geometrical properties of the CT system and the reconstruction algorithm. As a special application for this kind of CT experiment the in-situ measurement of the growth of potatoes tubers will be presented with a strong emphasis on the evaluation of the 3D volume data. This is of special interest due to the predicted climate change in the next years. Hot periods in early growth stages are critical for some varieties of potatoes. Different applications for phenotyping evaluation will be discussed additionally.

In contrast to most of the established techniques for tuber analysis the plant growth is not affected by CT directly. Depending on the application and the geometric access special CT acquisition and image evaluation methods had to be developed and used. A high quality 3D measurement requires a 3D access to the object as well. An outlook of developments in X-ray components, imaging and volume data set analysis methods, possible system setups, applications and possibilities will conclude the poster.

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APPLICATION BASED WIRELESS SENSOR NODE FOR UNDERGROUND MOISTURE SENSING FOR PRECISION AGRICULTURE

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In this paper, we are attempting to examine the WUWSN (wireless underground water sensor node*) for precision agriculture. The development and function of this sensor along with its software application is described in this paper. The equipment is under testing and the laboratory results and interpretations are discussed in this paper. This equipment is based on the new concept of sensing underground soil moisture. The sensor is cost effective sensor and has a long life span without any drawbacks of contamination of soil and it's surrounding environment. This system helps in precision agriculture and irrigation in monitoring 18 inches underground water for green house or the targeted field. It gives the status of the water required by the crop. It thus enhances the analysis and decision making system for controlling the growth and quality of yield. This equipment is based on the principal of measurement of a dielectric value of the surrounding media. In this case it is soil. We explore the different parameters such as the moisture content which affect the dielectric value of the soil. In future we would further focus on various other parameters such as pH value, electric conductivity, temperature, etc using the same equipment.

Wireless underground water sensor node contains sensors and communication unit. This node can detect the underground water with wireless communication capability. This is an innovative approach for determining the soil moisture content and to update the information to the server through RF. This system is more useful for precision agriculture in finding the exact requirement of water for different crops. The sensor works on the principle of change in capacitance which occurs due to the change in dielectric property of the soil. This change is acquired by data acquisition system and the data is transferred through the communication unit. It is transmitted to the collection point for further analysis and decision making of the system. The communication of each node is based on the application based protocol for wireless sensor network. This node is useful in various application sectors for remote underground water sensing and monitoring. *Patented IPI 453/MUM/2013
Keywords—Soil moisture sensor, Wireless Sensor for underground water sensing.

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DEVELOPMENT OF A PORTABLE PLANT GROWTH MONITORING AND DIAGNOSTIC INSTRUMENT

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In order to access the growth information of crop fast, non-destructively and in real-time, a portable crop growth monitoring diagnostic instrument was developed based on spectral monitoring mechanism of crop growth indicators. The instrument included a multi-spectral sensor, the processor and affiliated institutions, which can access the growth indexes of crop, such as leaf nitrogen content, leaf nitrogen accumulation, leaf area index and leaf dry weight. The multi- spectral sensor contained two optical channels to collect the crop canopy spectral data at the wavebands of 720nm and 810nm. Optical filtering technique was used to improve the input signal to noise ratio of optical radiation. Based on crop canopy characteristics and operating environment in the field, the suitable structure parameters of optical channels were designed, ensuring that sensitivity and resolution effect of multi-spectral sensor. The processor was consisted of weak signal conditioning circuit, microcomputer and interface circuit. The processor was used to receive, display and store all the date from sensor, fuse the crop growth monitoring model and obtain the crop growth indicators. The calibration tests verified a good performance in terms of the static and dynamic characteristic, linear correlation coefficient was over 0.95, the hysteresis error of optical channels at 720nm was 3.35%, and at 810nm was 2.22%, with the smaller measurement error caused by the solar light irradiation changes, the average error of optical channels at 720nm was 1.43% and at 810nm was 1.38%. The rice experiments showed that the instrument has excellent performance on monitoring growth indexes of crop, the value of DVI had relationship with rice canopy leaf nitrogen, nitrogen accumulation, leaf area index and leaf dry weight, the correlation coefficient R2 was 0.8596, 0.8393, 0.8795 and 0.883 respectively, and average measurement error of which were 6.14%, 8.29%, 6.24%, 6.18% respectively. The structure of instrument has character as simple, highly integrated, cost-effective, convenient to carry and easy to operate in fields.

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IN-SEASON DECISION SUPPORT TOOLS FOR ESTIMATING NITROGEN SIDE-DRESS RATES FOR MAIZE (ZEA MAYS L.)

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Nitrogen fertilizer has been synthetically produced to nourish plants, increase yield and improve harvest quality. One of the way to increase NUE is called split application which is apply portion of N fertilizer from the beginning and apply another portion during vegetative stage (V4-V6). Improving accuracy of corn side dress N rate recommendations can improve profitability and reduce potential negative environmental impacts of over fertilization. The objective of this experiment is to compare yield and NUE of side-dress rates prescribed by: 1) the Virginia Corn Algorithm (VCA); 2) the Maize-N computer simulation model; and 3) the Nutrient Expert (NE) for Maize computer simulation model to the standard rate growers would currently apply. Total of four field experiments were established in 2012 and 2013 with four replications in a randomized complete block design. Treatments evaluated included a complete factorial of four different pre-plant rates (0, 44.8, 89.6 and 134.4 kg ha-1) with the three different simulation model-prescribed rates and the standard Virginia method. In 2012 data showed that NE has the highest Nitrogen Use Efficiency (NUE) which produced 55 kg grain yield with every kilograms of nitrogen fertilizer applied. However data in 2013 showed two locations have the highest NUE by using Virginia Corn Algorithm with GreenSeeker sensor.

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ADVANCED REMOTE SENSING FROM AGRICULTURAL AIRCRAFT AND NEW UNMANNED AERIAL PLATFORMS IN PLANT HEALTH ASSESSMENT

S. Thomson, Y. Huang, K. N. Reddy, D. K. Fisher

USDA ARS

Remote sensing technology is critical for plant health assessment to aid in precision application and management programs. For solving different problems, various scales and bands of sensors are needed. We developed color-infrared (CIR) and thermal infrared (TIR) imaging systems for both airborne piloted and unmanned aircraft, and visible near-infrared (VNIR) hyperspectral imaging systems for ground-based and laboratory-scale operations. Using Color-Infrared (CIR) and thermal infrared imaging (TIR), we mapped crop injury induced by off-target drift from applied herbicides and assessed crop canopy temperature as it relates to crop water stress. With VNIR hyperspectral imaging systems, we characterized the subtle changes in crop spectrum to identify the onset of crop stress caused by factors such as herbicide damage, water deficit, and nitrogen deficiency. This allows crop stress to be detected early before symptoms become visible so appropriate actions for timely remediation can be taken. With the adoption of herbicide-resistant (HR) crops, repeated and intensive use of herbicide has exerted high selection pressure on weed populations, resulting in the evolution of HR weeds. Identification of HR weed species and populations in a crop field is important in practice, but the identification process is tedious and labor-intensive. Alternatively, sensitive optical remote sensing could provide a rapid, non-intrusive way to differentiate HR weeds from herbicide-sensitive (HS) weeds.

We demonstrate the systems and application of the systems, including aerial CIR mapping of crop injury from glyphosate, aerial TIR mapping for crop stress management, laboratory VNIR imaging for early detection crop injury from glyphosate, and field VNIR imaging for differentiation of GR and GS weed species. New low cost unmanned aerial systems for rapid plant health assessment are also described. Limitations for application of the systems are also discussed.

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STUDY ON PLANT HEALTH CONDITION MONITORING USING ACOUSTIC RADIATION FORCE

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When considering a future water problem, saving of water for agricultural use is important, and there is the optimal irrigation control as the one effective means. However, in order to realize it, it is necessary to grasp for what water the plant needs now in un-invading and real time. Then, we examined whether evaluation of plant health condition would be possible using change of the resonance frequency which occurs when vibrating a leaf and a stalk. It became clear from the experimental result using the acoustic radiation force of a parametric speaker that a plant water stress state can estimate from change of resonance frequency.

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MONITORING RATIO OF LEAF CARBON TO NITROGEN IN WINTER WHEAT BASED ON HYPERSPECTRAL MEASUREMENTS

X.-G. Xu, H.-K. Feng, Z.-H. Li, G.-J. Yang, X.-Y. Song

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Ratio of carbon to nitrogen (C/N) in leaves, defined as the ratio of LCC (leaf carbon concentration) to LNC (leaf nitrogen concentration), is a good indicator for synthetically diagnosing the balance of carbon and nitrogen, nutrient status, and growth vigor in crop plants. So it is very significant for effective diagnosis and dynamic regulation of crop growth in field to monitor changes of leaf C/N quickly and accurately. Considering the close relationships between chlorophyll, nitrogen (N) and C/N, five typical indices aimed at N estimation were tested to estimate C/N in winter wheat as well as five indices aimed at chlorophyll evaluation in this study. The multi-temporal hyperspectral data from the four stages (flag-leaf, anthesis, filling, and milk-ripe) of winter wheat were obtained to calculate these selected spectral indices for evaluating C/N in winter wheat. The results showed that some tested indices were able to estimate leaf C/N in winter wheat, especially the spectral indices, MCARI/OSAVI2 and MTCI had the better performance of estimating C/N with R2 of 0.51 and 0.49, RMSE of 1.35 and 1.39, respectively. In order to improve the accuracy of C/N estimates, PLS (Partial Least Squares) was used to estimate C/N in winter wheat, and the analyses showed that a better accuracy with R2 of 0.60 and RMSE of 1.23 was obtained when using PLS. It indicates that applying hyperspectral reflectance measurements for monitoring leaf C/N in winter wheat appears very potential.

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CREATION OF PRESCRIPTION FOR OPTIMAL NITROGEN FERTILIZATION THROUGH EVALUATION OF SOIL CARBON AMOUNT USING REMOTELY SENSED DATA

C. Hongo, E. Tamura, K. Aijima, K. Niwa, O. Nagata, K. Wakabayashi

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Ratio of carbon to nitrogen (C/N) in leaves, defined as the ratio of LCC (leaf carbon concentration) to LNC (leaf nitrogen concentration), is a good indicator for synthetically diagnosing the balance of carbon and nitrogen, nutrient status, and growth vigor in crop plants. So it is very significant for effective diagnosis and dynamic regulation of crop growth in field to monitor changes of leaf C/N quickly and accurately. Considering the close relationships between chlorophyll, nitrogen (N) and C/N, five typical indices aimed at N estimation were tested to estimate C/N in winter wheat as well as five indices aimed at chlorophyll evaluation in this study. The multi-temporal hyperspectral data from the four stages (flag-leaf, anthesis, filling, and milk-ripe) of winter wheat were obtained to calculate these selected spectral indices for evaluating C/N in winter wheat. The results showed that some tested indices were able to estimate leaf C/N in winter wheat, especially the spectral indices, MCARI/OSAVI2 and MTCI had the better performance of estimating C/N with R2 of 0.51 and 0.49, RMSE of 1.35 and 1.39, respectively. In order to improve the accuracy of C/N estimates, PLS (Partial Least Squares) was used to estimate C/N in winter wheat, and the analyses showed that a better accuracy with R2 of 0.60 and RMSE of 1.23 was obtained when using PLS. It indicates that applying hyperspectral reflectance measurements for monitoring leaf C/N in winter wheat appears very potential.

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UNDERSTANDING SPATIAL VARIABILITY OF RICE YIELD IN ITALY USING REMOTE SENSING

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Measuring plant bio-physiological parameters in a field can be expensive and time consuming. Vegetation indices from proximal and remote sensing can be used to estimate variables as well as to overcome the problem of entering in rice paddies. This study aims to explore the potential of vegetation indices (i) to identify presence of of weed and plant stand (ii) to assess Leaf Area Index (LAI) in rice paddies in Italy. The study field was located in south Sardinia (Italy). The experiment was carried out on three different rice cultivars during 2010 and 2011 summer. A time series of FieldSpec canopy reflectance data and multispectral satellite remote sensing imagery were acquired during both growing seasons. Analysis were carried out to compare the performance of thirty vegetation indices. In 2010 growing season, the CRM and MTCI (derived from new red-edge spectral band) proved to be the best predictors of green LAI (R2=0.72), while the traditional CGM (R2=0.67) index showed good linearity with green LAI. In 2011 growing season, the heterogeneity of seed density and the strong presence of weeds (despite the weeding control) caused the lack of correlation between LAI and vegetation indices since the beginning of the growing season but additional insights of the location of weeds was obtained.

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SOIL MAPPING AND MODELING ON TWENTY-FIVE INGREDIENTS USING A REAL-TIME SOIL SENSOR

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We obtained Twenty five calibration models based on Vis-NIR (305 - 1700 nm) underground soil reflectance spectra collected using a Real-time soil sensor with a differential global positioning system, in order to create each ingredient soil maps. The investigated soil ingredients were moisture content (MC), soil organic matter (SOM), pH, electrical conductivity (EC), cation exchange capacity (CEC), total carbon (C-t), ammonium nitrogen (N-a), hot water exchangeable nitrogen (N-h), nitrate nitrogen (N-n), total nitrogen (N-t), exchangeable potassium (K2O), exchangeable calcium (CaO), exchangeable magnesium (MgO), hot water soluble soil boron (B), soluble copper (Cu), exchangeable manganese (Mn), soluble zinc (Zn), available phosphate (P-a), C/N ratio (CN), MgO/K2O ratio (MgO K2O-1), CaO/MgO ratio (CaO MgO-1), lime saturation degree (LSP), base saturation degree (BSP), bulk density (BD) and phosphate absorption coefficient (PAC).
Twenty five soil maps were drawn using ArcGIS software.

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SUITABILITY OF CROP CANOPY SENSORS FOR DETERMINING IRRIGATION DIFFERENCES IN MAIZE

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Water is the most limiting factor for agricultural production in the semiarid Great Plains of the United States. Dry climate conditions combined with a large availability of ground water has led to crop production systems that are highly dependent on irrigation for maximum and stable yields (Opie, 2000). Increasing the efficiency of irrigation water used for crop production is important in semiarid environments (Howell, 2001). Crop canopy sensors may have the potential to determine the water status of crops. If this potential can be realized, an effective, non-invasive way to determine the water requirement of crops could be developed that may lead to decreased applications of water for crop growth. A study was initiated to evaluate the potential of a crop canopy sensor to differentiate between irrigation levels at two corn (Zea mays) growth stages (R3 and R5). The sensor was placed in three orientations to evaluate which best determined corn irrigation across two sensor calculated indices while avoiding taking measurements involving the corn tassel. These orientations were 1) nadir, between corn rows (above canopy), 2) 45° off nadir within the corn canopy (below corn tassel), and 3) 90° off nadir within the corn canopy.

Results show that the sensor could differentiate between irrigation levels at the R3 and R5 corn growth stages. At the R3 corn growth stage crop canopy calculated red-edge normalized difference vegetation index (ReNDVI) differentiated high and low irrigation treatments across all treatments tested (Fig. 1).

At the R5 corn growth stage normalized difference vegetation index (NDVI) differentiated high and low irrigation treatments at the 45 degree and inter-row orientations (Fig. 2).

There was no clear benefit to sensor readings by changing sensor orientation to within the canopy. Each sensor orientation was tested in eight ways; two growth stages (R3 and R5) and two indices (ReNDVI and NDVI) across two sites. The 45° within canopy orientation yielded significant trends in three out of eight measurements. The 90° within canopy orientation yielded significant trends in five out of eight measurements. The inter-row orientation also yielded significant trends in five out of eight measurements. This suggests that the 90° and inter-row orientations worked equally well for the determination of irrigation effects on corn growth. This could be of great benefit for practical application purposes. If the sensor can be used above the canopy inter-row, this is beneficial from a mounting standpoint. Placing the sensor within the canopy (as with the other two sensor orientations tested) could be quite challenging if readings are taken in manners other than by hand.

The results of this study suggest that a Crop Circle 430 (Holland Scientific, 2010) crop canopy sensor can distinguish among different irrigation rates in corn at later growth stages (R3 and R5) when irrigation is usually critical in the semiarid Great Plains. While more study is needed, this suggests that crop canopy sensors may be a valuable tool not only in increasing water use efficiency as well.

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SOUND BASED DETECTION OF MOTHS IN OPEN FIELDS

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In this article, we present an innovative electronic system designed for the detection and the counting of moths in open fields of tomatoes. Moth traps are placed in the field and coupled with microphones that capture sounds produced by moth flight. These signals are sent to a platform to estimate remotely and in real time the number of trapped moths through signal processing techniques. The proposed method is based on the continuous analysis of the signal on sliding temporal windows. In every window in which an event is detected, a Linear Predictive Coding (LPC) analysis is performed in order to characterize the spectrum and classify the event as “moth event” or not. The quantitative evaluation on real data has proved the accuracy and the robustness of the proposed method. An optimal classification threshold leads to a true positive rate above 80% for a corresponding false positive rate around 5% on the tested data.

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ANGULAR VELOCITY METER APPLICATION STUDY IN THE AGRICULTURAL VEHICLE NAVIGATION SYSTEM

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In the agricultural vehicle navigation system, most frequently used steering feedback sensors, such as rotary potentiometer, rotary encoder and linear potentiometer, are usually installed a miniature troublesomely, and often have relatively low reliability because of the more installation fittings. With the progress of MEMS technical, angular velocity meter achieves higher accuracy while the cost is lowered to a quite low level. Due to the simple installation, high reliability, the angular velocity meter is used more widely in the agricultural vehicle navigation system. In the steering control system which adopted angular velocity meter, if we use steering angle which was simply integrated of the angular velocity as the feedback of the steering algorithm, the control accuracy will be significantly decreased with the passage of time. This article studies with an angular velocity meter which attached on the top of the kingpin of a tractor. A double-loop PID steering control algorithm was proposed here. Based on tractor steering control, contrast to single loop PID steering control algorithm, a comparative test was made. The comparison indicates that the algorithm this article proposed has a higher precision.

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GENERIC ISOBUS COMPLIANT PRECISION AGRICULTURE FUNCTIONALITY IN A PROPRIETARY TERMINAL CONCEPT

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The manuscript and the presentation will depict overall challenges and the approach AGCO Fendt has taken for integrating such generic ISOBUS-based technologies into a proprietary logical GUI and Software concept. It will explain in detail the possibilities and the exceptional advantages of the ISOBUS data abstraction. Additionally, the presentation will deal with the general engineering challenge for perfect usability, facilitating intuitive handling for the customer by deriving dosed, interpretable and situation-dependent information.

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PERFORMANCE EVALUATION OF SINGLE AND MULTI-GNSS RECEIVERS IN AGRICULTURAL FIELD CONDITIONS

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Selection of appropriate receivers and utilization methods of positioning systems are important for better positioning in different applications of precision agriculture. Objective of this research was to evaluate the performance of single and multi-GNSS receivers at stationary and moving conditions in typical Korean agricultural sites such as open field, orchard area, and mountainous area A single-GNSS receiver (Model: R100; Hemisphere GNSS, Scottsdale, AZ, USA) and a multi-GNSS receiver (Model: SIGMA-G3T; JAVAD GNSS Inc., San Jose, CA, USA) were selected for this experiment. Data were measured using GPS and DGPS modes for the single GNSS receiver, and single point positioning mode (sp); code differential mode (cd); and carrier phase differential (RTK) with fixed ambiguities (pd) modes for the multi-GNSS receiver, including and excluding the differential correction signals from the Quasi-Zenith Satellite System (QZSS). Along with number of satellites being tracked, accuracy of the GNSS receivers were evaluated in terms of Circular Error Probability (CEP) and Twice the Distance Root Mean Square values. During the stationary tests, 2DRMS values were found as 0.162 m, 0.196 m, and 1.720 m for the single-GNSS receiver at open field, orchard area, and in mountainous area, respectively. In case of the multi-GNSS receiver, 2DRMS values were found as 0.077 m, 0.162 m, and 0.929 m for pd with QZSS mode at open field, orchard area, and in mountainous area, respectively. For the moving tests, RMSE values were found as 0.502 m, 0.346 m, and 3.052 m for the single-GNSS receiver at open field, orchard garden and in mountainous area, respectively. In moving tests, for the multi-GNSS receiver the RMSE values were found as 0.424 m, 0.127 m, and 1.821m for pd with QZSS mode at open field, orchard garden, and in mountainous area, respectively. The multi-GNSS receiver showed better accuracy than the single-GNSS receiver in all experimented conditions. Moreover, number of satellites tracked by the multi-GNSS receiver was also greater than the single-GNSS receiver in all of the cases. This research provides the capability and accuracy of a multi-GNSS receiver and comparison with a single-GNSS, which would be helpful for selecting appropriate receivers and methods in various agricultural conditions.

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NOAA'S NATIONAL GEODETIC SURVEY'S NATIONAL SPATIAL REFERENCE SYSTEM AND THE NATIONAL HEIGHT MODERNIZATIO

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The National Geodetic Survey (NGS) is responsible for the establishment and maintenance of the National Spatial Reference System (NSRS). NGS manages a network of Continuously Operating Reference Stations (CORS) that provides Global Navigation Satellite System (GNSS) data and serves as the backbone of the NSRS. Our goal is to maintain a network of stations to serve as control for any project undertaken by local surveyors. In addition, numerous other applications benefit from an accurate, consistent coordinate system and the fastest growing community of users is Agriculture.

The National Geodetic Survey's National Height Modernization Program is an initiative focused on establishing accurate, reliable heights using Global Navigation Satellite System (GNSS) technology in conjunction with traditional leveling, gravity, and modern remote sensing information. Precision agriculture applies GNSS technology along with remote sensing data to determine accurate field boundaries and slope (contour) management for land use.

Benefits that the National Spatial Reference System and the National Geodetic Survey's Height Modernization Program provide to the agriculture community include the use of accurate heights to more efficiently control equipment (machine guidance) and apply fertilizer; thus providing savings to farm businesses and minimizing the amount of non-point source pollution (fertilizer, herbicides, or pesticides) that enters the streams and rivers.

In 2008, the Michigan Department of Transportation (MDOT) CORS, a subset of the National CORS were made available to the Agriculture community. During the first year, there were 4 farms that begin using the products provided by MDOT. As of January 2014 there are 241 users that have signed up and are using CORS for their agriculture needs. Dansby Farm LLC, a family owned business, has seen a reduction of chemical usage by 3 – 5%, a 2% reduction of fertilizer, and estimates a savings of $3000 - $5000 in their first year of using the CORS. The user community ranges from family to corporate owned businesses.

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SPECIFICATION OF DATA DIMENSION TO MEASURE THE DATA QUALITY ON COTTON PRODUCTION

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The research proposes dimensions of data quality for qualifying masses of data with the specific farm. Despite of the evidence of the need for information technology resource to improve management in agriculture. In general there are relatively few initiatives developed or under development for this purpose. In general the requirements used in this process are generic and do not include the necessary privacy in agriculture. The aim of this research is to map the main requirements of data quality in agriculture and in particular the fiber cotton production in Brazil, providing subsidies to establish dimensions of the need data to measure data quality in this segment. The research focus is about the dimensions specification for analysis of specific data quality for cotton production; the proposal is to establish qualitative parameters to determine data enrichment actions when it is necessary. The specification of criteria for used dimensions qualification depends entirely on the context in which it is bounded on the research, metrics may take different amounts in different context. The absence of requirements for defining data structures can be seen in other dimensions like fill and duplication columns. There is no specific dimensions for measuring data quality in agriculture , dimensions may take different amounts depending on its context , the research presents a solution with the purpose of contributing to the qualification of data masses and hence with possible enrichments. The contribution presented will create criteria to provide a methodology for data qualification given to the particularities in this segment in Brazil, contributing to the complementary expert systems to generate information

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INTEGRATED SENSOR SYSTEM FOR RICE CONDITIONS MONITORING BASED UGV

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Ground-based platform systems have been widely used for monitoring crop conditions. In this study, a UGV-based multi sensors system (UGVS) was developed to real-time collect rice condition information including NDVI values, reflectance measurements and crop canopy temperature. Major components of the integrated system are GreenSeeker R100 system, hyper-spectroradiometer and infrared temperature sensor. The leaf area index (LAI) is measured by the CGMD302 Spectrometer. The relationship between of rice spectral vegetation indices and LAI are analyzed. The results show that the UGV-based multi sensors system can support multi-source information acquisition and is useful for crop management and precision agriculture applications.

The UGV was a light-weight and height/width-adjustable platform with the capabilities of auto-control, four-wheel drive, wireless data communication, and 3D rotary connector rotation. The width can be adapted to the planting ridge spacing from 1m to 2.2m, and the height of equipment install platform is adjustable from 0.5m to 2m. The travel speed is set to 3km/h to ensure stability of measurement data. The load capacity is more than 100 kg. The front frame and rear frame were connected by the 3D rotate connector. The 3D rotate coupler is main part of the platform to fulfill the turn and adjust front frame and rear frame when the four wheels in the uneven ground. It has a network camera, the video image in front of the platform can be sent to the control computer, and the operator could control its moving status by computer control software. It also can be set to automatic control mode. The embedded image process software will determine the crop and soil edge, and adjust the moving direction dynamically. The third control mode is GPS contorl mode, before experiment, the GPS position information for the desired track needs to be input into the control system. After the start button was pushed, it will move according the preset GPS information.

The Normalized Difference Vegetative Index (NDVI) which measured by the GreenSeeker R100 system is a commonly used measurement of crop health in agricultural applications. The wavelength bands select the visible (red, 660 nm) and infra-red (NIR, 770 nm) and he NDVI value is calculated. The one way ANOVA method was used to build the relationship between NDVI from GreenSeeker sensor and rice LAI, the variation and correlation model were demonstrated. When the NDVI value increased, the rice LAI value increased. The correlation coefficient (R2) was 0.728 and a significant positive correlation relationship was verified. This result shows that the automatic measurement based UGVS is more reliable so as to manual measurement and the relationship trend between NDVI and LAI is according to the results from other researchers.
An UGVS was developed to monitor crop conditions for precision agricultural application. The reliable and accurate information on rice field, such as NDVI values, reflectance measurements, and crop canopy temperature was acquired fast, automatically, non-destructively and simultaneously by the UGVS and used to monitor crop conditions. This preliminary study indicates the potential of the developed UGV-based multi sensors system in realizing multi-source information acquisition and management in the field. According to the needs of users, other sensors for monitoring field crop information can be easily integrated to this UGV-based multi sensors system for precision agriculture applications. In future study, it should focus on improving the performance of the UGV system, which may include improving steering flexibility, adding a suspension system, and ensuring attitudes

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ADOPTION LEVEL OF PRECISION AGRICULTURE FOR BRAZILIAN FARMERS - 2011/12 CROP YEAR

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Although Precision Agriculture (PA) concepts and technologies are widespread in Brazil, its application still little used in some important crop production regions. The purpose of this study was to survey the current adoption level of PA by printed and online questionnaire. We started making a specific questionnaire to farmers and PA service companies using some technology related to PA. The questionnaires were developed based on the methodology of Whipker and Akridge (2009), adapted to our regional conditions. In addition to printing the questionnaires, an informative email was created and available on-line. In this case, an email newsletter was prepared calling producers and technicians to access the questionnaire and reply spontaneously to the questions raised. Access to the questionnaire was done by the link: https://docs.google.com/spreadsheet/viewform?formkey=dDNfcWhvSUdXUj h2NkM1VnBtT09NbWc6MQ. The following information was raised: how long the growers started the PA in their farms, area with PA, considering lime, fertilizer and pesticides application; in which managements PA helps in decision making; conducting soil analysis georreferenced (chemistry and physics); grid sampling area; stratified sampling; how the work is done for PA (only for companies or have own equipment); PA equipment on the own machinery; which operations are performed on variable rate; observations after adoption the PA (reduction in costs production, e.g.); problems of equipment maintenance and software for use of PA; technical assistance, expected investment; observations of crop yield increase, barriers to implementation and use of the PA in the region, or even the entire property. A number of 250 questionnaires were distributed by e-mail inviting farmers and PA service companies to answer; moreover, a technical meeting was held at the city of Guaraí, Tocantins State. After response analysis, results showed that 67% of the farmers reported that the adoption time of the PA ranged from 2 to 5 years. The soil grid size was 5 ha and the soil sampling was carried out by PA companies; however, equipment and data interpretation are done by technical team of farm. Although the growers cannot realize reduction on the production costs for using PA technologies, they disagree that PA costs can be more than the benefits observed. The farmers pointed out that software and equipment used in the PA are the main constraints for increasing the investment in this technology. Considering that the survey was applied to farmers and PA service companies from different crop production regions of Brazil, we observed that the use of PA is recent. Even aware that PA and its benefits, PA use is still restricted to a small group of farmers and is necessary a strong information access and training in order to achieve a more effective and efficient PA use. PA adoption is increasing in several Brazilian regions mostly based on PA profitability; however, in some cases, growers are having difficult to measure the real impact and profitability of PA use in crop production. PA increase adoption constraints in Brazil are mostly related to profitability, growers with limited knowledge to use software and equipment, and limited available training of field team.

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DIFFERENCE IN TECHNOLOGICAL EFFICIENCY (DTE) – A METHOD USED TO ASSESS THE ECONOMIC EFFICIENCY OF PRODUCTION TECHNOLOGY WHICH INTEGRATES STATISTICAL ANALYSIS WITH ECONOMIC EVALUATION IN FIELD EXPERIMENT OF TYPE 23

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Plant production is governed by certain, well-defined cultivation recommendations, especially important when quality standards imposed by contract agreements are to be met. Due to technical and economic conditions, a farmer is not always able to adhere to such recommendations in practice, but at the same time changes on the farm produce market (progress in plant breeding and mechanization of field work, new agrochemicals, effective microorganisms, etc) enforce producers to either change or modify a production technology. Selecting an adequate combination of agro-technical factors depends on the qualitative and quantitative parameters of a market product (yield), but the decision is also shaped by such organization of plant production which enables the farmer to minimize production costs and maximize the profit. (Nasalski i in. 2004). Farmer who has a definite resource of land and capital must determine the minimum level of performance of working hours or efficiency per hectare. Instability of a market enforce producers to either change or modify a production technology. The yield is conditional on a large number of factors whose effects are complex and inter-modifying. Testing a number of agronomic factors is possible by using advanced experimental systems methodically type kn, which are tested at the same time n factors, each of k levels.However, to implement this, traditional plant cultivation technologies require a modification of agricultural factors or their de novo creation. The aim is to select agricultural engineering factors in the production technology which require relatively low inputs to obtain an optimal yield with accurate quality raw material parameters.

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ADOPTION OF PRECISION AGRICULTURE IN SWEDEN – THE CASE OF SOIL MAPS

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Precision agriculture is a tool to improve the efficiency of use of inputs and thereby improve resource utilization and reduction of the impact on the surrounding environment. In Sweden, POS (Precision Agriculture Sweden) has worked with precision agriculture since the mid -1990s. Nevertheless, the results in terms of the practical use of the gained knowledge have been limited. Increased site specific fertilization would require more usable and acceptable AgriDSSs, but also clearer incitements and guidelines from the authorities as well as an increased interest from extension services.

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USA CORN FARM PROFITS AND ADOPTION OF PRECISION AGRICULTURE

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Decisions by farm managers to adopt new technologies often involve weighing the full costs and benefits of proposed investments. Precision agricultural (PA) technologies require a significant investment of capital as well as the operator's time, and offer the potential of cost savings and higher yields through more precise management of inputs based on field information. Until very recently, the adoption of PA technologies had been sluggish, but the 2010 ARMS survey of corn producers showed an increase in the use of three PA technologies: GPS soil and yield mapping, tractor guidance systems, and variable rate input application. This study investigates whether the increase in adoption has corresponded to an increase in operating profits for U.S. corn production. The specific research questions addressed include:

Does adoption of PA have an effect on profits?

What are the factors influencing PA adoption?

What other factors, including PA adoption, determine operating profits on U.S. corn farms?

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WORLD PATENT MAP ANALYSIS OF MECHANIZATION TECHNOLOGIES RELATITNG TO RICE PRODUCTION

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This study focuses on worldwide patenting mechanization technologies of rice production in the past two decades, based on DWPI database and TI patent analysis software. The temporal examination shows that applications grew rapidly and the top applicants have only been active since 2009. The spatial distribution of the priority country's earliest-DWPI analysis points out the innovative, competitive, and perspective countries. The citations analysis exhibits the innovative technologies and the core ones. The IPC temporal analysis examines the top competitors' change of R&D trends.

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EVALUATING DECISION SYSTEMS FOR USING VARIABLE RATES IN PLANTING SOYBEAN

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Increased interest in managing seeding rates within soybean fields is being driven by advances in technologies and the need to increase productivity and economic returns. A wealth of previous research was focused on studying how different seeding rates affect soybean yields at small-plot scales. However, little is known about different site-specific factors influence the responsiveness of soybean to higher or lower plant population densities at field levels, especially across geographic areas with similar soils, weather, and management conditions. In addition, there is no system that farmers can use to evaluate various recommendations for variable rate seeding. The objective of this study was to use on-farm observations to identify major factors that affect yield response of soybean to seeding rates that are slightly above or below the planting rates currently used by farmers. Between 2009 and 2011, farmers conducted 83 field-scale replicated strip trials across Iowa with two soybean seeding rates, high, about 395 K seed ha-1 and the low, about 340 K seed ha-1. The two seeding rates were replicated at least four times in each trial. Yield responses to the higher seeding rates were estimated at 30-m grid patterns within each field. Hierarchical modeling and Bayesian analysis were used to identify field and within field-level factors that had significant effect on yield response to the higher seeding rate. For the field-level factors, we considered soybean row spacing, soybean planting dates, monthly and cumulative growing season rainfall. For the within field-level variables, we used relative elevation, slope, soil drainage class, crop suitability rating index, and soil organic matter levels. The Bayesian analyses helped to quantify the uncertainty in the parameters of observed yield response distributions and make predictions for potential yield responses to higher or lower seeding rates at field and within-field areas not studied but assumed to have similar crop management and weather conditions. Based on estimated predictive posterior probabilities of profitable yield response (a yield increase above the marginal cost for the seeds) to higher soybean seeding rates, a decision management system was developed that would help farmers and agronomists make economic decisions regarding where to increase or decrease soybean seeding rates within and across fields.

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THE MOST SENSITIVE GROWTH STAGE TO QUANTIFY NITROGEN STRESS IN SUGARCANE USING ACTIVE CROP CANOPY SENSOR

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The use of sensors that allow the application of nitrogen fertilizer at variable rate has been widely used by researchers in many agricultural crops, but without success in sugarcane, probably due to the difficulty of diagnosing the nutritional status of the crop for nitrogen (N). Active crop canopy sensors are based on the principle that the spectral reflectance curve of the leaves are modified by N level. Researchers in USA indicated that corn N stress in-season can be detected using a crop canopy sensor and N rate algorithms were developed to make in-season N rate applications. The objective of this study was to evaluate the nutritional status of sugarcane, fertilized with different nitrogen rate applied at different periods after harvest, using a crop canopy sensor in order to generate parameters to establish the most sensitive growth stage to detect N deficiency in order to guide N application. The experiment was installed in a commercial area of sugarcane (first ratoon). The experimental design was randomized blocks in 5x5 factorial with four replications, with five nitrogen rates applied at five different periods after sugarcane harvest. During the crop growing, its N nutritional status was assessed through leaf laboratory analysis and the results compared with canopy reflectance reading using an active optical sensor. In all evaluation periods, crop biometric parameters were measured. Pearson's correlation shows that the vegetation index presented the highest correlation with tiller height and the number of tillers when evaluated, indicating that the most appropriate period for use of active optical sensor in the field to predict N deficiency in sugarcane is when the average height 0.20 m with 16-20 tillers m-1.

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VARIABLE-RATE APPLICATION OF NITROGEN AND POTASSIUM FERTILIZERS IN LOUISIANA SUGARCANE PRODUCTION SYSTEMS

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For sugar and cane yields to be optimized and profitability maximized, it is critical that the developing sugarcane crop receive the prescribed level of plant nutrients. Under-fertilization can result in reduced cane yields, while over-fertilization can reduce sugar recovery. In addition, improper fertilization may increase crop susceptibility to environmental stress and disease and insect pests, as well as cause adverse impacts on the environment. Nitrogen (N) continues to be one of the most important and costly components of a sugarcane fertility program, directly affecting both cane and sugar yields. While potassium (K), a nutrient associated with plant water use, may aid in drought tolerance. Potassium deficient plants are also more prone to contract certain diseases and are more likely to lodge. It is therefore essential that the proper rates of both N and K be applied to optimize cane and sugar yields. The objective of these studies was to determine if variable-rate (VR) application of N and K could help optimize sugarcane yields, while increasing production efficiency.

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PRECISION NUTRIENT MANAGEMENT THROUGH USE OF LCC AND NUTRIENT EXPERT IN HYBRID MAIZE UNDER LATERITE SOIL OF INDIA

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Nutrient management has played a crucial role in achieving self sufficiency in food grain production. Energy crisis resulted in high price index of chemical fertilizers. Coupled with their limited production, fertilizer cost, soil health, sustainability and pollution have gave rise to interest in precision nutrient management tools. Field experiment was conducted to study the effect of variety and nutrient management on the growth and productivity of maize under lateritic belt of West Bengal during kharif season of 2013 at the farmers' field located in Birbhum district of West Bengal, on sandy loam lateritic soil having low fertility status and acidic reaction (pH5.6). The experiment consisted of the five levels of fertilizer i.e, F1 = control, F2 = state recommendation (150:75:75), F3= nutrient expert (120:34:51), F4=farmers practices (80:40:40), and F5= Basal application of 50:75:75 with split N application on basis of LCC, and two level of varieties viz.,V1= Rajkumar,V2= Sona, thus making ten treatment combinations, which were replicated thrice and was laid out in randomized block design(RBD). The "Nutrient Expert" is a Decision support tool developed by IPNI (International Plant Nutrition Institute) & CIMMYT. The values for growth parameter like plant height, length and girth of cob, number of cob per plant, harvest index were observed. It was the found that the growth parameter as well as yield component and yield were significantly affected by different level of fertilizer and different varieties. The result indicated that different schedules of fertilizer expressed significant effect on plant height, cob girth and length, grain per cob, grain weight per cob, test weight, Maize grain yield and stover yield at harvest. It was found that the application of split N on the basis of LCC gave highest yield and yield parameter values. The application of nutrient on the basis of recommendation obtained from the decision support system like "Nutrient expert" also proved satisfactory. The gross return, net return and Benefit: cost ratio indicated that the application of nutrients on basis of nutrient expert recommendation proved economically more remunerative.

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EFFECT OF LAND USE OVER SPATIAL VARIABILITY OF NITROGEN MINERALIZATION AND SOME OF CHEMICAL SOIL PROPERTIES IN MIRABAD AREA OF IRAN

S. Kaboodi

Any changes in ecosystem conditions and land management impact on ecology of soil inorganic nitrogen. Understanding of the biology soil is increasingly important for sustainable ecosystem. The aim of this study was to investigate the spatial variability and zoning of nitrogen mineralization, organic carbon and calcium carbonate influenced by the user of apple orchards, crop production and pasture, and compare the two interpolating method kriging and inverse distance weighting in Mirabad area, North West of Iran. In this case which are affected by three land uses including apple orchards, crop production and pasture, 65 soil samples (0-30cm) were taken from Mirabad which has located in the western part of Soulduz plain between the Naghadeh and Oshnaviyeh cities (west Azarbaijan). For normality of data distribution and the correlation coefficent was SPSS applied The value of unsampled points was interpolated using kriging and inverse distance weighting by geostatistics (GS+)software. The results show that the kriging method is best method interpolation for unsampled points for ammonium, nitrate, and organic carbon. Also was determined that the spherical model for interpolation values of ammonium, organic carbon and calcium carbonate equivalent and the exponential model as the best model for Interpolation values of nitrate were determined. If ratio of nugget variance to sill is less than 25%, then the variable has strong spatial dependence if the ratio is between 25% and 75%, the variable has moderate spatial dependence, and otherwise, the variable has weak spatial dependence. Results indicated that spatial dependence nitrogen mineralization of soil is medium and this reflected the effect of the users on the spatial distribution of these properties. Results obtained from variance analysis by application MSTATC showed that these properties are influenced by the different users. Spatial distribution maps of biological, chemical and physical soil properties were provided by integrating geostatistical out puts and GIS.

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PRECISION SENSORS FOR IMPROVED NITROGEN RECOMMENDATIONS IN WHEAT

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Crop sensor-based systems with developed algorithms for making mid-season fertilizer nitrogen (N) recommendations are commercially available to producers in some parts of the world. Although there is growing interest in these technologies by grain producers in Montana, use is limited by the lack of local research under Montana's semiarid conditions. A field study was carried out at two locations in 2011, three locations in 2012, and two locations in 2013 in North West Montana: the two dryland sites at the Western Triangle Agricultural Research Center (WTARC) and the Martin farm (Martin) near Conrad, MT, and one irrigated site at the Western Agricultural Research Center (WARC) near Corvallis, MT. The spring wheat variety Choteau was grown at all sites. The objectives of this research were: 1) to evaluate two optical sensors – GreenSeeker © (model 505) and Pocket Sensor (a prototype GreenSeeker Handheld Crop Sensor), 2) to assess whether the algorithms developed in other regions can be successfully utilized under Montana conditions, and 3) determine whether sensor-based recommendations need to be adjusted depending on what N fertilizer source - liquid urea ammonium nitrate (UAN), or granular urea - is used. The experimental design included ten treatments, an unfertilized check treatment (0 kg N ha-1), a non-limiting N-rich reference treatment (247 kg N ha-1), and four pre-plant N application treatment rates of 22, 45, 67, and 90 kg N ha-1 applied as broadcasted granular urea. The pre-plant N application treatments were repeated twice, once for in-crop application of UAN and another for granular urea. Individual plot size was 1.5 m x 7.6 m and each treatment was replicated 4 times. Wheat crop reflectance measurements – Normalized Difference Vegetative Index (NDVI) from each plot were collected at Feekes 5 growth stage. The Feekes 5, early jointing (beginning of stem elongation, prior to first visible node) has been identified in a course of multiple field studies as the most appropriate sensing time for wheat because it provides reliable prediction of both N uptake and biomass. The two GreenSeeker crop sensors (Trimble Navigation Ltd., Sunnyvale, CA) were used to collect the NDVI measurements. According to treatment structure top-dress N fertilizer was applied as broadcast urea, or as surface applied UAN (using a backpack sprayer with a fan nozzle). Top-dress N recommendations were generated using algorithms experimentally developed for spring wheat: 1. Spring Wheat (Canada), 2. Spring Wheat (US/Canada/Mexico), and 3. Generalized Algorithm. The algorithms are available at: http://www.soiltesting.okstate.edu/SBNRC/SBNRC.php. Generalized algorithms did not prescribe any top-dress N fertilizer to be applied at any of the experimental sites in both growing seasons. The top-dress rates prescribed by the Spring Wheat (US/Canada/Mexico) algorithm ranged from of 0 kg N ha-1 to 111 kg N ha-1 depending on the NDVI values measured. The prescribed N rates were applied to experimental plots, and harvested grain yields were measured at crop maturity. A strong linear relationship was observed between NDVI values obtained with GreenSeeker and with Pocket Sensor (R2=0.82). GreenSeeker and Pocket Sensor NDVI readings predicted 91% and 96% of variation in spring wheat grain yields respectively across site-years (R2 = 0.70 and 0.81). In all three growing season, the rates generated by the USA/Canada/Mexico Algorithm were not appropriate for grain yield optimization. Results indicated that both sensors performed well and were useful in predicting mid-season spring wheat grain yield potential. In addition, algorithms developed in other regions did not provide the appropriate top-dress N rates for Montana spring wheat varieties and growing conditions. Lastly, because there were no substantial differences in grain yields associated with top-dress fertilizer N source (urea vs. UAN) at any of 7 site-years, fertilizer rates do not need to be adjusted based on N fertilizer source, urea or UAN. Currently, additional research is being conducted state-wide in Montana to develop improved sensor-based N optimization algorithms for both spring wheat and winter wheat varieties for Montana growing conditions.

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RESEARCH ON MEASUREMENT DEVICE FOR NO3- ION CONCENTRATION OF NUTRIENT SOLUTION

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The management of water and ion concentration in nutrient solution is crucial in precision agriculture. Poor management may leads to the increasing of energy consumption and cost as well as low efficiency. The measurement of ion concentration in nutrient solution is prerequisite for optimal control and management of nutrient solution. Real-time detection of NO3-, as an important component of nitrogenous fertilizer, is always a big problem over the world. The ion selective electrode is a new branch which appeared in the analytical chemistry field in 1970's. It is a kind of electrochemistry sensor, containing sensitive membrane, internal conductor system and electrode cavity. With its sensitive membrane, the concentration of the ions measured is converted into electrical signal directly and selectively. Because of its special advantage, it offers a promising and practical means for online measurement of ion concentration in nutrient solution and will get more extensive application in precision agriculture. However, during actual measurement, the accuracy is seriously interfered by surrounding temperature. Traditional solution is setting a temperature parameter manually, which leads to the tedious operational procedure and low measurement accuracy, which restricts the wide utilization of ion selective electrode. Moreover, the ion concentration detection systems on present markets are generally large, high cost and hard to carry.

Due to the above problems, this research based on ion selective electrode uses SPCE061A MCU as control core to measure NO3- ion concentration in nutrient solution. The measuring methods of NO3- ion concentration is discussed in this paper. DS18B20 module is applied to measure temperature of the nutrient solution for auto temperature compensation whose mathematical model is established through theoretical research and determination experiment of ion selective electrode's input and output features. After all the researches above, this online measurement equipment is designed to measure the solution's temperature and momentary NO3- ion concentration value. The ion selective electrode and the temperature measurement module collect data and send them to SPCE061A MCU. NO3- ion concentration is calculated and shown on the LCD screen. This equipment achieves the goal of real-time, automation, intelligence and miniaturization. Contrast tests are conducted before and after auto temperature compensation. The final test experiment shows this equipment can detect NO3- ion concentration more accurately which obviously reduces the interference of solution's temperature. The maximum standard error and relative error of this equipment is 0.022mol/L and 10% respectively, which will have a well prospect in precision agriculture.

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WATER MANAGEMENT FOR CUCUMBER: GREENHOUSE EXPERIMENT IN SAUDI ARABIA AND MODELING STUDY USING SALTMED MODEL

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The increasing demand for irrigation water when water resources are limited requires proper water resource management and the use of unconventional water resources (e.g. saline/brackish water and treated waste water). The Kingdom of Saudi Arabia, like some other countries located in arid regions, suffers from the imbalance between the increasing water demand and the limited water supply. To cope with water scarcity, water use efficiency must be maximized (more crops per drop). A successful water management scheme for irrigated crops needs a holistic approach that takes into account water, crop, soil, and field management. Models can be very useful tools in this respect. Not only can they help in calculating crop water requirements and irrigation scheduling but they can also be used to predict yields and soil salinization under different management scenarios. The SALTMED model has been developed for such an integrated management approach. In order to investigate how much water can be saved with minimum yield reduction, a controlled greenhouse experiment was set up. Different water amounts were applied to cucumber (Cucumis sativus L) ranging from 100% to 40% irrigation requirement (ETc). The SALTMED model has been employed using the measured data of soil moisture, soil salinity and yield. The model was successfully calibrated using 100% ETc soil moisture data. This was followed by successful model validation using the other irrigation deficit treatments (80%, 60%, and 40% ETc). The results of calibration and validation of the SALTMED model showed that the model can simulate very accurately soil moisture content, soil salinity, and final cucumber yield. Subsequently, the model is considered reliable to run with "what if" scenarios depicting different management strategies. The results of these scenarios will be considered in future planning with the aim to save water and safeguard the environment.

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APPLICATION OF INFRARED THERMOGRAPHY FOR ASSESSING BEEF CATTLE COMFORT USING A FUZZY LOGIC CLASSIFIER

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This work aims to develop a fuzzy logic classifier that integrates both environmental and animal factors to determine the level of thermal comfort to allow the environmental assessment and control. An experiment was performed with Nellore steers during eight days where air temperature, relative humidity, skin temperature and rectal temperature were taken in different periods. Those data were used to construct a fuzzy classifier that has three inputs, air temperature, relative humidity, skin temperature, and a output that predict the rectal temperature. The fuzzy logic classifier is evaluated in comparison with a traditional temperature-humidity index and it shows some important benefits related the traditional indexes.

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USING A DECISION TREE TO PREDICT THE POPULATION DENSITY OF REDHEADED COCKCHAFER (ADORYPHORUS COULONI) IN DAIRY FIELDS

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The redheaded cockchafer (RHC) (Adoryphorus couloni) (Burmeister) is a significant insect pest causing damage to pastures. Ordinal decision trees were developed using environmental variables and current population data to predict the categorical risk of RHC infestation in a dairy field.

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DISEASE SCOUTING FOR AERIAL BLIGHT BASED ON LOGICAL AREAS OF COLLECTION IN SOYBEAN FIELDS ROTATED WITH RICE

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Rhizoctonia solani AG1-IA causes sheath blight in rice and aerial blight in soybean. In Arkansas, rice and soybean rotations facilitate a continuous source of R. solani AG1-IA inoculum from one year to the next. Aerial blight is a two stage disease where colonization of the plant occurs during the early vegetative growth stages and aerial blight symptoms occur during the reproductive growth stages after canopy closure (2). At canopy closure, aerial blight becomes problematic because the signs and symptoms of disease occur underneath the canopy and are not visible without extensive scouting. Disease develops rapidly and spreads plant to plant through the canopy and detection late in the reproductive growth stages is often too late for a fungicide application to be of economic value. Spatial analyses were used to determine the spatial aggregation of soil inoculum potential and plant colonization. Models indicated soil inoculum potential and plant recovery of R. solani AG1-IA was controlled by the levee system from the previous year and elevation (1). Dissemination of R. solani AG1-IA as floating residue or sclerotia appears to be important in distribution of inoculum in a rice field flooded much of the year in addition to this pathogen being soilborne. The inoculum of the pathogen aggregates in the collection areas, over winters and is available to cause disease in the next year's soybean crop at these positions. Disease scouting at or near areas in a soybean field that correspond to "logical areas of collection" from the levee system utilized the year before should result in a more efficient scouting methodology to detect and manage aerial blight. Subsequently, work has been done to determine what constitutes a logical area of collection using LiDAR elevation data (provided by USGS) for much of the agricultural region of Arkansas. In combination with LiDAR, GPS levee maps were quantified spatially (m/m2) using the line density tool in ArcGIS 10.1. Fields that were in levee rice the previous year and had sheath blight were assigned 5000 random points and predictive modeling based on line density and elevation (or both) using geographically weighted regression in ArcGIS 10.1 used to identify areas where collection of R. solani AG1-IA was most likely. After areas were identified in the fields, straight line verification strips were arbitrarily placed in the fields and disease assessments will be made after canopy closure on random points within the strips to determine disease severity at locations both identified as logical areas of collection and not. Spatial statistics and predictive modeling of logical areas of collection will be a valuable tool in making disease scouting more efficient and efficacious.

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A PORTABLE INSTRUMENT FOR RECOGNITION OF FARM WEEDS AND MANAGEMENT OF CHEMICAL SPRAY

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With the information technology being popularization and application and farmers' knowledge level being increase in China, smartphone has been accepted by peasants used as terminal of information collection and query. Recently, because of the serious diseases and insect pests, it is impossible to prevent and control these disasters when we only rely on grassroots staffs' investigation or professors' instruction. If each of these farmers distributed in all of the country can be regarded as a node, with the help of network, who can acquire some knowledge of farm weeds' recognition or chemical spray suggestions, collect and upload these information, it will be effective to prevent some sudden disasters. Therefore, it is necessary to develop the mobile with the function of recognizing farm weeds and managing chemical spray. According to the classification of crops, the article summarizes some knowledge and pictures of common weeds such as wheat land, cornfield, soybean field, and cotton field, etc. Combining with spraying knowledge, this article builds a database to recognize farm weeds and manage chemical spray, and designs a relevant operating platform based on Androids, which can be used by peasants to inquire the name, picture and spraying suggestion of specific weed, collect weeds picture and unload spraying experience in order to update the database. Furthermore, smartphone has been used to test this system. By using 3G network, it can acquire all kinds of weeds information, download high-quality picture and inquire associative spraying suggestions. At the same time, with the holding of mobile phone camera, the system can gather weeds picture and upload spraying experience. In sum, the system can assist peasants obtain the information of farm weeds recognizing and spraying immediately and conveniently, collect weeds information and share spraying experience based on the mobile, which can provide a convenient way for agricultural product and a effective method for weeds information collection.

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EFFECT OF SOIL AMENDMENTS ON BARLEY GROWTH AND PRODUCTIVITY UNDER FULLY AND MINIMUM IRRIGATION CONDITIONS IN SAUDI ARABIA

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A field experiment was carried out during the two consecutive seasons of 2012-2013 at the Agricultural experimental station of King Abdulaziz University located at Hada-Al Sham, 110 km north east of Jeddah (21° 48' 3'' N, 39° 43' 25'' E). The aim of the study was to investigate the effect of different soil amendments on growth traits and yield of barley crop grown under dry land conditions. Two irrigation treatments using sprinkler irrigation method were studied. The first treatment was full irrigation level which received 100% of required water during both growing seasons. The second treatment was a minimum irrigation level. In this treatment the water supply during both growing season was only 60% of full irrigation level treatment. Under each irrigation level, two soil amendments were investigated. Humic acid treatment was added to the soil with a rate of 10 kg ha-1. The second treatment was Gel Polymer which added to soil with a rate of 16 kg ha-1 beside the control (not amended). Irrigation event was every two days in full irrigation level and every 4 days in minimum irrigation level. Results revealed that, full irrigation level was better than minimum level in most investigated parameters. The barley growth and yield components increased with application of humic acid and gel polymers amendments compared to control. The best results obtained from humic acid treatment. Irrigation water use was enhanced under minimum irrigation level and with Ha treatment. Full irrigation level and amendment treatments increased N content in grains. On the basis of present experiment 10 kg ha-1 and full irrigating are recommended for barley growth and yield. But when water is the limited factor for agriculture production, minimum level is recommended to use because it saves 40% of irrigation water while the reduction in yield was not significant compared with full irrigation level. From economical point of view, losing part of yield and saving 40% of irrigation water is consider better and economical option than having the optimum yield with full irrigation level under dry land conditions.

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COMPARISON OF MANAGEMENT ZONES GENERATED BY THE K-MEANS AND FUZZY C-MEANS METHODS

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The clustering methods are highly suggested for the definition of MZ (TAYLOR et al., 2007; YAN et al., 2007). The most used clustering methods for defining management units correspond to the K-Means (FRIDGEN, et al., 2004; RIBEIRO, et al., 2011) and the Fuzzy C-Means algorithm (STAFFORD et al., 1998; JAYMES et al., 2003; PING & DOBERMANN, 2003; YAN et al., 2007). This study aimed to evaluate if there is an output difference between the clustering methods K-Means and Fuzzy C-Means. It has been done the selection of layers according Bazzi et al. (2013) and the evaluation was performed with the MZs mean comparison tests (ANOVA) and variance reduction. To evaluate the difference between MZs, Kappa and Tau maps indices comparison were used. The layer altitude was selected as best option, and 2, 3, 4 and 5 MZs were generated with both clustering methods. Comparing the thematic maps generated that represent the MZs, it was found that for two MZs, the divisions may be classified as excellent agreement (LANDIS & KOCH (1977, p.165) as well as the division into 3 classes. For the division into 4 classes, the agreement degree can be considered as substantial and moderate for the division into 5 classes. It could be concluded that although there are differences between the methods used to generate MZs, the results were the same for both methods. It was found that the division is valid for both as to set different levels of yield in field and as to perform division of the field to use as a source of recommendation and analysis.

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SPATIAL VARIABILITY OF SOIL COMPACTION IN ANNUAL CYCLE OF DIFFERENT CULTURE OF CANE SUGAR LAND CLAY SANDY

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The assessment of soil compaction levels and choosing the best management system are very important in modern agriculture, aiming to prevent or at least restore their physical conditions to a satisfactory level. The renewal of sugar cane plantation happens on average every 5 or 6 years. The current way repeats a sequence compaction and decompaction events during successive cycles of sugarcane, which promotes breakdown of soil structure. During the harvesting and transportation, the energy demanded in soil compaction is due tracks and tires rolling resistance, and in soil tillage is also expended a lot of energy to pull the equipments used at soil decompaction process. This work was carried out to evaluate the soil physical degradation in relation to the sequence of annual crop production of sugar cane, in a dystrophic Red Latosol (Oxisol) clayey texture calculating the Soil Cone Index (CI) in the folowing depth ranges: 0-10 , 10-20, 20-30 , 30-40 and 40-50 cm . The sugar cane productive area, belonging to Barra Grande mill, from Zilor group in Lençóis Paulista region, in São Paulo state, was evaluated during three subsequent seasons. For soil sampling it was used the Mobile Soil Sampling Unit - UMAS - belonging to Agroforestry Machinary and tire Test Center - NEMPA, Department of Rural Engineering, College of Agricultural Sciences - FCA - UNESP, Botucatu - SP. The sampling points in the areas and in subsequent crop cycles (subsequent years), collections were made using a sampling grid of 30 x 50 m , meaning 30 meters between points following the line of planting sugar cane and 50 meters between plant rows (traffic line) for penetration resistance. The models were adjusted by GS + 7.0 software. For the analysis of spatial dependence index (SDI) of attributes , it was used the relationship defined in GS + (C1/C0 + C1) software and the proposed ranges by Zimback that considers weak spatial dependence (IDE ≤ 25 %) ; moderate (25 % < IDE < 75 %) and strong (IDE ≥ 75 %) . As it was proved the spatial dependence, a interpolation was used to estimate values in not measured locations using the ordinary kriging method to create thematic maps. It was observed that every year, there was an increase in compaction of soil, and more intensive in the traffic lines and superficial layers (from 0 to 10, 10 to 20 and 20 to 30 cm).

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THE INFLUENCE OF THE INTERPOLATION METHOD IN THE MANAGEMENT ZONES GENERATION

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Several interpolation methods, with different levels of complexity, are available in literature (CARVALHO et al., 2002). The inverse of the distance raised to a power (IDW) and the kriging are the interpolation methods most used for precision agriculture and the difference between them is how the weights are assigned to different samples (MIRANDA et al., 2009). The objective of this study was to evaluate whether the type of interpolation used in the generation of thematic maps influences the quality of management zones (MZ). Yield, chemical, physical, and altimetry data were used in an area of 15.5 ha. The interpolation inverse distance, inverse distance squared and kriging were used and MZ were generated using the Fuzzy C-Means clustering method. To evaluated of MZ were used Anova and variance reduction. It was concluded that the interpolator has not influenced the generation of MZ, and that a less robust interpolator (IDW) can be used to generate thematic maps that are used to define MZ..

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DOES NITROGEN BALANCE SURPLUS DONE AT FIELD LEVEL HELP TO ASSESS ENVIRONMENTAL EFFECTS OF VARIABLE NITROGEN APPLICATION IN WINTER WHEAT?

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Increased nitrogen use efficiency (NUE) is important as a specific consideration to decrease negative impacts of nitrogen (N) on the environment and provide better crop quality. One of the methods available to increase NUE is to use sensor-based diagnostic information for variable N application (VNA). To assess the environmental effect of VNA, field strip-trials were conducted using early spring soil Nmin sampling, an active optical sensor (AOS) – OptRx (Ag Leader Technology), spatial grain yield data, and dense spatial information on wheat N content in straw and grain to calculate nitrogen surplus (Nsur). Strips were fertilized alternately with a variable or uniform N dose. The use of AOS for variable N application did not significantly reduce Nsur within both investigated fields. However, the site-specific N balance maps indicate where the areas more prone to Nsur are located within the fields. This allows investigation of which site-specific factors are most responsible for Nsur in these regions and what could be done to reduce the negative effect of Nsur on the environment in the future.

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SUITABILITY OF FLUORESCENCE SENSORS TO ESTIMATE THE SUSCEPTIBILITY DEGREE OF SPRING BARLEY TO POWDERY MILDEW AND LEAF RUST

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The target-oriented selection of stress-tolerant genotypes and its contribution for a more sustainable agriculture is receiving increased attention, also in the scope of precision agriculture. The selection of genotypes in breeding programs usually targets the increase of yield under consideration of production factors, and is done in the field by breeders and trained evaluators. Particularly in extensive breeding programs at advanced stages the evaluation, categorization and selection of promising and more adequate genotypes impose a big challenge even to experienced workers. Thus, the development and optimization of objective tools for fast and reliable data recording is essential to better estimate the potential and precisely differentiate genotypes in highly homogeneous populations. In plant sciences, the fluorescence spectroscopy is an established approach for basic and applied research. In agronomy and precision farming its potential is already confirmed e.g., for the site-specific nitrogen fertilization. Moreover, some studies suggest its potential for sensing of foliar diseases and other environmental stress. However, commercially available systems have very different technical specifications, not only related to the fluorescence excitation and recording (e.g., intensity and quality of excitation light, detection wavelengths, temporal resolution, camera-based recordings), but also to their robustness and suitability for the use in the field. Therefore, the quality and usefulness of the information provided by different systems might vary considerably.

In our work we explored the relation between the pathogen-induced alteration of characteristic fluorescence signals of four barley cultivars (Belana, Marthe, Conchita, Tocada) and their susceptibility degree (SD) to leaf rust (Puccinia hordei) and powdery mildew (Blumeria graminis). The susceptibility degree of the selected cultivars (classified by the German Federal Plant Variety Office, 2010 in a scheme from 1 (low) to 9 (high) susceptibility) ranged from 2 to 7 for powdery mildew, and 4-6 for leaf rust. The experimental plants were inoculated with either powdery mildew or leaf rust, and fluorescence recordings were taken at leaf level at three, six and nine days after inoculation (DAI). With a laboratory laser fluoroscope (IOM® Lambda 401, Berlin, Germany) we recorded the time-resolved fluorescence mean lifetime (LTmean) at six previously defined wavelengths (410, 440, 470, 500, 530, 560 nm); with a multispectral fluorescence camera (Nuance® CRI, Perkin-Elmer, USA) we recorded the fluorescence intensity (420-720 nm) with spatial resolution after UV, blue and/or green excitation, and calculated the area affected by pathogens; with a portable hand-held multiparametric fluorescence sensor (Multiplex®, Force-A, France) we recorded the fluorescence intensity in the blue, red, and far-red spectral bands after UV, green and/or red excitation, and used the signals to calculate specific fluorescence indices. In all cases, non-inoculated leaves served as control.

Evaluations at 3 DAI reveal a slight increase of the LTmean at specific wavelengths, but there was no clear relation with the SD to powdery mildew. At 9 DAI the cultivars Belana and Tocada (higher SD) had significantly higher LTmean in all wavelengths, while the cultivars Marthe and Conchita showed no significant differences, as compared to the respective controls. Differently, leaves inoculated with leaf rust had higher LTmean than control plants in several wavelengths at 3 DAI, and in all wavelengths at 9 DAI, irrespective of the SD (which ranged only from SD = 4 to SD = 6). With the spectrally-resolved fluorescence images we confirm the stronger impact of pathogen infection in the blue fluorescence (420-500 nm; excited with UV) and green fluorescence (500-580 nm, with blue light). In particular, the inoculation with powdery mildew was followed by a rapid increase in the affected leaf area (calculated from the fluorescence pictures) and the respective green fluorescence intensity in all cultivars. Differently, rust inoculated leaves showed an increase of the affected area over the time, while the intensity of green fluorescence decreased in inoculated leaves. These results confirm our previous observations and are strongly related to the green fluorescence emitted by the structures of the fungi.

With the hand-held multiparametric fluorescence sensor, we focused on two indices, the 'Blue-to-Far-red fluorescence ratio' (BFRR_UV) and the 'Simple Fluorescence Ratio' (SFR). Particularly in the cultivars susceptible to powdery mildew, BFRR had a stronger increase after inoculation as compared to the less susceptible ones. Moreover, the SFR, a ratio which depends on the intensity of the chlorophyll fluorescence, reveals a dynamic process characterized by increase of values in diseased leaves at 3 DAI followed by a decrease to 6 and 9 DAI.

In summary, we show that a) the fluorescence-based sensing of leaf rust and powdery mildew can be accomplished with selected fluorescence parameters already at 3 days after inoculation; b) the impact of the pathogens in changing the fluorescence signature becomes stronger in the time course of the experiments; and c) genotype-specific alterations of the fluorescence signature due to the occurrence of diseases might occur, but are not necessarily related to the susceptibility degree of the plant. Nevertheless, our results point to selected fluorescence indices for early sensing of diseases under laboratory and field conditions. Some of these selected indices might potentially be used as additional evaluation tool in plant breeding and supportive activities in precision farming.

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BUILDING PROACTIVE PREDICTIVE MODELS WITH BIG DATA TECHNOLOGY FOR PRECISION AGRICULTURE

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One drawback of many traditional precision agriculture (PA) paradigms is their reactionary approach in which only the current state of the field is provided to the growers without incorporating accurate predictive forecasts. Predictive modeling can be realized by integrating modern information technologies such as Big Data Analytics, GPS (Global Positioning Systems), remote sensing technology, and GIS (Geographic Information Systems). The research team at the University of St. Thomas (UST) strongly believe that a proactive approach will become more critical in PA applications. In the proactive approach, predictive models generate forecast reports to the growers, predicting the possible evolution of vegetation states and future risks in the field.

In order to provide highly accurate predictions to growers in real time, the predictive models must integrate tremendous amounts of information from numerous sources such as various sensor data (i.e. temperature, wind, soil pH, moisture) and aerial multi-spectral imagery data. Due to the amount of information that needs to be processed and the complexity of predictive models, the research team at UST plans to utilize a cloud computing platform such as Amazon's Cloud and SAP High performance ANAlytics (HANA) in-memory database. Without up-front infrastructure cost, this cloud computing approach is an affordable way to quickly setup a virtual computing platform to meet our processing needs. HANA provides an integrated environment for analytics solutions that allow data scientists to focus on examining data. Also, HANA can be hundreds of times faster than other big data solutions since it is a memory-based solution.

There are two major cloud-based tasks to our approach: image/data processing and prediction. The first task will process both the aerial multi-spectral image data and the ground-based sensor data. The processed data identified by the first task will then be sent to the second task where forecasts of items such as vegetation and soil health will be predicted.

Thus far, the UST team has worked on two predictive modelling techniques: 1) the "minimum-bounding-box" predictive model, and 2) the multi-variable rule-based predictive model. The proposed predictive modeling techniques take into account the spatio-temporal nature of the data. The "minimum-bounding-box" predictive model was the first modeling technique developed and it focuses solely on one variable – Normalized-Difference-Vegetation-Index (NDVI), which by using multispectral analysis measures the strength of photosynthesis occurring in vegetation. The goal of this predictive model is to predict the size & location of a region of concern. The NDVI images are stitched together to produce one large NDVI map of the field of interest. The areas of concern where the NDVI values indicate stressed vegetation are clustered before a minimum-sized rectangular bounding-box (minBB) is calculated to encapsulate each area of concern. For each point in time the minBB is applied to the NDVI maps, producing a time series of minBBs. Figure 1 shows a time series of false-color NDVI data indicating a growing area of concern over time. In turn, the size, location & orientation of the minBBs can be predicted over time using classical linear regression (CLR) techniques producing a final minBB that covers the predicted area of concern at the desired point in time. This final predicted minBB identifies the area of concern that could be focused on for applying treatments to recover the vegetation (figure 2). Lastly, "velocity" vectors are also applied to the final output showing the magnitude and direction of the NDVI change amongst the time frames.

The multi-variable rule-based predictive modeling technique takes into account spatial relationships between numerous variables beyond just NDVI. This technique attempts to capture these spatial relationships over time by using a combination of a data-mining concept called decision trees (DTs) and CLR. The fundamental steps of the algorithm are:

1. For each point in time, capture the key spatial relationships by building a DT to predict the NDVI value based on the variables' spatial relationships.
2. At each point in time, predict the classified NDVI value using the DTs.
3. Calculate the delta NDVI (ΔN) between points in the time.
4. Cluster the ΔN to filter and focus on various areas of change.
5. Lastly, apply CLR to the points in the areas of concern to predict NDVI values at the desired future time.

The end result of this second algorithm is a prediction that attempts to take into account key spatial relationships amongst the variables. Please note that this algorithm is scalable to take into account additional variables.

These aforementioned predictive model algorithms are just the beginning of the predictive modeling development, and the UST team believes their system may begin shifting the farming paradigm to more anticipatory rather than reactionary techniques.

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RADIO FREQUENCY IDENTIFICATION FOR IMPLEMENTING TRACEABILITY IN THE COTTON PRODUCTION IN THE BRAZILIAN MIDWEST

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This paper proposes a traceability chain in the context of cotton production presenting architecture for data collection along the cotton production chain from the planting to the processing stage in Mato Grosso State, located in the Brazilian Midwest. The proposal implementation was developed to provide a distributed environment with multiple data source collection in legacy systems, using Radio Frequency Identification – RFID to identify logical units at various stages of cotton production. This research is an innovation project developed at the Unisystem Agricultural Systems enterprise jointly with researchers from the Federal University of Mato Grosso – UFMT. This project intends to design and to implement an infrastructure model for cotton traceability, following a practical approach. The use of traceability in this case is focused on meeting the demands of a new value-added product market related to the consumer.

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DESIGN OF ECU MONITORING SYSTEM FOR AGRICULTURAL VEHICLE BASED ON ISO 11783

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International standard for implementation of electronic control unit (ECU) in agricultural tractors has been required for interoperability of various agricultural vehicles. The ISO 11783 standard is basically based on communication technology using the controller area network (CAN), it is typical standard technology for implementation of ECU in agricultural vehicle. CAN bus Communication system was developed by the distribution control of ECUs to comprise an agricultural tractor and implements. It can improve the performance, the productivity and the functions of agricultural vehicle through independent ECUs.

This study presents the implementation of method and evaluation about the monitoring system that displays the value of sensors and the status of actuator for agricultural vehicles.

We also call the real-time monitoring system because of collecting a large amount of data in ECU modules periodically. The prototype ECUs for the measurement of sensors or the control of actuators was laboratory experimental tests, and the requirement in accordance with ISO 11873 was satisfied.

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ANALYZING ORGANIC FARMING TRAINING IN THE CURRICULUM OF THE UNIVERSITY OF KWAZULU-NATAL, PIETERMARITZBURG

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The value invested in organic farming in the midst of the current environmental degradation is of great importance; hence the focus on organic farming training is crucial. Agricultural education should have a role to play. The study was conducted at the University of KwaZulu-Natal (UKZN), Pietermaritzburg, South Africa. UKZN is one of the largest academic agricultural institutions in the province where agriculture is taught. The aim of the research was to analyse the extent to which organic farming was included in the agricultural curriculum at UKZN. The study examined what is currently offered in terms of organic farming or sustainable agriculture. It identified the perceptions of students and lecturers about organic farming. Also it identified the challenges faced by academics and practitioners in respect to organic farming to provide insight into current and potential curricular offerings. The study was qualitative; data were collected through interviews, site visits, and observations. Interviews were conducted with 52 postgraduate students, 20 lecturers and eight nonuniversity key informants in the organic farming sector; all selected by purposive sampling. The study found that organic farming is present in the UKZN agricultural undergraduate curriculum to a small extent (5.5% was the highest rate of organic content concentration in the whole curriculum). There are no modules devoted exclusively to organic farming, but the subject was included in 10 modules offered in 2010 by five agriculture related disciplines (Agricultural Plant Science, Community Resource Management, Soil Science, Plant Pathology and Bioresources). The majority (88%) of students respondent indicated that it is important for organic farming to be taught at UKZN because it is a crucial knowledge for future generations. It addresses important issues such as the use of alternative methods in food production, human health protection, sustainability, and environmental protection. Those students who did not think it was important to include organic farming in the UKZN curriculum (6%) argued that organic farming would never feed the exponentially growing population of the world, hence enough yield production is the first priority. The academic staff interviewed related organic farming to sustainability, environmental protection, use of alternative methods for food production, human health protection and knowledge for future generations.

Organic farming was regarded as a crucial approach on different levels, including food security, environment, economy and market. It was indicated by 30% of lecturers that organic farming is of little importance to the economy and markets. Their reasons were similar to those of students who did not organic farming as being important, namely that organic farming is unable to feed a large number of population and it is not commercially profitable. The nonuniversity key informants considered as experts in organic farming felt strongly that the fact that people have committed themselves to business ventures in organic farming is a good indication of the viability of organic farming. Collectively, the respondents cited a number of challenges and issues which they suggested as reasons for the slow progress of organic farming in South Africa and why it is perceived as a difficult (perhaps unrealistic) route to follow. These included the cost involved in production of organic food, poor yields, making organic farming not competitive, lack of interest or awareness on the part of consumers, uncertainty for career opportunities, lack of expertise by academics and farmers in the domain, chemical companies driving all the support of investors, and government not supporting organic farming. The study recommended that of the presence of organic farming be enhanced in the UKZN agricultural curriculum. Modules dedicated to organic farming in which the theory and practice of organic farming is learned should be developed and set as compulsory modules for UKZN undergraduate agricultural qualifications. Existing production modules should be expanded to include an intelligent debate concerning organic farming. It further recommended that students should be involved in curriculum development as they can contribute with good ideas to improve their own learning, more research and open, objective debate about the merits and disadvantages of organic farming should be encouraged to eliminate uncertainty. Finally farmers' knowledge and skills in producing, marketing and initiation of partnerships among organic farmers, processors, retailers and government should be undertaken to establish a framework for taking the debate to grassroots level.

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A STUDY ON DIAGNOSTIC SYSTEM BASED ON ISOAGLIB FOR AGRICULTURAL VEHICLES

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In this paper work, we consider implementation of Diagnostic System for functionalities of handling internal errors and monitoring states into Implement ECUs. Software implementation is based on IsoAgLib library developed by OSB&IT Engineering Company. We develop a target system including diagnostic and monitoring with IsoAgLib Library that has the communication services and management systems according to the ISO 11783 standard. This library allows building ISOBUS compatible equipment without the protocols implementation contained in this standard. We focus on developing Smart Sprayer ECU that is capable of controlling Nozzles adaptively according to a working environment such as wind, ground, humidity and etc. Hardware implementations of ECUs are developed by using STM32F107 ARM 32-bit Cortex™ -M3 CPU and CAN-bus receiver/ transceiver driver chip. Time managing of the system is implemented using time stamp messages between ECUs and Diagnostic System with monitoring.

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