2016 7th International Conference on Computer Science and Information Technology (CSIT)

# Wireless Sensors for Modern Agriculture in KSA: A Survey

Mohammad Ammad Uddin[1,2], Muhammad Ayaz[1], Ali Mansour[2], Denis Le Jeune[2], el. Hadi M. Aggoune[1]
[1]Sensor Network and Cellular Systems (SNCS) Research Center, University of Tabuk, Tabuk 71491, KSA
[2]Lab STICC, ENSTA Bretagne, Brest, France,
mashfaq@ut.edu.sa, ayazsharif@hotmail.com, mansour@ieee.org, denis.le_jeune@ensta-bretagne.fr, haggoune.sncs@ut.edu.sa

*Abstract*— **Agriculture in Kingdom of Saudi Arabia (KSA) is not same as in other part of world where scarcity of water and very intense weather condition makes it more challenging. With the advancement in technology, sensors and other wireless devices are being integrated in different daily life applications. Agriculture is one of them, where sensor networks can be used to improve the quality and quantity of yield by utilizing precise amount of resources where water is the most critical. Wireless sensors for Smart Agriculture (SA) are being used from many years but facing different challenges like large and remote geographical areas, limited or unavailable communication infrastructure, reliability of un-attendant sensor nodes etc. Typical challenges faced by SA are even overstated in the considering case study by adding worst weather condition, and tight irrigation supervision. The purpose of this article is to survey the potential technologies and sensing devices that can be used in KSA environment to acquire data from field same time providing plausible mechanism to aggregate it. The most important objective of this survey is to identify such modifications, customizations or supplement parameters that are required to incorporate in SA system to adopt it for KSA environment.**

***Keywords-- Wireless Sensors, Sensor Applications, Smart Farming, Irrigation, Crop Health***.

## 1. INTRODUCTION

The total area of the Kingdom of Saudi Arabia (KSA) is 2,149,690 km2. While, about 1.6% of it is urban area, and about 80% (1,736,250 km2) is desert of which only 1.6% is arable land [1], [2]. The biggest hurdles for cultivation are shortage of water, large spread of land, and adverse weather and atmospheric conditions. KSA is a desert country with virtually no permanent rivers or lakes and with only limited bursts of rainfall during a short time span of year. Additionally, there is an ever-increasing demand for water to suit the population of a typical fast-developing country in terms of construction, industry, and lifestyle [3]–[5]. Crops are grown in dispersed circulator rectangular-shaped parcels of land having limited water resources and exposed to harsh environmental conditions including excessive heat or cold weather and sandstorms. Furthermore, the farming parcels have limited or no communication infrastructures. Most common crops include dates, seasonal fruits and vegetables, olives, wheat, and alfalfa. It is worth mentioning that wheat growing is receding because of its water requirements.

To produce quality crops in KSA, the following facts are need to focus 1) crop parameters (leaf wetness, leaf chlorophyll level, height of plant, water circulation, fruit size ect.) to monitor and maintain crop health 2) soil parameters as plant growth is also effected by soil quality as mentioned by International Center for Soil Fertility and Agricultural Development (IFDC) that owing to the limitations in farming practices such as fertilizer usage, the levels of soil nutrients are declining at an annual rate of 30 Kg /ha in 85 % of African farm land [6] and 3) Environmental factors like temperature, humidity, sunlight, presence of carbon dioxide and oxygen etc. Wireless Sensor Networks (WSNs) are considering as the enabling technology for smart agriculture as it can provide real time feed-back on a number of different crop, soil and site parameters. With the use of WSN, notable increase in yield amount is possible by utilizing precise amount of resources. Using WSN, crop health is being monitored as well as amount of water, fertilizer, and pesticides. This technology can isolate a single plant for monitoring and nurturing, or more typically an area in the tens or hundreds of square feet.

This survey presents: 1) survey of different type of technologies and sensors available for agriculture, and how we can use these technologies to improve quality and quantity of crops in KSA. 2) Short survey of potential data gathering schemes that can be used to collect data from different field sensors. 3) Identify short comings in existing crop monitoring systems and required modifications or improvements in these systems to cope with KSA agriculture needs.

The rest of the paper is organized as follows. Section 2 provides an overview on sensors, dividing them in different categories according to monitoring parameters. Section 3 discusses existing routing and data gathering schemes proposed for agriculture applications. Section 4 includes different comparison tables based on sensor types, manufactures and some of the famous test beds. Further, some suggested alterations or additional features that need to be considered to build in smart agriculture to make it compliance with KSA agriculture environment are provided in section 5, while section 6, briefly concludes this article including some future issues.

## 2. SENSOR CATEGORIES BASED ON MONITORING PARAMETERS

This section presents a survey of some renowned technologies that are being used to monitor crop parameters, so that resources like water, pesticide, fertilizer etc., can be used in more precise way. We can divide crop monitoring in following categories.

DOI Bookmark: http://doi.ieeecomputersociety.org/10.1109/CSIT.2016.7549442

### *A. Pests Monitoring*

Insects may cause two major kinds of damage for growing crops. Firstly, direct injury to the plant by the insect, which eats leaves or burrows in stems, fruit, or roots. There are hundreds of pest species like orthopterans, dipterans homopterans, coleopterans and heteropterans damage the plant at different stages in the form of larvae, pupa and adults. The second type of damage is indirect damage in which the insect itself does little or no harm but transmits a bacterial, viral, or fungal infection to the crop e.g. the viral diseases of sugar beets and potatoes. Many researches are being conducted for early detection of bug damage and prevention of crops from heavy loos, some examples are given below.

**Bug detector sensor:** Bug detection sensors are made and used to help the farmers to protect their crops from insect damage and to limit the spread of insect-borne diseases such as malaria and dengue fever. From more than five decades, researchers are working to detect and classify insects by using acoustic sensing devices, light spectrum devices and camera in combination with image processing devices. A handy device developed by Laurie Bedord [7] shown in figure 1-A, is used to make automated bug detection and classification rather than conventional sticky traps or interception traps. The proposed sensor uses phototransistor array and microphone to detect and classify bug on the basis of wing beat frequency, flight-behavior patterns and humming sound.

**Light sensor for parasites detection:** Hair worms or nematodes are parasites that attack the roots of the plant especially sugar beets. There is need to pluck the sugar beet from the ground to find these bugs. But Bonn University's Birgit Fricke [8] figure 1-B, lets the beet grow and finds the parasites with the help of a spectral sensor that measures light waves. Most of the sunlight hitting the plant is reflected immediately, but part of the light goes into the leaf, transmitted by the photosynthesis apparatus and is then reflected back. A plant's suffering from certain stress reflects modified light pattern, depending on the nature of stress. If a sugar beet suffers from parasite infestation, it reflects light differently than a healthy plant. This is how researchers are able to detect and infestation early, without harming the plant.

**Bug Visual Inspection:** Monitoring pest insect populations is currently a key issue in agriculture and forestry protection that is typically done by human operators by performing periodical surveys of the traps disseminated through the field. This is a labor, time and cost consuming activity in particular for large plantations or large forestry areas. In [9] author proposed an automated system capable of doing visual inspection in an accurate and a more efficient way as shown in figure 1-C. This research proposed an autonomous monitoring system based on a low-cost image sensor which is able to capture and send images of the trap contents to a remote control station with the periodicity demanded by the trapping application.

**Bug detection by sound:** During the last two decades Red Palm Weevil (RPW) has become one of the most dangerous threats to palm trees in many parts of the World. One of the early detection mechanisms proposed in the literature is based on acoustic monitoring [10] shown in figure 1-D, as the activity of RPW larvae inside the palm trunk is audible for human operators under acceptable environmental noise levels (rural areas, night periods, etc.). In proposed system bioacoustic sensor that can be installed in every palm tree is able to analyze the captured audio signal during large periods of time. The results of the audio analysis would be reported wirelessly to a control station, to be processed subsequently and conveniently stored.

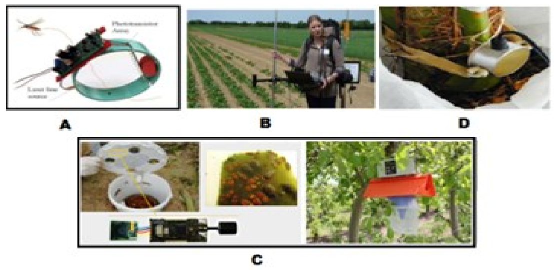


Figure 1: Bug detection (A) Bug detecting by photo array [7] (B) Bug detecting light spectrum [8] (C) Automatic visual inspection [9] (D) Acoustic sensor for RPW [10].

### *B. Monitoring Crop Health by Plant Leafs*

Leafs are the most important part of the plant that tells everything about its health and it is the part of plant which effects first as soon as having any problem (disease or deficiency). Different wireless sensors can be installed on the leafs as shown in figure 2, to monitor different parameters liken humidity, thickness, water deficiency, temperature and color and transmit all these attributes to remote side where farmer can analyze and estimate accurately about plant health. Many researches are conducted to monitor the crop health by using leafs and many sensors are made as shown in figure 2 [11]. These developed leaf sensors are used in verities of application for example affixing humidity leaf sensor to a crop can conserve 20% or more water that is required for its growth. Besides using less water this leads to less energy and nutrients utilization.

Figure 2: Leaf Monitoring [11].

### *C. Monitoring Crop Health by Plant Stem and Trunk*

Another way to monitor the crop health is by monitoring the stamp growth rate and we can preserve water and other resources like fertilizers and nutrients by monitoring circulation of water and flux in it. Some of the developed sensors for this purpose are Stem Micro variation Sensor, Sap Flow Relative Rate Sensor, Stem Flux Relative Rate Sensor, Auxanometer, and Trunk Dendrometer are shown in Figure 3 [12], [13].

Figure 3: Stem and trunk monitoring [12], [13]

### *D. Monitoring Crop Health by Fruit Size*

As markets around the world became more particular about fruit size and now profitability depends upon getting the right size fruit to the right market at the right time. Different sensors are available to monitor different fruits as shown in figure 4. Fruit size monitoring [14], [15] tracks the fruit development throughout the season and provides the opportunity to adjust different management strategy like.

- Thinning strategies - hand thinning, late thinning
- Irrigation strategy
- Use of growth and maturity regulators
- Selection of an exporter marketer

Figure 4: Fruit size monitoring [14], [15]

### *E. Soil Parameter Monitoring*

Soil is a natural resource which has been taken overlooked and for granted, but now to fulfill the massive demand of crops and yields there is a need to monitor the soil parameters from very early stage (land preparation) to the end (harvesting of fruits). All other resources like water and fertilizer are given to the crop according to the soil condition that can be helpful to produce quality and quantity crops with economy. Different types of soil parameters can help us to control crop growth like temperature, moisture, $CO_2$ flux [16], [17]. A typical sensor to monitor soil temperature and humidity is shown in figure 5.

Figure 5: Soil temperature and humidity probe [17]

### *F. Environment Monitoring*

Monitoring environment parameters like; atmospheric pressure, solar radiation, wind speed/direction, rainfall, air temperature, and air humidity are very important for getting good crop. We can use all these parameters to adjust our resources accordingly that can help us to produce better crops with economy. Some common use sensors are wind speed and direction sensor, ambient seismic energy sensor, precipitation sensor, tipping bucket, quantum sensors etc. some environment monitoring sensors are shown in figure 6, but not limited to.

Figure 6: Environment monitoring

### *G. Monitoring Crop Health by Aerial View using Multispectral Imaging*

Satellites, airborne, and UAV are used to carry visual light (RGB), near infrared (INR), and thermal cameras to capture multi or hyper spectral images of crop fields to help farmers and crop consultants to manage agricultural lands.

Hyperspectral imaging involves dividing light into thousands of small bands to gain detailed information. This compares with multi-spectral, which deals with far fewer bands. Every pixel has a complete spectrum in it and this can be used for a variety of applications including mineralogy, agriculture, astronomy, and surveillance. Accurate data over large areas can be analyzed by mounting a lightweight hyperspectral imaging systems over a fixed wing aircraft or small UAVs. These systems can effectively monitor the health of crops, 'seeing' water and nutrient levels and the presence of hard-to-spot diseases. It can provide access to challenging areas such as swamps, Antarctica, and mountainous regions. Multi-spectral imaging has a great potential for use in areas with wide pest management systems (such as weed control or detection of insect damage), crop monitoring for nutrients, water-stress, disease, overall plant health, characterization of soils, vegetative cover and yield estimation. It provides farmer to rely on site-specific management tactics to maximize yield and resources while reducing environmental impacts such as over-fertilization or watering or pesticides. Pin-pointing areas requiring attention – be it water, weed or pathogen treatment, or nutrient adjustments – allows for spot application rather than whole-field treatment.

We can divide agriculture sensors into three broad categories according to their data rates and power consumption as shown in table 1.

TABLE 1:- SENSOR CATEGORIES

| | **Examples** | **Expected Data size** | **Power consumption (active mode)** |
|---|---|---|---|
| **Small sized data and low power consumption** | (1) Air temperature/ humidity/ direction / speed (2) Soil temperature/ humidity (3) Leaf thickness/color (chlorophyll) (4) Trunk thickness/flux flow (5) Fruit size | 100s of bytes | 0.14 mA |
| **Medium sized data and medium power consumption** | (1) Still picture camera (2) Multi or hyper spectral camera (3) Acoustic sensors | 10s of Mb | 10 mA |
| **Large sized data and large power consumption** | Video streaming cameras | 10s of Mb per minute | 50 A |

## 3. EXISTING ROUTING AND DATA GATHERING SCHEMES

Many routing and data gathering schemes are already developed and proposed for wireless sensor networks; we categorize existing schemes into four categories, 1) static sink routing, 2) mobile sink direct contact data collection, 3) rendezvous based data collection and 4) hash table data collection

### A. *Static Sink Routing*

Protocols belong to this category mainly aim to prolong the network life time by preserving the sensor node energy as much as possible, the most famous is LEACH [18]–[23], it proposed probability based random Cluster Head (CH) selection, so that the nodes near to the base station should not die faster as they have to forward all the packets coming from different nodes and paths. Many versions and improvements have been made in LEACH protocol to add different functionalities and quality of services like, extended LEACH, mobile LEACH, centralized LEACH, distributed LEACH etc. HEED [8] is another competitor of LEACH that introduced sensor node proximity in addition with node residual energy to select a cluster head. Linked cluster [25], [26] suggested clustering and maximum network connectivity of moving nodes as nodes can elect their CH while moving and highest node id will be selected as cluster head.

There are many more examples like node id based adaptive clustering [27], random competition based clustering [28], node hierarchical control clustering [29], fast local clustering services etc. All these developed systems are used to deploy fixed architecture scenario where base station is fixed and mobility of sensor nodes may or may not be available, characteristics of some of these researches are given in table 2. All these proposed schemes contributed a little in terms of network life, convergence, adaptability and dynamicity. Ultimately research found that no other solution except mobile base station can cope with these issues.

### B. *Mobile Sink Direct Contact Data Collection*

In this category of protocols, data is collected from the sensor network by using mobile sinks. A sink has to communicate and collect data from each sensor node in the network. Some examples are given in table 2. All these data gathering schemes are not considered efficient, due of very high latency and small coverage area.

### C. *Rendezvous based Data Collection*

In this type of data collection, sensor nodes are grouped in clusters and the mobile sink has to visit each cluster at predefined rendezvous (appointment points) which acts as CH and delivers the data to the mobile sink. Pros and cons related to these types of protocols are mentioned in table 2.

### D. *Hash Table*

These protocols normally stores hash keys with geographic coordinates, and keep a key-value pair at the sensor node geographically nearest the hash of its key. The system replicates stored data locally to ensure persistence when nodes fail. In order to ensure that key-value pairs are stored at the appropriate nodes after topological changes some consistency protocols are used. Further, it supports load distribution throughout the network using a geographic hierarchy.[30],[31].

## 4. COMPARISON TABLES

As per our knowledge and survey, it is observed in table 2 that most of the existing data gathering techniques are lacking in heterogeneous sensor deployment considerations. Collection of dynamic nature of data from selective area is also not been considered, hence research is required in the scenarios where CH is mobile unit (drone) and all sensors are static (crop field sensors). Further, table 3 includes some important prototypes established for agriculture environment, what parameters are targeted including some appropriate information. Table 4 disclosed some of the essential parameters that are required to monitor during different agriculture applications and what sensors can be used. Lastly, table 5 contains information regarding, some of the leading manufactures and provide a glimpse of their components and products for this purpose.

TABLE 2:- SURVEY OF EXISTING PROTOCOLS FOR SMART AGRICULTURE

| | A | B | C | D | E | F | G | |
|---|---|---|---|---|---|---|---|---|
| **Direct contact data collection** | | | | | | | | |
| Stochastic data collection trajectory [32] | | | | | | | Y | 1. No clustering support<br>2. Fixed Mobile sink Path |
| Square Grid tessellation, Triangle tessellation, Snake like traversal, Boundary traversal [33] | | | | | | | Y | |
| Traveling salesman problem [34] | | | | | | | Y | |
| Partition based scheduling[35] | | | | | | | Y | |
| **Rendezvous based data collection** | | | | | | | | |
| Minimum spanning tree [36] [37],[38] | | Y | Y | | | | Y | Sensor node are equipped with GPS sensor |
| UAV-assisted data gathering in wireless sensor networks[39] | Y | Y | Y | | | Y | Y | Deployment of mobile CH is overhead and not feasible and practical |
| Unequal cluster size [40],[41] | | Y | Y | | | | | 1. At least 2 rounds are required to get data<br>2. Sink Path is fix |
| Distributed clustering approach for UAV integrated wireless sensor networks [24] | Y | Y | Y | | | | | All nods are located and cluster is made on RSSI value |
| Network Assisted Data Collection [42] | Y | Y | Y | | | | | Path of UAV is totally decided by sensor nodes and their topology. |
| energy-aware distributed intelligent data gathering algorithm | N | Y | | | | | Y | Each sensor is location aware and always need a connected graph to make cluster |
| Hash Table [30] | Y | Y | | | | | Y | Sink is static. Data is replicated on hashed and home node |
| Honeycomb tessellation [31], [43],[44] | Y | Y | Y | | | Y | Y | Nodes are mobile. Event detection. Virtual infrastructure |
| Virtual Grid [45] | Y | Y | Y | | | Y | Y | Nodes are location aware. Keep on tracking the UAV location |

A=Path controable B=Clustering C=Dynamic Clustering D=Heterogynous sensors E= Dynamic Data F= CH mobility G= GPS

TABLE 3:- EXAMPLES OF PROTOTYPES FOR AGRICULTURE SENSOR NETWORKS AND APPLICATIONS

| Prototype/Test-bed | Monitoring Parameters | Scale and Density | Data Amounts/ Frequency | Year | Country |
|---|---|---|---|---|---|
| Agrisensor [46] | Soil and air temp., Soil Moisture, Air humidity | Small number of nodes (5-8) in a Small-Plot | Every 15 mint, Frequent intervals, Over 8 days | 2011 | Czech Republic |
| Root Zone Sensors for Irrigation [47] | Irrigation, Moisture, Water Salinity | 6 Number of nodes and 3 Repeaters | Depends on irrigation interval, 5 Months duration | 2008 | Italy |
| Reactive Soil Moisture Network [48] | Rain storms, Soil Moisture, | 11 Sensors of different types, One hectare area, GSM Gateway | Frequent when raining (every 10 mints), Once a day without rain. | 2005 | Australia |
| Smart Irrigation System [49] | Irrigation, Moisture | 2-Sensor motes, 1 EC-5 Soil humidity sensors, Tiny OS | Small amount of data. After every 4.40 hours, Continue for 2 days | 2011 | Greece |
| Sensors for Vineyard Monitoring [50] | Temperature, Frost damage, Grape variety, Slop of surrounding | Dense and deep deployed as 65 Nodes deployed in two acres, Maximum 8 hops | Every 5 mints, Frequent intervals, Deployed for 6 months but results shown for 1 month. | 2003 | USA |
| Web Based Precision Farming [51] | Weather and solar related parameters | Spars as nodes deployed upto 180 meters | Frequent sampling as after 6 mints | 2014 | Germany |
| Wireless Sensor for Greenhouse Parameter [52] | Inside and outside Temperature, Humidity, Light, CO2 | Densely deployed as 40-50 sensors for 70*150 meter area | Small amount of data. Mostly infrequent as event based | 2010 | India |
| Precision Agriculture using WSN [53] | Soil moisture and condition | Laboratory based experiments only but not in field | Frequent reading, total 200 packets where each is 30 byte | 2011 | USA |
| Agro-Sense [54] | Humidity, Soil moisture and Conductivity | Sparse, only four nodes deployed in 200 meters. | Frequent, after every 3 hours for 3 days. | 2008 | India |
| Greenhouse Monitoring using WSN [55] | Temperature, light. Irradiance, Carbon dioxide | Lab setup, only 4 nodes in 18*80 meter area | Sleep and wakeup based periodic data gathering. | 2008 | Finland |
| APTEEN [56] | Light intensity, pH value, Soil moisture, Temp. | Densely, different number of nodes for different parameters. | Large data amounts, Monitoring time varies from half day to six weeks. | 2013 | Egypt |
| VineSense [57] | Temperature, Soil moisture, Humidity | Variable density, 255 nodes required, 50 nodes results are shown | Frequent but vary for different parameters, overall sense after each 10 minutes | 2011 | Italy |

TABLE 4:- DIFFERENT MONITORING PARAMETERS AND SUPPORTING SENSORS FOR AGRICULTURE APPLICATIONS

| Monitoring Parameter and Unit | Sensor | Supported Range | Accuracy | Power Supply | Product Reference |
|---|---|---|---|---|---|
| Photosynthesis (ppm) | CI-340 | 0 to 2000 ppm | < ± 2% | 7.2 VDC | www.ictinternational.com |
| | GPro 500 | 0-200,000 ppm | 2% | NA | www.mt.com |
| | PAR Sensor | 0 to 2000 μmol | ±5% | NA | www.vernier.com |
| | S-LIA-M003 | 0 to 2500 μmol | ±5 μmol | 0-5 VDC | www.onsetcomp.com |
| Irrigation (centibars) | Irrometer-SR | 0-100 cb | ± 3-2-3 % | NA | www.irrometer.com |
| Soil Moisture (VSW % ) | MP406 | 0-100 VSW% | ± 5 VSW% | 9-18 VDC | www.ictinternational.com |
| | Hydra Probe II | 1 to 80 | ± 1.5% | 30 mA active | www.stevenswater.com |
| Temperature (°C) | T/H Sensor | -50° to 140° F | ± 1°F | NA | www.davisnet.com |
| | pH100 | -10 to +120°C | ±0.3°C | 30 VDC | www.ysi.com |
| Salinity | PS-2195 | 1 to 55 ppt | ±1% | NA | www.pasco.com |
| | SAL-BTA | 0 to 50 ppt | ±1% | 5 VDC | www.vernier.com |
| Humidity (RH) | T/H Sensor | 0 to 100% RH | ± 3% | NA | www.davisnet.com |
| | HUM-M2 | 0 ~ 100 % RH | < 3% RH | 4.5 ~ 5.5 V | www.temcocontrols.com |
| | HMT330 | 0 to 100 %RH | ±1 %RH | 10 to 35 VDC | www.vaisala.com |
| | WT Sensor | 0 - 100%RH | ±2%RH | 5V USB Cable | www.connectsense.com |
| Wind | WMT52 | 0 to 60 m/s | ±3% | 5 to 32 VDC | www.vaisala.com |
| | OMC-160 | 0.3 to 75 m/s | 2% FRO | 8 TO 30 VDC | www.observator.com |

TABLE 5:- LEADING SENSOR MANUFACTURERS FOR DIFFERENT APPLICATIONS AND PARAMETERS

| Manufacturer | Components | Famous Products | Sensing Parameters/Applications | Reference |
|---|---|---|---|---|
| SensaTrack | Sensor, Adaptors, Gateways | MONNIT WIT | Saving Water, Soil Moisture, Temperature, Humidity, light | sensatrack.com |
| PYCNO | Sensors, | PYCNO System | Humidity, Temperature, Soil Moisture, Pesticides | pycno.co.uk |
| Stevens | Sensor, Data Loggers | HydraProbe, Hydrolab DS5/DS5X and MS5. | Irrigation, Golf Courses/Sports Turf | stevenswater.com |
| SOLCHIP | Sensors, RFIDs | Sol Chip Pak™ (SCP), SCC - M433 | Precision agriculture, Environmental monitoring, Traceability systems (RFID) | sol-chip.com |
| Landscape Technologies | Sensors, Data Loggers, Wire Systems | TDR-315, SDI-12 TDT | Soil Moisture, Irrigation, Precision Temp. | landscapetechnologies.com |
| IRROMETER | Sensors, Lysimeters, Data Loggers | IRROMETER Model R, SR, S, P etc, 900M Data Logger | Irrigation, Landscape | irrometer.com |
| ICT International | Sensors, Meters, Probes, Gauges | MPKit-406, SFMI flow meter, DBL60 Dendrometer | Horticulture, Irrigation, Plant Physiology | ictinternational.com |

## 5. SPECIAL CONSIDERATION FOR KSA AGRICULTURE

Shortage of water, very hot and dry weather in supplement with frequent dust storm augmented with desert area, are the factors make agriculture more challenging in KSA. As a result of this survey we are suggesting some adjustments or additions that need to incorporate in smart agriculture to map it on KSA environment, are as under:

*A. Vigilant irrigation supervision*

Water resources are precious in KSA. A very careful supervision is required during the irrigation process to make sure the watering is done according to area or plant specific requirements.

*B. More denser sensor network*

Frequency of unavailability of sensor nodes is high due to many factors like: become under sand or mud, unapproachable due to bad weather, hence a denser node deployment is required.

*C. Heterogeneous sensor nodes*

Different types of sensor nodes to monitor plant, yield, soil and environment parameters are required to deploy in the farm field and need to work with each other coordination.

*D. Dynamic nature of data*

Data from all the sensors is not required all the time. Only specific data from selective sensors is need to harvest. For example in specific situation, only temperature and humidity of soil is need to monitor while only fruit size is required in other.

*E. Dynamic range of data*

Data from whole the crop field is rarely needed. Mostly data is required from some area of interest or suspect.

*F. More flexible clustering algorithm*

There is a need to redesign clustering algorithm so that it has the capability to make virtual cluster as combination with physical clusters and data need to be collected in both the ways

*G. More sophisticated routing and data gathering algorithm*

Routing and data gathering scheme need to be redesigned very carefully to opt all above factors

## 6. CONCLUSION AND FUTURE ISSUES

It is not a simple task to replace sensor technology with status quo heavy machines; those are being used from decades. No doubt, implementing wireless sensors in smart agriculture can reduce number of people required with traditional methods however, it increases the demands of educational and competence level for the remaining workers. Further, the reliability of this new technology remains questionable unless being used for some complex and large projects. On the other hand, negative impact of old-fashioned bulky machines on environment like large in size and enormous fuel consumptions are the reasons allowing the sensors to become a better choice for some of the agricultural applications. As long as, demands for food quantity increasing without compromising environment, health and safety measures, the chance of this technology to replace traditional equipment becoming brighter. In this article, we conducted survey of technologies available for SA and tried to map it with agriculture of KSA where landscape, weather, cultural and condition differences are applicable. We found some serious issue that need to be addressed before implementing SA in KSA. The issues raised in this article will be taken as future work and open research area for students and researcher doing work in KSA agriculture.

## ACKNOWLEDGMENT:

This work was supported by Deanship of Research, University of Tabuk under project No.S-125-1436. Authors, also gratefully acknowledge the support of SNCS research center at University of Tabuk under the grant from the Ministry of Higher Education, Saudi Arabia.

## REFERENCES:

[1] Trading Economics, "Agricultural Land in Saudi Arabia." [Online]. Available: http://www.tradingeconomics.com. [Accessed: 01-Jun-2016].

[2] Worldstat Info, "Saudi Arabia," 2013. [Online]. Available: http://en.worldstat.info/Asia/Saudi_Arabia/Land. [Accessed: 01-Jun-2016].

[3] M.Makkawi, "Water Resources of Saudi Arabia," *King Fahd University of Petroleum and Minerals*, 2013. [Online]. Available: http://faculty.kfupm.edu.sa/ES/makkawi/ENVS524/module3.pdf. [Accessed: 01-Jun-2016].

[4] A. S. Al-Turbak, "Water Resources Supply and Demand in Saudi Arabia," 2012. [Online]. Available: http://static2.docstoccdn.com/docs/132698342/Water-Resources-Supply-and-Demand-in-Saudi-Arabia. [Accessed: 01-Jun-2016].

[5] A. A. Al-Ibrahim, "Water Use in Saudi Arabia: Problems and Policy Implications," *J. Water Resour. Plan. Manag.*, vol. 116, no. 3, pp. 375–388, May 1990.

[6] J. Henao and C. Baanante, "Agricultural production and soil nutrient mining in africa: implications for resource conservation and policy development," 2006. [Online]. Available: http://agris.fao.org/agris-search/search.do?recordID=GB2013202609. [Accessed: 01-Jun-2016].

[7] L. Bedord, "Sensors Protect Crops from Insect Damage," *2015*. [Online]. Available: http://www.agriculture.com/technology/crop-management/fieldwork/senss-protect-crops-from-insect-damage_590-ar47778. [Accessed: 28-Feb-2016].

[8] F. Schmidt, "Agricultural sensors: improving crop farming to help us feed the world." [Online]. Available: http://www.dw.com/en/agricultural-sensors-improving-crop-farming-to-help-us-feed-the-world/a-17733350. [Accessed: 28-Feb-2016].

[9] O. López, M. Rach, H. Migallon, M. Malumbres, A. Bonastre, and J. Serrano, "Monitoring Pest Insect Traps by Means of Low-Power Image Sensor Technologies," *Sensors*, vol. 12, no. 12, pp. 15801–15819, 2012.

[10] M. Rach, H. Gomis, O. Granado, M. Malumbres, A. Campoy, and J. Martín, "On the Design of a Bioacoustic Sensor for the Early Detection of the Red Palm Weevil," *Sensors*, vol. 13, no. 2, pp. 1706–1729, 2013.

[11] R. Stoner, "The Rev 3 Leaf Sensor," *2014*. [Online]. Available: https://leafsensor.wordpress.com/. [Accessed: 28-Feb-2016].

[12] "Agristore." [Online]. Available: http://www.agrisupportonline.com/store/Phytech/technical_data/de-1m.htm. [Accessed: 28-Feb-2016].

[13] "Hydraulic Conductivity in Plant Stems." [Online]. Available: http://www.ictinternational.com/casestudies/hydraulic-conductivity-in-plant-stems/. [Accessed: 28-Feb-2016].

[14] "Phyto-Sensor group connecting people and plants." [Online]. Available: http://phyto-sensor.com/FI-LM-FI-MM-FI-SM. [Accessed: 28-Feb-2016].

[15] K. LAWTON, "Wireless crop sensing technology keeps improving," *2010*. [Online]. Available: http://precision.agwired.com/2010/06/16/wireless-crop-sensing-technology-keeps-improving/.

[16] D. L. Karlen, M. J. Mausbach, J. W. Doran, R. G. Cline, R. F. Harris, and G. E. Schuman, "Soil Quality: A Concept, Definition, and Framework for Evaluation (A Guest Editorial)," *Soil Sci. Soc. Am. J.*, vol. 61, no. 1, p. 4, 1997.

[17] Alonewolfx, "Soil Moisture sensor possible." [Online]. Available: http://www.esp8266.com/viewtopic.php?f=21&t=2053. [Accessed: 01-Jun-2016].

[18] S. Bin Zeni, "Improving on the Network Lifetime of Clustered-Based Wireless Sensor Network Using Modified Leach Algorithm," Universiti Tun Hussein Onn Malaysia, 2012.

[19] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-

efficient communication protocol for wireless microsensor networks," in *33rd Annual Hawaii International Conference on System Sciences*, vol. vol.1, p. 10.

[20] G. S. Kumar, P. M. V Vinu, and K. P. Jacob, "Mobility Metric based LEACH-Mobile Protocol," in *6th International Conference on Advanced Computing and Communications*, 2008, pp. 248–253.

[21] C. Fu, Z. Jiang, W. Wei, and A. Wei, "An Energy Balanced Algorithm of LEACH Protocol in WSN," *Int. J. Comput. Sci.*, vol. 10, no. 1, pp. 354–359, 2013.

[22] W. Liu and L. Wang, "An improved algorithm based on LEACH protocol," in *2nd International Symposium on Computer, Communication, Control and Automation*, 2013, pp. 464–466.

[23] J. Liu and C. V Ravishankar, "LEACH-GA: Genetic Algorithm-BasedEnergy-Efficient Adaptive Clustering Protocolfor Wireless Sensor Networks," *Int. J. Mach. Learn. Comput.*, vol. 1, no. 1, pp. 79–85, 2011.

[24] H. Okcu and M. Soyturk, "Distributed clustering approach for UAV integrated wireless sensor networks," *Int. J. Ad Hoc Ubiquitous Comput.*, vol. 15, no. 1/2/3, p. 106, 2014.

[25] D. Baker and A. Ephremides, "The Architectural Organization of a Mobile Radio Network via a Distributed Algorithm," *IEEE Trans. Commun.*, vol. 29, no. 11, pp. 1694–1701, Nov. 1981.

[26] D. Baker, A. Ephremides, and J. Flynn, "The Design and Simulation of a Mobile Radio Network with Distributed Control," *IEEE J. Sel. Areas Commun.*, vol. 2, no. 1, pp. 226–237, Jan. 1984.

[27] C. R. Lin and M. Gerla, "Adaptive clustering for mobile wireless networks," *IEEE J. Sel. Areas Commun.*, vol. 15, no. 7, pp. 1265–1275, 1997.

[28] Kaixin Xu and M. Gerla, "A heterogeneous routing protocol based on a new stable clustering scheme," in *MILCOM 2002. Proceedings*, 2002, vol. 2, pp. 838–843.

[29] Seema Bandyopadhyay and E. J. Coyle, "An energy efficient hierarchical clustering algorithm for wireless sensor networks," in *IEEE INFOCOM 2003. Twenty-second Annual Joint Conference of the IEEE Computer and Communications Societies (IEEE Cat. No.03CH37428)*, 2003, vol. 3, pp. 1713–1723.

[30] S. Ratnasamy, B. Karp, L. Yin, F. Yu, D. Estrin, R. Govindan, and S. Shenker, "GHT: A Geographic Hash Table for Data-Centric Storage," in *1st ACM international workshop on Wireless sensor networks and applications - WSNA '02*, 2002, p. 78.

[31] H. Sabbineni and K. Chakrabarty, "Datacollection in Event-Driven Wireless Sensor Networks with Mobile Sinks," *Int. J. Distrib. Sens. Networks*, vol. 2010, pp. 1–12, 2010.

[32] R. C. Shah, S. Roy, S. Jain, and W. Brunette, "Data MULEs: Modeling and analysis of a three-tier architecture for sparse sensor networks," *Ad Hoc Networks*, vol. 1, no. 2–3, pp. 215–233, 2003.

[33] R. Tarjan, "Depth-First Search and Linear Graph Algorithms," *SIAM J. Comput.*, vol. 1, no. 2, pp. 146–160, Jun. 1972.

[34] P. L. Cowen, "The Traveling-Salesman Problem," *Oper. Res.*, no. 1, pp. 1–11, 2009.

[35] Yaoyao Gu, D. Bozdag, E. Ekici, F. Ozguner, and Chang-Gun Lee, "Partitioning based mobile element scheduling in wireless sensor networks," in *Second Annual IEEE Communications Society Conference on Sensor and Ad Hoc Communications and Networks*, 2005, pp. 386–395.

[36] J. B. Kruskal, "On the Shortest Spanning Subtree of a Graph and the Traveling Salesman Problem," *Proc. Am. Math. Soc.*, vol. 7, no. 1, p. 48, Feb. 1956.

[37] G. Xing, T. Wang, W. Jia, and M. Li, "Rendezvous design algorithms for wireless sensor networks with a mobile base station," in *Proceedings of the 9th ACM international symposium on Mobile ad hoc networking and computing - MobiHoc '08*, 2008, p. 231.

[38] G. Xing, T. Wang, Z. Xie, and W. Jia, "Rendezvous Planning in Mobility-Assisted Wireless Sensor Networks," in *28th IEEE International Real-Time Systems Symposium (RTSS 2007)*, 2007, pp. 311–320.

[39] M. Dong, K. Ota, M. Lin, Z. Tang, S. Du, and H. Zhu, "UAV-assisted data gathering in wireless sensor networks," *J. Supercomput.*, vol. 70, no. 3, pp. 1142–1155, Dec. 2014.

[40] C. Konstantopoulos, G. Pantziou, D. Gavalas, A. Mpitziopoulos, and B. Mamalis, "A Rendezvous-Based Approach Enabling Energy-Efficient Sensory Data Collection with Mobile Sinks," *IEEE Trans. Parallel Distrib. Syst.*, vol. 23, no. 5, pp. 809–817, May 2012.

[41] G. Pantziou, A. Mpitziopoulos, D. Gavalas, C. Konstantopoulos, and B. Mamalis, "Mobile Sinks for Information Retrieval from Cluster-Based WSN Islands," in *8th International Conference, ADHOC-NOW*, 2009, pp. 213–226.

[42] J. Rao and S. Biswas, "Joint routing and navigation protocols for data harvesting in sensor networks," in *5th IEEE International Conference on Mobile Ad Hoc and Sensor Systems*, 2008, pp. 143–152.

[43] A. Erman, A. Dilo, and P. Havinga, "A virtual infrastructure based on honeycomb tessellation for data dissemination in multi-sink mobile wireless sensor networks," *EURASIP J. Wirel. Commun. Netw.*, vol. 2012, no. 1, p. 17, 2012.

[44] A. Tuysuz Erman, A. Dilo, and P. Havinga, "A fault-tolerant data dissemination based on Honeycomb Architecture for Mobile Multi-Sink wireless sensor networks," in *Sixth International Conference on Intelligent Sensors, Sensor Networks and Information Processing*, 2010, pp. 97–102.

[45] A. W. Khan, A. H. Abdullah, M. A. Razzaque, and J. I. Bangash, "VGDRA: A Virtual Grid-Based Dynamic Routes Adjustment Scheme for Mobile Sink-Based Wireless Sensor Networks," *IEEE Sens. J.*, vol. 15, no. 1, pp. 526–534, Jan. 2015.

[46] P. Kubicek, J. Kozel, R. Stampach, and V. Lukas, "Prototyping the visualization of geographic and sensor data for agriculture," *Comput. Electron. Agric.*, vol. 97, pp. 83–91, Sep. 2013.

[47] A. Pardossi, L. Incrocci, G. Incrocci, F. Malorgio, P. Battista, L. Bacci, B. Rapi, P. Marzialetti, J. Hemming, and J. Balendonck, "Root Zone Sensors for Irrigation Management in Intensive Agriculture," *Sensors*, vol. 9, no. 4, pp. 2809–2835, Apr. 2009.

[48] R. Cardell-Oliver, M. Kranz, K. Smettem, and K. Mayer, "A Reactive Soil Moisture Sensor Network: Design and Field Evaluation," *Int. J. Distrib. Sens. Networks*, vol. 1, no. 2, pp. 149–162, 2005.

[49] C. M. Angelopoulos, S. Nikoletseas, and G. C. Theofanopoulos, "A smart system for garden watering using wireless sensor networks," in *Proceedings of the 9th ACM international symposium on Mobility management and wireless access - MobiWac '11*, 2011, p. 167.

[50] R. Beckwith, D. Teibel, and P. Bowen, "Report from the field: results from an agricultural wireless sensor network," in *29th Annual IEEE International Conference on Local Computer Networks*, 2004, pp. 471–478.

[51] J. Geipel, M. Jackenkroll, M. Weis, and W. Claupein, "A Sensor Web-Enabled Infrastructure for Precision Farming," *ISPRS Int. J. Geo-Information*, vol. 4, no. 1, pp. 385–399, Mar. 2015.

[52] D. D. Chaudhary, S. P. Nayse, and L. M. Waghmare, "Application of Wireless Sensor Networks for Greenhouse Parameter Control in Precision Agriculture," *Int. J. Wirel. Mob. Networks*, vol. 3, no. 1, pp. 140–149, Feb. 2011.

[53] X. Dong, M. C. Vuran, and S. Irmak, "Autonomous Precision Agriculture Through Integration of Wireless Underground Sensor Networks with Center Pivot Irrigation Systems," *Ad Hoc Networks J.*, vol. 11, no. 7, pp. 1975–1987, 2013.

[54] S. Roy and S. Bandyopadhyay, "A Test-bed on Real-time Monitoring of Agricultural Parameters using Wireless Sensor Networks for Precision Agriculture," in *First International Conference on Intelligent Infrastructure the 47th Annual National Convention at Computer Society of India*, 2013.

[55] T. Ahonen, R. Virrankoski, and M. Elmusrati, "Greenhouse Monitoring with Wireless Sensor Network," in *IEEE/ASME International Conference on Mechtronic and Embedded Systems and Applications*, 2008, pp. 403–408.

[56] S. M. Abd El-kader and B. M. Mohammad El-Basioni, "Precision farming solution in Egypt using the wireless sensor network technology," *Egypt. Informatics J.*, vol. 14, no. 3, pp. 221–233, Nov. 2013.

[57] J. Lloret, I. Bosch, S. Sendra, and A. Serrano, "A Wireless Sensor Network for Vineyard Monitoring That Uses Image Processing," *Sensors*, vol. 11, no. 12, pp. 6165–6196, Jun. 2011.