Assessment of Weather Risks for Agriculture using Big Data and Industrial Internet of Things Technologies

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Abstract
Climate change is irreversible, and agriculture is at risk from the unforeseen consequences. Unpredictable and sometimes severe weather is an important issue to address. No one can change the weather, but monitoring and forecasting can save a lot of money for agribusiness. Forecasting weather analytics and weather tracking technologies in agriculture can help. The application of big data in agriculture based on Internet of Things (IoT) technology is analyzed. An IoT information collection platform for agricultural land has been proposed.

Keywords
Agriculture, big data technology, IoT.

1. Introduction

Changing weather is a natural thing that farmers face from season to season. Changes in the weather certainly affect crop yields, but do not surprise farmers. But in the context of global climate change, nature seems to be making additional efforts to complicate the work of farmers by pushing them to climate-sustainable agricultural practices.

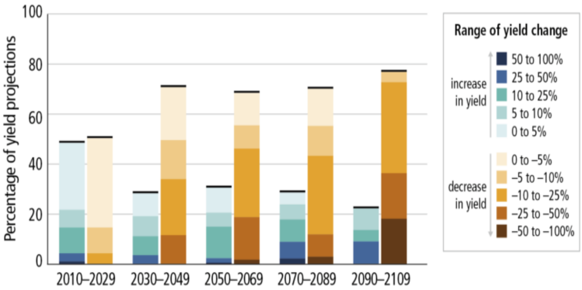

Figure 1: Summary of projected changes in crop yields due to climate change during the 21st century

The data include forecasts for different emission scenarios, for tropical and temperate regions, as well as for adaptation and non-adaptation cases together. Relatively few studies have looked at the impact on crop systems for scenarios where global average temperatures rise by 4°C or more. For the five short-term and long-term periods, data (n = 1090) are plotted over 20 years on a horizontal axis that includes the middle of each future forecast period. Changes in crop yields relative to the level of the late 20th century. The amount of data for each timeframe is 100%.

Suddenly, floods can engulf fields, mixing seeds in the soil and forcing farmers to guess where to harvest them. Many floods are caused by ordinary spring rains. They harm crops and add to agribusiness problems by significantly reducing profits.

Another important problem is when the soil freezes earlier than planned and significantly prevents the crop from fully ripening. Farmers often remain unarmed against weather deviations. Last year, social media was flooded with reports of snowfall in Dakota, which slowed down wheat harvesting and left no chance for corn to ripen. Farmers in other states soon expressed their concerns.

CPITS-2023-II: Cybersecurity Providing in Information and Telecommunication Systems, October 26, 2023, Kyiv, Ukraine
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2. Analysis of the Problem of the Influence of External Factors on the Environment

For agriculture, weather monitoring technologies are not only very useful but also one of the most important tools. As it turns out, weather forecasting software, along with the right data, can help you predict and mitigate the effects of dangerous weather.

Heat waves (periods of extremely high temperatures) are likely to become more frequent in the future and become a serious problem for agriculture. Heat waves can cause heat stress in both animals and plants and adversely affect food production. Extreme periods of high temperature are especially detrimental to crop production if they occur during flowering plants—if this single critical stage is disrupted, the seeds may not be present at all. In animals, heat stress can lead to decreased productivity and fertility, and can negatively affect the immune system, making them more susceptible to certain diseases.

Evidence of the increase in heat waves is the warming that has already taken place, as well as the increase in the frequency and magnitude of the heat waves more than expected.

It is difficult to make accurate predictions frequency and magnitude of heat waves, but there is a measured forecast that suggests that they will continue to grow in the UK, Europe, and globally. The impact of heat waves is expected to be uneven, with disproportionately negative effects in less developed countries. Along with other aspects of climate change, such as increasing droughts, they may exacerbate existing food security problems.

Predicted climate change is not limited to rising temperatures and heat waves; a significant change in precipitation structure is also expected. While some regions are likely to suffer from drought in the future, other regions are expected to face the opposite problems of torrential rains and increased floods. In coastal areas, rising sea levels can lead to the complete loss of agricultural land. A warmer climate can also lead to greater pest and disease problems and shifts in the geographical distribution of some pests. For example, disease-carrying insects are likely to migrate further toward the pole in the future, where cattle have not yet been exposed to the disease.

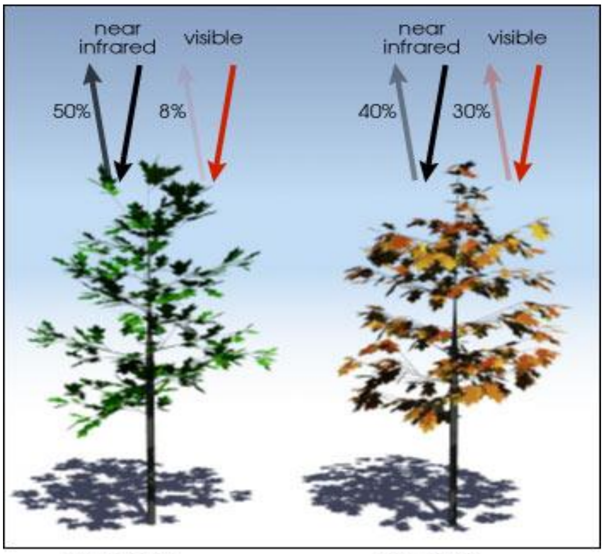
Yield response to various stresses was well determined by experiments on many crops. Quantifying these responses and identifying when agriculture is most vulnerable to stress is useful in determining the most effective adaptation strategies. Adaptation at the crop level to climate change is expected to be key to minimizing future crop losses and may include: crop varieties change, sowing dates, cultivation technologies, and/or irrigation methods. Ongoing research solves the problem of maintaining and/or increasing crop production in the context of global change. Some risks to crop production due to climate change and extreme weather events have been identified, and strategies to support production have been proposed. These include restoring the diversity of farm types, crops, or varieties in food systems to increase their resilience and improve crops that increase resilience to stress. Other strategies may include the development of pre-defined international food insecurity measures to prevent food price shocks that could reduce people's access to food [1].

3. Technologies and Methods of Plant Development Analysis

Satellite crop monitoring is a technology for observing changes in the vegetation index obtained by spectral analysis of high-resolution satellite images. Used in individual fields or for individual crops and allows you to track the positive and negative dynamics of plant development. The difference in the dynamics of the vegetation index indicates disparities in development within one crop or field. This indicates the need for additional agricultural work in some areas, so this technology is attributed to the methods of precision farming.

The vegetation index is an indicator calculated as a result of operations with different spectral ranges of remote sensing data, which is related to the vegetation parameters in a given pixel of the image. The effectiveness of vegetation indices is determined by the characteristics of the reflection. The calculation of most vegetation indices is based on the two most stable sections of the plant spectral reflectivity curve.

Normalized Difference Vegetation Index (NDVI) is a normalized relative vegetation index. Most common in agriculture, it characterizes vegetation density and allows farmers to assess germination, growth, weeds, or diseases, and predict field productivity. The index is formed by satellite images of green mass, which absorb electromagnetic waves in the visible red range and reflect them in the near-infrared. The red zone of the spectrum (0.62–0.75 μm) has the maximum absorption of solar radiation by chlorophyll but in the near-infrared zone (0.75–1.30 μm) the maximum reflection of energy by the cellular structure of the leaf. That is, high photosynthetic activity leads to lower values of reflection coefficients in the red zone of the spectrum and higher values in the near-infrared. The ratio of these indicators to each other allows you to separate vegetation from other natural objects. As a result, it is possible to obtain a full spectral analysis and identify areas that require reseeding, and application of PPE or fertilizers. The index is moderately sensitive to changes in soil and atmospheric background, except in cases of poor vegetation, and may be oversaturated in dense vegetation when the Leaf Surface Index (LAI) becomes high [2–3].



$$\frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72 \qquad \frac{(0.4 - 0.30)}{(0.4 + 0.30)} = 0.14$$

Figure 2: Calculate of Leaf Area Index

English Enhanced Vegetation Index (EVI)—advanced vegetation index. Developed to improve NDVI by optimizing vegetation signal in areas with a high LAI. The index uses the blue display area to correct background soil signals and reduce weathering, including aerosol scattering. It is most useful in regions with high LAI levels, where NDVI can be oversaturated. EVI values for vegetation pixels should be in the range 0 to 1. Bright objects such as clouds and white buildings, along with dark objects such as water, can cause abnormal pixel values in the EVI image. It is used to assess the variability of development both in conditions of dense vegetation and in conditions of sparse vegetation [3].

Green Normalized Difference Vegetation Index (GNDVI) is a green normalized relative vegetation index. Similar to NDVI in that it measures green instead of the red spectrum in the range from 0.54 to 0.57 μm. This is an indicator of the photosynthetic activity of vegetation, which is most often used in assessing the moisture content and nitrogen concentration in plant leaves according to multispectral data, which do not have an extreme red channel. Compared with the NDVI index, it is more sensitive to chlorophyll concentrations. It is used in the assessment of depressed and aging vegetation [4–5].

The Chlorophyll Vegetation Index (CVI) is the chlorophyll vegetation index. Has a hypersensitivity to the content of chlorophyll in the leaf cover. It is used from the beginning to the middle of the crop growth cycle for a wide range of soils and sowing conditions by analyzing a large set of synthetic data obtained using a leaf surface mapping model. Hypersensitivity of the index to the concentration of chlorophyll in the leaf is due to the effective normalization of the various values of LAI obtained by the introduction of red and green [6].

True Color—true color. Visual interpretation of the earth's crust. An image presentation and storage method that displays a large number of colors, halftones, and shades. The true color image is displayed in a combination of red, green, and blue stripes.

4. Development Technologies of Intellectual Monitoring

Using real-time weather data for the current location and season helps farmers take care of soil and crops and manage all weather risks.

When it comes to choosing technologies for weather forecasting, agribusiness should consider a combination of agricultural technology solutions that complement each other. The three main technologies that contribute to the development of intelligent weather monitoring for agriculture are smart IoT sensors for data collection and analysis, satellites and meteorological stations, as well as artificial intelligence systems, and machine learning for weather forecasting [7].

IoT sensors lay the foundation for a larger connected system for tracking weather in agriculture. These systems rely on a network of connected sensors that collect data in the field. Cloud computing platforms then process the collected data to provide alarms and alerts about potential weather hazards affecting crops.

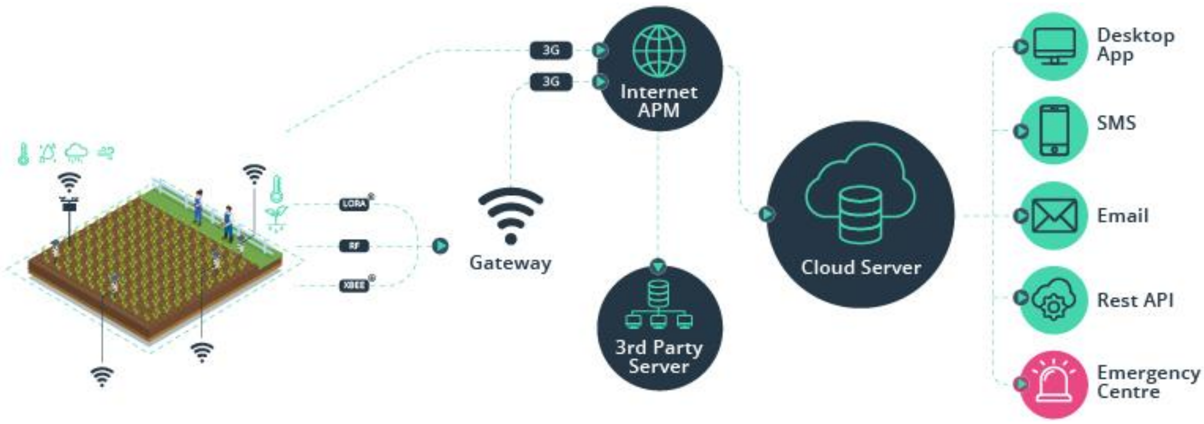


Figure 3: Principle of IoT sensors

Using the IoT, farmers can access real-time information about the environment and soil to plan ahead of weather changes. When the system receives alarm data from weather sensors, it can send notifications of future frosts or rains [8].

Advantages of IoT solutions for weather monitoring:

- Reduces crop risks by monitoring severe weather conditions.
- Helps farmers optimize resource use and protect crops.
- Improves product quality by offering the best time to harvest.
- Sends notifications to multiple devices and platforms in real time.
- Collects reliable data in the field that are relevant to the location of the farm and the current season.
- Integrated with third-party services and available to the community.

5. Data Collection and Analysis in Big Data

Big data is data that is so large that if you compare the characteristics of its acquisition, storage, management, and analysis of management analysis software, it will surpass traditional databases in these respects. Big data is also an information asset. It is also a data set that uses common software tools to collect, manage, and process data that can be retrieved and processed in real-time. Big data is essentially a data set, and the characteristics of big data can be displayed compared to previous methods of data management analysis. Big data is an extremely large collection of data that cannot be collected, processed, stored, and calculated in the time required by traditional data processing methods or tools. This type of data has five main characteristics: a large amount of data, large collections of data by different categories, storage and calculation; and a wide range of types, including categories, sources, and structures. Low-density values and large amounts of data can in some cases depreciate these data, so they need to be verified to obtain valid data. Speed is high and time efficient, data processing speed is high and scale is growing rapidly. Always back on the line, data is always produced as shown in Fig. 4.

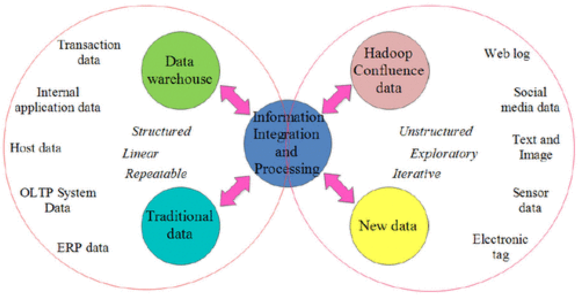


Figure 4: Big Data coverage map

Due to the maturity and intelligence of big data technology, big data technology is widely used, particularly in industries such as agriculture, metallurgy, mining, medicine, machining, aerospace, and more. Big data, thanks to the improvement of their processing and analysis, allows to solve problems effectively in any field and allows to bring huge benefits for its development.

Currently, agricultural big data are mainly used for agricultural condition monitoring, agricultural product monitoring and early warning, accurate agricultural decision-making, and building a comprehensive information service system for agriculture. For monitoring data-based agricultural conditions, according to the analysis and processing of the data processing platform, the agricultural monitoring system can be improved by opening up new opportunities for agricultural monitoring. To detect an early warning by analyzing the collected meteorological data combined with meteorological modeling, soil analysis, analysis of the root situation of plants and other elements, improving the accuracy of disaster forecasting and improving the method of disaster assessment to improve forecasting accuracy; and with the help of big data in agriculture, we can provide feedback on crop growth data and provide important information and analytical data for crop assessment and dynamic growth monitoring [9].

In agricultural decision-making, big data processing and analysis technology can be integrated into crop growth and development and climate, the soil in the crop growth environment. Taking into account economic, environmental, and sustainable development, provide more accurate, real-time, and efficient agricultural decisions for those who make decisions about agricultural production. When building a rural integrated information service system, sufficient and accurate data provide the necessary technical support for building an integrated information service system in the field of agriculture.

It can be seen that the amount of data generated by agricultural production is large and diverse, and the quantitative indicators between different data are not the same, which leads to difficulties in processing data on agricultural production. As an intelligent algorithm, a neural network can process big data based on a large amount of agricultural data accurately predict agricultural production according to big data created by the production process, and then manage agricultural production [10–12].

Given that the use of big data is not a new approach in agriculture, there are many examples of how companies have effectively used big data to address issues of concern to the industry. This can help assess how big data integration decisions can have a real, significant impact on doing business in this area [13].

6. Information Gathering and Forecasting Tools

The Digital Transmission Network (DTN), a division of Schneider Electric, provides its customers with agricultural information solutions and market analysis. With DTN, farmers and commodity traders can access up-to-date weather and pricing data to better manage their business.

Faced with the challenge of managing a complex network of data sources—Enterprise Resource Planning (ERP), financial applications, GIS, agronomy packages, and sensor applications—to display real-time information for customers, the current DTN method of connecting these systems proved too expensive to integrate and further maintenance.

DTN has invested in a modern data integration tool that consolidates data from multiple sources without having to write a ton of special code. With a clean and consistent set of interfaces, DTN can now combine important weather and agronomic data from fields to give accurate forecasts. Using this set of technologies, farmers can increase yields and reduce costs based on these forecasts.

DTN quickly became the industry standard for the exchange of information on agribusiness and became an information center for the online community of farmers and agribusiness.

InVivo is France's leading agricultural cooperative group with 220 members and €6.4 billion in sales of its product. SMAG, its subsidiary, is a French leader in the development of agronomic information systems. Its software is used by 80% of cooperatives and 50% of merchants in France. While SMAG has developed many mobile applications to support farmers in their day-to-day operations, they wanted to combine all their data—30 years of weather history, satellite images and drone images, and soil types—to make informed decisions faster. Their goal: is to use digitization to solve the food problems of the 21st century.

Using a tool to process a huge amount of stored and accumulated data, SMAG has developed a sophisticated agronomic algorithm Data Crop that allows you to use different types of data to optimize decision making. For example, Data Crop allows users to track crop progress and forecast yields, a data point that has led to incredible wheat production results. Currently, 80% of France's agricultural land under wheat is managed through Data Crop. SMAG plans to spread this to other cultures and countries.

Success in agriculture has largely depended on favorable natural conditions, but as mentioned earlier, in the face of rapid climate change, it is sometimes quite difficult to count on favorable conditions. The combination of cloud computing and big data has provided farmers with enough data points to make the right decisions [14].

Cloud computing has democratized the availability of huge computing power, as data centers and storage are now available on a pay-as-you-go basis. This combined knowledge repositories with data such as weather, irrigation methods, plant nutrient requirements, and several other farming methods.

Cloud programs can help farmers adjust production to market demand and increase yields and profitability. Today, a farmer can manage agriculture and all related activities—even before planting crops, you can evaluate the results by adjusting the appropriate variables.

IoT technology is mainly a set of sensors, sensor gateways, Radio Frequency Identification (RFID), and cloud computing. IoT technology is used in many industries, and different industries often have different industry requirements and technical forms. However, among these different technical systems, IoT technology mainly consists of four main systems. The four systems are perception systems, network systems, computing and service systems, and management and support systems. Perception and identification technology are the main components of IoT. The network layer ensures secure and reliable transmission of information. Services and applications are key ways to use IoT technology to realize the value of information. Management and support technology is the key to ensuring the efficient operation of IoT.

The IoT information collection platform for agricultural land mainly consists of a data collection module, a data transfer module, and a remote monitoring of the top computer.

The data acquisition module mainly includes a Wireless Sensor Network (WSN) module consisting of a plurality of sensors and a ZigBee module, an image acquisition module, and a weather acquisition module. The wireless sensor module is mainly used to obtain environmental data on agricultural land in real-time. The image acquisition module is mainly used to capture real-time environmental conditions of agricultural land. The meteorological collection module mainly receives a wide range of meteorological data. The data collection module is mainly used to complete the collection of data on the microclimate of agricultural lands, including ecological data of agricultural lands, temperature and humidity, light intensity, water content in the soil, and so on. Agricultural land imaging data mainly uses WSN, which consists of appropriate agricultural sensors and ZigBee modules to obtain environmental data, and industrial cameras to obtain image data. Wide range of meteorological data collection. Meteorological data and crop growth are also closely linked. Timely weather warnings can effectively improve farmers' response to natural disasters, reduce disaster losses, and increase yields [15].

GPRS communication technology and 3G network card in the data module, respectively, transmit environmental and image data to the host computer, and finally, the main computer monitoring platform stores and analyzes the received data and uses the web page for the table forms, statistical charts, query interfaces, etc. The form is presented in the computer user interface, and the user can view environmental data, images, and results of analysis of data obtained from agricultural land, through a real-time web page, thus improving the provision of agricultural land management services. The general structure of the system is shown in Fig. 6. As can be seen from the figure, it is mainly divided into three parts: the data reception module, the data transmission module, and the data storage module. The three modules work together to complete data collection and processing [16].

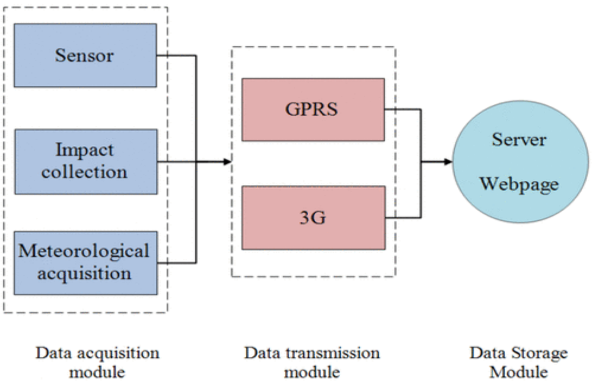


Figure 6: IoT system architecture for agriculture

7. Analysis of Research Results

The Business Insider article notes that the IoT is evolving in agriculture. The current world population of 7.3 billion is expected to reach 9.7 billion in 2050, according to the United Nations. Accordingly, according to the Food and Agriculture Organization of the United Nations, in 2050 the world will need to produce 70% more food than in 2006 to feed the world's growing population. Farmers will have to turn to new technologies to meet the growing demand for food production in the world.

The IoT is a network of physical devices that have a network connection that allows you to collect and exchange data between them. The IoT is a great opportunity for farmers to monitor their crops and increase productivity. Satellites, drones, wireless sensor networks, agricultural analytical systems, farm management systems, and big data applied to the farm and the food management chain are all examples of IoT and smart agriculture.

A study by OnFarm found that after using the IoT on a medium farm, yields rose by 1.75%, energy costs fell by $7–13 per acre, and water use for irrigation fell by 8%. The United States, where the IoT is most common, produces 7,340 kg of grain per hectare of agricultural land, compared to the world average of 3,851 kg of grain per hectare. Given these figures, it is easy to recognize that the installation of IoT devices in the agricultural world will increase from 30 million in 2015 to 75 million in 2020.

As we have already said about e-agriculture, there are many examples of IoT projects that have already been launched: the EU has launched a €30 million project called Food & Farm 2020 to evaluate and improve IoT technologies. In Kansas, farmers are already using sensors to save water, and a new sensor technology project will soon be implemented in Bangladesh. Last but not least, NanoGanesh, a mobile remote control for water pumps and water tanks, will be on display at the forthcoming World Mobile Congress in Barcelona (March 27, April 2).

To increase the efficiency of their work, agricultural enterprises need data and not a small amount. This opens the door to technological innovation, as the size of these enterprises and their land plots do not allow for any manual surveys.

We are already seeing the active use of IoT devices to analyze the state of crops, collecting real-time data using sensors. For example, with the help of soil sensors, farmers can detect any irregular conditions, such as high acidity, and effectively solve these problems to increase their yields.

Data collected from sensors allows for advanced analytics and insights to help make harvest decisions, while machine learning can turn numbers into reliable predictions. Using advanced analytics, farmers can forecast yields, anticipate unexpected weather conditions, forecast market demand mitigate risks, and better plan their capacity.

The agricultural drone is also a key component of smart agriculture today. The task of inspecting crops and livestock from a height, and their use over time in on-board chambers helps farmers identify problems in areas such as irrigation that would otherwise go unnoticed.

Other members of the drone family allow you to spray crops with more precision than a tractor. As an added benefit, it also aims to reduce the risk of exposure to harmful chemicals. Once back to ground level, other jobs can help with manual tasks such as planting, plowing, and meat production.
Ultimately, the use of such technologies significantly increases the efficiency of the farm.

Almost every solution for intelligent weather monitoring is based on data. This applies not only to forecasting extreme weather conditions, such as floods but also to regular weather conditions in the field, which affect the harvest daily. With technologies such as IoT weather stations, weather collection data, and AI weather forecasts, agribusinesses can store and process countless datasets to be prepared for, respond to, and promote climate change initiatives.

8. Aids for Predicting the Accuracy of Estimates

Precipitation is the analysis of historical data on rain for certain periods gives interesting results of observation and serves as valuable material for future forecasts based on artificial intelligence algorithms.

Temperature tracking temperature changes during the day, month, and year provide a forecast of crop conditions and input data for further analysis of conditions that determine weather changes.

The direction and speed of the wind can warn farmers about the coming storm.

Air pressure is one of the most important measures for predicting weather changes.

Humidity is this indicator is critical, especially in preparation for rain and wise use of water.

Later, all these datasets can be collected into a single platform for weather monitoring and accessible from any device. Farmers can set up dashboards to monitor critical data and visualize analytics for better decision-making. In a smart weather panel, farmers should also be able to:

- Set the number of measurements collected for a certain period (hours, days, weeks, months, years).
- Track all historical data or select a period to display.
- Monitor community data from other farms as open-source information.
- Place all sensors in the fields to know where weather changes are already affecting crops.
- Correlate indicators to make predictions based on all potential hazards and receive proposals for field protection.

Farmers can use satellite data for a variety of purposes and use aerial photographs to monitor crop yields and forecast weather in agriculture. Satellites can be used in two ways. First, as a source of data for farm applications for weather forecasting, and second, as transmitters of data collected from agricultural meteorological stations on Earth. However, this second use is a bit expensive, as data transmission via satellite costs a lot—almost $1,000 per kilobyte. Agricultural weather forecasting technology allows farmers to use satellites to access geospatial and meteorological data to prepare fields for unusual or severe weather conditions [17].

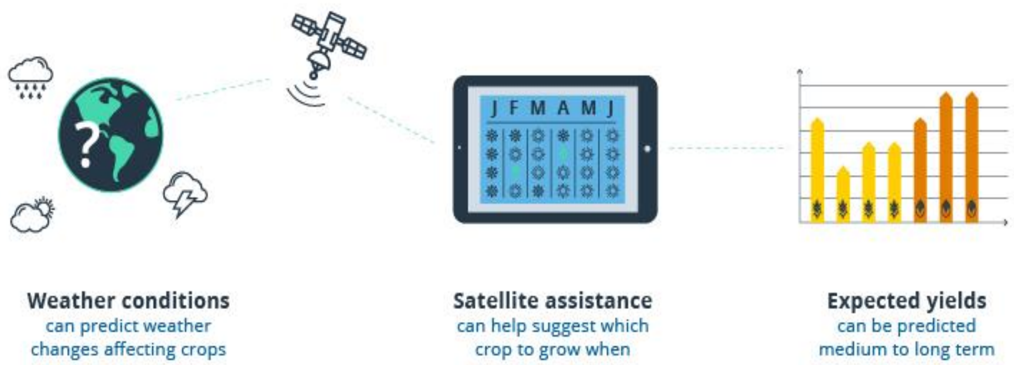


Figure 7: Forecasting from satellites

Agribusiness also uses weather forecasting satellites to monitor global climate change and predict weather disasters such as fires and floods. Satellites are often controlled by government organizations, so they are not flexible enough for individual use. However, they give a general picture of the weather conditions in the area. The collection of satellite images and data allows applications to analyze conditions, and assist in forecasting yields based on weather conditions and field monitoring. It also helps to plan smart irrigation based on weather changes that may spread potentially hazardous herbicides throughout the area.

Weather forecasting as a practice has existed since the first person wondered if it would rain the next day. Over the years, the methods have become more sophisticated. The location of weather satellites has helped to gain a clearer picture of weather models as they evolve. However, companies now have access to even more data.

Businesses have recently been able to plan not only the day when it snows, but they can know how much, which city is likely to suffer the most, and where the greatest concentration of ice will be on the road. The IoT provides a more concise weather forecast than ever before.

According to Computerworld, the first sensors that meteorologists relied on to predict the weather were located mainly in airports or ocean-going ships. These facilities needed immediate, accurate weather information, and they were also large enough to store equipment without interfering with daily work.

Thanks to IoT-enabled technology, these sensors, which measure factors such as light, motion, temperature, pressure, and humidity, have become more accessible. Weather forecasters can now tie this equipment to cars to ensure accurate road conditions. Even most smartphones have at least a few such sensors. Using smartphone sensors [18], IoT technology allows forecasters to see a more complete map with far more data points than just airports and ships [19].

Excess sensors also allow for more experiments with data. Meteorologists can see exactly where on a vehicle the equipment is providing the most accurate results, and adjust their input to prioritize this information [20].

The excess of sensors led to monitoring not only the weather but also air quality. According to Data-Smart City Solutions, air quality sensors have been implemented in major US cities using a variety of IoT-enabled methods [21]. The simplest is smartphone data, which provides accurate user tracking to see how often a resident is in areas with poor air quality. However, this source alone is not powerful enough to provide all the necessary data, so it must be combined with additional sensors.

As with other weather equipment, air quality sensors are stored in vehicles for greater mobile data collection. The problem is that the data is recorded in real time, i.e. the flow of information stops when the car leaves the area. This method alone cannot provide a view of the changes in air pollution during the day unless the vehicle travels here and there in the same area constantly.

The third way is the strongest. Air quality sensors can be built into existing infrastructure. In some cities, such as Boston, there are even sofa benches and park benches equipped with solar panels for charging USB devices and providing ports for data collection. This method is accurate and continuous, but the initial cost of installation is high.

9. Artificial Intelligence and Machine Learning in Forecasting

The use of artificial intelligence and machine learning to forecast the weather is the latest and most promising technological progress for agriculture. For example, IBM has created an agricultural decision-making platform by implementing its IBM Watson technology. Like any solution with artificial intelligence, weather forecasting requires a huge amount of data to teach machine learning algorithms. This data can be obtained from connected sensors, satellites, and local hardware weather stations to create accurate localized weather forecasts. These predictions require a lot of computing power to process large data sets and powerful storage is required to store this data for future use.

Because deep learning algorithms rely heavily on the quality of educational data, data quality, and labeling are critical to accurate predictions. Sorting data and recognizing weather conditions should help to gain an accurate idea of the definition of weather conditions after learning the deep learning model [22].

Increasing accurate data sources plays an important role in successful weather forecasting. There are now more than 1,000 weather monitoring satellites in Earth orbit, and there are thousands of weather stations on Earth's surface. The latest addition is IoT-connected sensors installed by individual farmers in their fields. All of this provides enough input to teach algorithms to distinguish between cloud models, recognize the effects of the smallest changes in temperature and humidity, and identify potential hazards based on changes in wind direction that can cause weather fronts from other areas.

No matter how much data you collect and what type of machine learning technique or IoT development services you use, any weather forecast has some inaccuracies. Teaching artificial intelligence models can take too much time to prepare relevant data and work with a huge amount of input. However, the growth of computer power and the experience of using AI for other solutions promise excellent results in weather forecasting. The development of wireless connectivity and the introduction of 5G technology facilitates accurate and timely data collection from IoT sensors. Meanwhile, satellite data is becoming available to businesses in various industries and allows the use of weather forecasting in agriculture.

The idea of creating a solution for weather forecasting for agriculture looks more than promising. Such a decision should mitigate the effects of climate change by anticipating unusual weather that harms crops. Weather forecasting will enable agribusinesses to optimize resources, preserve yields, and automate decision-making on growing and harvesting periods, and will promote the concept of climate-friendly agriculture.

Farmers can get better weather forecasts thanks to IoT sensors. Schneider Electric has released more than 4,000 WeatherSentry sensors in the United States to give a better picture of weather conditions across the country.

The system will use big data techniques to more accurately forecast the weather, and the firm says it will help farmers increase efficiency, profitability, and sustainability.

WeatherSentry sensors record field and ground-level weather conditions, which are used to create accurate local temperature and precipitation forecasts, as well as storm records and historical weather history archives to help assess and plan the effects of weather on day-to-day agriculture.

The firm claimed that its sensor generated more agricultural data than any other supplier. Its Geographic Information System (GIS) system is reported to provide real-time data to allow farmers to plan crops, optimize water and soil use, and prioritize activities based on 15-day forecasts.

"Despite the many technological advances in agriculture over the past century, the weather remains a high-risk, high-risk variable that affects all corners of the industry," said Ron Schneider, senior vice president of cloud services at Schneider Electric.

"Using weather assumptions allows farmers, ranchers, and landowners to make better operational and financial decisions that directly contribute to the stability and health of their profits."

Schneider said the use of big data and the IoT could be used to mitigate the effects of climate change and solve one of the most critical problems for farmers around the world.

"The IoT will revolutionize the way we ensure sustainable food production, and we are excited to be at the forefront of providing accurate technologies that help meet this truly global need," he added.

Gartner Vice President of Research Bettina Tratz-Ryan said the IoT plays an important role in minimizing the impact of climate change.

She said the IoT would unlock the potential of real-time data analysis from a variety of business processes and visualize resource inefficiencies.

"In addition, increasing the availability of data sources from the IoT will bring more information about the context in which the sensor monitors an environmental event or condition. This context gives an idea of the relationship between user or operator behavior, machine process operations, or external influences that can lead to environmental inefficiencies," added Tratz-Ryan.

Tratz-Ryan said that programs and social networks have allowed us to share other personal best practices about the environment, creating a dynamic approach in the community. "All of these methods have one thing in common: the ability to use data to make real-time changes for a more sustainable outcome," she said.

Intellias is one of those companies that has launched its agricultural management systems with a set of convenient tools and services. The software installed on their clients' farms is designed to give them a clear and comprehensive view of current agricultural operations by tracking field activities, monitoring weather conditions, and planning plant protection measures. Crop farmers can use this software to populate the agricultural database to better manage the crops in their fields, plan harvests, get advice on choosing the right varieties of crops, review crop schedules, select the right fertilizers, and more.

The farm management software offered by this company includes a variety of features that allow growers to manage their farms as required by their forecasts and business goals, namely:

A crop rotation chart with histogram analysis gives farmers an idea of the order of sowing fields with different types of crops to increase soil fertility. This feature is especially useful for managing multiple harvests when the correct timing and schedule are difficult to perform.

The functionality for the weather includes detailed weather forecasts for the coming period, weather analysis for periods with dynamic layers (temperature, humidity, precipitation, clouds, wind direction, etc.), as well as a guide to spraying based on weather factors and models.

Disease management gives an idea of plant growth and disease risks throughout the economy and in each field. In the event of an outbreak of disease or pests, the affected field is highlighted to inform the user of the necessary spraying measures.

NDVI satellite image analysis allows growers to scan crop health and detect anomalies. With the help of space images, users can track seed coverage and germination, vegetation growth rate, the level of photosynthesis in plants, and other crop details [2].

The choice of varieties helps farmers to choose the most appropriate type of crop for the field, giving a quick comparison from A to Z of different varieties of crops by seedling level, yield levels, and disease resistance. It also provides feedback from other producers on specific varieties of crops.

Seeder maps and soil maps allow farmers to mark different types of soil on a field map. The soil profile of the field provides a better understanding of soil compaction, texture, moisture retention, and root zone depth for the selection of optimal crop varieties and cultivation methods.

The gatekeeper acts as an inventory, combining all the field data that is then imported into the platform and made available in the import history, where users can make and save changes. As a result, all the farmer's fields will be displayed on the map along with detailed information on location, size, ownership, and crops grown.

An interactive whiteboard with moving cards and lists allows farmers to visualize the workflow, measure progress in the fields, and create operational plans. With each operation (sowing, planting, watering, spraying, etc.) that moves through the statuses on the board (task, completed, completed), the user guarantees that his business will meet the schedule of the farm.

The Intellias team has taken on the project's research and development functions and works closely with key decision-makers, providing end-user feedback, insights into manufacturers, new requirements, and requests for additional features. Based on human-oriented data and practices in the application of geoinformatics in agriculture, they developed prototypes of farm accounting software and launched them after approval by stakeholders.

The idea of creating a solution for weather forecasting for agriculture based on integration with big data and the IoT seems more than promising. Such a decision should mitigate the effects of climate change by anticipating unusual weather on time. Weather forecasting will enable agribusinesses to optimize resources, preserve yields, and automate decision-making on growing and harvesting periods, and will promote the concept of climate-friendly agriculture. Given that climate change is currently happening at a very high rate and the world's population is growing, smart agriculture is not only a business idea, but also reaching the level of basic human needs [23].

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