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An Automatic Data Acquisition and Control Mobile Laboratory Network for Crop Production Systems Data Management and Spatial Variability Studies in the Brazilian Center-West Region

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Abstract. *This paper describes all tools and procedures used to structure and implement an automatic data acquisition and control mobile laboratory network for crop production systems data management and spatial variability studies in the Brazilian Center-West Region. It was set up with base in remote sensing and microprocessor techniques, microelectronic devices, sensors, controls, sampling systems, data loggers, portable microcomputers, automatic data acquisition, RF communications link, and the global positioning system (GPS), allowing for the acquisition of spatially related data during tilling, planting, and harvesting. Physical chemistries and biological characteristics of the continuous soil-water-plant-atmosphere were monitored along of the crop growth period, at field conditions, seeking the rationalization of the agricultural inputs use and the performance improvement of agricultural systems. Some results are presented.*

Keywords. Precision agriculture, automatic data acquisition and radio frequency networking, spatial variability, remote sensing, sensors controls, crop data management system.

Introduction

Agricultural production systems evaluation is timing consuming and very difficult to assess by means of selected crops fields visits because involves measurements and registration of certain physical-chemistry and biological characteristics of the cultivated areas. This has been the main problem that technicians and farmers face to trace support decision strategies for crop production systems management, looking for a sustainable agricultural exploration, competitiveness market, and business opportunities. To evaluate a crop production system, the continuous soil-water-plant-atmosphere (SWPA) may be considered as a dynamic system, physically integrated, where the absorption, transport and assimilation processes occur interactively. Thus, a great number of field attributes measurements related to the SWPA continuous is necessary (local field survey, soil water availability, soil compaction, soil fertility, biomass yield, leaf area index, leaves temperature, leaves chlorophyll content, plant water status, local climate data, insect-disease-weeds infestation, etc.) in order to assess the field actual situation and to select and prioritize where the investment should take place. Field survey on these subjects is becoming a key issue.

An automatic data acquisition and control mobile laboratory network for crop production system data management and spatial variability studies have been the main focuses of researchers interest in Brazil. Unavoidably, that requests the technology use, involving instrumentation, automation, wireless data transmission, and remote sensing. More recently, with the technology of precision agriculture it is possible the organization and maintenance of databases that are important for the techniques development, seeking the rational use of natural resources and optimization of agricultural inputs, with consequent reduction of production systems costs and environmental impacts, assuring the systems sustainability. Among several responsible factors for the crop production risk in the Brazilian Center-West region, may be pointed out spatial soil and rainfall variability. The soil variability in the field is one of the most important factors, because it influences the nutrients and water availability directly for the crops. The rainfall presents two distinct periods, dry and rainy seasons, offering great risk for the agriculture practice. This kind of study demands the automatic data acquisition and geographic information system (GIS), requesting the intensive use of the global positioning system (GPS). Technologies demand for larger stabilization of the agricultural production has been accentuating in the last ten years in Brazil. The entire field uniform treatment adoption of agricultural practices, based on medium values of the parameters used in the crop management, may result in economic losses for the farmers and provoke damages to the environment, as the water resources contamination. The recognition of the spatial field variability has been the reason for division of the field in zones, seeking a more technical agriculture and looking for homogeneous characteristic specific sites.

The instrumentation and automation of crop production system processes in the Brazilian agriculture are still very incipient. With the use of microprocessors, sensors, dataloggers, microelectronic devices and portable computers it is possible to improve this picture and look for automatic field data acquisition alternatives. Overall, the final objective is to improve the quality and cost of agricultural products. In order to revert this picture, investigation must be carried out, seeking the agricultural inputs application according to actual amounts requested by the crops in the correct sites of the field.

The objective of this work is to describe all tools and procedures used to structure and implement an automatic data acquisition and control mobile laboratory network for crop production systems data management and spatial variability studies in the Brazilian Center-West Region. This laboratory was set up with base in remote sensing and microprocessor

techniques, microelectronic devices, sensors, controls, sampling systems, data loggers, portable computers, automatic data acquisition, RF communications link, and the GPS, allowing for the acquisition of spatially related data during tilling, planting, and harvesting. Physical chemistries and biological characteristics of the continuous SWPA are being monitored along of the crop growth period, at field conditions, seeking the rationalization of the agricultural inputs use and the performance improvement of agricultural systems.

Remote Agricultural Areas Application

An automatic data acquisition and control mobile laboratory (ADAC-MobLab) network is being developed for registering and evaluating field agricultural attributes, operations and processes for agricultural research use on farms machinery in the field. This laboratory is being used as a tool to aid researchers carrying out field scouting in the selected remote agricultural areas experiments of the Embrapa's Precision Agriculture Technologies Program, seeking the complete accompaniment of the crop production systems during the tilling, planting or harvesting season, helping taking decisions for near real time crop management. These experiments are being conducted on the Brazil Southeastern and Center-western farms.

The Embrapa's Precision Agriculture Technologies Program was initiated three years ago to integrate efforts for using and generating of knowledge and information on precision agriculture instruments and techniques for increasing efficiency and better management of the crop production systems. A group of scientists from different Embrapa's Units and Institutions is involved in this program, in order to study the feasibility of using precision agriculture technique under Brazilian field conditions, based on detailed measurements of many different production system attributes related to the SWPA continuous, seeking the parameters which best describe in-field variation of crop production system in a consistent way. The two first years research work started on an area (38 ha), irrigated by a center pivot system, at Sete Lagoas (19° 28' South latitude, 44° 15' West Greenwich longitude, and 732 m elevation), MG, Brazil, by doing a soil sampling grid of 25m by 25m for soil survey and fertility analysis. Corn, pear millet and soybean were planted, under no tillage condition, in the whole area. Different ways of fertilizer application has been studied by comparing the traditional whole area soil nutrients medium values method against the divided sub areas variable rate (VR) application method based on spatial variability maps of the soil fertility. The soil profile penetration resistance was measured using an automatic cone penetration meter for checking soil compaction. The yield maps were generated and an economical analysis performed. All the attributes have been monitored by means of the differential global positioning system (DGPS) in order to obtain the maps.

The experience acquired on the pilot area in Sete Lagoas (38 ha center pivot) led to the idea of developing an ADAC-MobLab for use on field scouting and field farm machinery in order to ensure that data are reliably taken and immediately available through the use of remote radio-frequency (RF) Ethernet networking

Mobile Laboratory Network Description

A ground-based ADAC-MobLab network is being developed at the Embrapa's Precision Agriculture Program for agricultural research use on farms machinery in order to acquire spatially distributed field agricultural attributes data during the tilling, planting or harvesting season. It is based on a dedicated data collection vehicle, the mobile laboratory, and associated farm machinery, farm manager's vehicle, and field fix instrumentation/equipment (Figure 1).

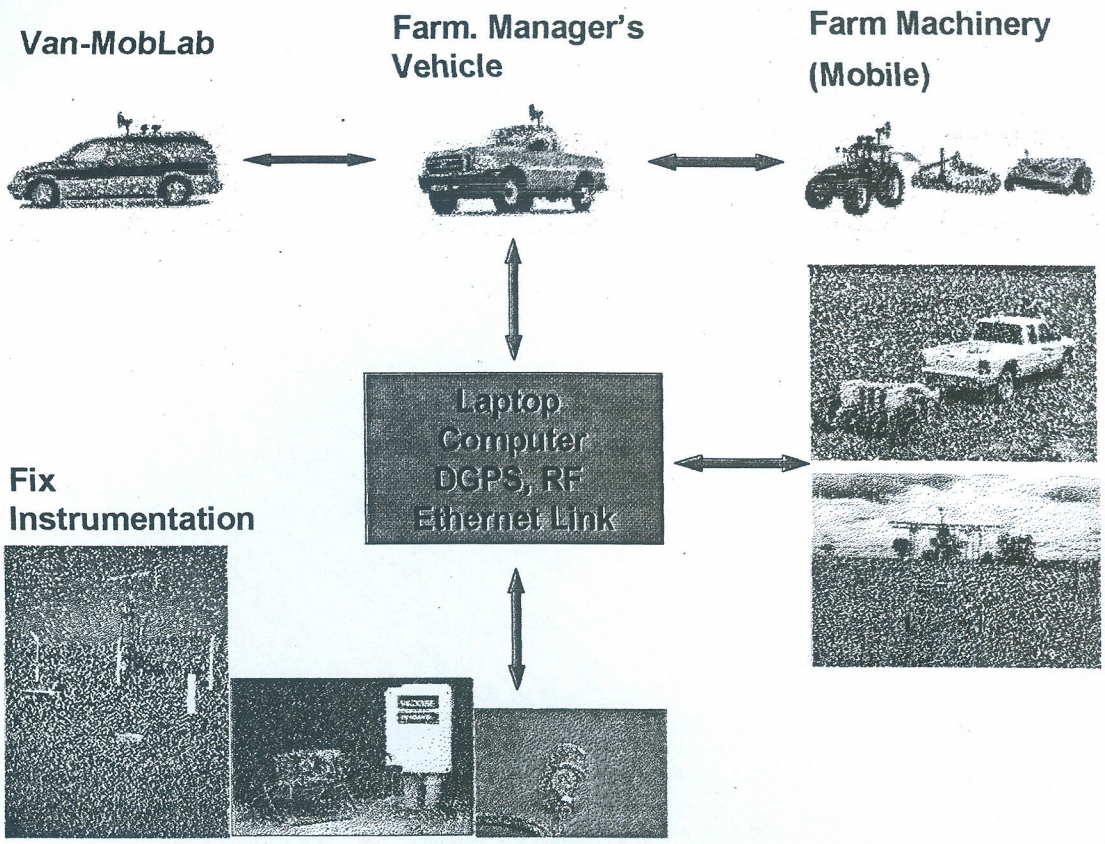

Figure 1. Automatic data acquisition and control mobile laboratory network block overview for crop production systems data management and spatial variability studies.

The dedicated data collection vehicle (Van-MobLab) is utilized basically for network routing data storage server, data display engineering and crop production system analysis, local wireless ethernet, monitoring, and data archival functions. The Van-MobLab contains networked computers, display software, and an RF communications link to the farm machinery, farm manager's vehicle, and field fix instrumentation/equipment. The farm machinery is comprised of tractors and implements which are instrumented with differential global position system (DGPS), electronic sensors, controls, sampling systems, dataloggers, and RF medium distance communications link designed to register a great number of field attributes measurements related to the SWPA continuous, such as, local field survey, soil water availability, soil compaction, soil fertility, biomass yield, leaf area index, leaves temperature, leaves chlorophyll content, plant water status, local climate data, insect-disease-weeds infestation, grain yield, etc, in order to assess the field actual situation and variability during tilling, planting, and harvesting. The field fix instrumentation/equipment also consists of electronic sensors, controls, sampling systems, dataloggers, and RF communications link used to register soil, plants, and atmosphere field attributes. The farm manager's vehicle is a pickup which is used for troubleshoot the electronic devices in-the-field link and communication with the farm machinery, containing a laptop computer with graphical display software and the same RF communication link. These four elements together constitute the ground-based ADAC-MobLab network for crop production systems data monitoring and management. The following is a brief description of the ADAC-MobLab network elements.

Dedicated Data Collection Vehicle (Van-MobLab)

The physical space of a Van is being used as versatile and compact Mobile Laboratory, a dedicated data collection vehicle (Van-MobLab). The back part of this vehicle is being completely adjusted and equipped for automation and control of field data acquisition. It contains conditioned air, electric power generator (120 Vac), water reservoir, drawers, desks, and file cabinets, all mounted fixed in order to facilitate the vehicle locomotion. The Van-MobLab is equipped with storage for spare components and electronic devices where equipment can be repaired, sensors can be tested, data can be analyzed, samples can be stored, and software can be worked out without leaving the field. It also contains a networked computer system used to monitor daily operations and analyze data. This computer has an Ethernet (RF) card with a directional antenna connected to it and performs network routing, modem communication, data storage, and program development. The antenna allows medium distance links (about 3 Km) with the farm machinery. The computer allows data transfer to and from the farm machinery and runs LabView for operator-display generation, data analysis, and real-time viewing of farm-machinery operating attributes.

Farm Manager's Vehicle

A pickup is being used as farm manager's vehicle which contains a laptop computer equipped with a PCMCIA RF Ethernet card, data handling utilities, LabView graphical display applications, and a directional antenna connected to it for troubleshoot the electronic devices in-the-field link and communication with the farm machinery over the same connectivity as the Van-MobLab, allowing remote logins and files uploading and downloading. The antenna also allows medium distance links (about 3 Km) with the farm machinery. With this vehicle, either the manager or engineer can connect in real time at the operating-system level for trouble-shooting purposes and keep track of data on the laptop in order to examine machine and data acquisition system performance.

Farm Machinery

The farm machinery is comprised of tractors, combines, planters and others implements. Each farm machine is equipped with automatic acquisition and control systems. The following instrumentation, designed to register a great number of field attributes related to the SWPA continuous, such as, local field survey, soil water availability, soil compaction, soil fertility, biomass yield, leaf area index, leaves temperature, leaves chlorophyll content, plant water status, local climate data, insect-disease-weeds infestation, grain yield, etc, form the core of the farm machinery: differential global position system (DGPS), electronic sensors, controls, sampling systems, dataloggers, and RF medium distance communications link in order to assess the field actual situation and variability during tilling, planting, and harvesting.

The automatic acquisition and control systems are modular and can be easily moved from one machine to other as soil sampling, planting, cultivating, crop surveying, and harvesting requires. Basically these systems consists of portable computer (laptop), DGPS, data acquisition system (sensors, electronic circuit, datalogger, storage module, software), RF Ethernet link, and power conditioning module.

The portable computer consists of a laptop which is responsible for the control of farm-machine data acquisition and storage, and also telemetry of data. Serial communication cables (RS-232) are used to connect with the DGPS and sensors through the computer serial ports. The laptop computer is equipped with a PCMCIA card interface, data handling utilities, LabView graphical

display applications, and a directional antenna connected to it for troubleshoot the electronic devices in-the-field link and communication with each farm machine.

For the acquisition of spatially related field attributes (SWPA continuous) data during soil sampling, planting, tilling, and harvesting, a DGPS, which has an accuracy under 1 meter is being used.

Automatic remote sensing of a crop surface with radiometers and infrared thermometry are being used with a mobile platform ("skinny boy") in order to assess the cultivated area water and nutrients status (Nitrogen and Phosphorus) through measurements of crop foliage temperature and reflectance (Figure 1). These technique are being used to detect soil moisture and plant nutrients spatial variability, using plants anatomical and physiological changes as indicator. Thermal infrared radiation data (canopy temperatures) are being utilized to estimate crop water stress directly and water availability to a cultivated field. Automatic remote sensing methods applied to the water and nutrients status of a crop is a relatively new field of investigation in Brazil.

The soil compaction is being monitored with DGPS by means of an automatic penetrometer, consisting of a box containing the electronics and a stainless steel rod with a conical tip which is attached to the box via a force transducer (load cell). Also the speed and depth of the stainless steel rod insertion is being measured along with the force The penetrometer used is attached to the hydraulic cylinder by a quick connect coupling (Figure 1).

Fix Instrumentation/Equipment

The field fix instrumentation/equipment also consists of electronic sensors, controls, sampling systems, dataloggers, and RF communications link used to register soil, plants, and atmosphere field attributes. Automatic weather station is being used to assess weather influences on crop production system. Time domain reflectometry (TDR) technique is being used to register the propagation of an electrical signal which is dependent on the soil water content and electrical conductivity (dielectric constant of soil).

Conclusion

Automatic field crop data acquisition, describing spatially variable continuous SWPA attributes and state-variables, is required to seek the complete accompaniment of the crop production systems during the tilling, planting or harvesting season, helping farmers and technicians taking decisions for near real time crop management in order to better understand the acquisition of spatially related data and to improve land management (rationalization and optimization of the agricultural inputs and improvement of agricultural systems performance). Automatic remote sensing of a crop surface with radiometers and infrared thermometry can provide some of this data economically; however, there is a need for reliable and cheaper ground based attributes measurement methods which cannot be remotely sensed, for high resolution data. A ground-based ADAC-MobLab network for acquiring spatially field agricultural variable data, during the tilling, planting or harvesting season, is being developed. It is based on a dedicated data collection vehicle, the mobile laboratory, and associated farm machinery, farm manager's vehicle, and field fix instrumentation/equipment. The rapid spatially data collection rates make the system extremely useful for crop production systems management. The ADAC-MobLab network is currently being used to study spatial variation of soil water availability, soil compaction, soil fertility, leaves temperature, leaves chlorophyll content, plant water status, local climate data, insect-disease-weeds infestation, grain yield. It is being used as a tool to aid

researchers carrying out field scouting in the selected remote agricultural areas experiments of the Embrapa's Precision Agriculture Program in the Brazilian center-west region.

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