# Improving the Yield and Quality of Grape Production in China with IoT

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# Executive Summary

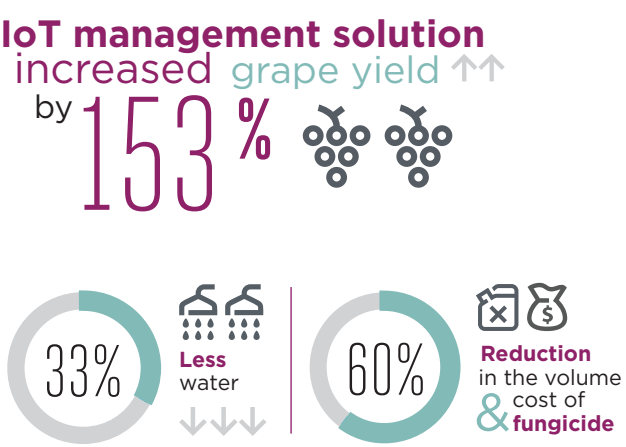
This report documents how the China Mobile IoT Company and its ecosystem partners developed a solution to optimise small-scale grape production in China. The proof of concept used data collected from IoT sensors to deliver accurate and timely environmental insights to the farmer. The result was a significant improvement to the yield and quality of the crop, while reducing the volume of water, fertiliser and fungicides applied.

The IoT management solution **increased grape yield by 153 per cent** compared to standard production. **Higher quality indicators** were also observed, including fruits weighing up to **39 per cent heavier**, and greater levels of accumulated sugars, soluble solids and vitamin C.

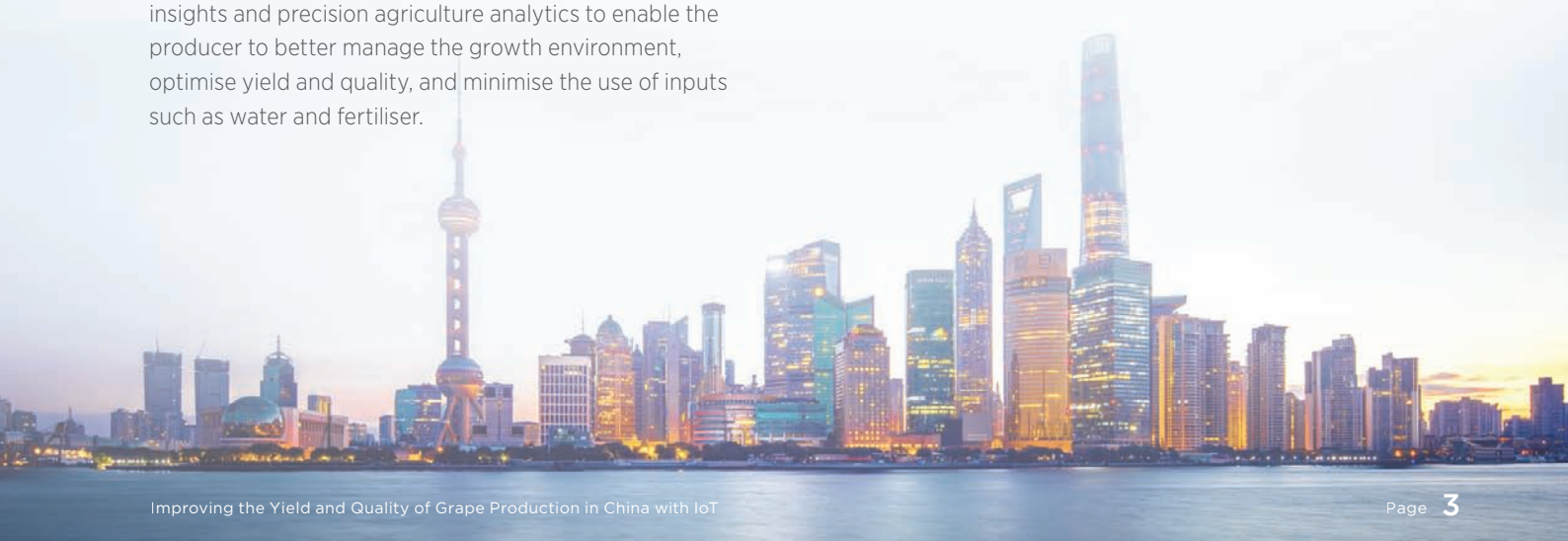
The IoT system enabled the project team to optimise the environment and resources (water and fertiliser). Soil moisture data enabled the drip irrigation system to operate with **33.3 per cent less water,** together with a **60 per cent reduction in the volume and cost of fungicide** applied by measuring and responding to humidity levels.

China Mobile IoT Company, China Agricultural University "Science and Technology Backyard" and GSMA collaborated on the proof of concept which focused on table grape cultivation in Quzhou County by small-scale farmers cultivating crops in poly-tunnel greenhouses. These farmers have limited technology and rely on experience for decision-making in crop management.

The project tested the hypothesis that IoT data can be used to optimise grape production leveraging unique insights and precision agriculture analytics to enable the producer to better manage the growth environment, optimise yield and quality, and minimise the use of inputs such as water and fertiliser.




This report describes how the operator partnered with key ecosystem players and provided critical capabilities to develop an end to end solution for grape growers in China. The project proved the benefits of IoT big data for small-scale grape producers. It has also driven the development of standardised, cost effective, IoT enabled devices by the project partners and informed the new "beyond connectivity" business model operating in the China Mobile IoT Company.



The proof of concept has demonstrated that:

1. Analysis of big data from IoT devices provides actionable insights that improve the yield, quality and efficiency of crop production
2. The mobile operator can play a significant role in the development and provision of smart agriculture solutions beyond connectivity
3. IoT in agriculture can directly contribute to the United Nations' Sustainable Development Goals (SDGs) including greater sustainability and efficient use of fertilisers in food production (SDG 2), improving water quality by reducing pollution (SDG 6) and minimising water consumption (SDG12)
4. NB-IoT, an optimised Low Power Wide Area (LPWA) licensed spectrum cellular network technology, offers the optimal connectivity solution for IoT deployments and is very well suited to a rural environment.

There are many market opportunities for Smart Agriculture in China. New technologies such as Mobile IoT (e.g. NB-IoT), 5G and Artificial Intelligence (AI) are enabling new product development. Technology advancement allows the proliferation of cheaper devices, and the volume of potential customers is high in the addressable markets[1]. China Mobile IoT Company have demonstrated that the mobile operator is well positioned to orchestrate the market and deliver solutions for producers to significantly improve the input-output ratio in farming.

The business model developed from this proof of concept has already been extended and made commercially available to greenhouse strawberry production in Beijing[2], and plans are underway to roll the solution out further across China.

[1] https://www.gsma.com/iot/resources/the-iot-big-data-revenue-opportunity-for-mobile-operators/
[2] https://www.gsma.com/iot/beyond-connectivity/#how-china-mobile-is-harnessing-iot-big-data-solutions-to-create-value-in-strawberry-production

# 1 The Smart Agriculture Opportunity

Smart agriculture, and precision farming, have been identified as an area of significant opportunity for Mobile IoT based solutions. In Asia, the precision farming market was worth USD 0.68 billion in 2018 and is projected to grow at a Compound Annual Growth Rate (CAGR) of 16.4 per cent, to reach USD 1.46 billion by 2023.[3] Huawei has reported that the broader smart agricultural market size for the Asia-Pacific (APAC) region will grow from 4.7 billion USD in 2015 to 10.4 Billion in 2020.[4]

Credence Research predict the global market for agriculture sensors is expected to exceed USD 2.75 billion by 2026 at a CAGR of 12.5 per cent[5]. India and China are expected to be the leading markets for agriculture sensors owing to a significant volume of agricultural land and an increased focus on precision and smart farming methods to meet the rising demand for agricultural production.

The opportunity for mobile operators goes beyond simply offering connectivity. A 2018 report by IDC for GSMA described how "IoT solutions generally perform several functions. They collect data, analyse it, draw conclusions and take actions based on those conclusions. IoT solutions require connectivity, but they also involve substantial spending on IoT devices, applications, back-end computing and storage, analytics, consulting, design, integration and management. As a result, connectivity is only a small part of the total IoT market – in 2025, GSMA Intelligence anticipates that connectivity will account for only 5 per cent of total IoT market revenues. As operators move towards new roles in the IoT market, they have an opportunity to transform their business and deliver value across the IoT value chain"[6].

More recent analysis conducted by PwC for the GSMA[7] has also identified a market opportunity of $386 billion in 2025 for mobile network operators in 'IoT Beyond Connectivity' i.e. for applications, cloud platforms & services, professional services, cloud, analytics, machine learning and AI. This is within a broader market of $1.1 trillion in 2025 forecasted by GSMA Intelligence for the whole IoT. Based on this data the IoT revenue opportunity in the agriculture sector is estimated at USD $69.5 billion by 2025. This project shows just how operators can deliver projects which go 'Beyond Connectivity'.

**IoT revenue opportunity**

$69.5bn in the agricultural sector by 2025

[3] https://www.marketdataforecast.com/market-reports/asia-pacific-precision-farming-market-6458
[4] https://www.huawei.com/en/industry-insights/outlook/mobile-broadband/xlabs/insights-whitepapers/Smart%20Agriculture
[5] https://www.globenewswire.com/news-release/2018/08/14/1551512/0/en/Agriculture-Sensors-Market-is-Expected-to-Reach-US-2-75-Billion-By-2026-Credence-Research.html
[6] https://www.gsma.com/iot/resources/iot-opportunities-report/
[7] https://www.gsma.com/iot/resources/the-iot-big-data-revenue-opportunity-for-mobile-operators/

# 2 Background

China has a long history of small-scale table grape production which has grown in scale as a valuable commercial crop since the 1980's. Quzhou County in Hebei Province has almost 200hm$^2$ of land given over to grape production which is mainly cultivated in the open field. Grape cultivation has developed rapidly in recent years with the introduction of greenhouses and the availability of pesticides and fungicides providing better returns for producers. However, most of the grape cultivation in Quzhou County is produced by small-scale farmers. Most of these farmers have small areas for cultivation, rely on manually managed plastic greenhouses and have limited access to technology and therefore information. Decisions about crop management are based on experience rather than scientific approaches and standardised methods.

**Figure 1:** External view of a polytunnel at Dezhong Grape Ecological Park

**Figure 2:** Internal view of a polytunnel at Dezhong Grape Ecological Park

China is committed to achieving the Sustainable Development Goals (SDGs)[8] and aims to remain self-sufficient in staple foods, without increasing inputs[9] to agriculture from 2020. The challenges facing China are echoed around the globe. Technology, and data-driven innovation, offers the potential to deliver a transformation to the agricultural sector at the pace and scale required. At the project commencement in April 2018 a number of factors were in place to support a smart agriculture proof of concept in grape production in China:

- The Central Government of China plan for greater sustainability in food production[10]
- A national plan to implement the United Nations SDGs, including targets for "zero growth" in the use of fertilisers (SDG 2) and a limitation in national water consumption to below 700billion cubic meters by 2030 (SDG 12)


- An increased consumer focus on quality and consciousness of food safety in table grapes[11]
- The desire for collaboration of expert contributors such as China Mobile Group, China Mobile IoT Company, China Agricultural University (STB) and IoT sensor manufacturers.

[8] http://sdg.iisd.org/news/china-releases-national-plan-to-implement-sdgs/
[9] Such as water, fertilisers or pesticides.
[10] http://en.people.cn/n/2015/0601/c98649-8900480.html
[11] Mu Weisong, Li Chengcheng, Tian Dong, Feng Jianying, (2016) "Chinese consumers' behavior and preference to table grapes: Based on a comparative study of 2009 and 2014", British Food Journal, Vol. 118 Issue: 1, pp.231-246, https://doi.org/10.1108/BFJ-06-2015-0211

# 3 Proof of concept

Within China, smart agriculture has moved through the policy stages and into a stage focused on demonstration and application. This project provided an opportunity to focus the application of IoT to table grapes.

In April 2018, the GSMA convened a project partnering with China Mobile, the China Mobile IoT Company, China Agricultural University, and a number of China Mobile OneNET Certification Programme Partners[12]. The aim of this being to test and learn how mobile connectivity, the Internet of Things (IoT Sensors) and data analytics could be applied to maximise the sustainable production of table grapes in China.

The proof of concept first aimed to test the hypothesis that connected IoT sensors and data analytics could create informative insights to support sustainable grape production, and second, sought to understand the role of the mobile network operator in the ecosystem and the opportunity for the operator to develop value adding capabilities and revenue opportunities beyond connectivity. The summary project objectives were to:

- Establish a technology system, based on IoT decision-making, to increase efficiency
- Deploy IoT sensors to measure production impacting factors such as temperature, humidity, fertilisation and irrigation
- Provide decision support for farmers to improve management of risk, reduce manual effort, and optimise the use of water and fertiliser while maximising production yield and quality
- Develop a business model that can be deployed at scale in China

China Mobile IoT Company and GSMA had a particular interest to identify the role that the mobile operator can play to deliver value and generate revenue through IoT capabilities beyond connectivity.

[12] The OneNET Certification Program (OCP) is an initiative of the China Mobile IoT Alliance Open Platform Executive Committee. It aims to introduce quality partners to the China Mobile OneNET platform, establish platform standards, and promote synergy to provide a full range of value services to corporate customers. It has five types of partner; hardware, software, solution, marketing and innovation, and venture partners. OCP provides multiple benefits for OneNET partner companies, such as corporate certification, marketing, cost advantages and technical support. https://open.iot.10086.cn/ocp/

## 3.1 DATA COLLECTION

China Agricultural University defined the data requirements to effectively monitor and manage the grape vines and crop. The data requirements enabled the project team to identify the types, quantities, and specifications of the IoT devices and sensors required. Together, China Mobile IoT Company, China Agricultural University and the China Mobile OneNET Certification Programme Partners worked to develop specific implementation projects for collecting the required data and developing the analytics.

## 3.2 IOT DEVICES

Five of the China Mobile IoT Company OneNET Certification Programme partners supplied and managed the IoT devices and the irrigation system for the project, and three additional "off the shelf" IoT devices were deployed and managed by China Agricultural University.

The IoT devices collected data related to the plant growth environment, including luminous (light) intensity, soil conditions ($CO_2$ concentration, temperature, humidity), and leaf moisture. A "connected" weather station was also deployed to obtain more accurate environmental data at the location, collecting the luminous intensity, temperature and humidity, wind speed and direction, pressure, and rainfall data. Devices were also deployed to support "intelligent" irrigation. These various devices provide air pressure meters, soil moisture sensors, irrigation controllers, solenoid valves (an electromagnetically controlled valve), and smart water meters. A list of the IoT devices, vendors, data collected, frequency of sampling, and connectivity is summarised in Appendix 1.

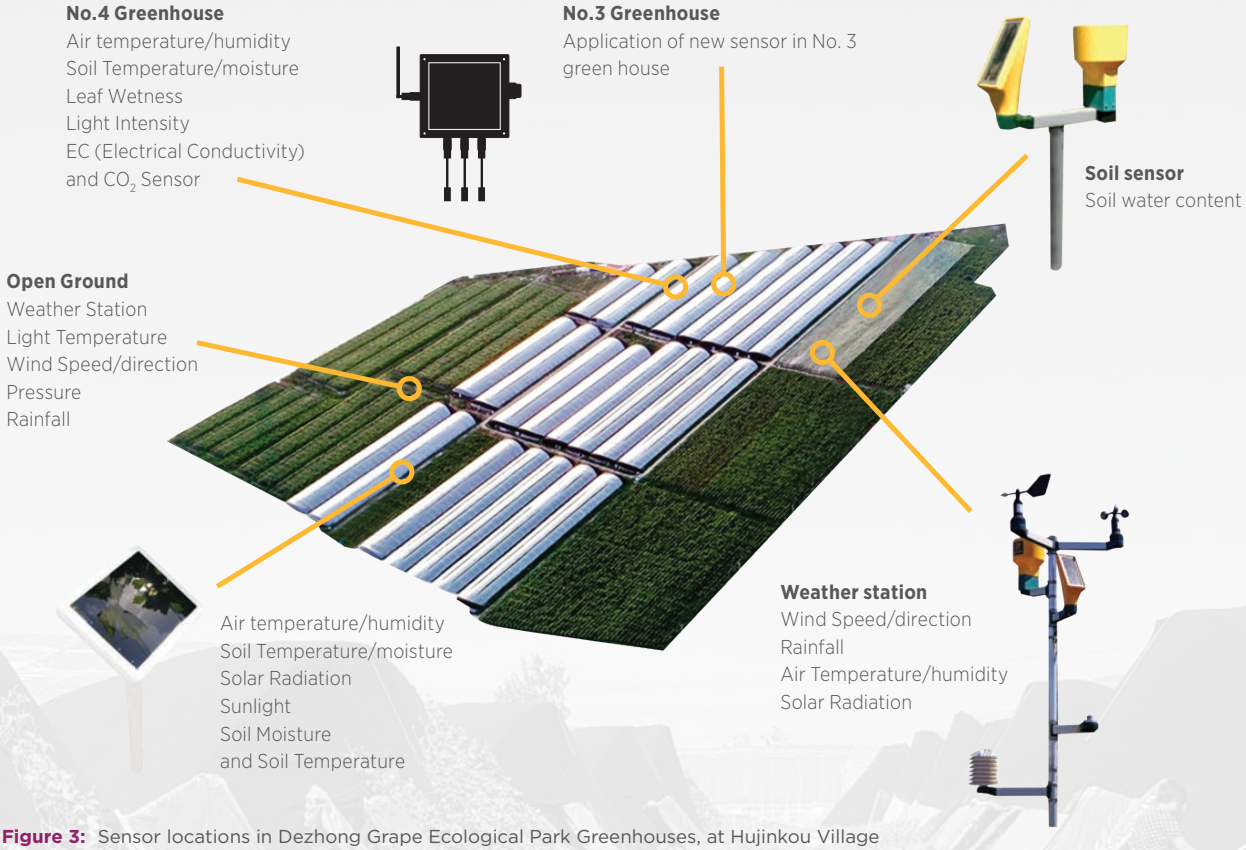



**Figure 3:** Sensor locations in Dezhong Grape Ecological Park Greenhouses, at Hujinkou Village

## 3.3 DATA STORE

The data, collected from multiple sources and devices, was aggregated on the China Mobile IoT Company OneNET[13] platform. OneNET is a Platform as a Service (PaaS) cloud solution which enables IoT devices to easily transfer data to a "big data" store. It also supports software applications, such as specialist crop analytics, to simply integrate and access the stored data. This capability developed by China Mobile IoT Company provides the critical platform and interfaces required for the different parts of the ecosystem to come together and deliver end to end solutions for the agricultural market.

[13] https://www.gsma.com/iot/wp-content/uploads/2019/02/Growing-IoT-in-China-case-study-web.pdf

For this project the OneNET platform stored two types of data resource:

**Data directly from devices**
The OneNET Certification Programme Partner devices were configured to send raw data directly to the OneNET platform. Agricultural data was sent to the OneNET platform using an NB-IoT data collection standard.

**Data from 3rd Party stores**
Data is accessed from the sensor manufacturers' cloud services and exported to OneNET Data Platform via API or CSV file. The OneNET IoT platform could then be invoked to integrate the 3rd Party data with the OneNET data.

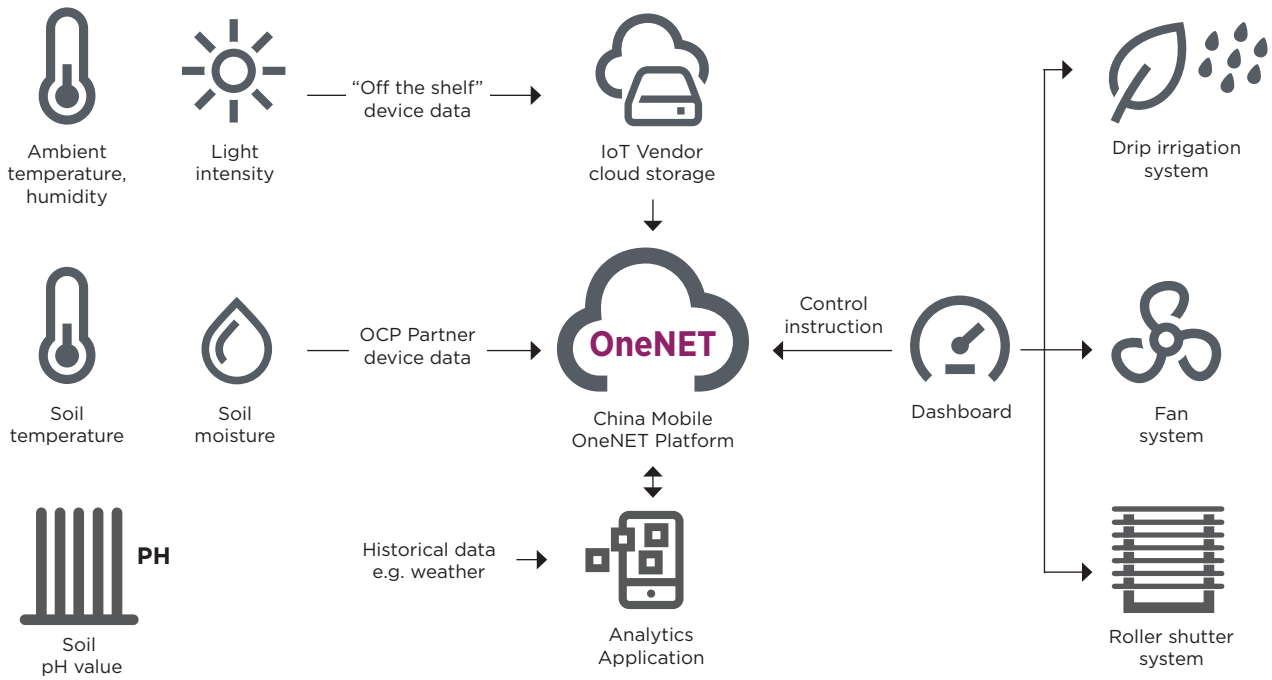



**Figure 4:** The OneNET platform aggregates data from the OneNET Certification Programme partner devices and from "off the shelf" device vendor cloud services and manages access to the stored data by integrated smart hardware solutions (such as irrigation) and analytics applications.

# 4 Summary of Analysis and Results

China Agricultural University undertook a comprehensive analysis by comparing the environment between the traditional greenhouse, where operations and routine management processes are based on the observations and expertise of the farmer and workers, and the greenhouse equipped with the IoT systems.

The impact of the insight derived from the individual IoT sensor measurements (temperature, moisture, nutrient levels) was measured by China Agricultural University, as was the impact of the combined IoT solution. In summary, the analysis considered:

- A standard greenhouse with no IoT sensors deployed (the 'base case')
- Temperature optimisation using temperature measurements
- Irrigation optimisation using moisture measurements
- Fertilisation optimisation using soil testing analysis and soil electrical conductivity (measuring salinity of soil)[14]
- Integrated management combining temperature, leaf humidity, soil moisture and soil electrical conductivity measurements

The full analysis includes assessment of the quality and yield of the final grape harvest, variations at each growth stage across each environment, impact on inputs (water and fertiliser), and economic implications. This section highlights the key findings, further details of the research can be found in Appendix 2.

[14] Soil electrical conductivity devices only played a supporting part in the nutrients measurements during this proof of concept. Decisions were mainly based on soil testing and fertiliser formula analysis undertaken by the CAU STB students. The project was unable to access stable data from the continuous EC monitoring sensors due to problems with the power supply to the remote site.

## 4.1 FRUIT YIELD

The highest yield resulted from the 'integrated IoT management system' with an overall yield of 38t/hm² (tonnes per square hectometre) compared to 15t/hm² in the base case of the traditionally managed greenhouse. This represented a **yield increase of 153 per cent** compared to the base case. While the integrated IoT management system was by some way the most successful for yield, it is also notable that the simpler application of IoT to manage the temperature and irrigation independently **each increased the yield by 23t/hm² (53 per cent)**, while optimising fertilisation alone using IoT resulted **increased yield to 28t/hm² (87 per cent)**. This shows there are multiple opportunities for deploying and benefitting from precision agriculture approaches.

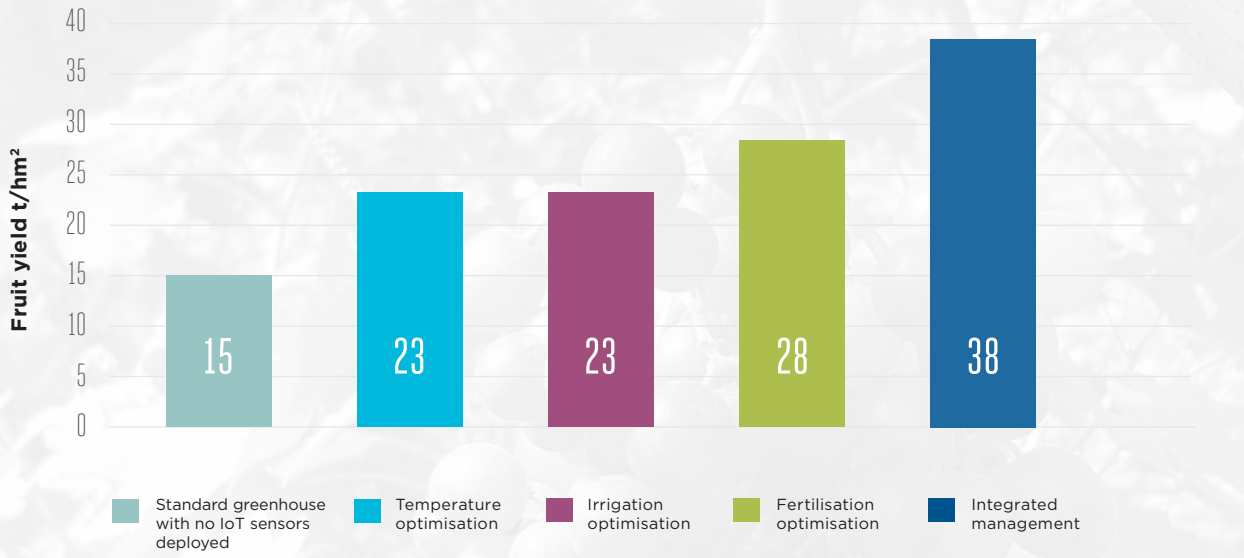



**Figure 5:** Fruit yield by regime

Figure 6 and Figure 7 below compare images of standard production grapes and grapes from the IoT integrated solution respectively. The images show the grapes from the IoT integrated solution to be much fuller fruiting and clearly more visually appealing for customers.

**Figure 6:** Grapes produced in the standard greenhouse

**Figure 7:** Grapes produced in the IoT greenhouse using an integrated management process

## 4.2 FRUIT QUALITY

It was found that the fruit in the greenhouses that had been managed based on decisions informed by IoT benefitted from early maturity and significantly improved quality. Earlier maturity has commercial advantages for growers as they can achieve premium prices at market in advance of the conventionally produced crops. Fruit quality is measured by the average weight of each grape, the content of soluble solids (which mainly refers to soluble sugars,[15] and used to measure the degree of fruit ripening) and the vitamin C content.

The grapes produced in the IoT greenhouses, in both the fertiliser optimised environment and in the integrated management process, delivered the highest average weight per individual grape at 2.5g. This is marginally heavier than the temperature and irrigation optimised crops at 2.4g, and almost **40 per cent** heavier than the traditionally managed grapes.

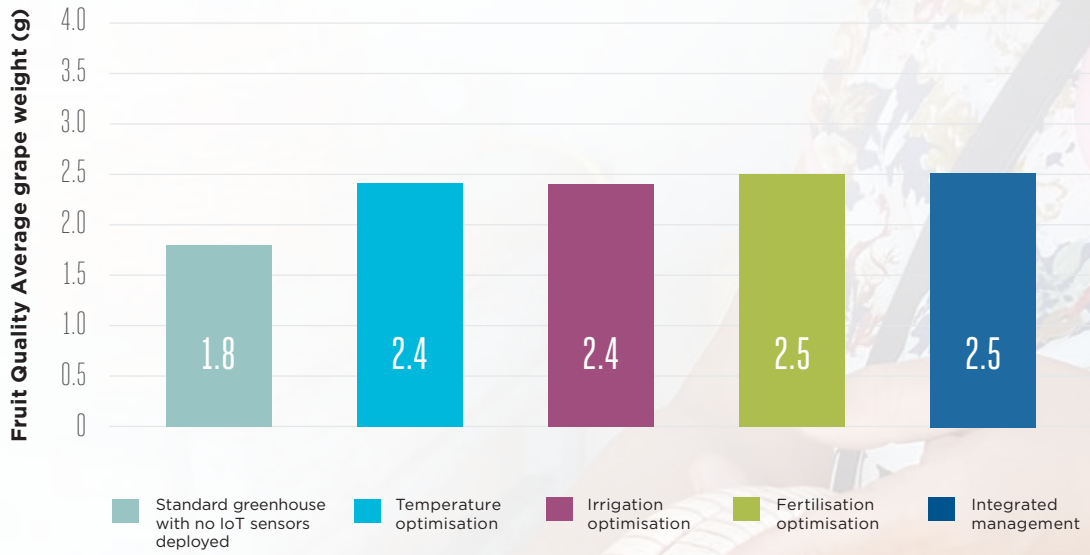



**Figure 8:** Fruit quality (weight) by regime

[15] Including monosaccharides, disaccharides and polysaccharides (except starch, cellulose, chitin and hemicellulose which are insoluble in water).

Detailed analysis also found the **vitamin C content to be 260% higher concentration** in grapes that had been managed using the integrated solution compared to conventional cultivation methods. Furthermore, optimising the temperature and the irrigation in isolation had a detrimental impact on the vitamin C content compared to standard greenhouse management method. The greater vitamin C content achieved by the integrated management solution clearly demonstrates how a complex big data approach can positively affect grape production.

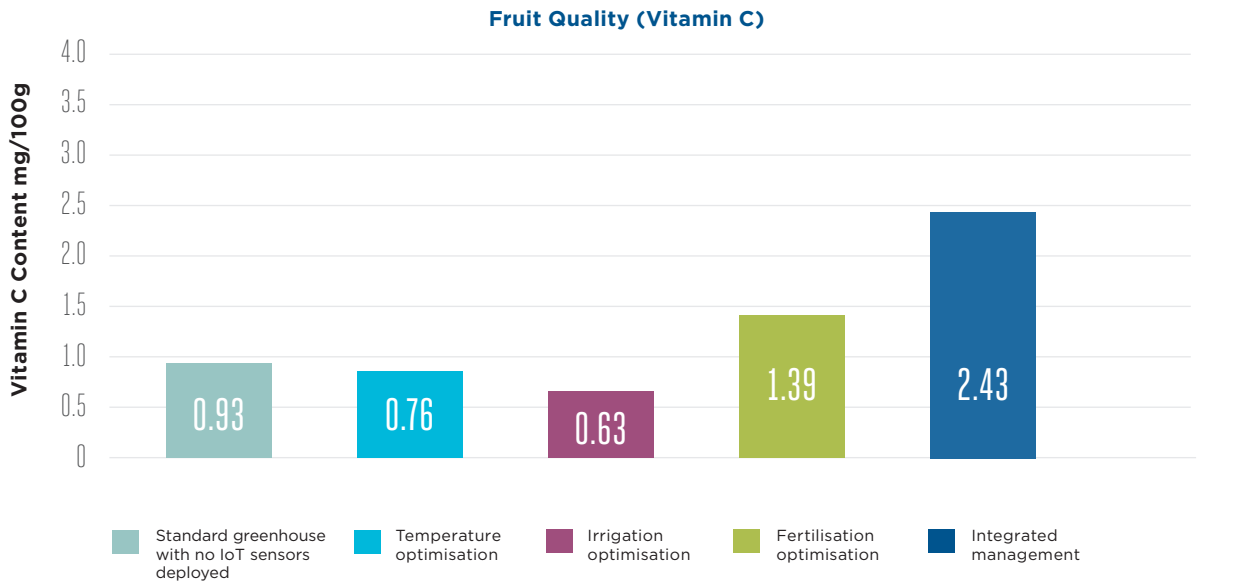



**Figure 9:** Fruit quality (Vitamin C) by regime

**Table 1 -** Fruit yield and quality (weight) results by management process

| | STANDARD GREENHOUSE - NO IOT SENSORS | TEMPERATURE OPTIMISATION | IRRIGATION OPTIMISATION | FERTILISATION OPTIMISATION | INTEGRATED MANAGEMENT |
|---|---|---|---|---|---|
| Fruit yield | 15t/hm$^2$ | 23t/hm$^2$ | 23t/hm$^2$ | 28t/hm$^2$ | 38t/hm$^2$ |
| Fruit Quality - Average weight of each grape | 1.8g | 2.4g | 2.4g | 2.5g | 2.5g |
| Fruit Quality – Vitamin C | 0.93mg/100g | 0.76mg/100g | 0.63mg/100g | 1.39mg/100g | 2.43mg/100g |

Higher quality fruit generally achieve a higher sale price, as does early season availability which is of importance to the farmer. Greenhouse grapes are generally mature earlier than open field production due to the managed and protected environment, and with IoT insights this can be brought earlier when availability is even more limited and the market price is therefore at a premium. IoT informed decision making can enable the farmer to grow a larger yield of higher quality early season grapes and improve the revenue achieved for the harvest.

## 4.3 WATER USAGE

Flood irrigation is a common method used by small-scale farmers in grape production in China. This is an inefficient use of water and also brings a series of risks to the plant, including root absorption problems and exposure to diseases and pests through high greenhouse humidity. In 2019, Dezhong grapery introduced drip irrigation, and the **water consumption decreased from 4,500m³/hm² to 3,024m³/hm²**, with a water-saving efficiency of 32.8 per cent.

Soil moisture sensors were then combined with the drip irrigation method and the analysis compared the difference between the results of decisions made using IoT sensor data compared to decisions made by the farmer without sensor data. Water consumption further decreased from 3,024m³/hm² to 2,016m³/hm² in the greenhouse supported by IoT driven insights reducing use by an additional 33.3 per cent. Compared with the usual flood irrigation method, the IoT data informed drip **irrigation reduced usage by 55.2 per cent**. This is of course whilst increasing the yield by 153 per cent in the IoT integrated environment.

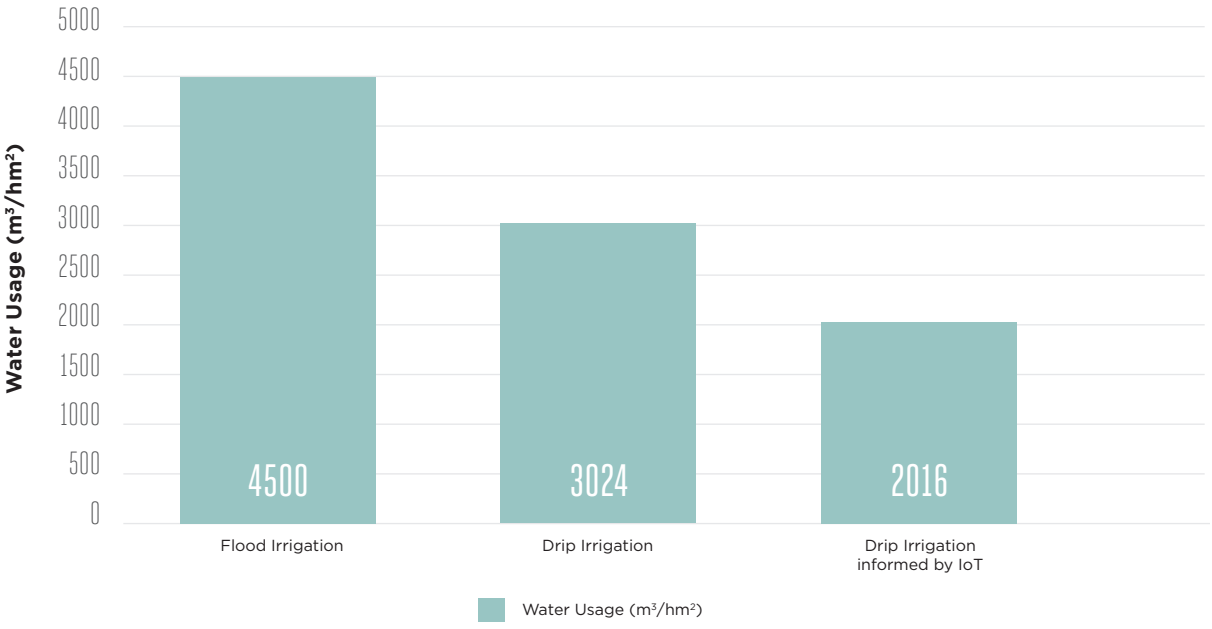



**Figure 10:** Water Usage by Irrigation Method

13 CLIMATE ACTION

## CLIMATE FOCUS

The continuous exploitation of groundwater and high volume of water waste is a serious problem in agriculture in China. In the North China Plain, the continuous decline of groundwater level has brought great challenges to agricultural production, threatening China's food security, and driving the need for agricultural water reform. The move from traditional flood irrigation to drip irrigation has produced significant water savings in grape production and the application of IoT is shown to enhance this even further.

Figure 11 shows the yield achieved in kilograms per cubic meter of water applied for each irrigation method. It shows that the traditional flood irrigation method produced 3.33kg of fruit per cubic meter of water applied compared to 18.849kg of fruit harvested under the IoT management solution. This is a **yield uplift of 283 per cent per unit volume of water** compared to the traditional flood irrigation method.

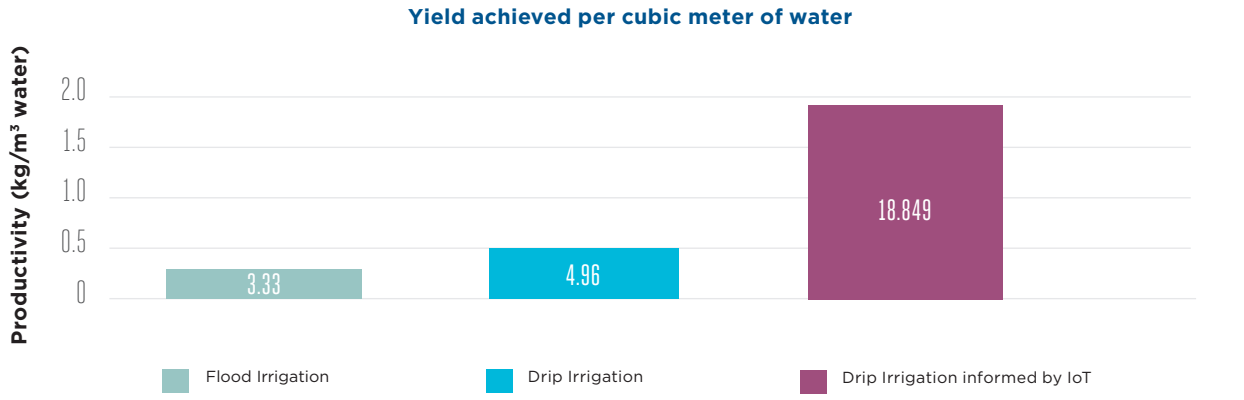



**Figure 11:** Yield per cubic meter of water by irrigation method

China Agricultural University also calculated a 33 per cent reduction in running costs for the IoT informed drip irrigation solution compared to the standard drip irrigation, and **57 per cent cost savings compared to traditional flood irrigation**[16]. These calculations factor the price of agricultural water (0.4 yuan/$m^3$), the energy cost of accessing irrigation water from a deep well using a 30kW power pump (0.61 yuan / kWh for agricultural electricity) and the labour cost of irrigating each row manually for the flood irrigation method (120 yuan / $hm^2$).

[16] Operational costs include water, electricity and labour for each irrigation system. Cost of equipment (CAPEX) is not included.

## 4.4 USE OF FUNGICIDE

High humidity in the greenhouse causes diseases such as “Brown Spot”. Fungicide is used as a prevention method. The IoT solution was used to indicate when the humidity had reached a specific threshold. Using this method, the farmers only applied the fungicide four times in the IoT greenhouses through the season compared to 10 times in the standard greenhouse. Taking into account the costs of the fungicide, labour costs and fuel required for application, **this saved the farmer 2,430 yuan/hm² per season (60 per cent)**.

## 4.5 CROP PROTECTION FROM EXTREME HEAT

While it is recognised among the small-scale farmers that high heat causes damage to the vine and grape development, there is no commonly adopted mitigation approach. For this project China Agricultural University recommended, based on previous academic research, that the greenhouse temperatures should not exceed 35 degrees Celsius. This was monitored using the IoT system and enabled the farmer and workers to respond in a timely way when the heat was reaching the maximum. Figure 12 and Figure 13 show images of heat damaged vines (2018) in the year before IoT insights were available and vines protected from excessive heat (2019) through IoT informed decision making respectively.

**Figure 12:** Heat damage in 2018

**Figure 13:** The IoT greenhouse was regulated to not exceed 35 Celsius in 2019

# 5 Operator Value Creation

The proof of concept at Dezhong Grape Ecological Park was an early opportunity for China Mobile IoT Company to demonstrate how mobile operators can deliver value to customers in the agricultural sector and develop new revenue streams beyond connectivity. China Mobile IoT took the opportunity to develop a solution, extending beyond their traditional network connectivity product, towards a full proposition for small and medium agricultural producers in China.

## 5.1 CONNECTIVITY

China Mobile IoT Company provided NB-IoT connectivity – a dedicated low power wide area (LPWA) technology that supports the IoT need for scalability at low cost. NB-IoT and LTE-M networks are highly optimised network connectivity options offering the advantage of a greater communication range and improved battery life, greatly assisting agricultural deployments. NB-IoT connectivity also enables the sensor to enter sleep and/or power save modes when not in use which reduces energy demand, this is also beneficial in a remote environment.

### Mobile IoT: NB-IoT and LTE-M

IoT deployments are made more effective through the use of optimised license spectrum 3GPP standardised technologies 'Narrowband IoT' (NB-IoT) and 'LTE for Machines' (LTE-M). These technologies work in complement to existing mobile operator networks offerings:

- Substantial improvements to transmission ranges suiting wide area deployments and better in-building penetration (up to 20dB improvement)
- Much reduced power consumption enabling longer battery life operation of connected devices (up to 10 years)
- Rapid deployment and configuration leveraging mobile network capabilities
- Carrier grade security leveraging key technologies including the mobile SIM
- Bi-directional communications enabling data uploads, control, remote configuration and patching
- Scalability, reliability and quality of service

For more information see **gsma.com/iot/mobile-iot/**

## 5.2 BIG DATA CLOUD PLATFORM

The OneNET platform has a number of features that made it highly suitable for this smart agriculture project, including bulk data storage, massive scalability (supporting many millions of IoT devices), secure transmission and a broad range of communications protocols and APIs. The platform provided effective support for the NB-IoT deployments by collecting data from IoT sensors and enabling that data to be made available to third-party application platforms for further processing.

## 5.3 CONVENING EXPERTISE

Alongside China Agricultural University and GSMA, China Mobile IoT was able to convene five project partners to supply and manage the IoT devices and the irrigation system for the project. These project partners were identified and selected through the OneNET Certification Programme which demonstrates that mobile operators can build a network of partnerships to help their customers. The initiative is designed to introduce quality partners to the China Mobile OneNET platform, establish platform protocols, and promote the opportunity to develop solutions and grow the IoT solution ecosystem. The grape project proof of concept provided an early example of how mobile network operators can draw on functionality and expertise from across the IoT ecosystem to deliver value to customers.

# 6 Next Steps

This report has documented how the China Mobile IoT Company and ecosystem partners have delivered significant improvements to the yield and quality of greenhouse grapes, while reducing the amount of resources required (i.e. water, fertiliser). This demonstrates the value of IoT smart agriculture services.

The proof of concept demonstrated, that in conjunction with cost savings from the reduced inputs and labour required, IoT based decision making solutions could be highly attractive to small-scale grape producers in China. Greater yields lead to increased financial return for the producer, further enhanced by higher quality fruit and early season availability attracting a premium price. These solutions can also directly contribute to the Sustainable Development Goals (SDGs) described earlier in this report, including greater sustainability and efficient use of fertilisers in food production (SDG 2), improving water quality by reducing pollution (SDG 6) and minimising water consumption (SDG12, SDG13).

China Mobile IoT Company have since moved into a pilot phase, developing the model identified within this proof of concept and deploying a solution with a commercial strawberry producer in Beijing[17]. China Mobile IoT Company has also developed the "Standard Agriculture Service Package", a proposition that offers IoT connectivity, the OneNET PaaS (Platform as a Service), and access to agriculture specific software solutions.

The success of both the grape proof of concept and the strawberry pilot is leading to a commercial roll out of the IoT proposition across the agricultural vertical. The flexibility of the architecture also makes this proposition and business model potentially adaptable to any vertical market.


[17] https://www.gsma.com/iot/beyond-connectivity/#how-china-mobile-is-harnessing-iot-big-data-solutions-to-create-value-in-strawberry-production

# 7 Summary

The proof of concept demonstrated that IoT solutions can power actionable insights into the crop production and enable the producer to better manage the growing environment. The results showed **grape yield to increase by 153 per cent** under the IoT solution. Crop quality also improved, grapes were heavier and showed an increase in other quality factors such as accumulated sugars; soluble solids and vitamin C. IoT sensors also improved the water efficiency, **improving drip irrigation by 33.3 per cent**, and **using 55.2 per cent less water** compared to flood irrigation.

The project also showed how the mobile network operator has an opportunity to play a central role in the ecosystem. China Mobile IoT Company demonstrated how it is possible for an operator to identify and convene the stakeholders and the appropriate skills to deliver a successful solution. In addition to offering connectivity, such as the dedicated NB-IoT network, platforms such as OneNET enabled the operator to play a central role in connecting a wide range, and high volume, of IoT devices to applications designed by industry experts for different verticals. The OneNET Certification Programme is a further example of how an operator can develop and expand the IoT ecosystem in a region.

This proof of concept provided the opportunity for China Mobile IoT Company to develop an early proposition model. It has since been developed further into a commercial solution for Strawberry production in Beijing. China Mobile IoT Company have established a standard IoT proposition for agriculture incorporating connectivity, platform access and software solution.

The successful model developed from the proof of concept has the potential for application across many industry verticals in addition to multiple crops across the agricultural sector.

## Results from the fully integrated solution

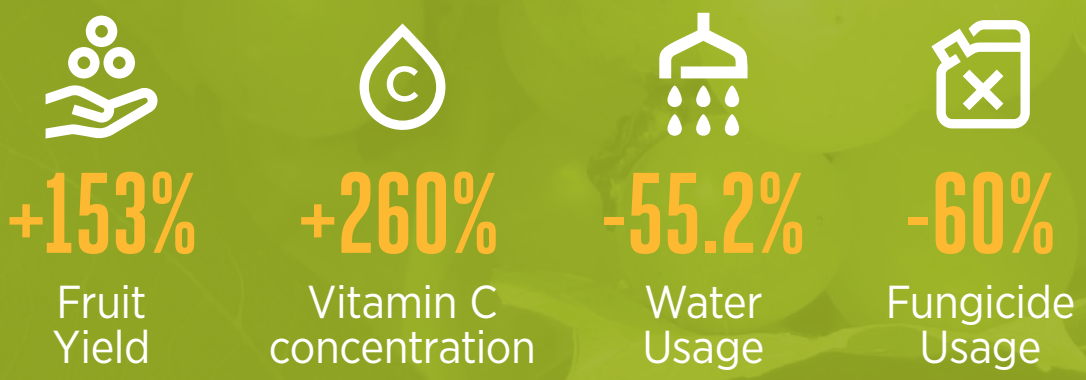



**Figure 14:** Fruit Quality = Concentration in vitamin C content

# Appendix 1: Devices capturing data through IoT Sensors

Sensor data: Acquisition frequency is every 15 minutes, and the collected data is divided into greenhouse temperature, soil moisture, leaf humidity, outside air temperature and humidity, and rainfall.

| | Agricultural Sensor Data Gathered | Connectivity | Target frequency of samples taken | Images |
|---|---|---|---|---|
| **Suzhou Linkdotter Data Technology** | Luminous intensity | NB-IoT | Upload data every 15 mins |  |
| | Soil electrical conductivity | NB-IoT | Upload data every 15 mins and it uploads data per minute when irrigating |  |
| | Soil temperature and humidity | NB-IoT | Upload data every 15 mins and it uploads data per minute when irrigating |  |
| | $CO_2$ concentration | NB-IoT | Upload data every 15 mins |  |
| **Zibo Wanan Intelligent Technology** | Provide temperature and humidity<br><br>Leaf moisture | NB-IoT | Upload data every 15 mins |  |
| **Nanjing 30000 IoT Technology** | A weather station measurement Agricultural Sensors the luminous intensity, temperature and humidity, wind speed and direction, pressure and rain fall | NB-IoT | Upload data every 15 mins |  |

| | Agricultural Sensor Data Gathered | Connectivity | Target frequency of samples taken | Images |
|---|---|---|---|---|
| **Beijing Hdiot Technology** | **Irrigation system:** Pressure meters, Soil moisture sensors, Irrigation controllers, Solenoid valves, Converters, Switches, Smart water meters | 2G | When irrigating, the Irrigation controller uploads per minute |   |
| **Sichuan Tianfu Honey Technology** | Gravity sensor, Temperature sensor, Gas sensor | 2G | Upload data every 10 mins |   |
| **Dacom** | **Soil sensor:** Soil moisture and temperature in five layers every 10cm to 50cm with additional rain gauge | GPRS quad-band modem and SIM card | 60 mins |  |
| | **Weather station:** Temperature, relative air humidity, rain gauge, wind speed, wind direction, UV meter | GPRS quad-band modem and SIM card | 60 mins | |
| **Pycno** | Air temperature, air relative humidity, solar radiation, sunlight, **soil moisture:** 10cm, 25cm, 40cm, 55cm, soil **temperature:** 10cm and 40 cm | Cellular GSM | 10 mins |  |
| **Libelium** | Temperature, humidity, pressure, soil moisture, leaf wetness | 4G | 15 mins |  |

# Appendix 2: China Agricultural University Academic Analysis

Further details of the China Agricultural University research and associated articles can be obtained from:

College of Resources and Environment Sciences, China Agricultural University,
*Professor Zhang Weifeng*

College of Resources and Environment Sciences, China Agricultural University, Science andTechnology Backyard,
*Li Zengyuan*

## About the GSMA

The GSMA represents the interests of mobile operators worldwide, uniting more than 750 operators and nearly 400 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and internet companies, as well as organisations in adjacent industry sectors. The GSMA also produces the industry-leading MWC events held annually in Barcelona, Los Angeles and Shanghai, as well as the Mobile 360 Series of regional conferences.

For more information, please visit the GSMA corporate website at www.gsma.com.

Follow the GSMA on Twitter: @GSMA.

## About China Mobile IoT Company

China Mobile IoT Company Limited is a wholly owned subsidiary of China Mobile. Based on the overall strategy of China Mobile, China Mobile IoT Company aims to become the supporter of IoT business services, the provider of IoT chips & modules and the promoter of IoT products & applications. In practice, China Mobile IoT focuses on operating IoT private network, designing IoT chips and modules, producing IoV, smart home applications and wearable, Development and operation of IOT card connection management platform OneLink and IOT open platform OneNET, promoting IoT solutions, which makes a comprehensive architecture name "Cloud-Pipeline-Device". China Mobile IoT Company collaborates with China Mobile provincial and professional companies to provide the community with the most advanced IoT technologies. Following the philosophy of open, cooperation and sharing, China Mobile IoT strives to become a China based, globally leading IoT Company which promotes IoT applications in various industries.

## About China Agricultural University (CAU) Science and Technology Backyard programme (STB)

China Agricultural University (CAU) Science and Technology Backyard programme (STB) has been established to improve productivity in the agricultural sector and plays a major role in leading agricultural education, science and technology innovation in China.

STB is stationed in the countryside and the front line of production, and carries out "zero distance" with farmers, enterprises and governments to carry out new models of scientific and technological innovation, technical services and personnel training. The STB comprises a network of more than 127 villages across China where intensive interaction with scientists has enabled farmers to increase yields, decrease inputs such as water and fertiliser and increase income for a range of crops.

CAU is focused on establishing innovative models of sustainable agriculture and supporting the national green development strategy. To that end CAU has established a series of demonstration areas for sustainable development. STB's mission is to simultaneously improve crop yield and resource utilisation efficiency, ensure national food and environmental security, and promote the transformation of agricultural development methods; innovate agricultural production organisations and service models to promote the transformation of agricultural production relations; improve farmers' lives and rural ecological environment, Harmonious development of agriculture, rural areas and farmers; take root in rural and agricultural production, cultivate ideal talents, "know agriculture, love farmers, and love rural areas", and contribute to social development.

This pilot project is located in one of these demonstration areas, at Dezhong Grape Ecological Park (Dezhong Science and Technology Backyard), in Hujinkou Village, Quzhou County, Handan City.

More information about can be found at http://chinastb.com/

For more information please visit:
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