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Agricultural Sensors: A Step towards Smart Agriculture

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Introduction:

As the worldwide population has risen, farming operations have grown increasingly complex, vast and optimized. Technological revolutions have leaded farming operations to be more productive than ever, harvesting more crops per area and yielding higher quality products. Smart agriculture, also known as precision agriculture, allows farmers to maximize yields using minimal resources such as water, fertilizers and seeds. In this context, agricultural sensors have been proven beneficial. The sensors used in smart farming are known as agricultural sensors. These sensors provide data which assist farmers to monitor and optimize crops by adapting to changes in the environmental conditions. These are installed on weather stations, drones and robots used in the agriculture industry. They can be controlled using mobile apps specifically developed for the purpose. Based on wireless connectivity, either they can be controlled directly using wi-fi or through cellular towers with cellular frequencies with the help of mobile phone apps.

In this article, we will explore how these sensing technologies have been woven into modern large agribusiness and discuss how progression of the technology can increase our capacity to feed the world along with advantages and limitations of this technology.

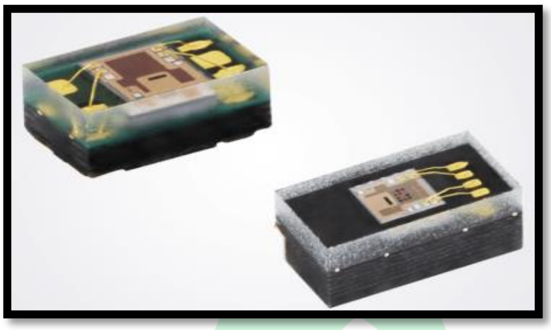
Types of Agricultural Sensors:

A number of sensing technologies are used in precision agriculture, providing data that helps farmers monitor and optimize crops, as well as adapt to changing environmental factors. These are:

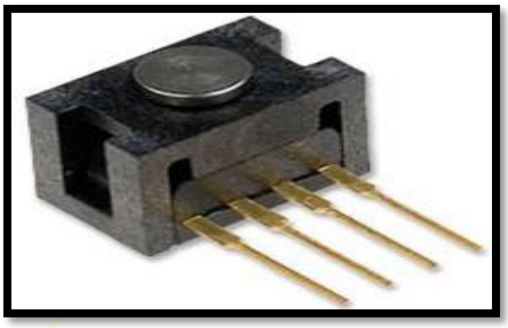
1. **Location Sensors:** Use signals from GPS satellites to determine latitude, longitude, and altitude to within feet. Minimum 3 satellites are required to triangulate a position. Precise positioning is the cornerstone of precision agriculture. GPS integrated circuits like the NJR NJG1157PCD-TE1 are a good example of location sensors.

2. **Optical Sensors:** They use light to measure soil properties. The sensors measure different frequencies of light reflectance in near-infrared, mid-infrared, and polarized light spectrums. Sensors can be placed on vehicles or aerial platforms such as drones or even satellites. Soil reflectance and plant color data are just two variables from optical sensors that can be aggregated and processed. Optical sensors have been developed to determine clay, organic matter, and moisture content of the soil. For example, Vishay offers hundreds of photo detectors and photodiodes, a basic building block for optical sensors.
3. **Electrochemical Sensors:** These sensors provide key information required in precision agriculture like pH and soil nutrient levels. Sensor electrodes work by detecting specific ions in the soil. Currently, sensors are mounted to specially designed "sleds" which help gather, process, and map soil chemical data.
4. **Mechanical Sensors:** These sensors measure soil compaction or "mechanical resistance." These sensors use a probe that penetrates the soil and records resistive forces through the use of load cells or strain gauges. A similar form of this technology is used on large tractors to predict pulling requirements for ground engaging equipment. Tensiometers, like Honeywell FSG15N1A, detect the force used by the roots in water absorption and are very useful for irrigation interventions.
5. **Dielectric Soil Moisture Sensors:** These sensors assess moisture levels by measuring the dielectric constant (an electrical property that changes depending on the amount of moisture present) in the soil.
6. **Airflow Sensors:** They measure soil air permeability. Measurements can be made at singular locations or dynamically while in motion. The desired output is the pressure required to push a predetermined amount of air into the ground at a prescribed depth. Various types of soil properties, including compaction, structure, soil type, and moisture level, produce unique identifying signatures.
7. **Agricultural Weather Stations:** These are self-contained units that are placed at various locations throughout growing fields. These stations have a combination of sensors appropriate for the local crops and climate. Information such as air temperature, soil temperature at a various depths, rainfall, leaf wetness, chlorophyll, wind speed, dew point temperature, wind direction, relative humidity, solar radiation,

and atmospheric pressure are measured and recorded at predetermined intervals. This data is compiled and sent wirelessly to a central data logger at programmed intervals. Their portability and decreasing prices make weather stations attractive for farms of all sizes.



Vishay Photo IC Sensor



Honeywell Force Sensor

Sensor Output Applied:

Sensing technologies provide actionable data to be processed and implemented as and when needed to optimize crop yield while minimizing environmental effects. Here are a few of the ways that precision farming takes advantage of this data:

- Yield Monitoring systems are placed on crop harvesting vehicles such as combines and corn harvesters which provide a crop weight yield by time, distance, or GPS location measured and recorded within 30cm.
- Yield Mapping uses spatial coordinate data from GPS sensors mounted on harvesting equipments. Yield monitoring data is combined with the coordinates to create yield maps.
- Variable Rate Fertilizer application tools use yield maps and perhaps optical surveys of plant health determined by coloration to control granular, liquid, and gaseous fertilizer materials.
- Weed Mapping currently uses operator interpretation and input to generate maps by quickly marking the location with a GPS receiver and data logger. The weed occurrences can then be overlapped with yield maps, fertilizer maps, and spray maps.
- Topography and Boundaries can be recorded using high-precision GPS, which allows for a very precise topographic representation to be made of any field. These precision maps are useful when interpreting yield maps and weed maps. Field boundaries, existing roads, and wetlands can be accurately located to aid in farm planning.

- Salinity Mapping is done with a salinity meter on a sled towed across fields affected by salinity. Salinity mapping interprets emergent issues as well as change in salinity over time.
- Guidance Systems can accurately position a moving vehicle within 30cm or less using GPS. Guidance systems replace conventional equipment for spraying or seeding. Autonomous vehicles are currently under development and will likely be put into use in the very near future.

Scaling to "Small" Agriculture:

Smartphone sensors and apps, as well as small-scale machinery, allow smaller farms to take advantage of smart agriculture technologies.

Smartphone Tools:

The smartphone alone has several tools that can be adapted to farming applications. For instance, crop and soil observations can be logged in the form of snapped pictures, pinpoint locations, soil colors, water, plant leaves, and light properties. Table 1 lists some in-phone tools that are useful for gathering data:

Table 1: Agricultural uses of existing smartphone tools

Smartphone Tool	Smart Farming Applications
Camera	Provides pictures of leaf health, lighting brightness, chlorophyll measurement, and ripeness level. Also used for measuring Leaf Area Index (LAI) and measuring soil organic and carbon makeup.
GPS	Provides location for crop mapping, disease/pest location alerts, solar radiation predictions, and fertilizing.
Microphone	Helps with predictive maintenance of machinery.
Accelerometer	Helps determine Leaf Angle Index. Also used as an equipment rollover alarm.
Gyroscope	Detects equipment rollover.

Smartphone Apps:

Many smartphone applications have begun to incorporate Internet of Things (IoT) ideals, data aggregation, and speedy processing to bring up-to-date, actionable information to small farmers regarding seeding, weeding, fertilizing, and watering. These applications gather data from handheld sensors, remote sensors, and weather stations, creating in-depth analyses and valuable recommendations. Several applications have been developed specifically targeting the small-scale farmer:

- **Disease Detection and Diagnosis:** Photos taken of suspect plants can be forwarded to experts for analysis.
- **Fertilizer Calculator:** Soil sensors and leaf color can determine what nutrients are needed.
- **Soil Study:** Capturing soil images, as well as pH and chemical data from sensors, allows farmers to monitor and adjust to changing soil conditions.
- **Water Study:** Determining Leaf Area Index from photos and brightness logging can help farmers determine water needs.
- **Crop Harvest Readiness:** Camera photos with UV and white lights accurately predict ripeness.

Global Implications:

Solving problems for farms both large and small and helping farmers meet ever-increasing food demands aren't the only solutions smart, precision agriculture can provide. Smart farming offers a number of other benefits, such as:

- Lowering fuel and energy consumption thus reducing carbon dioxide emissions.
- Reducing nitrous oxide released from soil by optimizing nitrogen fertilizer use.
- Reducing chemical use by pinpointing fertilizer and pest control needs.
- Eliminating nutrient depletion through monitoring and managing soil health.
- Controlling soil compaction by minimizing equipment traffic.
- Maximizing water use efficiency.

Advantages:

- They are simple to use and easy to install.
- They are cheaper.
- In addition to agricultural use, they can also be used for pollution and global warming.
- They are equipped with wireless chip so that they can be remotely controlled.

Limitations:

- Smart farming and IoT technology require continuous internet connectivity. This is not available in developing countries such as INDIA and other part of the world.

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- There is presumption in the market that consumers are not always ready to adopt latest IoT devices equipped with agriculture sensors.
- The basic infrastructure requirements such as smart grids, traffic systems and cellular towers are not available everywhere. This further hinders the growth of its use.

Conclusion:

Agricultural sensors are contributing solutions to problems that extend beyond farms, including pollution, global warming, and conservation. Future developments in precision agriculture will likely include increased autonomous farm vehicle use, as well as improved wireless data transmission and acquisition from smarter, smaller Unmanned Aerial and Unmanned Ground Vehicles (UAVs and UGVs, respectively). In addition to monitoring crop and soil conditions, these smaller vehicles can also monitor the status of farm equipment, allowing farmers to improve machine servicing and maintenance. In general, process improvements learned in the industrial manufacturing arena will continue to find their way into agriculture.