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Data Warehouse Design for Soil Nutrients with IoT Based Data Sources

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***Abstract*—Plant fertility is very dependent on the levels of nutrients present in the soil. Measurement of soil nutrients can be done through laboratory tests and can also be done using IoT technology. IoT equipment is supported by sensors that can be used to measure soil nutrients and the location of the soil is measured. Data from land measurements made through IoT technology can be stored and displayed in real-time through the cloud. This paper designs data sources derived from IoT-based nutrient measurement data to build data warehouse locations and soil nutrients. A data warehouse that is formed later can be done for analysis of the types of plants and fertilizers needed at a soil location.**

Keywords— soil nutrients, IoT, Data Warehouse, Sensor

I. INTRODUCTION

Nutrients are substances needed by animals or plants for tissue formation, growth, and other living activities. Nutrients can be organic (derived from living things) or unorganic (non-living things, elements from water, acids, gases and minerals). For plants, nutrients are inorganic compounds (chemicals) in the soil that plants need to grow and develop. Nutrients in terms of their level of needs can be classified into 2, namely macronutrients and micronutrients.

Macronutrients are nutrients required by plants in a considerable amount (macro), namely potassium (K), Calcium (Cal), Magnesium (Mg), Nitrogen (N), Phosphor IP), and Sulfur (S). While the micronutrients are substances needed by plants in small quantities (micro), namely zinc (Zn), iron (Fe), Barium (B), Chlor (Cl), manganese (Mn), molybdenum (Mo) and copper (Cu).

The need for plant nutrients is absolute, it cannot be replaced by other elements. The lack or absence of nutrients can lead to poor plant growth, symptoms of deficiency and decreased production. The nutrients role that cannot be replaced by other elements are called essential nutrients. Essential nutrient elements include: phosphorus (P), Nitrogen (N), potassium (K), Magnesium (Mg), sulfur (S), calcium (Ca), iron (Fe), Carbon ©, hydrogen (H), Molybdenum (Mo), copper (Cu), Boron (B), zinc (Zn), oxygen (O), manganese (Mn), and Clenbuterol (Cl). If the plant lacks essential nutrient elements it will cause the plant to grow abnormal. The macronutrients that plants need in large quantities are the nutrients N, P and K.

Plants can grow and develop well if the 3 nutrients (N, P and K) fulfilled its needs. Therefore if we know the amount of nutrient content of N, P and K that is in the land that will be planted, then we can determine the number of NPK fertilizer that must be given to the land.

The content of N, P, and K nutrients and soil pH are already many measuring instruments that can be used, either by measuring in the laboratory or which is directly done in the field.

A. Internet of thing (IoT)

The development of information technology continues to grow to encourage rapid technological change. Technology for agriculture continues to be developed to increase the production of agricultural products. Agricultural soil fertility is very important in increasing agricultural yields. IoT is part of the Industrial 4.0 revolution is the integration of the Cyber-Physical System (CPS) and the Internet of Things and Services (IoT and IoS) into industrial processes including manufacturing and logistics and other [1]. The Internet of Things refers to the close connectedness between the digital world and the real world [2]. Applications are developed based on IoT enabled devices for monitoring and control in various domains including industrial processes, home appliances, health monitoring applications, smart homes, smart cities[3][4][5][6].

IoT technology allows for a lot of data obtained from the readings of data sensors sent to cloud storage. Data acquisition can be done on the sensor data used and collected in a database. IoT technology can be applied to measure soil fertility, pH levels and can be equipped with GPS to know the location of the soil to be measured. Soil fertility data that includes N, P and K nutrients and soil acidity levels based on soil location can be in the acquisition of its data to be stored in a database system. The database system formed can be used as a data source for the development of soil fertility data Warehouse based on land location.

IoT is a concept in which an object that has the ability to transfer data through a network without requiring human-to-human or human-computer interaction, so the IoT concept is very possible to be used in almost all daily activities. Starting from the use of individuals, offices, homes sickness, tourism, industry, transportation, animal conservation, agriculture and animal husbandry, to the government.

B. IoT Cloud

The advent of Cloud and IoT has witnessed a rapid and independent evolution. These worlds are very different from one another and, even better, their characteristics often complement each other, such as Table 1. These complementarities are the main reasons why many researchers have proposed and proposed their integration, generally to benefit in certain application scenarios[7][8][9][10].

TABLE I. COMPLEMENTARY ASPECTS OF CLOUD AND IOT

	IoT	Cloud
Displacement	Pervasive	Centralized
Reachability	Limited	Ubiquitous
Components	Real-world Things	Virtual resources
Computational capabilities	Limited	Virtually unlimited
Storage	Limited or none	Virtually unlimited
Role of the Internet	Point of convergence	Means for delivering services
Big data	Source	Means to manage

C. Data Warehouse

A data warehouse as a storehouse is a repository of data collected from multiple data sources (often heterogeneous) and is intended to be used as a whole under the same unified schema. A data warehouse gives the option to analyze data from different sources under the same roof [11]. The data warehouse has several characteristics: subject-oriented, integrated data, nonvolatile, time-variant, and not normalized [12][13]. A data warehouse is a place to store information that is devoted to helping make decisions[12].

Figure 1 shows components for building a data warehouse. Consisting of source data, data staging, data storage, metadata, management and control, and information delivery. The data source that can be used to build data Warehouse consists of Production Data, Internal Data, Archived Data and External data as shown in Figure 1 [14].

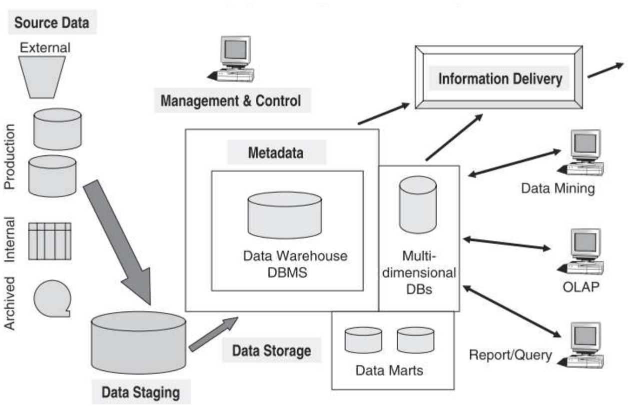

Fig. 1. Data warehouse: building blocks or components

Production Data: Data is derived from various operational systems of the company. These normally include financial systems, manufacturing systems, systems along the supply chain, and customer relationship management systems.

Internal Data: In every organization, users keep their "private" spreadsheets, documents, customer profiles, and sometimes even departmental databases. This is the internal data, parts of which could be useful in a data warehouse.

Archived Data: Operational systems are primarily intended to run the current business. In every operational system, you periodically take the old data and store it in archived files. The circumstances in your organization dictate how often and which portions of the operational databases are archived for storage.

External Data: Most executives depend on data from external sources for a high percentage of the information they use. They use statistics relating to their industry produced by external agencies and national statistical offices. They use market share data of competitors. They use standard values of financial indicators for their business to check on their performance.

II. LITERATURE REVIEW

Some research has been conducted related to the development of IoT in agriculture, including:

"How to utilize sensors in paddy fields and explain about Wireless Sensor Network (WSN), application of sensors created and results obtained from the application of this system. The data obtained can be stored in detail in the cloud and can be monitored and controlled using IoT" [15].

"IoT implementation in the form of wireless sensor network (WSN) and Wireless Moisture Sensor Network (WMSN) are used in agricultural applications especially in greenhouse environments. The results obtained are the efficiency of the feedback control method in irrigation of greenhouse plants"[16].

"Developing research on the application technology of the Internet of Things agriculture. For monitoring in real-time moisture, and nutrients soil citrus plants as well as the integration of the decision-making system for fertilization and irrigation. The results showed that the system could help farmers to fertilize or do scientifically, increase the precision operation level of citrus production, reduce labor costs and reduce pollution caused by chemical fertilizers" [17]

"Building a system using wireless sensors that can measure soil macronutrients and send data to the cloud, with this system users can see soil fertility through a mobile application and find out the condition of soil nutrition"[18].

III. PROPOSED SYSTEM

This paper presents how to make data sources derived from soil data sensor readings consisting of temperature, humidity, N, P and K nutrient content where sensor data is published using IoT technology to build a soil fertility data warehouse. IoT technology has been widely applied in agriculture, both for agricultural automation and soil nutrient measurements affecting crop fertility. Traditionally, soil nutrient harvesting is done by sampling soil in a particular location and carried out tests in the laboratory then the data of the measurement results are stored in a data file. If applying IoT technology then the process of measuring soil nutrients can be done in the location where the land is located. The process can use a tool that can directly read the content of the soil nutrients or, there is also a chemical test to obtain soil nutrient content. The data obtained can be directly sent to the cloud storage or can be manually inputted to the supplied database system including the location coordinates of the measured land.

The speed of measuring the content of soil nutrients using IoT leads to a lot of data obtained. Consideration of a large amount of data obtained using this IoT system needs to be done with the existing data acquisition. This process of data acquisition aims to form a database system of data measurement results of soil nutrient content data in a location. Figure 3 shows the source of data derived from the reading of

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temperature, humidity, and nutrient sensors based on IoT technology to build a soil fertility data warehouseSensor

Sensors are used for analyzing the various parameters in the agricultural domain based on the wireless sensor network technology. In that, the proposed system is used to collect the soil properties and then it will be stored in the cloud database [19].

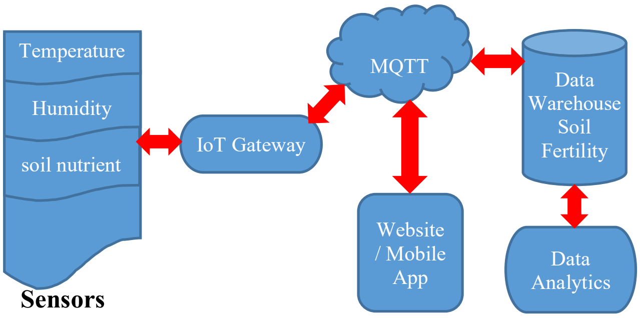


Fig. 2. IoT-based data source design for soil fertility data warehouse

Sensors that can be used include moisture sensors, temperature sensors and soil nutrient sensors. Moisture sensors will transmit data about soil moisture. Temperature sensors to monitor soil temperature and nutrient sensors to determine the nutrient content of the soil that has been marked through the GPS sensor. Table 2 is a sample of soil data that is tested in a laboratory; the results of the data after testing are recorded in the form of hardcopy and softcopy. IoT technology has made it possible to carry out direct measurements of soil nutrients in the field by using sensors measuring soil nutrients such as NPK sensors, temperature sensors and soil moisture sensors.

TABLE II. SOIL SAMPLE DATA TESTING RESULTS IN THE LABORATORY

No	Sample Code	pH H_2O (1:1)	N-Total (g/kg)	P-Available (mg/kg)	K-dd
1	S1T1(I)	4.65	2.02	1.85	0.34
2	S1T1(II)	4.75	1.98	1.50	0.28
3	S1T1(III)	4.98	1.98	3.65	0.35
4	S1T2(I)	4.99	2.34	3.40	0.29
5	S1T2(II)	4.94	2.16	2.50	0.29
6	S1T2(III)	5.55	2.38	3.60	0.35
7	S2T1(I)	5.18	2.06	2.70	0.42
8	S2T1(II)	5.16	1.93	1.40	0.37
9	S2T1(III)	5.06	2.21	1.15	0.29
10	S2T2(I)	5.01	2.35	1.45	0.35

A. *IoT Gateway*

IoT gateway is a device that is prepared to control the sensors that are installed and read the data generated by the sensors which will then be sent in real-time to cloud data storage via the internet. Devices that can be used to read sensor values and send data to cloud storage include ESP8266 or raspberry pi. Data stored in cloud storage through an internet gateway can be used directly through mobile applications, computers, and other devices that can display data stored in cloud storage. Data stored in cloud storage can be in the form of historical data because the data is the result of continuous reading in real-time through sensors that are installed and connected to the IoT gateway.

B. *MQTT (Message Queuing Telemetry Transport)*

The main component in charge of taking data from sensors and transforming it into a database is MQTT. MQTT is an ISO standard (ISO/IEC PRF 20922) publish-subscribe-based messaging protocol. It works on top of the TCP/IP protocol. It is designed for connections with remote locations where a small code footprint is required or the network bandwidth is limited. MQTT is lightweight publish-subscribe based messaging protocol, it is quicker (faster) than other request-response based APIs like HTTP. It allows remote location devices to connect, subscribe, and publish to a specific topic on the server with the help of message broker. MQTT Broker is a module in between the sender and the receiver; it is an element for message validation, transformation and routing.

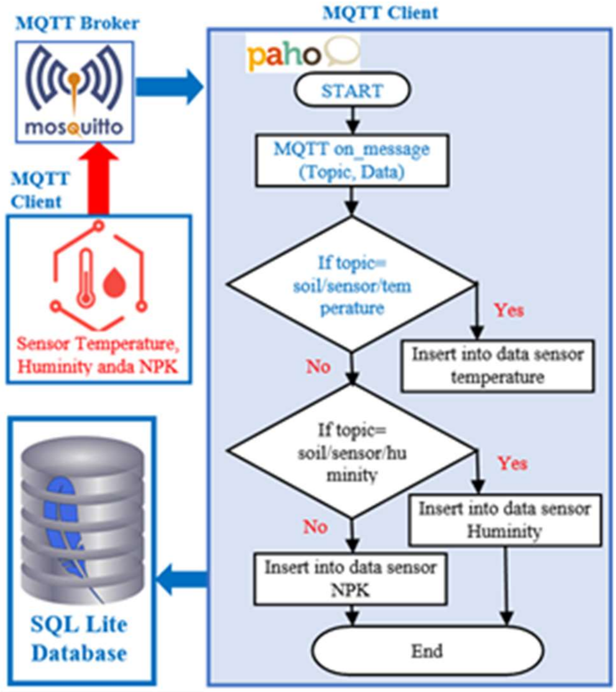


Fig. 3. Data transfer process from MQTT broker into SQL lite database

MQTT is widely used in IoT embedded applications, where every sensor is connected to a server and we have access to control them over the internet. Figure 3 is showing if soil temperature sensor publishes the temperature data (message) on the topic “temperature” then interested clients who have subscribed to “temperature” topic get that published soil temperature data, if soil humidity sensor publishes the humidity data on the topic “humanity” then interested clients who have subscribed to “humanity” topic get that published soil humidity data.

Figure 4 is showing data stream in the MQTT broker, these data will be sent to database SQL Lite using Paho-MQTT command.

C. *Website / Mobile App*

Data stored in cloud storage can be read directly through the website or can also use the mobile application. Website or Mobile Application is designed in such a way that it can retrieve and display existing data on cloud storage to display its data. The data displayed can be used as monitoring data from the results of the built-in sensor readings.

D. *Data Warehouse Soil Fertility*

The data contained in the SQLite Database is data sourced from MQTT Broker, and then an ETL process is carried out to send the data into the data warehouse. The dimensional model has an impact on most aspects of a Data Warehouse implementation, beginning with the translation of business requirements, through the ETL processes, and finally, to the unveiling of data warehouse through analytic data applications.

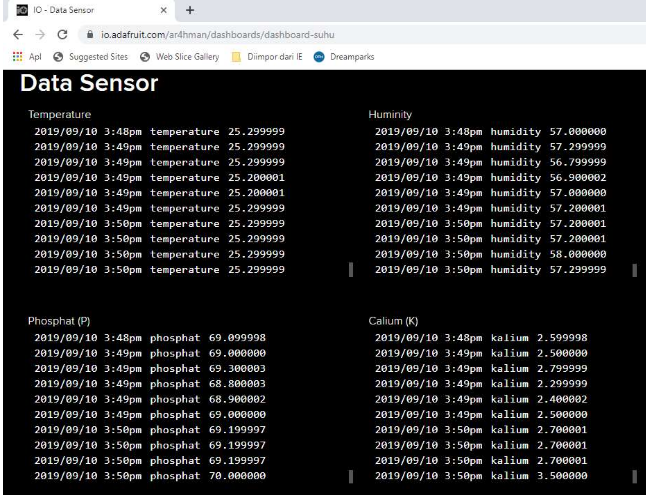


Fig. 4. Datastream in MQTT Broker

The ETL process will fetch data that is in the MQTT Broker that will be inserted into the fertility data Warehouse using a dimensional star scheme consisting of 1 fact table and 5-dimensional tables, as seen in Figure 5.

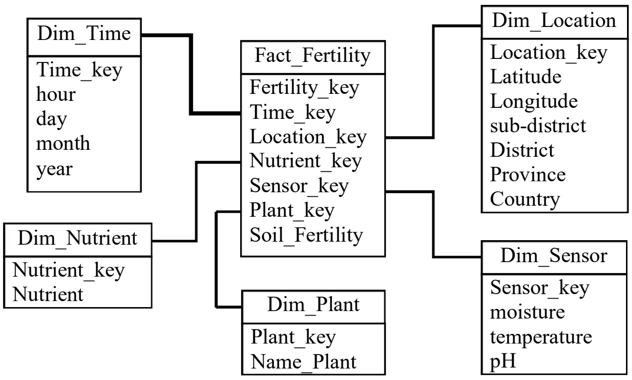
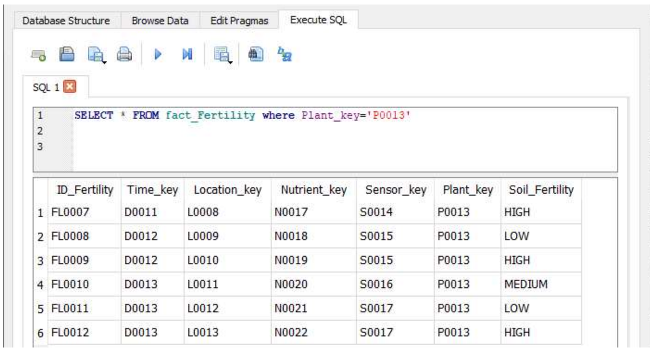


Fig. 5. Dimensional Modeling Data Warehouse Soil Fertility

Soil fertility data warehouse has 5 dimension tables, namely: time dimension, location dimension, nutrient dimension, plant dimension, and sensor dimension, and has 1 fact table which is a soil fertility fact table. In the fact_fertility table contains all information about location, temperature, humidity, soil nutrient content, measurement time, plant name and soil fertility level as shown in table 3. In the fact_fertility fact table, we only see the key of each dimension including time_key, location_key, Nutrient_key, Sensor_key, and Plant_key. We can query to get more detailed information from dimensional modelling, in Figure 6 shows the results of the query that we did to find out the plants in Plant_key = P0013 with conditions of temperature, humidity, and NPK content that exist in the location of the land can be planted for this plant. Detailed data for P0013 is a coconut plant with data as shown in table 4, based on the data in the data warehouse we can find out that coconut plants in certain locations have been fulfilled nutrients, and in other locations there are those that lack nutrients.


Database Structure | Browse Data | Edit Pragmas | Execute SQL

SQL 1

```
SELECT * FROM fact_Fertility where Plant_key='P0013'
```

	ID_Fertility	Time_key	Location_key	Nutrient_key	Sensor_key	Plant_key	Soil_Fertility
1	FL0007	D0011	L0008	N0017	S0014	P0013	HIGH
2	FL0008	D0012	L0009	N0018	S0015	P0013	LOW
3	FL0009	D0012	L0010	N0019	S0015	P0013	HIGH
4	FL0010	D0013	L0011	N0020	S0016	P0013	MEDIUM
5	FL0011	D0013	L0012	N0021	S0017	P0013	LOW
6	FL0012	D0013	L0013	N0022	S0017	P0013	HIGH

Fig. 6. The query results in the fact fertility table for plant_key = 'P0013'

Table 3 shows detailed data from the soil data for coconut plants in several locations, from these data we can find out the fertility of the soil for coconut plants in that location. If it is not suitable, we can find out the nutrients that need to be added to the location of the land. This soil fertility data warehouse can be used for various analyses related to soil fertility, types of plants that are suitable for soil conditions based on the location of the soil.

TABLE III. DETAIL DATA FOR PLANT_KEY = P0013

	Plant_key	Name_plant	Latitude	Longitude	N	P	K	pH	Soil_fertility
	Filter	Filter	Filter	Filter		...	F...	...	Filter
1	P0013	Coconut	-2.612227	104.742091	1.84	43.22	315.67	6.36	HIGH
2	P0013	Coconut	-3.220527	104.502199	0.13	17.62	123.12	5.14	LOW
3	P0013	Coconut	-2.495072	104.797975	1.35	38.12	308.87	6.21	HIGH
4	P0013	Coconut	-2.895648	104.746692	1.12	29.56	163.83	5.53	MEDIUM
5	P0013	Coconut	-2.985651	104.720395	0.17	19.32	145.34	4.56	LOW
6	P0013	Coconut	-2.744660	104.746160	2.14	41.24	298.73	6.14	HIGH

IV. CONCLUSION

The application of IoT technology in the measurement of soil fertility, not only merely display data that is read by sensors to the mobile application or user interface such as websites. Data transmitted by IoT gateways into IoT Cloud Storage can be used as a data source to soil fertility data warehouse. Data Warehouse soil fertility can be used as information delivery using the techniques of data mining or knowledge discovery

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