Role of Wireless Sensor Networks in Agriculture

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Abstract
The Wireless Sensors Network (WSN) is now-a-days widely used to build decision support systems to overcome many problems in the real-world. This paper presents WSN as the best way to solve the agricultural problems related to crops identification, crop condition, yield estimation etc. This approach provides real-time information about the lands and crops that will help farmers make right decisions. The software monitors data from the sensors in a feedback loop which activates the control devices based on threshold value. Implementation of WSN in agriculture will optimize the usage of water fertilizer and also maximized the yield of the crops.WSN is an intelligent system which can monitor the agricultural environments of crops and provides service to farmers. The wireless sensor network (WSN) technique attracts increasing attention in recent years. The purpose of such systems is to improve the outputs of crops by means of managing and monitoring the growth period.
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1) Introduction

Wireless sensor networks are being used in a wide variety of critical applications such as military and healthcare applications, agriculture and industrial process monitoring. WSN is an intelligent private network made by a large number of sensor nodes which do specific functions. Wireless transmission allows deploy the sensors at remote, dangerous, and hazardous location. WSN has several advantages including easy installation, cost-effectiveness, small size and low power consumption. In recent years, agriculture faces many challenges, while humanity depends on agriculture and water for survival, so precision agriculture monitoring is critical and the demand for environmental monitoring and remote controlling in agriculture is rapidly growing. However, there have been few researches on the applications of WSN for agriculture.

2) How the Sensor Network Technology works

The sensor nodes are planted in the area which is under experiment. They sense the different parameters for which they are meant. These all individual nodes perform the minimal data processing and then send back the data via a base station to a single server where they are processed further. Data is transmitted between the individual nodes via a wireless sensor link. Then between the head nodes and the base station through some other link depending on the technology which suits most. At last there is the Data Access Subsystem in which a web-based interface is used for the display and upload of both raw and processed data. As most of the farmers do not have access to the web, those data are made available at a local village center in the form of graphs and spread-sheets.

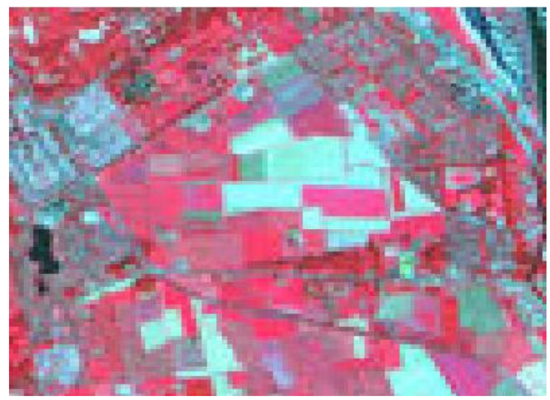
3) Contribution of Sensors in Agriculture

Different sensors are employed for sensing various parameters like soil moisture, water levels, climate change, pest detection, humidity to various other things in the fields. For sensing these parameters, the sensors are deployed in the field. They are spread in such a way that they cover the whole field. Now these sensors can be used in many different ways. The basic technology employed in the sensors is the same. Only the way they are spread out differs. But this different arrangement plays an important role as when used efficiently these sensors save time, save the required power and also may decrease the channel congestion, thus increasing the overall efficiency of the whole network.

3.1) Crop identification

It is based on the fact that each crop has unique spectral signature. Typical spectral reflectance of a crop shows absorption due to pigments in the visible region, high reflectance in the near infrared region because of internal cellular structure of the leaves and absorption at 1.45, 1.95 and 2.6m spectral bands due to water content. If we compare the same fields in the two images, we can see that in some cases the signal is different. Fields that appear red (high near-infrared reflectance) are full of vegetation, whereas those that appear blue (low near-infrared reflectance) either have very little or no vegetation at all. In that case the recorded signal is originating from the ground. Having the knowledge of when each crop is planted and harvested, we can estimate the percentage of vegetation cover through the growth period, assuming no external factors affect its growth. With this knowledge and by studying two or more images from the same growth period, we can look at the multispectral reflectance signal at each growth stage and identify what crops are grown in each field.

Crop field in May



Crop field in May

3.2) Crop Acreage estimation

It is the procedure which composed of identifies the various crops/ land on the image based on the ground. Traditionally acquiring data about yield and acreage of crops is an extremely tedious job, including extensive travel and various interpolation methods based on the sample taken. Currently the agriculture department officials visit the village or Tehsil where they inquire about crop acreage and expected yield. Based on these types of sampling the results are projected to acquire the acreage and yield information. This methodology, though prevalent from a long time is neither very accurate nor very scientific. On the other hand, it is predicted on the basic production pattern over the previous year. Yield depends on various factors, like climatic, physical etc. Apart from being cumbersome, counter cost effective and lengthy, these traditional methods are also too generalized and can't be fully relied upon. Alternatively, sensing is a very important tool for acreage estimation. With the help of sensing it is possible in a short time with much accuracy to measure the crop acreage estimation. [4]

3.3) Crop condition assessment /Yield Estimation

Accurate, early estimation of grain yield is an important skill. Farmers require accurate yield estimates for a number of reasons:

- Crop insurance purposes
- Delivery estimates
- Planning harvest and storage requirements
- Cash-flow budgeting

Extensive personal experience is essential for estimating yield at early stages of growth. As crops near maturity, it becomes easier to estimate yield with greater accuracy. Use of remote sensing to estimate biological crop yield is being explored in many countries and likely will become the basis of agricultural statistics in the future (Zhao et al., 2007). Crop yield estimation using remote sensing is based on the principle of spectral reflectance of green plants, which can be captured in satellite images as spectral data, depends on the state, structure and composition of the plant. The spectral data can be used to construct several vegetation indices such as normalized difference vegetation index (NDVI) which indicates the green biomass that can be used as proxy indicator of the yield (Prasad et al., 2006). The limitation in the use of satellite images to estimate crop yields of smallholder farmers is that the resolution of available satellite imagery (pixel size) is not sufficiently detailed to capture the variability of crops and crop performance in smallholder fields, (Fermont and Benson, 2011). In India, for example, vegetation indices from satellite images show only a moderate correlation (R2 between 0.45 to 0.54) with crop cut data (Singh, 2013). [6]

3.4) Identification of planting and harvesting dates

Electronic-nose devices have been utilized in a wide range of diverse applications in the agriculture and forestry industries to improve the effectiveness, efficiency and safety of processes involved in the production of quality food and fibre plant-based products. Sensors help to identify the best suiting time for each and every vegetation for planting and harvesting. It directly affects the production of crop. The sensor network technology will help the farmers to know the exact values of the requirements that they need to improve the crop productivity. It will help them in taking better decisions at the right time. This will save their time and labor also. The basic aim here is to transport the Indian farmers from prediction to the exact values which are beneficial for their farms. [2]

3.5) Identification of Pest and Disease Infestation

Pest detection and control is at least as old as agriculture because there has always been a need to keep crops free from pests. A number of techniques so far proposed for pest control in agriculture using wireless sensor network. There is a solution for monitoring traps which they used to capture pest by means of image sensors. A low-cost system based on battery powered wireless image sensors, which are able to capture and send images of the trap contents to a remote control station with specific frequency demanded by trapping application. These image sensors accurately monitor pest population with a higher temporal resolution. During this monitoring process no human intervention is demanded. There is a significant reduction in monitoring cost as well. Trap monitoring process which works on unattended mode has some extra benefits like it reduces the monitoring cost: it is programmable and higher temporal resolution of trap monitoring data. In addition, monitoring data can be available in real time through an internet connection. There have been a number of valuable studies to monitor pest insect using latest technologies. However, none of these studies provide a self-sufficient monitoring system based on low cost image sensors covering areas with very low energy utilization. High scalability with low power consumption made it possible to deploy both green houses and larger plantations. It is also used for several kinds of insects instead of some specific insects.

3.6) Soil moisture estimation

Estimating soil properties, including soil moisture, is important for many water-budgeting processes, and for meteorological and agricultural applications. Soil-moisture information can also be used as an indicator for the prediction of natural disasters, such as flooding and droughts, and for environment changing, such as dust storms and erosions. The most accurate results are achieved when there is no or low soil cover, especially when the test area is flat. On the basis of the active remote sensing methods, estimating soil moisture on bare soil or soil with less vegetation gives more accurate results, as compared to using the methods on a mixture of land-cover soil. Moreover, the estimation process becomes more challenging when the vegetation cover is dense. From the other side, under similar soil cover conditions, retrieving soil moisture using a combination of both active and passive soil information gives reasonably accurate results. [5]

3.7) Irrigation Monitoring and management

This monitoring can be accomplished by different techniques, including sensors in the soil, like a C-Probe, or a water budget modeling approach using climate parameters, such as evapotranspiration and rainfall. All of these techniques have been tested and validated for different crops around the world, showing promising results. By adopting irrigation monitoring techniques growers will be able to irrigate rationally, improving crop yield and quality, increasing the effectiveness of fertilizers and encouraging the proper balance of micro-organisms. In addition, the proper management of irrigation will reduce soil salinity and increase soil oxygen content, improving root activity. Irrigation monitoring allows for improved crop performance and can reduce the grower’s water bill directly in maximizing water usage along with extending the lifetime usage of the irrigation equipment. [9]

3.8) Soil Mapping

Soil survey provides an accurate and scientific inventory of different soils, their kind and nature, and extent of distribution so that one can make prediction about their characters and potentialities. It also provides adequate information in terms of land form, terraces, vegetation as well as characteristics of soils (viz., texture, depth, structure, stoniness, drainage, acidity, salinity and so on) which can be utilized for the planning and development. The use of digital image processing for soil survey and mapping was initiated with the establishment of National Remote Sensing Agency and Regional Remote Sensing Service Centres. The initial works carried out by Venkatratnam (1980); Kudrat et al (1990) and Karale (1992) demonstrated the potential of digital image processing techniques for soil survey. A number of modelling studies were simultaneously carried out to derive a variety of information from soil maps, e.g. land evaluation, land productivity, soil erosion and hydrologic budget (Kudrat et al 1990; Saha et al 1991; Kudrat 1996; Kudrat et al 1995, Kudrat et al 1997). The soil maps are required on different scales varying from 1:1 million to 1:4,000 to meet the requirements of planning at various levels. Because the scale of a soil map has direct correlation with the information content and field investigations that are carried out. Small scale soil maps of 1:1 million are needed for macro level planning at national level. The soil maps at 1:250,000 scales provide information for planning at regional or state level with generalized interpretation of soil information for determining the suitability and limitations for several agricultural uses and require less intensity of soil observations and time. The soil maps at 1:50,000 scales where association of soil series are depicted serve the purpose for planning resources conservation and optimum land use at district level and require moderate intensity of observations in the field. The large scale soil maps at 1:8,000 or 1:4,000 scale are specific purpose maps which can be generated through high intensity of field observations based on maps at 1:50,000 scale of large scale aerial photographs or very high resolution satellite data. Similarly, information on degraded lands like salt affected soils, eroded soils, waterlogged areas, shifting cultivation etc., is required at different scales for planning strategies for reclamation and conservation of degraded lands (Venkataratnam 1999). [7]

3.9) Monitoring of Draughts

Monitoring and assessment of drought through remote sensing and GIS depend on the factors that cause drought and the factors of drought impact. Based on the causative factors, drought can be classified into Meteorological, Hydrological and Agricultural droughts. An extensive survey of the definition of droughts by WMO found that droughts are classified on the basis of: (i) rainfall, (ii) combinations of rainfall with temperature, humidity and or evaporation, (iii) soil moisture and crop parameter, (iv) climatic indices and estimates of evapotranspiration, and finally (v) the general definitions and statements. Drought is a normal, recurrent feature of climate and occurs in all climatic zones, although its characteristics vary significantly from one region to another. Drought produces a complex web of impacts that span many sectors of the economy and reach well beyond the area experiencing physical drought. Drought impacts are commonly referred to as direct or indirect. Reduced crop, rangeland, and forest productivity; increased fire hazard; reduced water levels; increased livestock and wildlife mortality rates; and damage to wildlife and fish habitat are a few examples of direct impacts. The consequences of these impacts illustrate indirect impacts. The remote sensing and GIS technology significantly contributes to all the activities of drought management. [10]

3.10) Land cover and land degradation mapping

Land degradation caused by deforestation, overgrazing, and inappropriate irrigation practices. It causes decline in productive capacity of the land. It encompasses the whole environment but includes individual factors concerning soils, water resources (surface, ground), forests (woodlands), grasslands (rangelands), croplands (rainfed, irrigated) and biodiversity (animals, vegetative cover, soil). It is complex and involves the interaction of changes in the physical, chemical and biological properties of the soil and vegetation. The complexity of land degradation means its definition differs from area to area, depending on the subject to be emphasized. [8]The knowledge of land use and land cover is important for many planning and management activities as it is considered as an essential element for modelling and understanding the earth feature system. Land use is defined as to the human activity or economy related function associated with a specific piece of land, while the term land cover relates to the type of feature present on the surface of the earth (Lillesand and Kiefer, 2000). [3]

3.11) Identification of problematic soil

Soil salinity caused by natural or human-induced processes is certainly a severe environmental problem that already affects 400 million hectares and seriously threatens an equivalent surface. Stalinization causes negative effects on the ground; it affects agricultural production, infrastructure, water resources and biodiversity. In semi-arid and arid areas, 21% of irrigated lands suffer from water logging, salinity and/or sodicity that reduce their yields. 77 million hectares are saline soils induced by human activity, including 58% in the irrigated areas. In the irrigated perimeter of Tadla plain (central Morocco), the increased use of saline groundwater and surface water, coupled with agricultural intensification leads to the deterioration of soil quality. Experimental methods for monitoring soil salinity by direct measurements in situ are very demanding of time and resources, and also very limited in terms of spatial coverage. Several studies have described the usefulness of remote sensing for mapping salinity by its synoptic coverage and the sensitivity of the electromagnetic signal to surface soil parameters. [1]

4) Conclusion

The wireless sensors networks helps in agricultural monitoring at remote sites and reachable locations. It increases the crop yield and improvement in the quality in the agricultural field by supporting the decision making of producers through the analysis of the collected information. Various methods are used to identify the problematic soil which prevents the farmers from loss of money and time. Monitoring of draughts and proper irrigation time help the farmers for better yield of the crop.

5) References

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