Innovation on Climate Smart Mechanization Technologies for Dryland Farming in China

—Research and Application of Key Technologies in Intelligent Fertigation Equipment

中国旱地农业智能机械化技术创新—智能水肥装备关键技术研究

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WeChat

OUTLINE

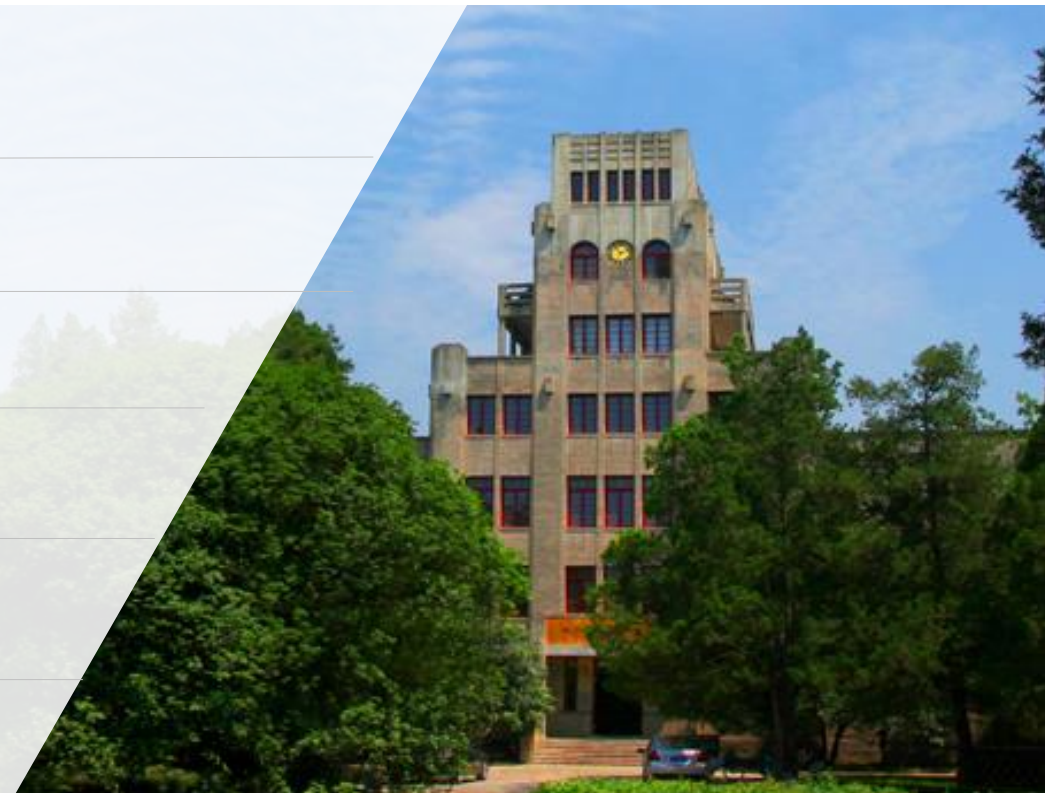1 **Background**

2 **Fertigation**

3 **Intelligent perception**

4 **Dielectric spectrum**

5 **Other Technologies**

➢ 到2030年，全球人口将突破80亿，地球上每人每天都需要水和粮食。
By 2023, the earth will be inhabited by more than eight billion (that's 8,000,000,000) humans. Every single one of them needs fresh water and food every day.

➢ 人类社会已进入智能时代，但自然灾害等仍然让人类无法免于饥饿，粮食安全仍是全球重要问题。
Human society has entered the era of intelligence, but natural disasters still make many people trapped in hunger. Food security is still a big problem in the world.

➢ 全球耕地面积有限，提高农田生产能力（亩产产量）是解决粮食安全的首选办法。
The land suitable for cultivation in the world is limited, the only way we can feed the entire human race is by continually making our farming processes more efficient.
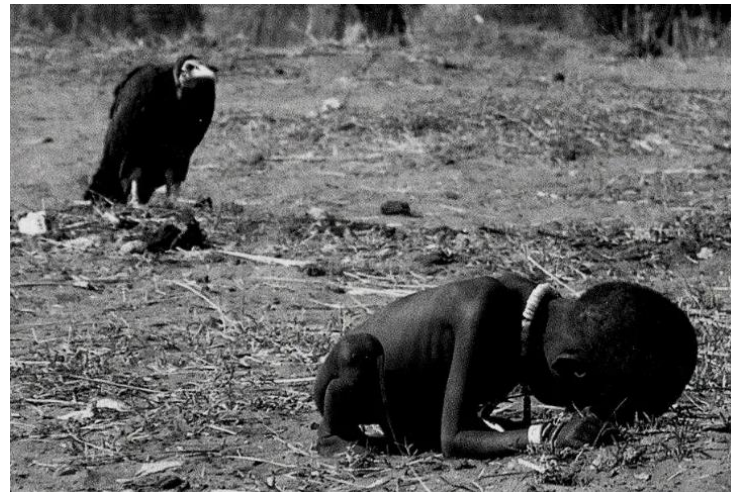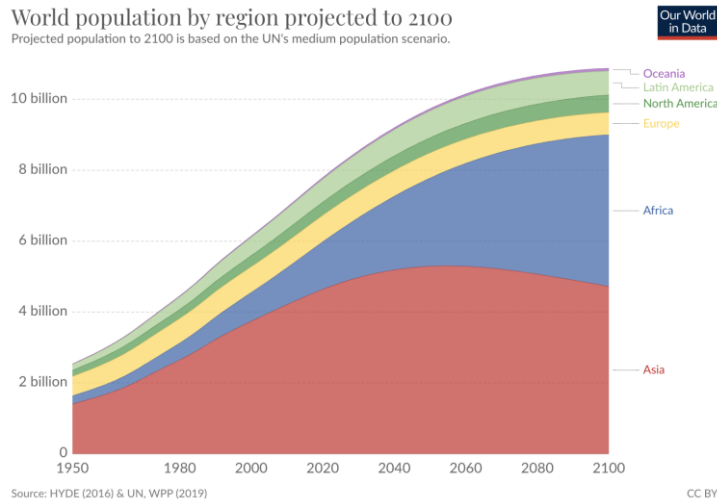
人类历史发展过程中，为了提高农田产能（产量），农业经历了4个阶段：

In the history of mankind, in order to improve efficient of farming processes, agricultural development is divided into four stages:

➢ 传统农业（农业1.0），通过人和牲畜的劳力，用精耕细作的办法来提高一定的农田产量；
Traditional agriculture (agriculture V1.0), which is dominated by the power of human and livestock;

➢ 生物化学农业（农业2.0），通过大量化肥和农药的使用来提高农田产量；
Biochemical agriculture stage (agriculture V2.0) in which a large number of chemical fertilizers and pesticides are used to improve the level of agricultural production;

➢ 机械化农业（农业3.0），通过农业机械代替人力和畜力，农业劳动效率大幅度提升；
Mechanical agriculture stage(agriculture V3.0) with agricultural machinery as the production tool.

➢ 智慧农业（农业4.0），通过智能信息技术，控制农机，建立种植模型，走生态、绿色农业发展之路；
Smart agriculture stage (agriculture V4.0) represented by information technology.

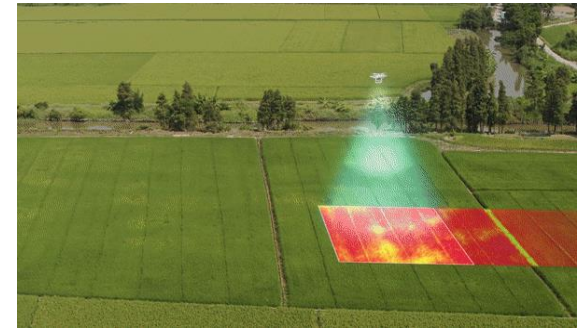**V1.0**　　　　**V2.0**　　　　**V3.0**　　　　**V4.0**

➢ **智慧农业**通过人工智能技术的附能（由农业劳动工具向种植管理转变），是农业生产的一场新的技术革命，是全球粮食安全的重要保障性措施之一。
Smart agriculture(SA) is a new technological revolution with the continuous application of artificial intelligence(AI) and the increasing demand for global food security.

➢ **智慧农业**技术能让农业生产更加简易、精准、高产、高质、高效，实现农业生产的标准化、节约化和精益化，实现生态化环境保护，实现真正的绿色生态农业。
Smart agriculture helps farmers manage agricultural production activities with simple, precision, efficiency, high quality and high yield, standardization, water and fertilizer saving, and ecological and environmental protection.

➢ 智能农机装备是智慧农业中非常重要的技术组成。智慧农业将综合协调耕、种、管、收、储、销的农业机械生产链过程，让农业生产实现全面无人化、精准化、高效化和效益化。
Smart Machinery is a very important technology component in smart agriculture. Smart agriculture will comprehensively coordinate the agricultural machinery processes of farming, plant protection, harvesting, food grading, and food processing, so that agricultural production can be fully unmanned, accurate, efficient, and cost-effective.

➢ 在农业生产中，水和肥是作物生长的重要条件。智能水肥灌溉装备可对水、肥进行精准调控，提高农田产量和质量，减少化肥污染，提高农业管理效率，节约水肥及能源消耗。Water and fertilizer are important two parameters for crop growth. Precise regulation of water and fertilizer is of great significance to improve the yield and quality of farmland, reduce chemical fertilizer pollution, improve agricultural management efficiency, and save water and energy consumption.

➢ 水肥一体化灌溉装备能根据作物对水肥的真实数据需求，通过微控制进行一键顺控，实现对水、肥的精量控制。通过水肥调控，实现作物不同生育期的水肥管理需求，提高水肥利用效率。

Fertigation (Integrated management of water and fertilizer) aims to control irrigation water and nutrient application comprehensively according to crop requirements. It can be realized by one key sequential control programming in the microcontroller. It can meet the needs of water and fertilizer management in different crop growth stages, and improve water and fertilizer utilization efficiency.
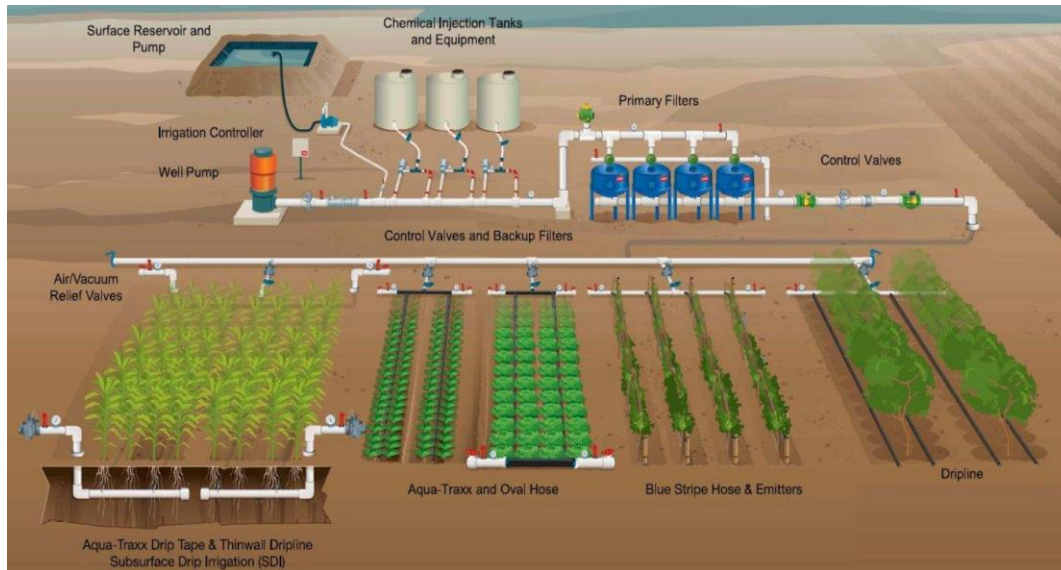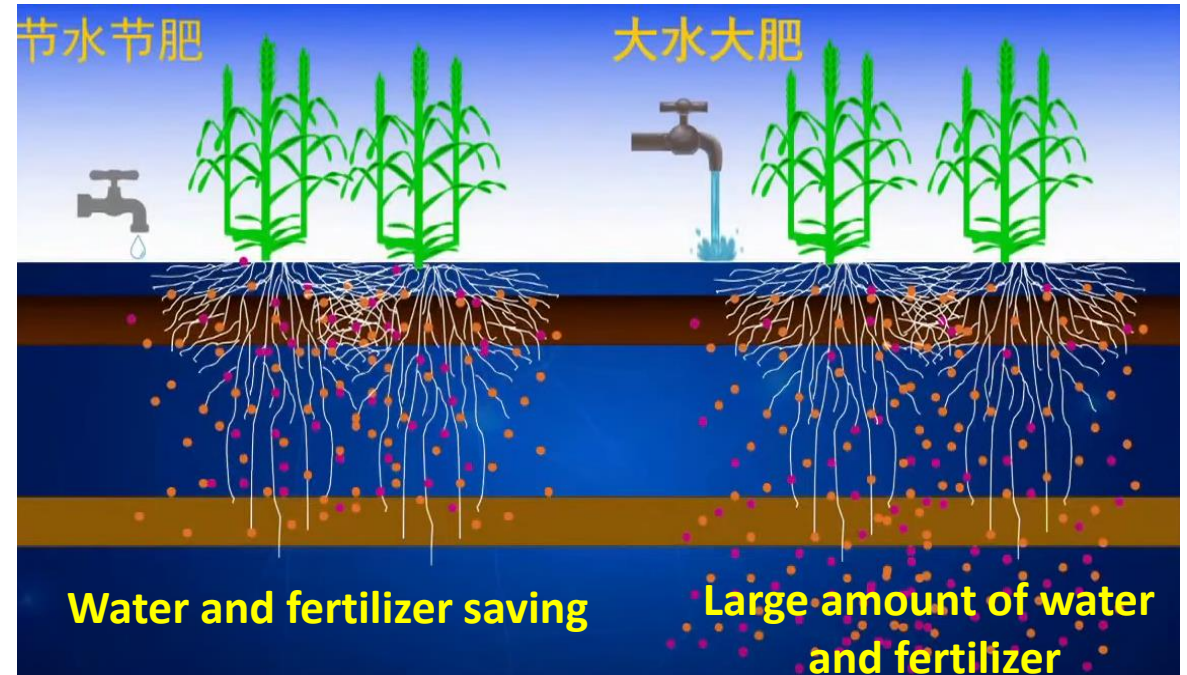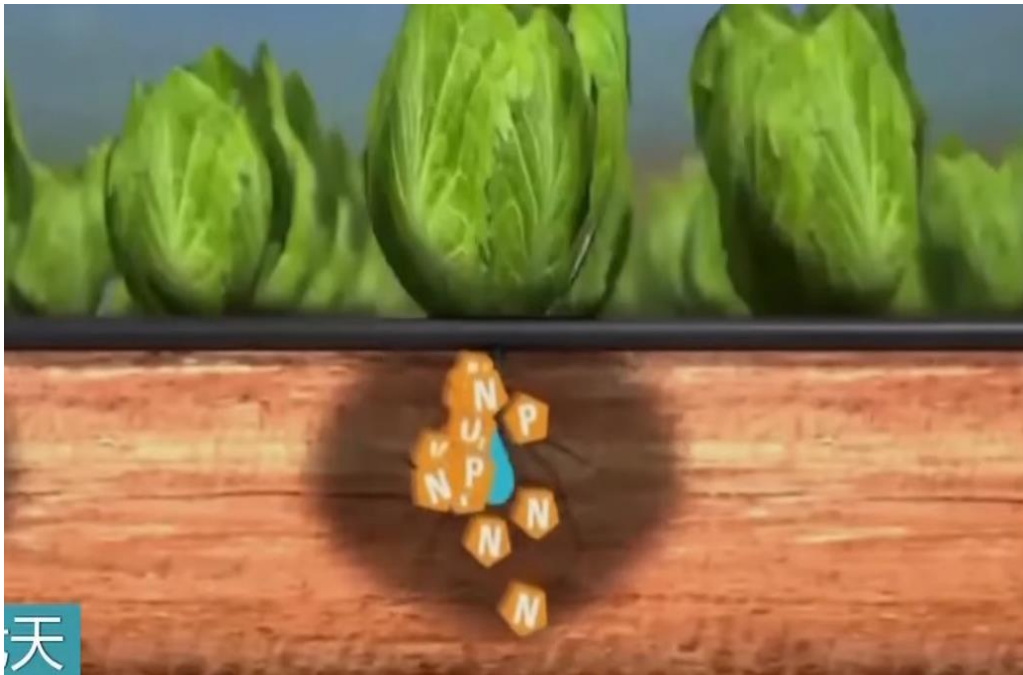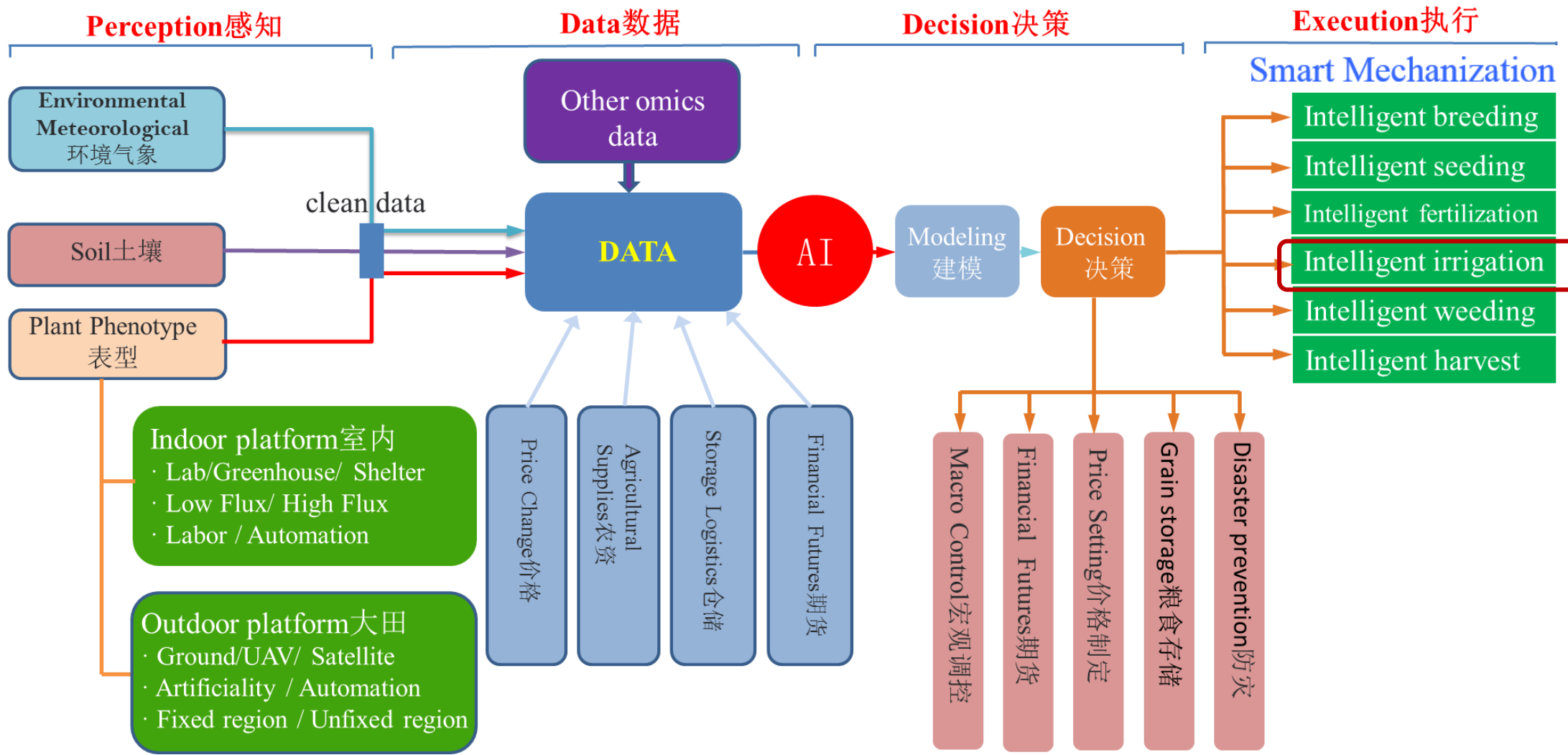
➤ 通过精准水肥控制系统，可实现水场、养分场的**靶向控制**，可实现节水、节肥以及提高粮食产量，减少化肥污染。
Through the precision irrigation control system, the targeted control of water and fertilizer field is realized, so as to save water and the use of fertilizer and improve grain yield, reduce fertilizer pollution.

The key knowledge links of Smart Agriculture

➢ 智能信息感知是智慧灌溉装备以及智慧农业中最薄弱的一个环节，智能信息感知是水肥机械装备的卡脖子技术。
Intelligent information perception (sensor) is the weakest link in intelligent irrigation equipment and even smart agriculture. Intelligent information perception is the bottleneck problem in the field of fertigation equipment.

➢ 精准数据和多种农田数据是智能农业生产和科学研究的重要基础。
Credible and multiple parameters are the important basic parameters of agricultural production and scientific research for the smart agriculture.

西北农林科技大学
NORTHWEST A&F UNIVERSITY
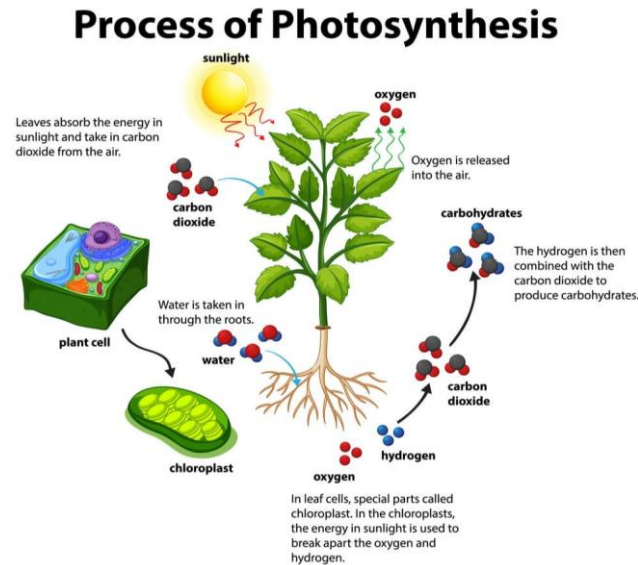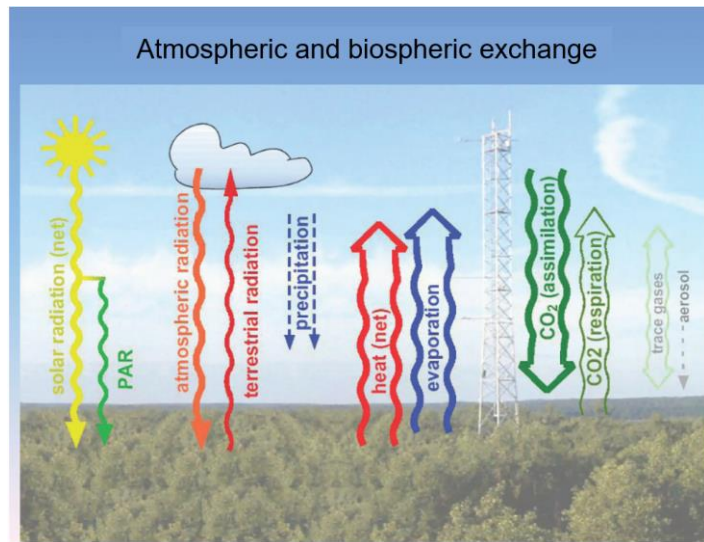
➤ **美国非常重视传感器技术，美国科学院将其列为未来农业研究的核心技术之一。**
In 2020, USA, the National Academy of Sciences, the Academy of engineering and the school of Medicine jointly released a research report entitled Science Breakthroughs to Advance Food and Agricultural Research by 2030.

1. Holistic thinking and systematic cognitive analysis technology are the primary premise for realizing the breakthrough of agricultural science and technology.

2. **The new generation of sensor technology will become the bottom driving technology to promote the progress of agriculture.**

3. Data science and information technology are strategic key technologies in the field of agriculture.

4. Breakthrough genomics and precision breeding techniques should be encouraged and adopted.

5. Microbiome technology is very important to recognize and understand the operation of agricultural systems.


The National Academies of
SCIENCES · ENGINEERING · MEDICINE

CONSENSUS STUDY REPORT

Science Breakthroughs to Advance Food and Agricultural Research by 2030

➢ 传感器精度和质量非常关键，以土壤水分传感器为例，测量误差1%，中国耕地（19亿亩）会丢掉19179亿m³水，可够1.9亿人（尼日利亚人口数）正常生活用水1年。

The accuracy of agricultural information perception is very important. Take the soil moisture sensor as an example. If the error of China cultivated land soil moisture is 1%, 1278.6 billion square meters land will lost 1917.9 billion cubic meters water which can support the domestic water of people in Nigeria(190million people) for 1 years.
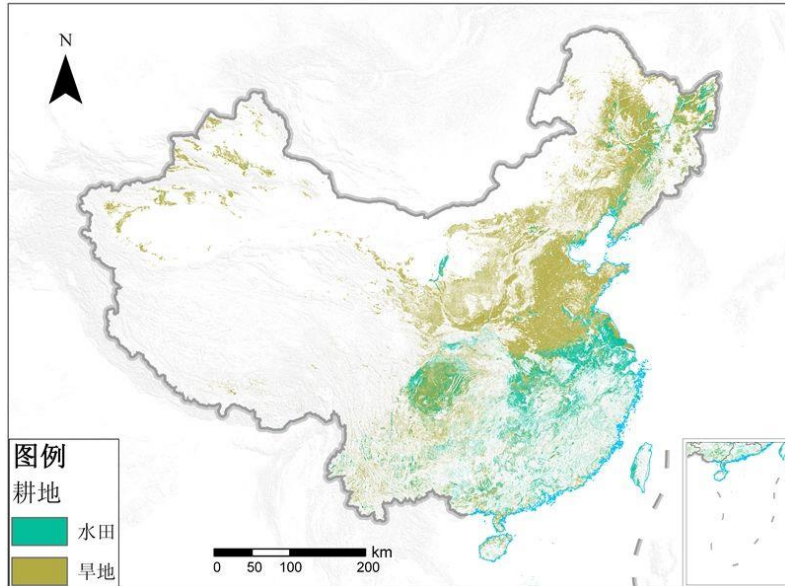
➢ 农田灌溉智能控制系统需要在多参数（传感器）融合的基础上做出正确的水肥控制决策，如水、肥、气、热、盐、药、光、电等。农田信息感知技术是智能灌溉装备的核心技术。
The correct control decision of irrigation intelligent control system is based on multi parameter (sensor) fusion. The parameters involved include water, fertilizer, gas, thermal characteristics, salinity, pesticide, daylighting, electrical signal, etc. Farmland information perception technology is the core technology of intelligent irrigation equipment.
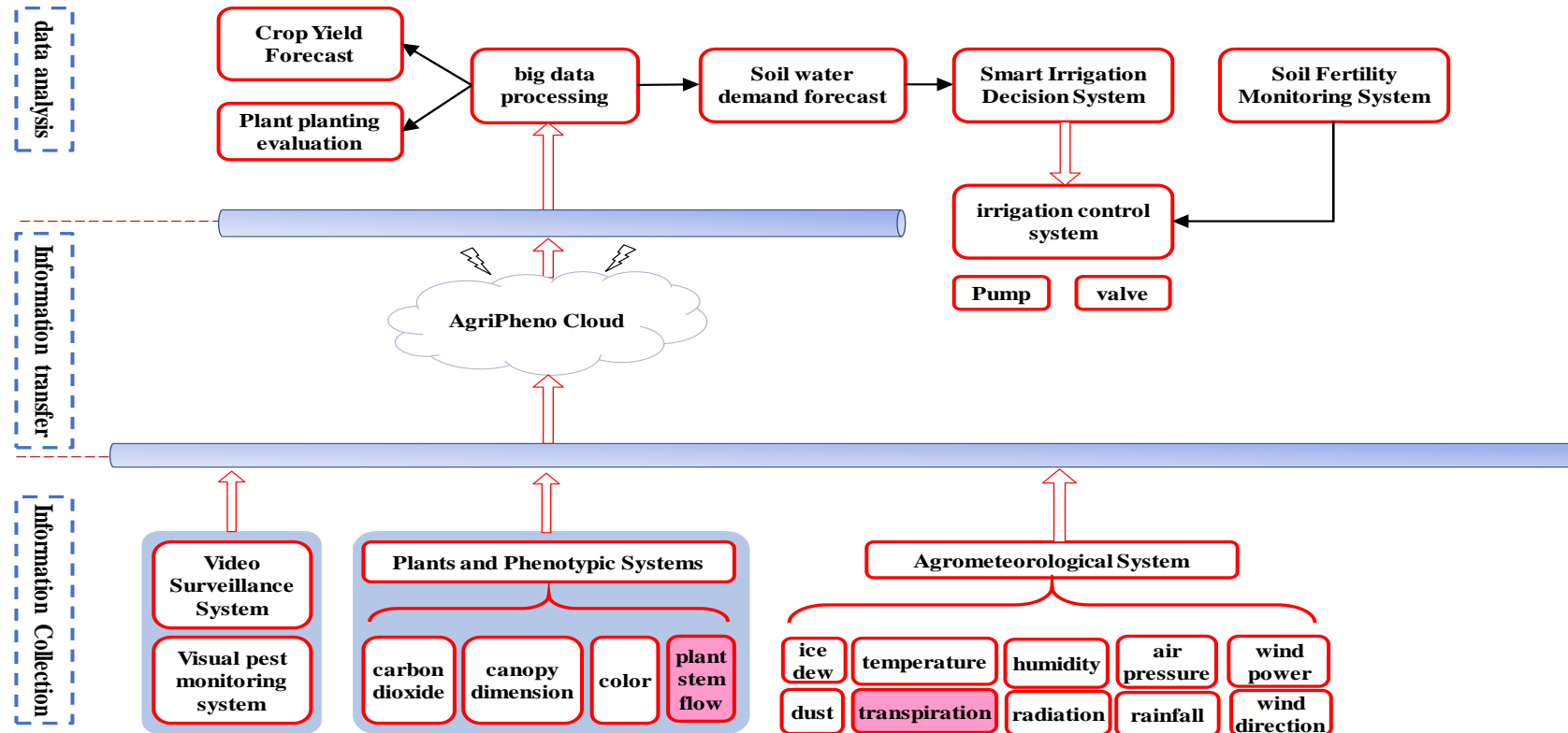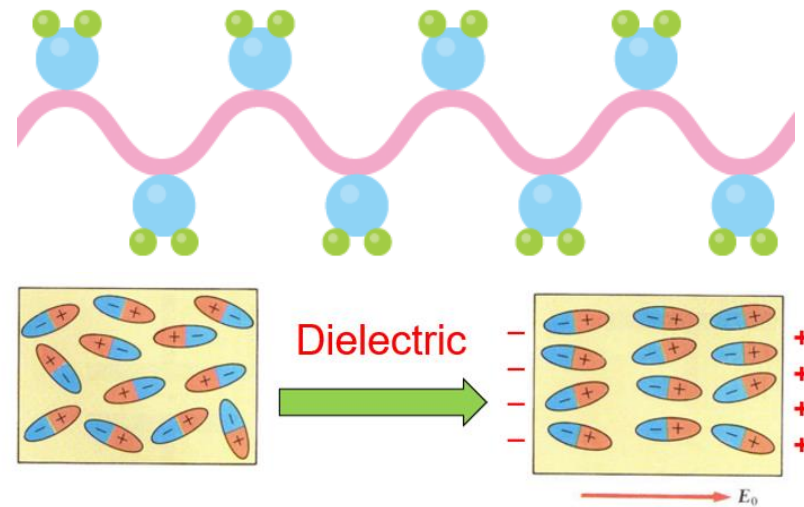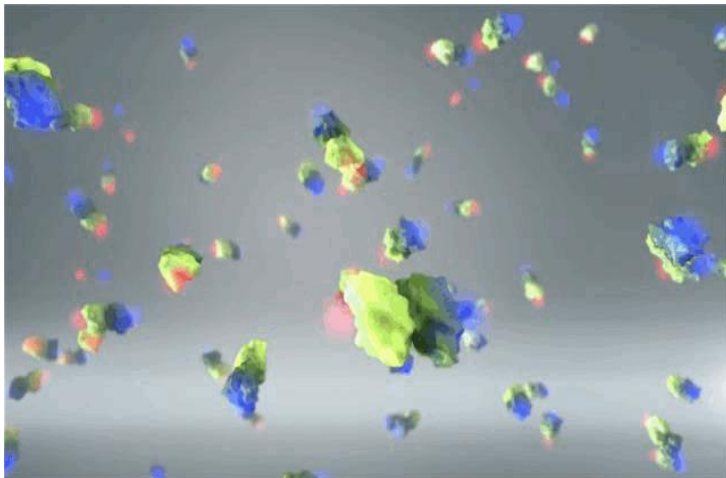
4.Dielectric spectrum

➢ 介电特性是电介质材料（非金属）的基本物理参数，它影响了电磁波的传播速度。
Dielectric or permittivity is one of the fundamental material parameters, which affects the propagation of Electric Fields.

➢ 材料介电特性与其离子（原子）组成以及晶格有紧密关系，离子组成的变化会引起介电谱的显著差异。通过矢量网络分析仪进行材料介电谱的测量，可以获取材料组成成分等大量信息。
The dielectric properties of materials are related to the lattice or composition of molecules or atoms of materials. The change of lattice, composition of molecules or atoms will cause the change of the dielectric properties.

4.Dielectric spectrum

➤ 介电值还和微波测量频率、材料的温度、湿度、密度等有关。测量的介电谱也可以反馈这些参数。基于介电谱的 介电指纹，可以表达农业材料的很多信息。
The dielectric value is affected by frequency, temperature, humidity, density, composition and so on. The dielectric spectra can feeback those parameters too.
Dielectric fingerprint can express a lot of information about agricultural products .

Porous media
多孔介质

Moisture content
Microbial content
Density
Bacterial content
Fruit ripeness
Sugar content
Tumor Identification
Mutual chemical interactions
between substances

Soil Dielectric Permittivity
土壤介电值

Ingredients（water, gas, heavy metals）
Texture (sand grain, powder grain, sticky grain)
Particle characteristics (size, shape)
Soil structure (grain, block, prism, column, sheet)
Soil porosity (swelling, shrinking, compaction and cracking)
Soil salinity (conductivity)
Soil temperature
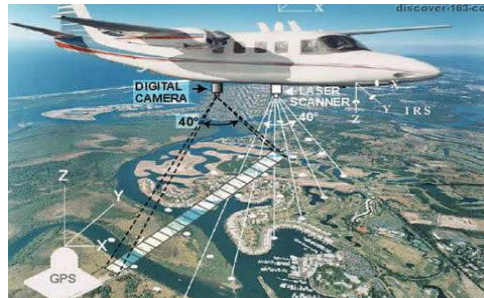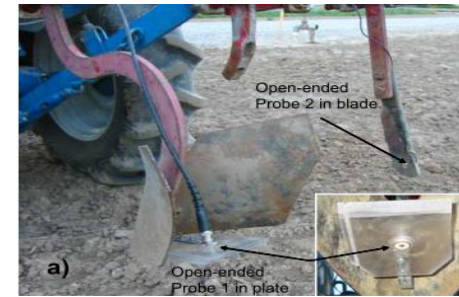Organic matter content (colloidal adsorption)

➢ 介电谱技术广泛应用在农业传感器、遥感和农业机械装备之中，可用于土壤、食品、动物、饮品（葡萄酒）的无损测量。如耕地的犁上安装传感器可测量农田水分、养分图谱。
Dielectric spectrum have been widely used in agriculture applications and could play an important role in quality determination of soil and other porous media including food products.
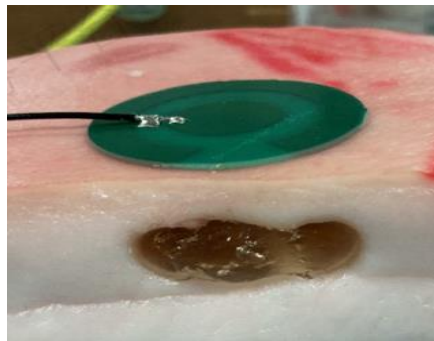

Soil sensor

Microwave remote sensing

Agricultural intelligent machinery

Animal disease


Fruit quality

Wine quality

1. Soil moisture sensor

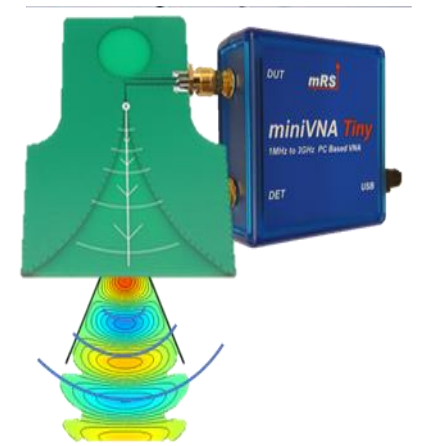➢ 通过土壤介电谱测量与分析，75MHz是土壤传感器的最佳工作频率。研究了探针结构电磁场对传感器性能的影响关系。

Through the measurement and analysis of soil dielectric spectrum, 75MHz is the best working frequency of soil sensor. The differences of electromagnetic field caused by different probe structures are studied, which will have different effects on the accuracy of the sensor.
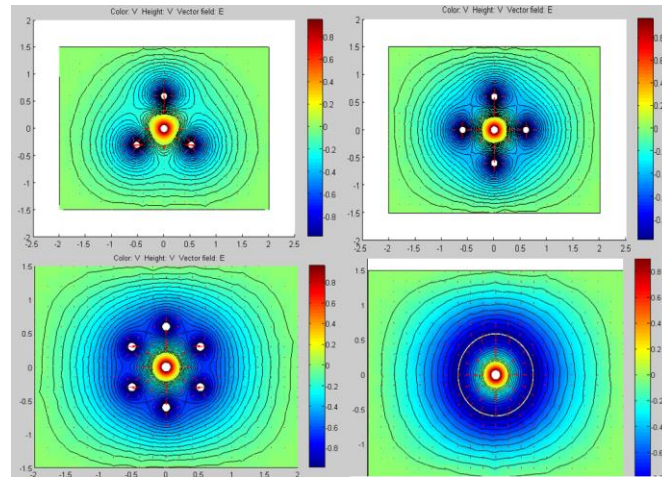
FDR传感器

Sally Logsdon

Scott Jones

表层土壤传感器

微波土壤传感器

多层传感器

2. Soil Nutrient Sensor - Nitrogen

➢ 氮素是植物生长的重要养分之一。氮素传感器的研发意义重大。团队通过土壤复介电谱进行了土壤氮素测量研究，确定低于680MHz的介电实部对氮素敏感。
Nitrogen fertilizer is one of the important nutrients of plants. The development of nitrogen sensors is of great significance for plant. Dielectric measurement of nitrogen is one of the most potential methods. In the low frequency range of 680MHz, the dielectric spectra are obviously distinguished for the different nitrogen contents.
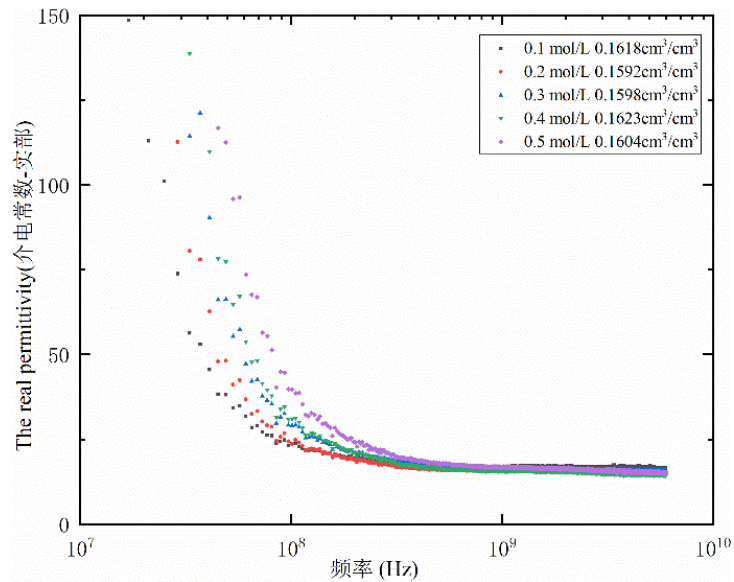

(a) 15%
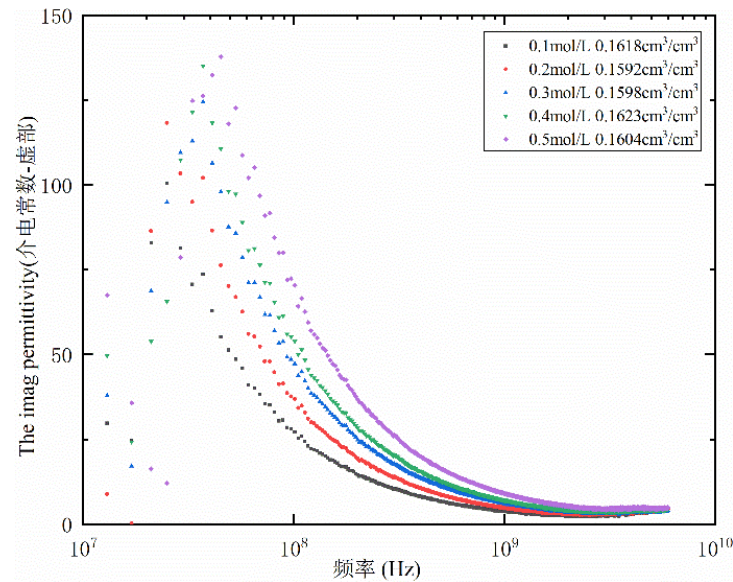
(b)15%

3. Irrigation Infiltration Line sensor

➢ 在干旱地区，土壤盐渍化是非常棘手的问题之一。水本来稀缺，但灌水压盐又是必要手段，因此精准测量灌溉浸润锋是节水控制的关键技术难点。
Soil salinization is a difficult problem to deal with in arid areas of the world. Water is scarce in arid areas, but irrigation and salt drainage need a lot of water. Therefore, how to obtain the infiltration line of irrigation is the guarantee to realize precision irrigation.
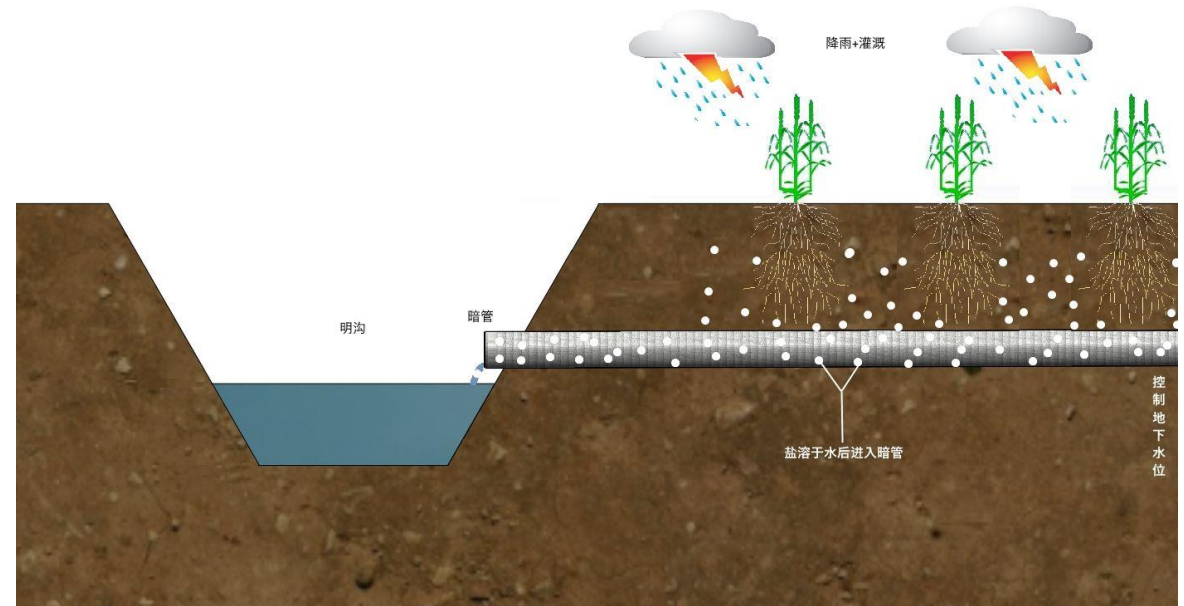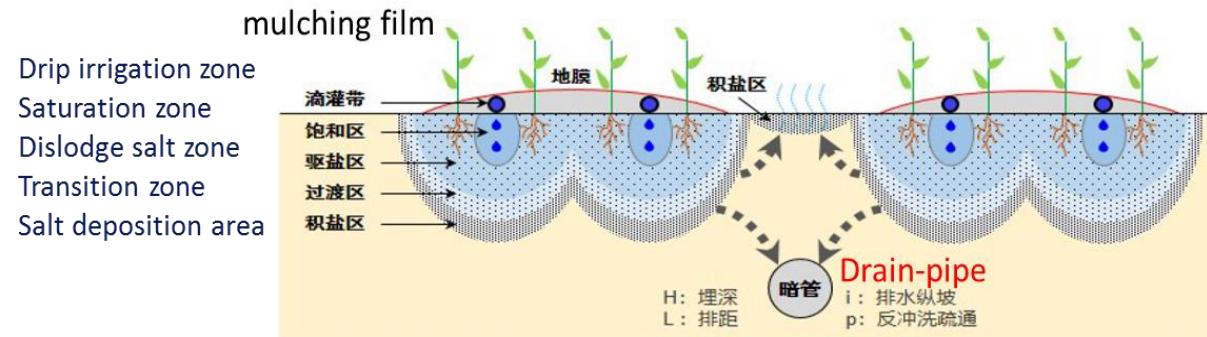
3. Irrigation Infiltration Line sensor

➤ 团队开发了一种正弦信号驱动的新型时域反射传感器S-TDR，与多传感器埋设方法对比，该传感器价格低廉，测量精度高，能准确测定驱盐区的位置，实现灌水的精量控制。

Compared with the embedding of multiple sensors, a single S-TDR porbe is a new cheap sensor to accurately obtain the position of the irrigation infiltration Line .

15$

- **Bulk soil moisture content**
- **Layered soil moisture content**
- **Phreatic line**
- **Salt intrusion area**
- **Drip irrigation humid area**

mulching film

Drip irrigation zone
Saturation zone
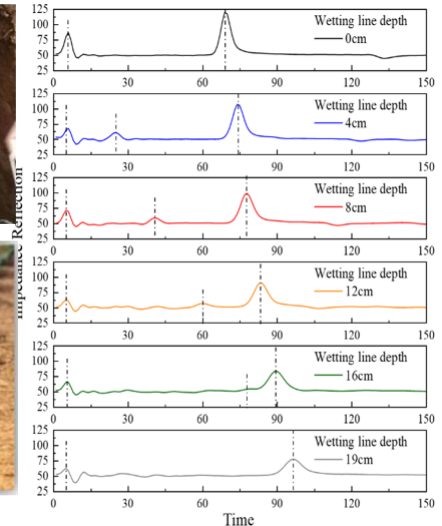Dislodge salt zone
Transition zone
Salt deposition area

Store water drip irrigation

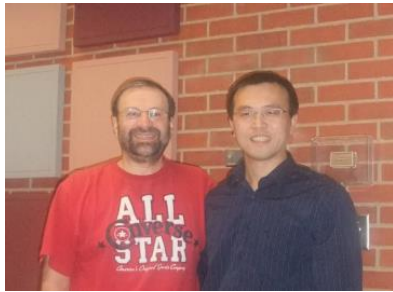Root irrigation

Subsurface drip irrigation

Drip irrigation

（a）Floor soil of shaanxi

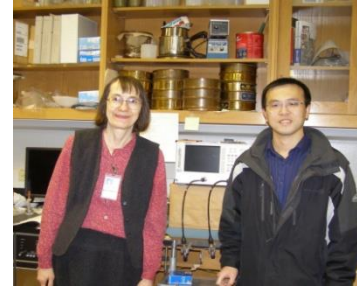➢ 在土壤介电传感器研究方面，团队与世界多个学校和公司建立了合作关系，通过共同协作，不断研发更多的新型土壤传感器。
Through the work of soil dielectric research, we have established cooperative with international famous university and company to make joint efforts for the research and development of new sensors.

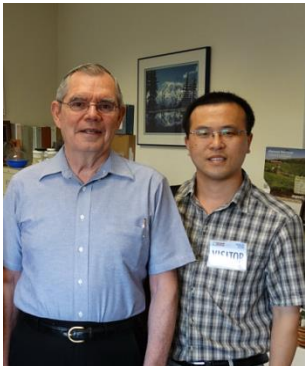**Iowa State University
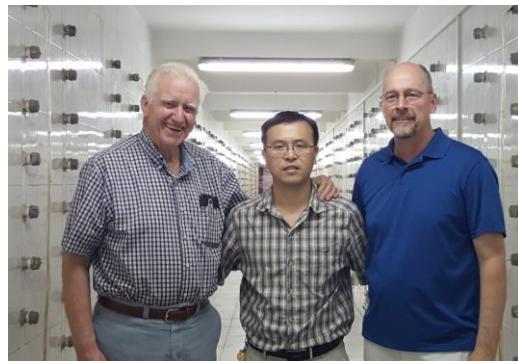Robort Horton**

Washington State University

**USDA, USA,
Sally Logsdon**

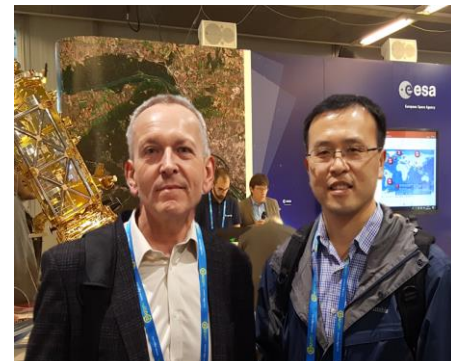**Oklahoma State University
Paul Weckler**

**Meter/Decagon CEO
Gaylon S. Campbell**

**Acclima
Scott Anderson**

**Campbell
Chod**

**Polish Academy of Sciences
Wojciech Skierucha**

HP(Heat pulse) Probe

➤ T-TDR是一种能同时、同测点测量多种土壤参数的多功能传感器。
T-TDR sensor is very powerful and can measure multiple parameters at the same time and in the same place.

T-TDR
传感器功能（The function of sensor）：

土壤含水量(Soil water content)
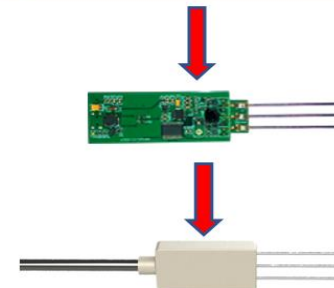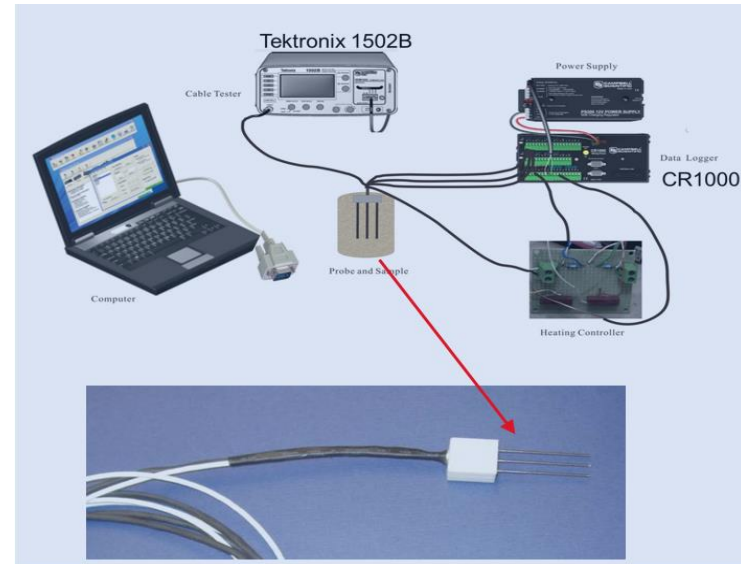
土壤温度(Temperature)

土壤热传导率(Thermal conductivity)

土壤热容量(Heat capacity)

土壤热扩散率(Thermal diffusivity)

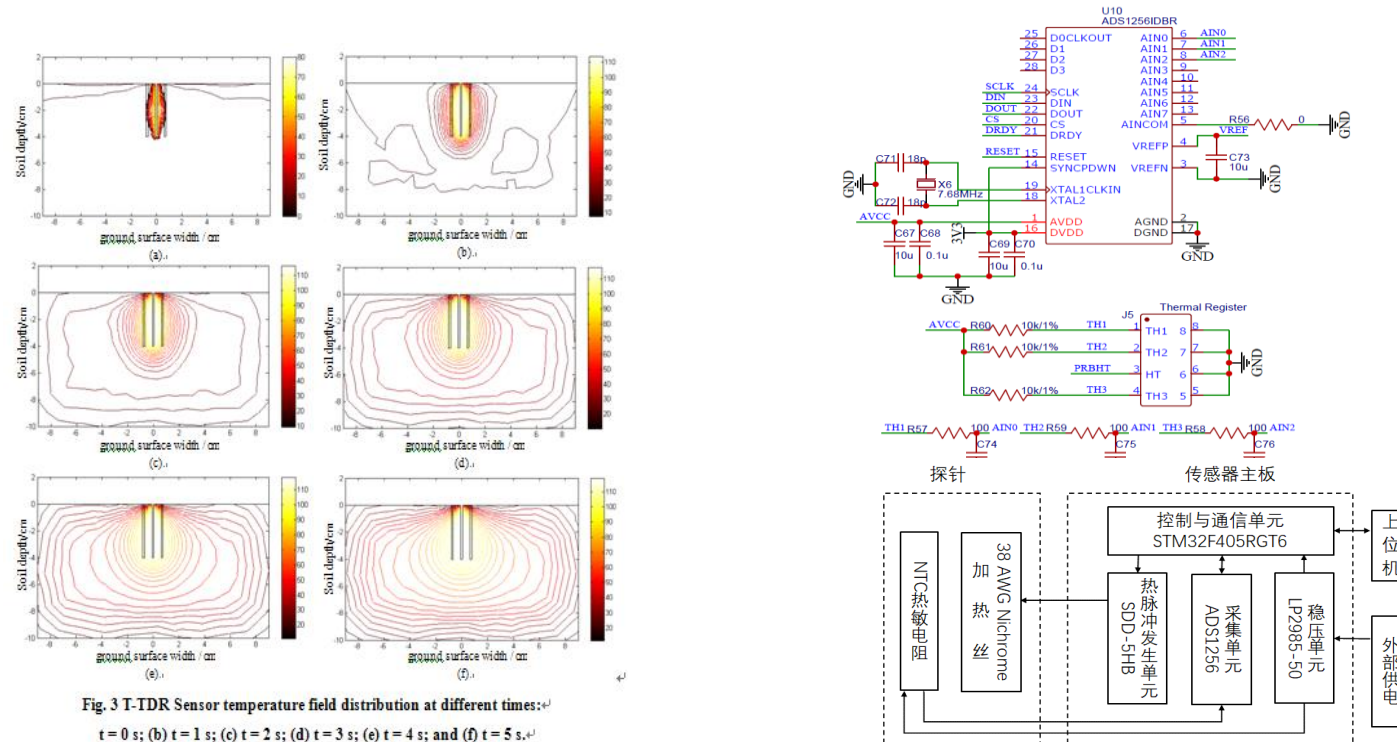土壤水通量(Water flux)

土壤蒸发(Evaporation)

………

HP(Heat pulse) Probe

➢ 通过探针温度场分析和元件、电路优化，研发了新型热脉冲传感器，其测量准确，稳定性好。

The sensor is improved by thermal field analysis of the needle and high-precision component selection. The circuit is optimized. The measurement accuracy and stability of the sensor have been significantly improved.


Fig. 3 T-TDR Sensor temperature field distribution at different times:
t = 0 s; (b) t = 1 s; (c) t = 2 s; (d) t = 3 s; (e) t = 4 s; and (f) t = 5 s.

➢ 其他农田要素如EC、PH、环境温湿度、光照辐射、PM2.5、有机物等传感器的研发可保证农田数据实时采集，实现农田管理的智能化和精准化。
The others key parameters, such as EC, pH, temperature, humidity, light, PM2.5, soil organic are monitored and managed in situ through different sensor research, It can realize the intelligence and precision of farmland planting management.
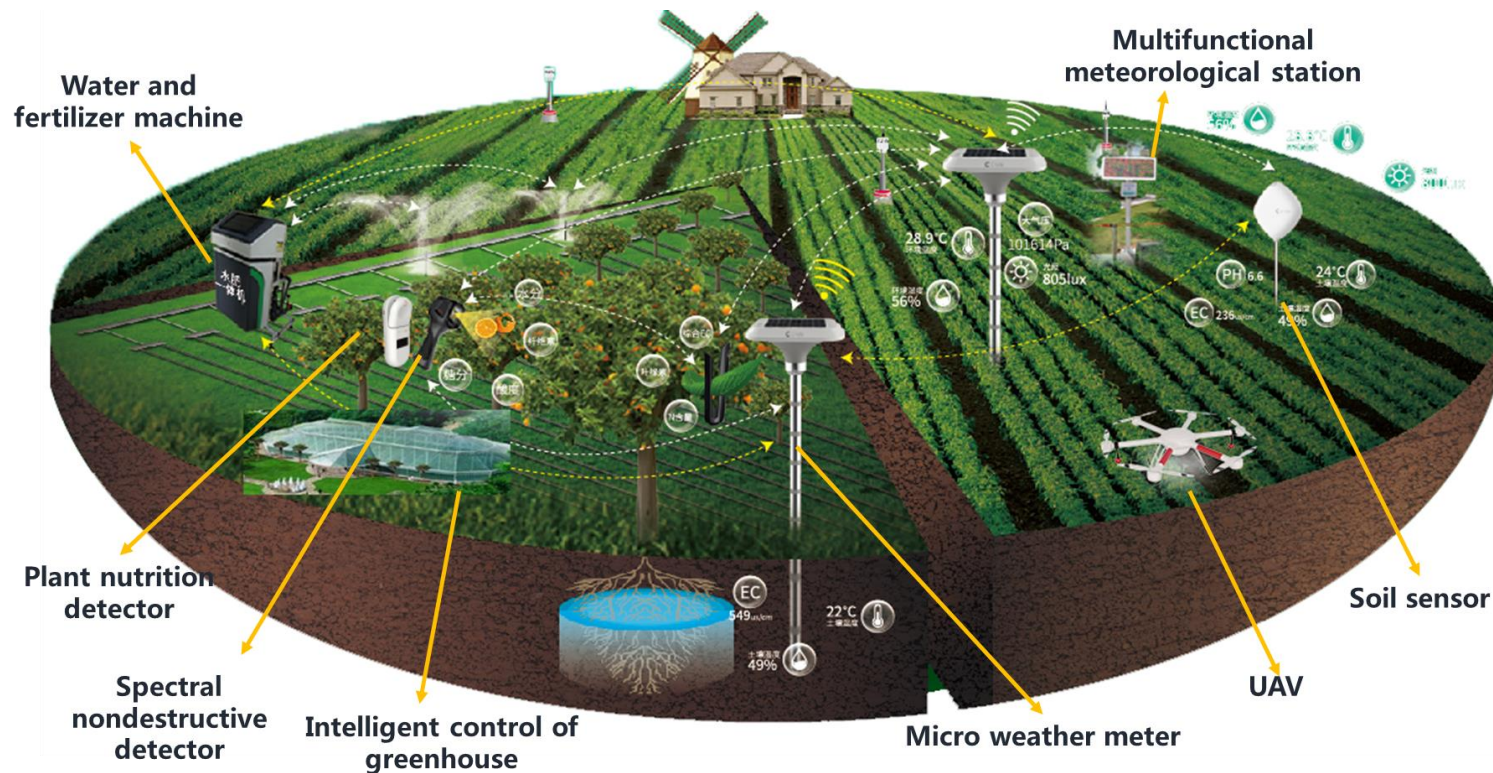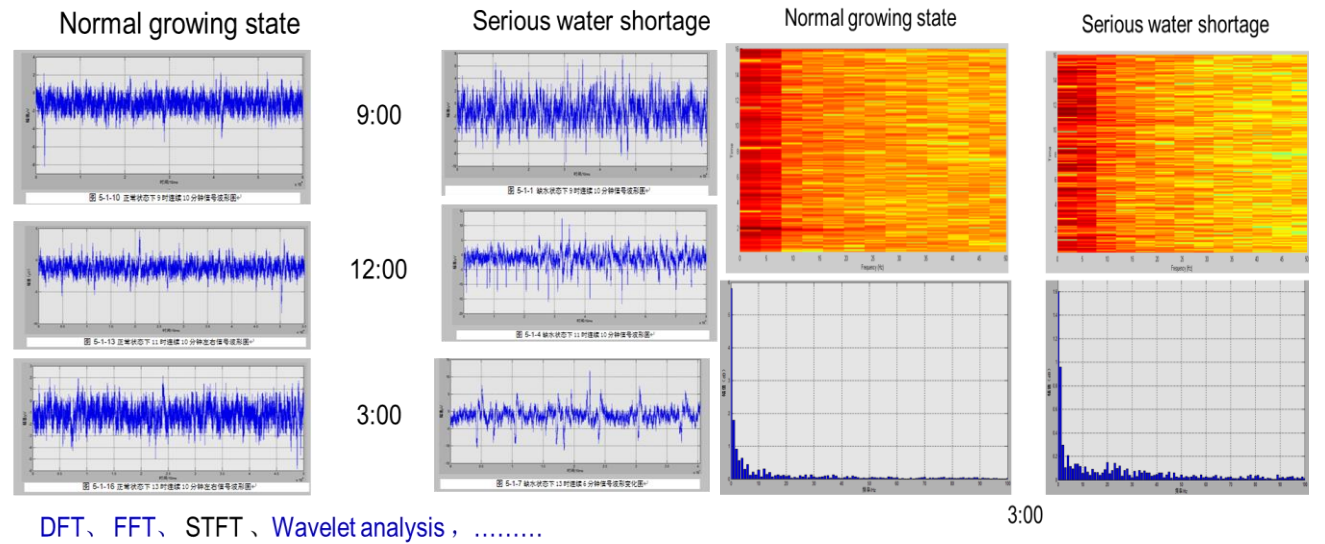
Plant electrical signal

➢ 作物是被控主体，应通过智能传感器直接监测"植物电信号"，读懂植物的"话"。微弱电流监测技术能测量植物生理变化，通过深度学习算法和信号分析，实现植物胁迫的监测。
Plants cannot speak or act, so they need more intelligent sensors to read the plant's words. Weak current (uA/nA) measurement technology can express the physiological changes of plants. Through deep learning and waveform analysis, plants can tell us their own stress mechanism.


test plants

guiding electrode

analog signal

experimental syster

amplification, filtering, sampling

computer

digital signals

produce electrical signal images

store and display data after export

Normal growing state

Serious water shortage

Normal growing state

Serious water shortage

9:00

12:00

3:00

3:00

DFT、 FFT、 STFT 、Wavelet analysis，………

➢ 团队实现了农田信息智能感知、物联网、大数据采集的云平台系统。系统可实现作物灌溉决策云计算、水肥精准智能决策系统、基于机器学习的农田气象（降雨）预测、土壤水分运移、农田精益决策系统等初步开发。

A cloud platform system based on farmland information perception, Internet of Things and big data collection has been built. The system can realize crop irrigation decision-making based on cloud computing, accurate control of water and fertilizer, and farmland weather (rainfall) prediction based on machine learning.
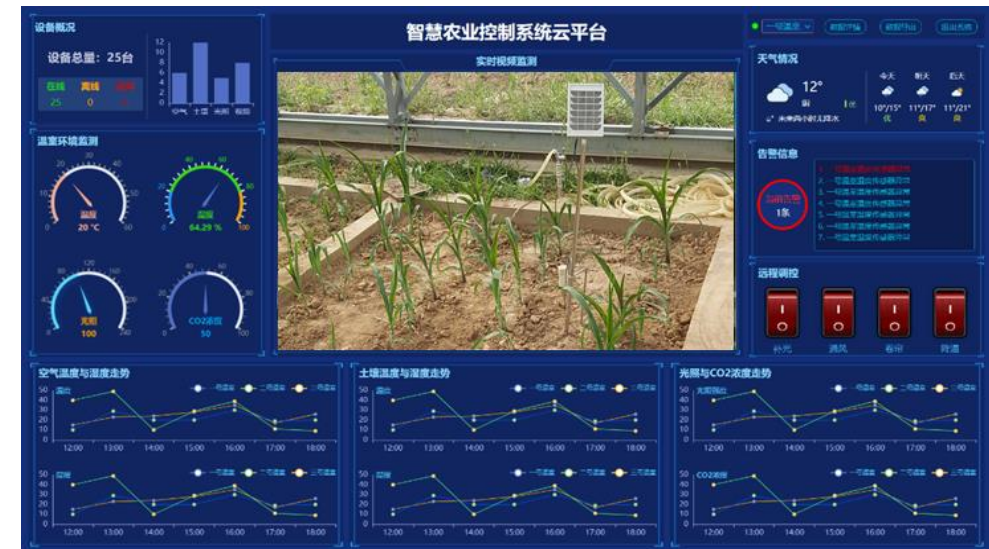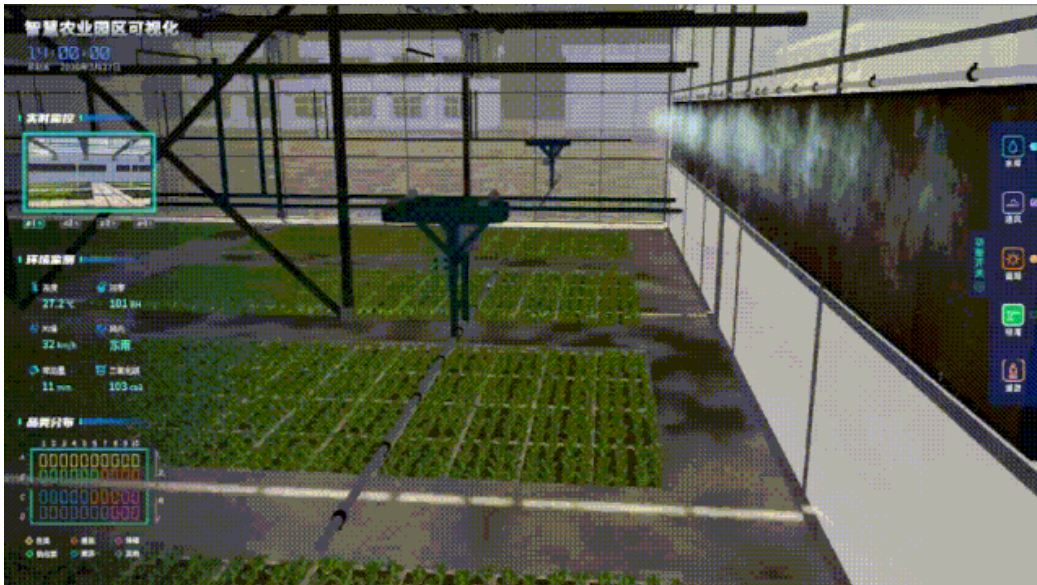
➢ 智能灌溉系统与环境控制系统的的数字孪生平台正在积极研发。通过智能技术的附能，农业灌溉装备将更加智能、操作更加方便，管理更加科学。农业生产效率将进一步提高。The digital twin platform of intelligent irrigation system and environmental control system is being developed. Through the continuous application of intelligent technology, agricultural irrigation equipment will be more intelligent, more convenient to operate, and more scientific in management. Agricultural production efficiency will be further improved.

Thank you!