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GPS and remote sensing adoption in precision agriculture

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ABSTRACT : Precision farming is information and technology based agricultural management system to identify, analyze and manage site-soil, spatial and temporal variability within fields for optimum profitability, sustainability and protection of the environment. Precision farming or satellite farming is a farming management concept based on observing and responding to intra-field variations. Today, precision agriculture is about whole farm management with the goal of optimizing returns on inputs while preserving resources. It relies on new technologies like satellite imagery, information technology, and geospatial tools. It is also aided by farmers' ability to locate their precise position in a field using satellite positioning system like the GPS or other GNSS. This article presents outline of progress and present standing of GPS and remote sensing precision agriculture technologies.

KEY WORDS : Precision agriculture, GPS, Remote sensing, GIS, Agricultural management

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In many developing countries, agriculture is still the backbone of the economy. The success of precision farming depends on numerous factors, including the extent to which conditions within a field are known, how best we can manage, the exact quantity of input recommendation and the degree of application control, (Robert *et al.*, 1995). Precision agriculture concept was initiated for site specific crop management as a combination of positioning system technology, variable rate technology, remote sensing, yield mapping etc. to optimize the profitability, sustainability with a reduced environmental impact. From centuries Indian farms are experiencing some sort of soft precision agriculture technology. But the challenges of free and globalized market as well as ever-increasing population with huge food grain demand create the scope of adoption of hard precision agriculture technology in Indian farms. So learning the new agricultural technology invented in developed countries and its proper modification and application according to the domestic condition is necessary, (Mondal *et al.*, 2011). The rapid revolution of precision agriculture has sparked research in many areas. These include the evaluation of these technologies, development of appropriate uses of the technologies, demographic patterns of use of these technologies, and economic and environmental benefits of the technologies. Research has suggested that adoption of precision agricultural technologies has been influenced by socioeconomic characteristics, such as farm size (Khanna, 2001).

With the progress and application of information technology in agriculture and IT revolution in developing countries like India, China etc., precision agriculture has been increasingly gaining attentions worldwide (Luo *et al.*, 2006). The adoption of precision agriculture technologies has been uneven, both geographically and temporally. The economic theory of induced innovation predicts that new technologies will be developed and adopted where they make more efficient use of the scarcest productive resources, (Norton and Swinton, 2001). PA is conceptualized by a system approach to re-organize the total system of agriculture towards a low-input, high-efficiency, sustainable agriculture (Shibusawa, 1998). Precision farming makes use of remote sensing to macro-control of GPS to locate precisely ground position and of GIS to store ground information. It precisely establishes various operations, such as the best tillage, application of fertilizer, sowing, irrigation, harvesting etc., and turns traditional extensive production to intensive production according to space variable data, (Shanwad *et al.*, 2004). Precision farming will likely gain in importance only when viable additional benefits such as reduced environmental burdens and increased flow of information, are recognized and evaluated and becomes part of the reward itself, (Auernhammer, 2001).

Zhang *et al.* (2002) studied worldwide applications and adoption trend of precision-agriculture technologies and potentials of the technologies in modernizing the agriculture in China. The use of computers, global positioning systems (GPS), variable rate technology farm implements, geographic information systems (GIS), machine guidance and remote sensing provide farm managers with unprecedented levels of information. Site specific information available on every square meter of the farm is now being used to reverse the practice of uniform inputs to large fields (McKinion *et al*., 2001). Precision agriculture involves using electronic technology to collect a large amount of data in the field for use in site-specific crop management. Major issues in the implementation of PA include interpreting the huge amount of data collected, understanding the causes of variability, and being able to propose sound strategies for field variability management, (Murakami *et al*., 2007).

When a decision has been made to adopt some aspect of PA, the timing of that adoption may be delayed by problems in the equipment replacement cycle for the underlying machines on which GPS, sensors and other electronics are to be installed (Krause and Black, 1995). The development of proper decision-support systems for implementing precision decisions remains a major stumbling block to adoption. Other critical research issues are discussed, namely, insufficient recognition of temporal variation, lack of whole-farm focus, crop quality assessment methods, product tracking and environmental auditing. A generic research programme for precision agriculture is presented. A typology of agriculture countries is introduced and the potential of each type for precision agriculture discussed (McBratney and Ancev, 2005). Agriculture production systems have benefited from incorporation of technological advances primarily developed for other industries. The industrial age brought mechanization and synthesized fertilizers to agriculture. The technology age offered genetic engineering and automation. The information age brings the potential for integrating the technological advances into precision agriculture, (Whelan *et al*., 1997). Attitudes of confidence toward using the precision agriculture technologies, perceptions of net benefit, farm size and farmer educational levels positively influenced the intention to adopt precision agriculture technologies. The perception of usefulness positively influenced perception of net benefit, (Adrian *et al*., 2005).

GPS in precision agriculture :

At a basic level, precision agriculture can include simple practices such as field scouting and the spot application of pesticides. However, precision agriculture usually brings to mind complex, intensely managed production systems using global positioning system (GPS) technology to spatially reference soil, water, yield, and other data for the variable rate application of agricultural inputs within a field.

Runquist *et al*. (2001) developed a field-level GIS (FIS) containing analytical functions for spatial data analysis in PA research.Global positioning system (GPS) is a satellite navigation system developed and maintained by the United States. GPS receivers on the ground can collect data and convert the radio signals from satellites into position data (Bernhardsen, 1992). Dingemans (1997) emphasized the necessity of an accurate and reliable DGPS data collection to be used with a yield monitoring system. Yield maps are produced by fitting a yield monitor to a combine harvester to measure the amount of yield at a particular time. Each GPS satellite continuously broadcasts two radio signals on separate L band frequencies. Positioning system based coarse/ acquisition (C/A) code of L1 signal is known as Standard Positioning System (SPS) and civilian users can use only this SPS (Pfost *et al.,* 1998).

The global positioning system (GPS) receivers, used to locate and navigate agricultural vehicles within a field, have become the most common sensor in precision agriculture. In addition to having the capability to determine geographic coordinates (latitude and longitude), high-accuracy GPS receivers allow measurement of altitude (elevation) and the data can be used to calculate slope, aspect and other parameters relevant to the landscape.(Adamchuk *et al*., 2004). At the end of the 1980, the ‘global positioning systems’ (GPS), NAVSTAR-GPS and GLONASS, introduced a new era. For the military, positioning and time became available at any time and place. Both kinds of information could also be used for civilian purposes, even if the accuracy obtained was somewhat diminished, (Auernhammer, 2001). All the position data should be stored and distributed from only one system, installed at a central vehicle (e.g. the tractor), for any task (Mondal and Tewari, 2007). Elevation and slope of the field were measured from a global positioning system (GPS) unit on the combine. Both were related to yield variability in the field. The study showed that high grain yield, straw yield and biomass could be related to flat, high places in the field with little erosion, whereas high straw yield and low grain yield were found at low places in the field on relatively steep slopes. Lowest grain yield, straw yield and biomass were located on steepest slopes with high erosion and in depressions where accumulation of eroded soil took place (Reyniers *et al.,* 2006).

A management zone also can be delineated by more than one specific crop inputs. In this case, a single rate is applied for each of the specific inputs within a zone. The number of distinct management zones within a field is a function of the natural variability within the field, the size of the field, and certain management factors. The minimum size of a zone is limited by the ability of the farmer to differentially manage regions within a field. If a GPS is involved to control the application or to guide the implement, there seems no reason for restrictions on the shape of the zone. However, in reality, the pattern in which the application equipment traverses the field should be considered when delineating the management

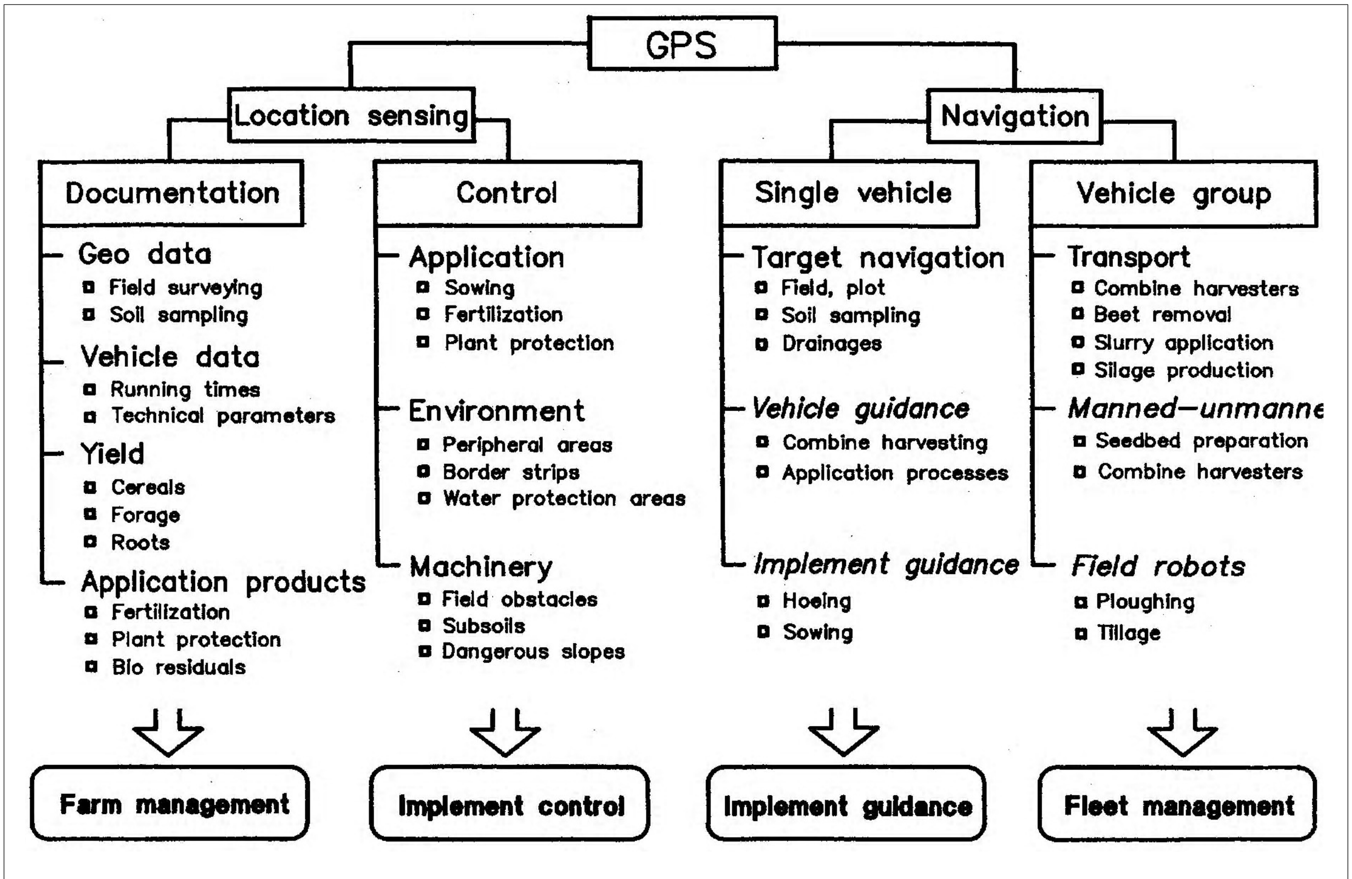

Fig 1: GPS in agriculture

zones (Kvien and Pocknee, 2000). The use of global positioning system in agriculture has been shown in Fig. 1.

Commercial sensors receiving and processing GPS signals have become affordable for most farmers in developed countries. Handheld GPS receivers provide positioning accuracy within 9/100 m. Differential GPS (DGPS) reduces the error to 9/2 m. A relative positioning GPS brings the error down to the sub-centimeter level. This accuracy can be maintained for moving vehicles using a real-time kinematics (RTK) GPS, Dux *et al.* (1999). PA technologies also have been used in forest production. In Washington, GPS receivers and dataloggers were used to track activities of log harvesting machines (Reutebuch *et al.*, 1999).

Remote sensing in precision agriculture :

Remote sensing is the science and art of acquiring information about the earth's surface without actually coming in contact with it. This is done by recording energy, which is either reflected or emitted from the earth's surface. The information recorded is then processed and analyzed, and the information is used to develop a prescription map that can be used in a variable-rate application. Remotely sensed data, obtained either by aircraft or satellite, containing electromagnetic emittance and reflectance data of crop can provide information useful for soil condition, plant growth, weed infestation etc. This type of information is cost effective and can be very useful for site-specific crop management programs (Plant, 2001). The sensors have been based on electrical and electromagnetic, optical and radiometric, mechanical, acoustic, pneumatic and electrochemical measurement concepts. While only electric and electromagnetic sensors are widely used at this time, other technologies presented in this review may also be suitable to improve the quality of soil-related information in the near future, (Adamchuk *et al.*, 2004). Mapping of weeds against bare soil for row crops at early stages of seedlings has been carried out successfully. Depending on the principle that weed, bare soil and crop has different spectral signature, weed patches, in both 18 and 30 cm row spacing, have been detected (Lamb, 1995). The potential for dedicated satellite systems for agricultural applications has improved with the development of "small-Sat" constellations of relatively cheap sensors that can be pointed and targeted and that provide the frequency of coverage needed (for example, the Compact High Resolution Imaging Spectrometer (CHRIS) used for structural retrievals

(Chopping *et al.*, 2004). Ground penetrating radar (GPR) with 100 MHz surface GPR antennas was used to estimate soil moisture content (Lunt *et al.,* 2005).

The development of sensors is expected to increase the effectiveness of precision agriculture (Pierce and Nowak, 1999). Schellberg *et al.* (2008) discussed current developments and future perspectives of digital image processing, remote sensing, yield measurement and site-specific management on grassland. At fine scales, on-board sensors can provide information on sward properties that application techniques could respond to. At larger scales, remotely sensed information can provide digital maps of type and status of vegetation that allows a precise management, although the mix of spatial coverage and spatial resolution is not yet ideal. The site-specific management on arable land, however, has not yet proven its applicability in different environments. On grassland, some of these technologies are either already implemented as prototypes into research projects or under development with a short-term perspective to be introduced into practice. A capacitance sensor, a sensor measuring power required at the PTO shaft, a microwave sensor and a NIR sensor were tested to measure moisture content of forage (Marcotte *et al*., 1999). McLaughlin and Burtt (2000) used draft sensors on a three-point hitch of a tractor to record draft data and made a tillage-energy map in Ontario, Canada. Such maps may provide an additional, inexpensive map layer for soil-related information for PA applications.

A penetrometer equipped with a near-infrared reflectance sensor measured soil penetration resistance as well as moisture content and organic matter (Newman and Hummel, 1999). Wang *et al.* (2001) developed an optical weed sensor based on a study on spectral characteristics of weeds, crops, and soil. Operation speed and height, soil moisture and temperature, topsoil depth, and simply instrumentation drift with time may cause significant effects on EC measurements while using an electromagnetic sensor (Sudduth *et al.*, 2001). Whalley and Bull (1991) theoretically examined the feasibility of using a microwave sensor to predict soil moisture content. They reported potential difficulties with sensor calibration and measurements below 10 cm. Monitoring different parameters of interest in a crop has been proven as a useful tool to improve agricultural production. Crop monitoring in precision agriculture may be achieved by a multiplicity of technologies; however, the use of Wireless Sensor Networks (WSNs) results in low-cost and low-power consumption deployments, therefore, becoming a dominant option. It is also well-known that crops are also negatively affected by intruders (human or animals) and by insufficient control of the production process, (Garcia-Sanchez *et al.,* 2011). Soil apparent electrical conductivity (ECa) has been used as a surrogate measure for such soil properties as salinity, moisture content, topsoil depth (TD) and clay content. Measurements of ECa can be accomplished with commercially available sensors and can be used to efficiently and inexpensively develop the dense datasets desirable for describing within-field spatial variability in precision agriculture. The objective of this research was to investigate accuracy issues in the collection of soil ECa data, (Sudduth *et al.,* 2001).

Moran *et al.* (1997) reviewed the potentials and limitations of remote sensing data for precision crop management. Based on precision crop management systems, they identified eight areas where remotely sensed imagery could provide missing information. These relate to zone management, crop yield prediction, soil type mapping, seasonal variations, production of Digital Elevation Models, aerial imagery for damage control, etc. Remote sensing techniques can also be utilized to detect soil related variables, pest incidence and water stress, (Leone *et al.*, 1995). Recent research in precision farming has focused on site-specific management zones (SSMZ) as a means to generate application maps and improve nutrient management in cropping systems, (Fleming *et al.*, 2001). Remote sensing provides a great deal of fundamental information relating spectral reflectance and thermal remittance properties of soils and crops to their agronomic and biophysical characteristics at scales that may range from small patches within a field to large regions (Pinter *et al.*, 2003).

Conclusion :

Therefore, it is anticipated that some of the reviewed sensor prototypes will be involved in agronomic and economic studies demonstrating the value and potential of information accessible through on-the-go soil sensors for precision agriculture. On-the-go yield monitors, proximal plant-canopy and electromagnetic soil sensors and airborne/satellite remote sensing have all been introduced into mainstream agriculture practice under the auspices of precision agriculture. While these technologies have been shown to provide production and environmental benefits, widespread adoption has been slow. In many cases, new technologies have been produced through developer push rather than user pull. Insufficient attention is paid to well-known technology adoption paradigms and as a consequence, the adoption of precision agriculture technologies is not as great as it could and should be.

In precision agriculture there is commonly a large knowledge gap between developers and users and not enough attempts is being used up on closing this gap. By paying attention to developing of protocols and realistic performance criteria, developers can exert a stronger, positive influence on the rate and breadth of adoption. Precision agriculture is economically and ecologically promising. One day, it will be a standard practice. Predicting exactly when that day arrives is difficult. A decisive factor will be how quickly cadres of producers acquire and use the acquaintance of geospatial techniques.

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■ REFERENCES

Adamchuk, V.I., Hummel, J.W., Morgan, M.T. and Upadhyaya, S.K. (2004). On-the-go soil sensors for precision agriculture. *Compu.& Electro. Agric.,* **44**:71–91.

Adrian, A.M., Shannon, H., Norwood, P. and Mask, L. (2005). Producers' perceptions and attitudes toward precision agriculture technologies. *Compu.& Electro. Agric.*, **48**:256–271.

Auernhammer, H. (2001). Precision farming - the environmental challenge. *Compu.& Electro. Agric.,* **30**: 31–43.

Bernhardsen, T. (1992). *Geographic information systems.* Arendal, Norway: Viak IT, pp. 1-318.

Chopping, M., Laliberte, A. and Rango, A. (2004). Multi-angle data from CHRIS/Proba fordetermination of canopy structure in desert rangelands. Geoscience and Remote Sensing Symposium. *Proc. IEEE Internat.,* **7**:4742–4745.

Dingemans. M.J. (1997). The practical implementation of precision farming for European agriculture. In: Stafford, J.V. (ed.) *Precision Agric.,* **97** (2): 727-733.

Dux, D.L.,Strickland, R.M. and Ess, D.R. (1999). Generating field maps from data collected by speech recognition.ASAE Paper No. 99-1099,American Society of Agricultural Engineers, St. Joseph, MI, USA.

Fleming, K.L., Westfall, D.G. and Bausch, W.C (2001). Evaluating management zone technology and grid soil sampling for variable rate nitrogen application. In: Proceedings 5th International Conference on Precision Agriculture, Madison.

Garcia-Sanchez, A.J., Garcia-Sanchez, F. and Garcia-Haro, J. (2011). Wireless sensor network deployment for integrating video-surveillance and data-monitoring in precision agriculture over distributed crops. *Compu. & Electro. Agric.*, **75**:288–303.

Khanna, M. (2001). Sequential adoption of site-specific technologies and its implications for nitrogen productivity: a double selectivity model. *Am. J. Agric. Econ.* **83**: 35–45.

Krause, M.A. and Black, J.R. (1995). Optimal adoption strategies for no-till technology in Michigan. *Review Agric.Econ.,* **17**:299-310.

Kvien, C. and Pocknee, S. (2000). Introduction to why management zone. National Environmentally Sound Production Agriculture Laboratory (NESPAL), College of Agricultural and Environmental Science, University of Georgia, GEORGIA.

Lamb, D.W. (1995). Aerial video and spatial data. In: Riverinal Outlook Conference Information Management, Wagga Wagga, Australia pp. 45-54.

Lunt, I.A., Hubbard, S.S. and Rubin, Y. (2005). Soil moisture content estimation using groundpenetrating radar reflection data. *J. Hydrol.*, **307**(1-4): 254–269.

Luo, X., Zang, Y. and Zhou, Z. (2006). Research progress in farming information acquisition technique for precision agriculture. *Trans. Chinese Soc. Agric. Engg.,* **22**: 167-173.

Murakami, E., Saraiva, A.M.,RibeiroCugnasca, C.E., Hirakawa, A.R. and Correa, P.L.P. (2007). An infrastructure for the development of distributed service-oriented information systems for precision agriculture. *Compu.& Electro. Agric.,* **67**:213–228.

Marcotte, D., Savoie, P., Martel, H. and Theriault, R.(1999). Precision agriculture for hay and forage crops: a review of sensors and potential applications. ASAE Paper No. 99-1049, American Society of Agricultural Engineers, St. Joseph, MI, USA.

McBratney, A. and Ancev, T. (2005). Future directions of precision agriculture, *Precision Agric.,* **6**: 7–23.

McKinion, J.M., Jenkins, J.N., Akins, D., Turner, S.B., Willers, J.L., Jallas, E. and Whisler, F.D. (2001). Analysis of a precision agriculture approach to cotton production. *Compu.& Electro. Agric.,* **32**:213–228.

McLaughlin, N.B. and Burtt, S.D. (2000). Spatial mapping of tillage energy. Proceedings of Fifth International Conference on Precision Agriculture(CD), July 16-19, 2000.Bloomington, MN, USA.

Mondal, P. and Tewari, V.K. (2007). Present status of precision farming: A Review. *Internat. J. Agric. Res.*, **1** (2): 1-10.

Mondal, P., Basu, M. and Bhadoria, P.B.S. (2011). Critical review of precision agriculture technologies and its scope of adoption in India. *American J. Exp. Agric.,* **1**(3): 49-68.

Moran, M.S., Inoue, Y. and Barnes, E.M. (1997). Opportunities and limitations for image-based remote sensing in precision crop management. *Remote Sensing Environ.*, **61**: 319–346.

Newman, S.C. and Hummel, J.W. (1999). Soil penetration resistance with moisture correction. ASAE Paper No. 99-3028, American Society of Agricultural Engineers, St. Joseph, MI, USA.

Norton, G.W. and Swinton, S.M. (2001). Precision agriculture: Global prospects and environmental implications. Tomorrow's agriculture: Incentives, institutions, infrastructure and innovations. Aldershot, U.K., ASHGATE.

Pfost, D., Casady, W. and Shanon, K. (1998). Precision agriculture; global positioning system (GPS). Water quality, University Extension, University of Missouri -system.

Pierce, F.J. and Nowak, P. (1999). Aspects of precision agriculture. *Adv. Agron.*, **67**:1–85.

Pinter, Jr. P.J., Ritchie, J.C., Hatfield, J.L. and Hart, G.F. (2003). The agricultural research swervice's remote sensing program: An example of interagency collaboration, *Photogrammetric Engg. & Remote Sensing,* **69**(6):615–618.

Plant, R.E. (2001). Site specific management: the application of information technology to crop production. *Compu. Electron. Agric.*, **30**: 9-29.

Reutebuch, S.E., Fridle, J.L. and Johnson, L.R. (1999). Integrating real-time forest machine activity with GPS positional data. ASAE Paper No. 99-5037, American Society of Agricultural Engineers, St. Joseph, MI, USA.

Reyniers, M., Maertens, K., Vrindts, E. and Baerdemaeker, J.D. (2006). Yield variability related to landscape properties of a loamy soil in central Belgium. *Soil Till. Res.,* **88**(1-2):262-273.

Robert, P.C., Rust, R.H. and Larson, W.E. (1995). In proceedings of site specific Management for Agriculture system, 27-30 March 1994, Minneaports, MN, Madison.

Runquist, S., Zhang, N. and Taylor, R. (2001). Development a field-level geographic information system. *Compu.& Electro. Agric.,* **31**: 201-209.

Schellberg, J., Hill, M.J., Gerhards, R., Rothmund, M. and Braun, M.(2008). Precision agriculture on grassland: Applications, perspectives and constraints. *European J. Agron.*,**29**:59–71.

Shanwad, U.K., Patil, V.C. and Gowda, H.H. (2004). Precision Farming: Dreams and Realities for Indian agriculture. Map India Conference.

Shibusawa, S.(1998). Precision farming and terra-mechanics. Fifth ISTVS Asia-Pacific Regional Conference in Korea, October 20, 1998.

Sudduth, K.A., Drummond, S.T. and Kitchen, N.R. (2001). Accuracy issues in electromagnetic induction sensing of soil electrical conductivity for precision agriculture. Compu.& Electro. Agric., **31**:239–264.

Sudduth, K.A., Drummondl, S.T. and Kitchen, N.R. (2001). Accuracy issues in electromagnetic induction sensing of soil electrical conductivity for precision agriculture. Compu.& Electro. Agric., **31**:239–264.

Wang, N., Zhang, N., Dowell, F.E. and Peterson, D.E. (2001). Design of an optical weed sensor using plant spectral characteristics. *Trans. ASAE,* **44** (2): 409-419.

Whalley, W.R. and Bull, C.R. (1991). An assessment of microwave reflectance as a technique for estimating the volumetric water content of soil. *J. Agric. Engg. Res.,* **50**: 315–326.

Whelan, B.M., McBratney, A.B. and Boydell,B.C. (1997). The impact of precision agriculture. Proceedings of the ABARE Outlook Conference, 'The Future of Cropping in NW NSW', Moree, UK, 5p.

Zhang, N., Wang, M. and Wang, N. (2002). Precision agriculture-a worldwide overview. *Compu.& Electro. Agric.,* **36**(2-3): 113-132.

■ WEBLIOGRAPHY

Gibbons, G. (2000). Turning a farm art into science an overview of precision farming. URL:*http:// www.precisionfarming.com.* Accessed on 12/12/2012.

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