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Review Article

Application of Common Information Platform and Agricultural Management System "i-PLANT" for Consumer-Friendly Food Production in Taiwan

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Abstract

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The traceability system of agro-product is considered an approach that may lead to create product differentiation in the market, elevate product competitiveness, and bring better production and consumption environment for agro-products in Taiwan. Through the integration of self-monitoring by agro-product operators, verification of product sources by distributors, feedback from consumers and government oversight with regulation, the local agricultural sector is able to promote the effectiveness of Taiwan's agro-product traceability system and help to differentiate these products in the market. "Smart Agriculture (SA)", a 6-year research program initiated by the Council of Agriculture in 2017, based on sensor/sensing technology, intelligent robot, internet of things (IoT) and big data analytics, is expected to build local smart production, marketing and digital service systems to efficiently enhance the whole agricultural productivity and capacity. Furthermore, it is anticipated to build an active, all-purpose agricultural consumption/service platform to earn customer's trust for food safety by completing the program. In the SA program, a common information platform which uses the Open Application Programming Interface (Open API) to connect with a range of existing application databases has been established. According to the policy of the food safety, all primary and secondary schools need to use traceable agricultural and aquaculture products tagged with the information of the "Three Labels and One QR Code (3L1Q)". The Campus Food Ingredients Registration Platform of the Ministry of Education can get food safety information daily from the common information platform by Open API mechanism to ensure safety of campus lunch. The agriculture management system "i-PLANT" applies technologies in terms of geographic information system (GIS), IoT and aerial photography, as well as cumulative agricultural experience and the information recorded via the mobile application (APP) of crop production. That is, "i-PLANT" combines environmental layer nesting with data services for field production risk management and decision analysis. It promotes a new type of "agriculture service industry", which allows farmers to cultivate and record field data more easily and also enables consumers to eat with confidence for food safety. Moreover, the relationship between agricultural operations and food can be further strengthened by the system, connecting the upstream agricultural production and middle/lower reached logistics sales to smart agri-food supply chains.

Key words: Smart Agriculture, Common information platform, Big data, Agriculture management system, i-PLANT.

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INTRODUCTION

As a food-importing country, Taiwan is facing a situation that the self-sufficiency rate of the calorie-based food is relatively low (ca.32%) and therefore, is very sensitive to effect of food production and supply. Occasionally, due to extreme weather events caused by rapid climate change, food shortage sometimes leads to higher food prices. There is also potential risk to food production. To improve such situations, modification of industry structure and innovation of technological development are necessary to increase agricultural productivity.

Because of shifts in consumption behavior and the newly evolved technologies, cross-industry alliances and innovative marketing models are needed to establish in conjunction with existing value chains for improving agricultural industry and its structure. When new products, advanced technologies and marketing patterns are developed, they will push forward current agricultural value chains reaching to a new realm. With that, small-scale farming economy may have a chance to transform into an international competitive agribusiness. It could also overcome the predicament of small farmers struggling alone, and increase their efficiency and capability of farming activities.

To enhance farming management and efficiency, a 6-year Smart Agriculture (SA) research program has been initiated by the Council of Agriculture (COA) of Taiwan since 2017 (Fig. 1). It incorporates sensor/sensing technology, intelligent robot, internet of things (IoT) and big data analytics in order to build a smart production, marketing and digital service system to efficiently enhance the whole agricultural productivity and capacity. Serving as an active, all-purpose agricultural consumption/service platform, it would facilitate an intelligent and automated production of safe and quality products to earn customer's trust on food safety. Moreover, through big data analysis on production as well as supply and demand, strategic marketing and business model may be pre-planned and the internationalization of the agricultural industry can be established. There are three strategies for the SA research program as follows:

(1) Improving the ability to stably supply products by innovating the agricultural management model with SA alliance and develop-

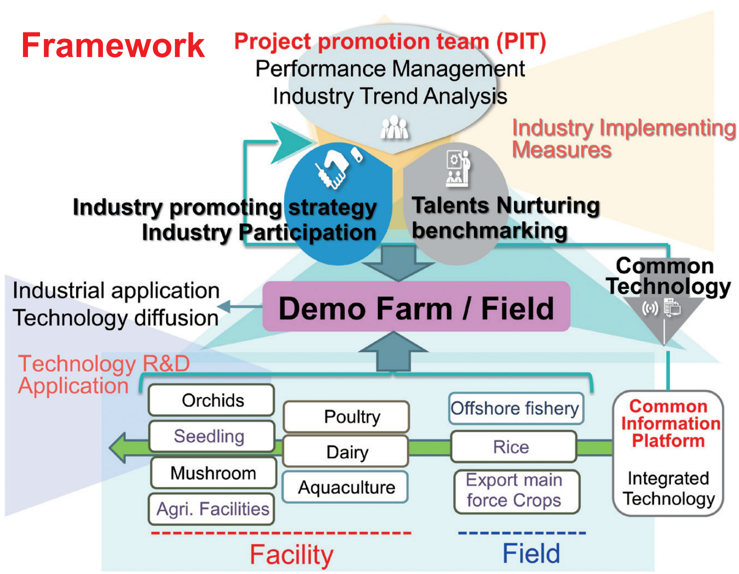


Fig. 1. Framework of the Smart Agriculture research program.

ing intelligent production technologies and applications.

(2) Building information and communication technologies (ICTs)-based application models integrating convenient and diversified agricultural digital services with value chains.

(3) Creating new communication models between growers and consumers via friendly interactive technologies.

With these strategies, 10 targeted industries have been selected to be transformed into "smart" production ways. The competitiveness of concern is anticipated to be strengthened. They are moth orchid, seedling, mushroom, rice, agricultural facility, aquaculture, water fowl, export main force crops, dairy and off-shore fishery (Fig. 1) (Council of Agriculture, Executive Yuan, R.O.C. 2016; Tsay *et al*. 2016). Several achievements have been done to date, we have selected two cases of best practices of SA that benefit eco-friendly food production are described in sections 3 and 4 due to space limit.

THE "THREE LABELS AND ONE QR CODE" IN TAIWAN

In order to achieve domestic food safety, COA has promoted the use of "Three Labels and One QR Code (3L1Q)" labeling system, which includes Traceable Agricultural Products (TAPs), Organic Traceable Agricultural Products (OTAPs), those are produced in compliance with Certified Agriculture Standard (CAS), and agricultural products with traceability QR code.

The TAP provides certified products for consumers who need safe, sustainable and traceable agro-products in open information. The promotion of TAP system was carried out by formulating operation standards, such as the Taiwan Good Agricultural Practice (TGAP), and setting up a TAP information platform. Agricultural product operators are advised to adopt risk management measures and production methods that conform to the concept of sustainable agriculture to produce safe and traceable agro-products, which are then verified by international third-party accredited certification systems. Only those certified are entitled to use the TAP mark/logo and relevant labeling, allowing consumers to easily identify, purchase and look over complete record of production.

According to the Agricultural Production and Certification Act, Organic Agricultural Product and Organic Agricultural Processed Product Certification Management Regulations, Imported Organic Agricultural Product and Organic Agricultural Processed Product Management Regulations and other relevant regulations, only those certified in compliance with organic standards stipulated by the central governing body can be sold under the name of "organic". To establish the credibility for our national organic standards, a third-party certification system has been introduced. With this arrangement, certifiers should be accredited by COA authorized accreditation bodies before carrying out their certification works under the certification standards for organic agricultural products and organic agricultural processed products.

The logo of CAS represents the certification for Taiwan premium domestic agricultural produce and their processed products. As a matter of fact, CAS has progressively become the byword for the premium domestic agricultural products because of the strict standard. The main purpose for COA to promote CAS logo is to upgrade the quality and to add value to domestic agricultural, aquaculture, animal and forestry produce and their processed products. At present, there are a total of 15 major CAS certified categories, including meat, frozen foods, fruit and vegetable juice, quality rice, preserved fruits and vegetables, ready-to-serve meals, refrigerated foods, fresh edible mushrooms, fermented foods, snack foods, egg products, minimum processed fruits and vegetables, aquaculture, forestry products and fresh milk.

Through the promotion of “Taiwan Agricultural Traceability”, consumers may gain timely access to all relevant details (producers’ contact information, photos, as well as origins and overviews) of their products by scanning the QR codes along the way. By doing so, it also enhances consumer confidence. Distributors may also utilize it to confirm the origins of their purchases and locate the problem within the supply chain for reducing risks of food safety. The competent authority exercises within their power to audit the entire course by imposing mechanisms, such as on-site investigation, label verification, quality sampling and violation disciplining, to ensure the traceability is functioning properly, therefore deepening such practices in Taiwan agricultural industry.

The agro-product traceability system would create product differentiation in the market, elevate product competitiveness, and create better production and consumption environment for agro-products. Through the integration of self-monitoring by agro-product operators, verification of product sources by distributors, feedback from consumers and government oversight with regulation, the local agriculture sector is able to promote the effectiveness of Taiwan’s agro-product traceability system and help to differentiate these products in the market.

THE COMMON INFORMATION PLATFORM IN SA RESEARCH PROGRAM

By deploying the next generation of agricultural production with supporting sales and tracking services, a common information platform (CIP) focused on comprehensive production, consumption and service is developed to raise the efficiency and predictability of agricultural production, as well as to enhance consumer confidence on the safety of agricultural products. Three main goals of the CIP are Sharing, Service and Synergy (SSS).

Sharing

Standards and rules for data-sharing in different agri-areas will be established. The collected data will be provided for each other to create innovative, collaborative agri-service and solve complex agri-problems.

Service

Heterogeneous data (public data, such as agri-weather, market condition, pesticide, fertilizer and food safety, and private data, such as data from IoT sensors of the agribusiness companies) will be provided by a service under the clear announcement of the rights and obligations. It allows free access for academic research, but will be charged for a commercial use.

Synergy

Combining the power of agri-research institutes, government departments and agribusiness companies are to support agri-innovation. This platform will make it possible to collaborate and cooperate with various agri-experts, agriculture-information and communication technologies (agri-ICTs), agri-machinery and sensors.

The structure of agriculture CIP can be divided into 7 layers from data source to application (Fig. 2), including data source, collection, integration, storage, analysis, access interface and application layer. For data processing, there are three categories in terms of big data exchange, big data lake and big data analytics. Production or environmental sensor/sensing technology, IoT, other big data collection and analysis, production of required materials or traceability data collection and analysis are encompassed for the development of SA to effectively improve agricultural productivity and efficiency.

To create the convenient usage of agri-data and agri-digital service, the program integrated official data and open data such as weather, pesticide, fertilizer, food safety and

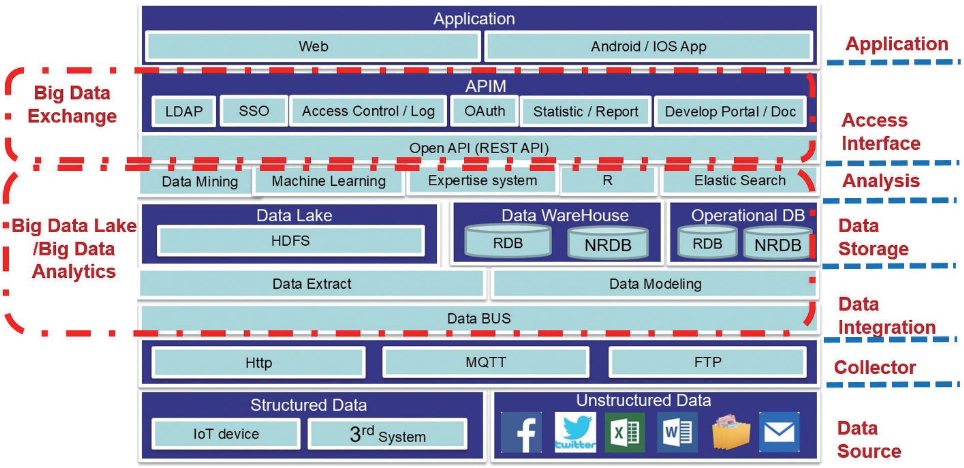


Fig. 2. The structure of agriculture common information platform.

market conditions is designed to share every stakeholder in agriculture sector by Open Application Programming Interface (Open API) mechanism (big data exchange). Each third party vendors or research institutes can easily take advantage of the Open API to get agriculture data or digital service they need and develop innovative services to solve all kinds of farmers' problems.

Besides providing agri-data, another assigned mission of the CIP is to provide agri-digital service, such as analysis of agricultural IoT data, big data analysis of heterogeneous agricultural data, etc. For example, the CIP helps the Ministry of Education to provide kinds of food safety certification data for Campus Food Ingredients Registration Platform (CFIRP).

In this case of big data exchange, the resources of 3L1Q data originally come from several different departments of COA. To provide the CFIRP for national primary and secondary schools with useful data, the CIP integrated these heterogeneous data and solved the data asynchronous problem. Therefore, this kind of big data exchange application based on agri-data integration and sharing can help the government to strengthen consumers' trust on food safety.

Due to the complex sources of agricultural production and sales, the CIP must be designed to include structured data, semi-structured data and unstructured data to support the integration of heterogeneous agricultural data, big data analysis and different kinds of big data applications. In order to meet the need of big data analytics, the CIP uses the Apache Hadoop framework to deal with heterogeneous data in agriculture and to implement reliable, scalable and decentralized computing.

At present, types of big data lake of the CIP are divided into four categories, including the food safety database of agricultural and fishery products, the meteorological database, the pesticide/fertilizer database, and the market condition database. The number of data collection is over 100 million records with 37 items. Among all the data collection, the meteorological data collection is the largest (about 40 million records), the traceability data the second (about 12 million records), and the market data is the third (about 10 million records). The method of big data exchange adopts the Open API mechanism.

To date, totally 56 Open APIs have been provided for 3rd parties or research institutes. The third parties or research institutes register for the CIP have exceeded 25 units, and the usage frequency of Open API reaches nearly 450,000 times. The highest usage frequency of Open API is for traceability data of agricultural and fishery products.

According to the policy of food safety, all primary and secondary schools (about 3,000) need to use traceable agricultural and aquaculture products tagged with the information of the "3L1Q". The CFIRP of the Ministry of Education can get food safety information daily from the CIP by Open API mechanism to ensure safety of campus lunch (Fig. 3). This coordination of food safety information from platform to platform by Open API enable parents to understand what their kids eat at school, and improve the convenience and benefit for the third parties in accessing food safety information.

In addition to data sharing, the CIP also develops digital services such as the analysis for food safety. By integrating heterogeneous food safety data with the traceability data of agricultural and livestock products and the materials used by the Ministry of Education on campus, a Sankey diagram can be used as an analysis tool to establish a food safety

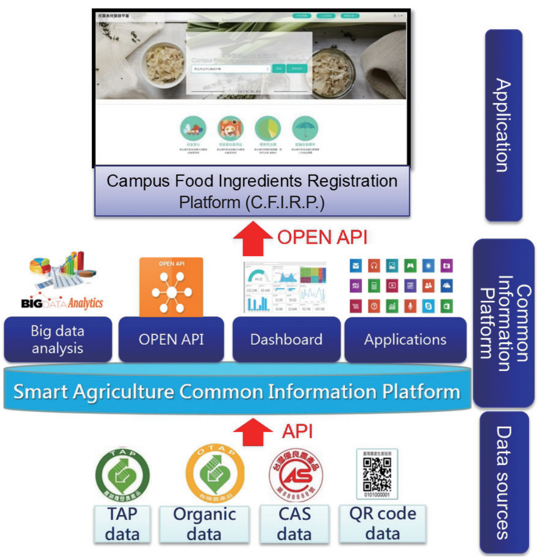


Fig. 3. Big Data Exchange through Open API for food safety.

traceability chain (Fig. 4). Through selecting several parameters such as certification, date, production area, food company and school in the Sankey diagram, we can show clearly that where and when the materials of campus lunch come from and which food company cook. In other words, all traceable data can be displayed in various ways by Sankey diagram to query different parameters needed. For example, if someone wants to know the traceability chain of the schools in Yilan County, Yizhen Group Food Center as shown providing most ingredients for Yilan's schools need to be a targeted object for strengthening counseling and auditing. At the same time, the food suppliers and production areas are also included as counseling objects to reduce food safety scandals.

In Fig. 4, it also indicates how the Sankey diagram for heterogeneous food safety information works by selecting certification, location of agricultural product, food supply chain company and county which school is located. First, choose what kind of certification you want in the left. Second, you can choose where the agricultural product with this certification is (location of production) and which food company to deal with these products. Lastly, you can choose the county and know these agricultural products are bought by which schools in the very county you care.

The alert function for pesticide residue monitoring is also a unique function. The results of pesticide residue testing for agricultural products are integrated in the CIP. If pesticide residue testing is unqualified, the CIP will show a red alert on the Sankey diagram so that users can figure out what happen to this food safety chain. The information of this kind alert is about the details of unqualified agricultural products, which food company and school are effected (Fig. 5). This function will help government officials, teachers and parents to understand quickly the situation of the food safety misconduct and avoid the society panic.

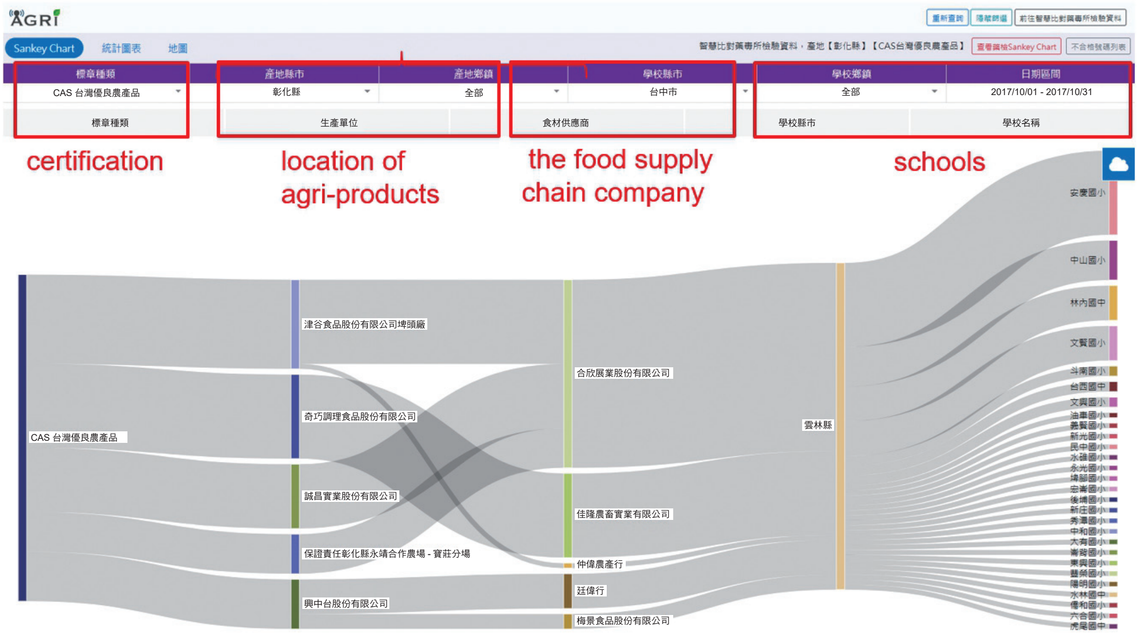


Fig. 4. Sankey diagram of the food safety traceability chain for campus food.

GREENHOUSE VEGETABLE AND FRUIT PRODUCTION DECISION SYSTEM

With the assistance of the SA Project, Yumei Yen Co., Ltd. under the guidance of the Taiwan Agricultural Research Institute pioneered on developing the "Greenhouse Fruit and Vegetable Production Decision System (PDS)" in Taiwan. The PDS can use visual statistics chart to link the production and performance indicators of sales that are the most concerned by corporate managers. Also, it can help accumulate daily statistical records to provide comprehensive and transparent information on cultivation benefits of greenhouse fruit and vegetable production, including cost and utilization analysis of production resources invested, harvest day prediction, crop yield information, sales, retail price and trade price information. Furthermore, through multi-dimensional charts, managers can handle the best sales opportunities according to the real-time crop yield and its quality. In addition, the soil moisture, irrigation, vegetable yield and greenhouse environmental data are analyzed to help identify the improvement method of cultivation technology for improving production quality. The PDS not only assists production regulation but also grasps future sales operation, thereby innovating the agricultural business mode (Fig. 6). As mentioned above, Greenhouse Fruit and Vegetable PDS makes Yumei Yen's farm as an ideal demonstration field for advanced facility agricultural production.

It is expected to effectively handle the use of assets and production resources through the PDS and thus increase possible benefits. Six management performance indicators influencing the production and marketing are chosen as the vital points of system design for constructing the PDS, including resource utilization, cost control, crop yield and quality, profitability and its growth efficiency. Only by making cost control well and selling price of agricultural products stable, the operational efficiency of the enterprise can be ensured. Therefore, along the whole production process,

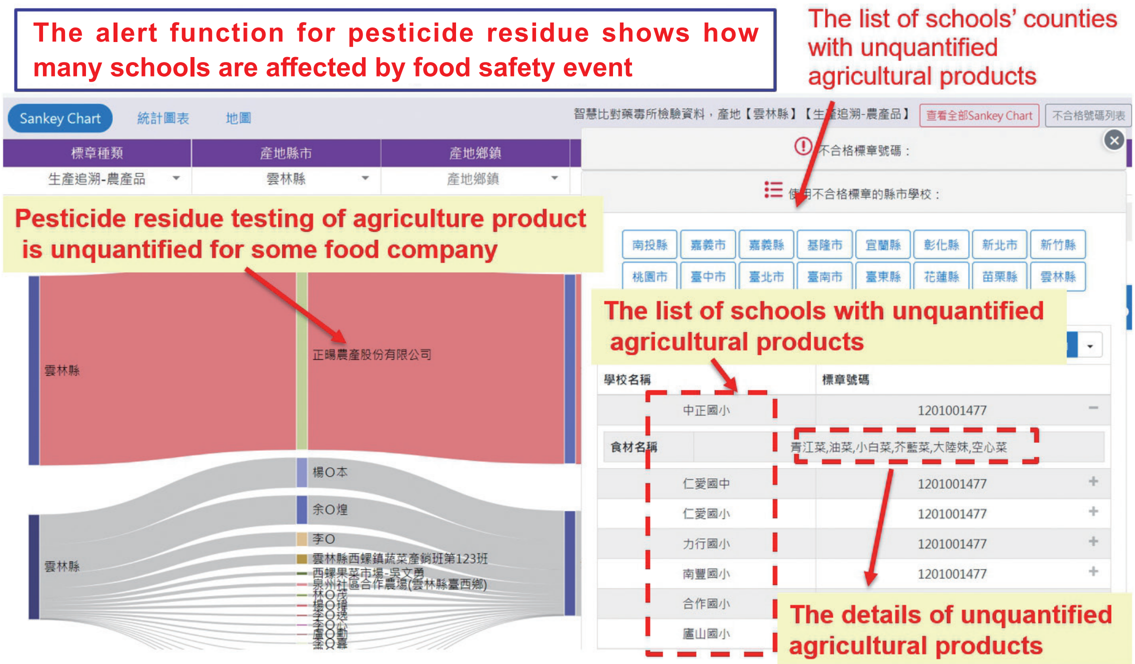
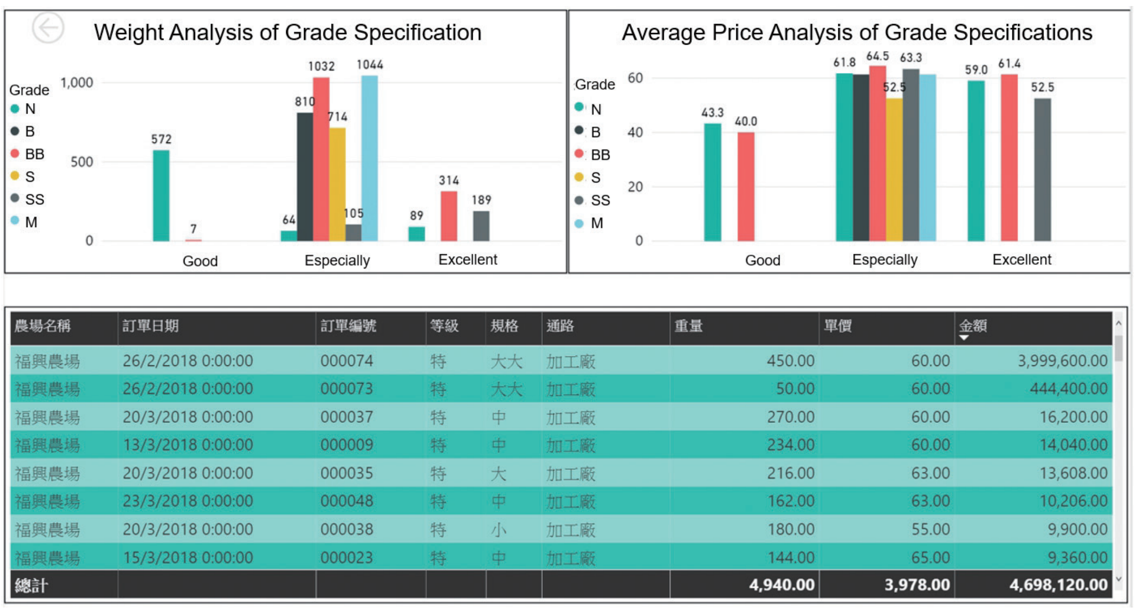


Fig. 5. Alert function for pesticide residue monitoring.



農場名稱	訂單日期	訂單編號	等級	規格	通路	重量	單價	金額
福興農場	26/2/2018 0:00:00	000074	特	大大	加工廠	450.00	60.00	3,999,600.00
福興農場	26/2/2018 0:00:00	000073	特	大大	加工廠	50.00	60.00	444,400.00
福興農場	20/3/2018 0:00:00	000037	特	中	加工廠	270.00	60.00	16,200.00
福興農場	13/3/2018 0:00:00	000009	特	中	加工廠	234.00	60.00	14,040.00
福興農場	20/3/2018 0:00:00	000035	特	大	加工廠	216.00	63.00	13,608.00
福興農場	23/3/2018 0:00:00	000048	特	中	加工廠	162.00	63.00	10,206.00
福興農場	20/3/2018 0:00:00	000038	特	小	加工廠	180.00	55.00	9,900.00
福興農場	15/3/2018 0:00:00	000023	特	中	加工廠	144.00	65.00	9,360.00
總計						4,940.00	3,978.00	4,698,120.00

Fig. 6. Different product grades and their price analysis.

in addition to cultivation duration, the cost of personnel, machinery and materials need to be gauged together to check if they are reasonably invested to research the largest benefits. The useful services of PDS heavily rely on the collection and accumulation of relevant data.

Therefore, Yumei Yen Co., Ltd. employed Knowledge & Service Information Co., Ltd. to integrate various systems and relevant data, including field production information system, greenhouse environmental control system, market data, etc. The PDS can adjust the information disclosure degree according to the user's need under real-time production and operation situation, and thus every class manager at preset authorization can obtain appropriate and comprehensive decision-making information to affect and improve the management flexibility and adaptability of agricultural enterprises.

Currently, the PDS is still in prototype period, thus its function reinforcement and operation optimization will be continued. It is expected to display all integrated charts and information as mentioned above, including environmental data, records and photographs collected by sensors and/or on-site technicians, via any kind of mobile device. Therefore, all management classes can use their cell phones conveniently to handle real-time integrated information and make the decision on production/sales. Based on enterprise management performance indices, the Greenhouse Fruit and Vegetable PDS has extraordinary features in terms of market commercial value and creative, on-site environmentally measurable, production controllable, quality traceable and whole process analyzable. In the future, it will be extended to other agricultural enterprises to expand industrial applications and enhance the competitiveness of Taiwan's agricultural enterprises.

I-PLANT - AN AGRICULTURAL MANAGEMENT SYSTEM

In Taiwan, lacking scientific data and difficulty in mastering production risks is one of the biggest problems encountered in agriculture industry from large-scale agricultural enterprises to individual farmers. For example, it is often based on the rule of thumb to determine when to seed, where to plant, how to produce and benefit. Whereas, scientific data can provide actual insights with more considerable significance for agricultural farmers.

At the early stage of SA research program, an agricultural management system "i-PLANT" was developed, using technology of geographic information system (GIS), IoT and aerial photography, as well as cumulative agriculture experience and the information recorded via the APP of crop production. The i-PLANT combines environmental layer nesting with data services for field production risk management and decision analysis. Behind the i-PLANT, there is a high-precision agricultural database that provides differentiated environment and management information for each farmland in Taiwan to effectively assist farmers or agricultural enterprises in precise site selection, field operation decisions, and pest and disease risk management. It could not only create the highest production capacity per unit area but setup a demonstration zone for high-efficiency, energy-saving, and innovative agricultural transformation. The ultimate objective of i-PLANT is to provide the right suggestion at the best time and place for whole farm management to optimize returns on inputs while preserving resources.

The i-PLANT accumulates the farmer's farming records through APP, and integrates them with the environmental database of each farm to grasp the suitable growth environment parameters of different crops accurately. Through big data analysis, all the gathered data are then further transformed into insights for various feedback service. Thus, i-PLANT provides the most accurate and immediate farming decision support, including weather information for risk warning to reduce damage, pest warning, yield estimation, precision fertilization and pesticide suggestions, harvesting advice, etc., for agricultural enterprises and contracting farmers. For large-scale agribusinesses, the introduction of i-PLANT can be particularly helpful in optimizing the farmer's farmland management. Recommendations and forecasts from this system can effectively avoid problems such as poor production, poor quality, over-production and slow sales.

Overall, i-PLANT includes the following services (Fig. 7). For example, as individual farmers, they can easily record the field and crop status instantly through simple words or pictures via the APP of i-PLANT. As for the managers of individual farmers, records of crop growth or production nesting environment layer can be used to effectively support decision-making or management. At the beginning of system introduction, leading farmers or the leaders of production and marketing group take the lead. The other farmers are only required to take photos of their fields, record status of crops and then upload them to i-PLANT.

Currently, i-PLANT has more than 100 users in Taiwan, among them ten agricultural enterprises have a long-term partnership, and farming information of more than 3,000 farmlands has been established. Progress in analysis of crops and environment will be continuously made with more and more agricultural enterprises and farmlands joining i-PLANT.

In recent years, agricultural policies are focused on not only the promotion of production, but also the value of agriculture in response to the internationalization of trade and economics, trend of liberalization and environmental protection in the world. The detailed production process recorded by farmers via i-PLANT is also following the trends, enhancing the added value of agricultural products (Fig. 8). In addition, i-PLANT provides a consumer-friendly interactive module (Fig. 9). By scanning the QR code on the agricultural product packaging, consumers can know exactly the product flow process with a beautiful, vivid and technologically-friendly page, Agri-food Tracker.

Due to problems such as land pollution, pesticide residue and unqualified inspection of farming products in Taiwan, consumers' concern about food safety is quite common. As a result, COA has carried out some policies on traceability of production, but the current agricultural product verification system still has difficulties in implementing universally because of high cost and complicated operation.

To narrow the knowledge gap between producers and consumers, i-PLANT encour-

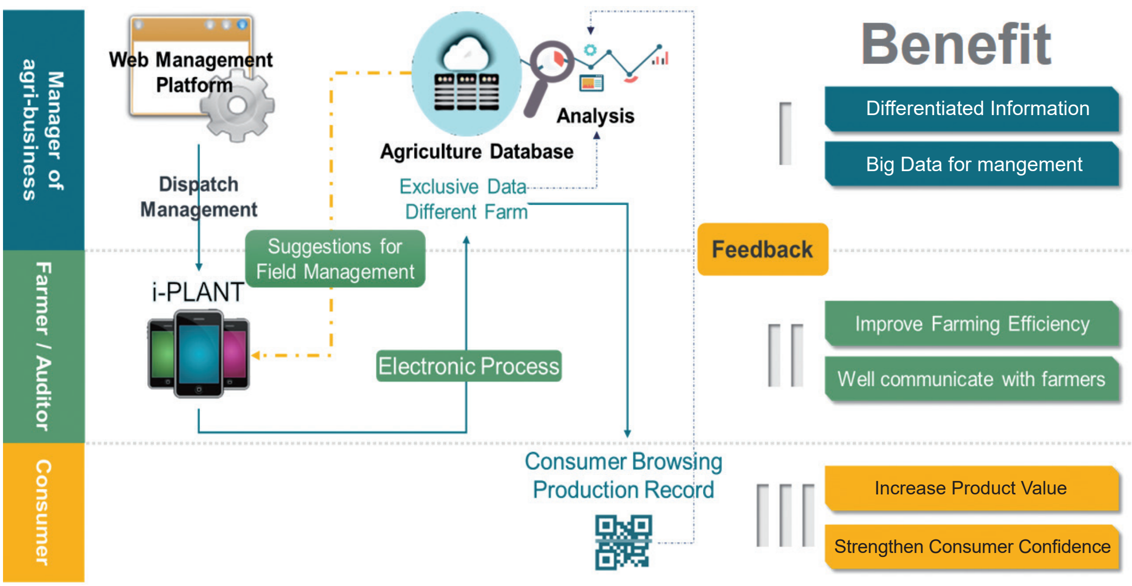


Fig. 7. Service process and benefits of i-PLANT.

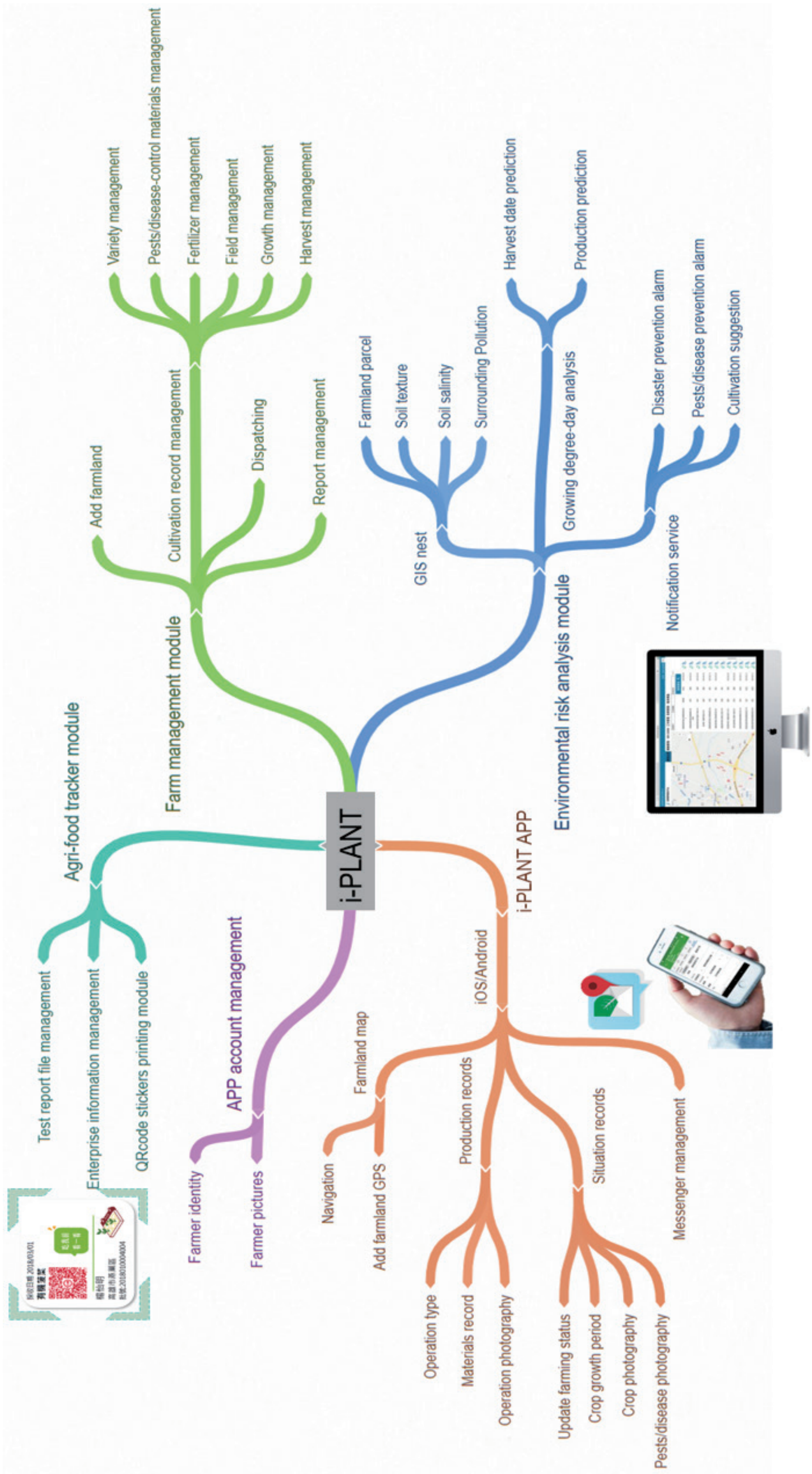


Fig. 8. The structure of i-PLANT.

Fig. 9. An interactive module of agricultural food calendar (left), information about production place (middle) and records of crop growth history (right).

ages producers to record information and self-manage to establish mutual trust between consumers and producers. The Agri-food Tracker presents the painstaking results of producers to the consumers, including complete growth history, environmental information, photos of field operations, packaging process and inspection reports. Furthermore, it integrates food nutrition labeling, food mileage, food advice, business links, and so forth. The purpose of this friendly interactive communication model between growers and consumers is to help everyone eat healthy and contentedly.

CONCLUDING REMARKS

The motivation of SA research program is for innovation in agriculture by using science and technology such as sensor technologies, intelligent devices, IoT and big data. Diversified models and concepts of SA are being developed to promote productivity and food safety. The CIP developed in SA research program is applied to connect CFIRP effectively. By querying on line, it provides immediate, transparent school food information to the community, teachers, students and parents. It also jointly supervises the quality of school food and beverage management by combining the campus food safety management system to increase the peace of mind and trust. The CIP provides a unique entrance of food safety certifications information for the CFIRP, especially for food safety certifications information from different agriculture agencies or departments.

Agricultural management system i-PLANT promises a new type of "agriculture service industry", which allows farmers to cultivate and record field data more easily and conveniently. It also enables consumers to eat with confidence for food safety and lead to sustainable agriculture in the long run. Moreover, the relationship between agricultural operations and food can be further strengthened by the system, connecting the upstream agricultural production and middle or lower reached logistics sales to smart agri-food supply chains.

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台灣應用共通資訊平台和農業管理資訊系統 i-PLANT 於消費者友善農產品的生產

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摘要

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農產品的生產追溯系統可在市場上創造產品差異化與提升產品競爭力，並能為台灣農產品帶來更好的生產和消費環境。透過農業生產者自主監控與整合，經銷商對農產品來源的驗證，消費者的回饋及政府法規的監督，讓各地農業單位能夠有效的執行農產品追溯系統，提升此類農產品在市場的差異化。「智慧農業」(Smart Agriculture; SA) 是農業委員會於 2017 年提出的 6 年期研究計畫，基於感測器/感測技術、智能機器人、物聯網 (internet of things; IoT) 和大數據分析，預期將可建立地區性的智慧生產、銷售和數位服務系統，有利於提高整體農業生產力和效率。此外，希望透過此計畫的執行，建構主動式且全方位農業消費/服務平台，提高消費者對農產品安全的信賴感。在智慧農業的共通資訊平台已使用開放式應用程式介面 (Open Application Programming Interface; Open API) 技術提供與現有的資料庫進行介接。根據食品安全政策的推動，全國國中小學之學生午餐都必需使用「三章一 Q」(Three Labels and One QR Code; 3L1Q) 的可追溯農漁畜產品。教育部的校園食材登錄平台可以通過 Open API 機制，每天從共通資訊平台取得食材溯源資料以確保學生午餐的安全。農業管理系統 i-PLANT 應用地理資訊系統 (geographic information system; GIS)、物聯網及衛星影像資料，以手機 APP 記錄農作物的生產資訊，也就是結合環境層與資料服務，以 APP 方式應用於田間的生產風險管理和決策分析。這是一種新型態的農業服務業，提供農民能夠更容易地栽培和記錄田間的數據，讓消費者可以放心食用並確保農產品安全。此外，該系統可進一步強化農業經營者與農產品的關係，將上游農產品和中低層物流銷售與智慧農產品供應鏈串聯起來。

關鍵詞：智慧農業、共通資訊平台、大數據、農業管理系統、i-PLANT。

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