ENABLING THE SMART AGRICULTURE REVOLUTION

THE FUTURE OF FARMING THROUGH THE IoT PERSPECTIVE

Beecham Research
Market Specialists in M2M/IoT

libelium 10 YEARS
TEN YEARS POWERING THE IoT REVOLUTION

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THE NEEDS OF THE SMART AGRICULTURE COMMUNITY

Farming yields have greatly increased during the 20th century due to new methods and the application of science. This technology revolution has been marked with breakthroughs in nutrition, genetics, informatics, satellite imaging and meteorology, to name a few.

Advances in plant science have increased crop yields while at the same time modern irrigation strategies help farmers make more efficient use of water. However with all of this, costs and the price of end products must not be allowed to increase. As well as foodstuffs, agriculture must meet the demand for forage to feed farm animals and increasingly, the production of biofuels.

> " To keep pace with growth, food production must increase by 70 % by 2050. "

However yields must be increased further, because The Food and Agricultural Organisation of the UN (FAO) has predicted[1] that the global population will reach 8 billion people by 2025 and 9.6 billion people by 2050. In order to keep pace therefore with this growth, food production must increase by 70 percent by 2050. Agriculture consumes 70 percent of the world's fresh water supply; hence water management will go hand in hand with assuring food security.

In addition, a globally rising population needs to be fed in accordance with western lifestyles, set against growing shortages of land, water and energy. All these factors place huge pressures on the farming industry. Hence for governments world-wide, food supply assurance and a water supply of suitable quality have become priority issues to address.

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Technology will play a central role in achieving these imperatives. It is already established in farming with the arrival of mechanised tools as in the milking industry. By combining scientific expertise, soil chemistry, disease management with intelligent sensors and information technology, farmers can increase crop yield and reduce waste. The FAO recommends that all farming sectors should be equipped with innovative tools and techniques, particularly digital technologies.

The agriculture industry is faced with a number of challenges in achieving these imperatives, including:

- The limited availability of arable land
- Global climate change
- The growing scarcity of water
- The price and availability of energy, particularly from fossil fuels
- The impact of urbanisation on rural labour supply.

Another controversial issue is genetic modified food. The US National Academy of Sciences published in May 2016[2] a powerful report that reviewed all published research on the impact of transgenic since it began using three decades ago. The first conclusion is that food from modified organisms are as safe as those produced from conventional crops. And the second reveals that the resistance of GMOs to certain herbicides and insecticides is causing a serious agricultural problem.

[1] Alexandratos, N and Bruinsma, J. World Agriculture Towards 2030-2050. FAO

[2] The National Academy Press. 2016. Genetically Engineered Crops: Experiences and Prospects. http://www.nap.edu/read/23395/chapter/1

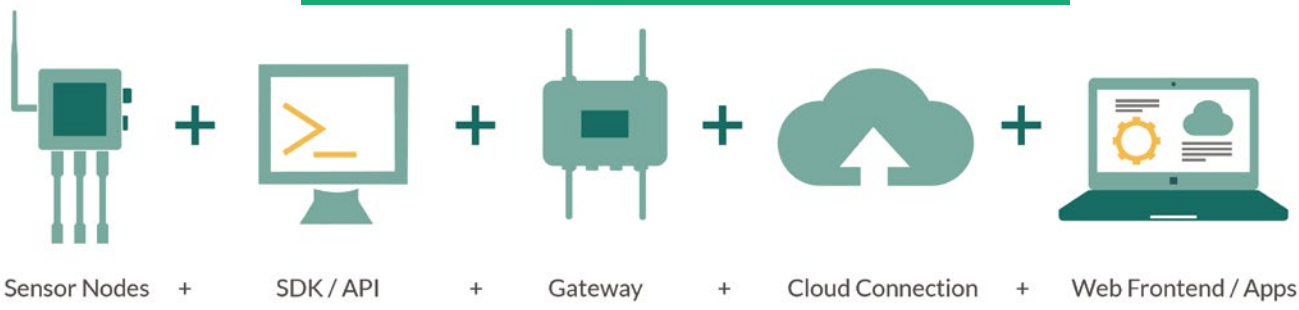
INTRODUCING THE CONCEPT OF SMART AGRICULTURE

> " Special sensors collect data regarding soil & crop behaviour, animal conduct, machine status, storage tank & out-buildings status emanating from remote sites."

Precision agriculture is sometimes known as 'smart farming', an umbrella term for easier comparison with other M2M based implementations such as smart metering, smart cities and so on. Precision agriculture is based on sensor technologies whose use is well established in other industries, for example, telematics for fleet management, environmental monitoring for pollutants, remote health monitoring in patients, buildings management and others. However without food, even the smartest cities cannot exist; for this reason, precision agriculture is getting a lot of attention.

For all M2M implementations, IT systems gather, collate, analyse the data and present it in such a way as to initiate an appropriate response by the end user to the information received. For farmers and growers, depending on the type of farming involved, special sensors collect data regarding soil and crop behaviour, animal conduct, machine status, storage tank and outbuildings status emanating from remote sites. This is forwarded to IT systems for tracking and analytics. The results from the analytics are noted and used to respond to what is happening in the field by taking the most appropriate future decisions and actions.

Figure 1.1 - Value Chain Illustrating Data Collection from Sensor Nodes & Analysis Chain to Web based Decision Support System



Source: Libelium

Whilst experienced farmers have the knowledge to make the best judgements by just walking around their farms, in larger farms in particular this is simply not practicable. Hence a remote 'eye in the field' or 'eye in the barn' makes remote monitoring possible in real time; farmers can detect signs of disease in crops and animals much than they would otherwise become noticeable. In essence, M2M-derived data feeds into a decision support system that allows farmers to see what is happening at a much higher level of granularity than previously possible. The approach of science to the field is a new trend emerging from the new generations of farmers. The tradition is giving way to the modernization so that activities such as planting, irrigation planning, spraying and harvesting can be planned.

The Concept of Continuous Improvement, well known in the manufacturing and service industries, can be usefully applied to precision farming – a constant cycle of improvement is enabled by the addition of new insights, from data collected from farms plus publicly available data from various sources, all of which affect the outcomes of the various farming activities. M2M collected data, well analysed, can afford greater insight into farming activities, leading to process improvements in those activities. Valuable adjunct data can be brought in to add to the analytical process, for example:

- Weather conditions and forecasts
- Scientific crop formation
- Plant and animal diseases and their symptoms
- Rules and regulations that apply to the country where the farm is located

All data collected has value, some of which may prove useful beyond its present use. Other parties will want to make use of that data. These insights can be shared with other interested parties, as for example, the makers of the agricultural equipment used by the farmer, or suppliers of the fertilisers or chemicals applied.

THE APPLICATIONS OF THE SMART AGRICULTURE REVOLUTION

Smart Agriculture differs in its implementation, depending on the type of farming in question. Here, the paper discusses different farming contexts.

Large Field Arable Farming

Precision agriculture has started its adventure in large field arable farming with positioning technologies. Currently, farm vehicles used in these contexts are becoming more sophisticated with state of the art functionality, equipped with GPS, several sensors embedded in different parts of the vehicles, with elaborated data visualisations tools on board, and the ability to transmit data.

Consequently, their capabilities have improved dramatically over the years. Telematics and tracking technologies continuously record location and travel routes to avoid going over the same patch twice, record working times and utilisation of vehicles, as well as their condition in real-time. Farm vehicles differ in design depending on their purpose, e.g. for ploughing, planting, harvesting, applying fertiliser, slurry spreading, to name but a few.

These technological advances are also related to crops; sensors are installed in plots to monitor environmental and soil conditions that could affect health and growing cycle of the harvest. Through these deployments, farmers can know in real-time what is happening in their farms and make decisions in relation to actual facts.

Microclimate strategy in large fields is important as weather conditions can vary from one part of the farm to another (wind hills, more shading, etc.) and these conditions need to be taken into account and planned for. A single approach is not always appropriate for the whole farm, and you need high granularity for better decisions.

> “ Spatially-enabled mobile sensing technologies provide detailed analysis of field conditions. ”

Small to Medium Sized Field Arable Farming

Medium and small sized fields can benefit from connected and intelligent vehicles as described in the previous section. Moreover, they also need sophisticated sensing activities at soil and plant level. Spatially-enabled mobile sensing technologies provide detailed analysis of field conditions such as the humidity in different soil layers, the amount of nutrients in the soil, temperature, rainfall, wind direction and speed.

Precision agriculture follows the crop growth cycle in all its steps from seeding, planting, application of fertilisers and pesticides, through harvesting. Preparation of soils is important to do correctly because of the diversity of soils - there are 10,000 different types of soils in Europe alone. Moreover, a single field may contain many different soil types and it is essential to adapt to each one features.

Farmers and agronomic engineers look also to an important parameter called evapotranspiration to decide when and how much irrigation crops need. Evapotranspiration (ET) is the sum of evaporation and plant transpiration from the land surface to the atmosphere. Evaporation accounts for the movement of water to the air from sources such as the soil, canopy interception and waterbodies. Transpiration accounts for the movement of water within a plant and the subsequent loss of water as vapour through stomata in its leaves.

Livestock and Animal Monitoring in the Field and in Houses

IoT solutions are deployed in order to monitor the location and the health of cows, pigs and poultry in a number of ways. In the case of cows, sensors are placed within the animal and an alert is sent wirelessly to a tag mounted on the cow ear. The data is then sent to the farm management information system, which can also be available on the farmer’s mobile phone or tablet.

There are different applications in this area. Oestrus monitoring allows farmers to know

the precise time when the animal is on heat ready for insemination. A sensor mounted in a collar worn by the animal can detect lameness and other ailments. A rumen monitoring system records acidity levels and temperature within the animal, enabling farmers, vets and nutritionists to achieve optimum conditions which in turn lead to healthier cows.

“ Greenhouses need frequent monitoring in order to ensure that any failure is detected immediately and a range of conditions are constantly under control.”

For pigs, in-vivo RFID and temperature tags gather data on parameters such as temperature, drinking water flow, animal feed rate and humidity, all of which affect animal health. For poultry farming, the intensive and crowded conditions in sheds can affect animal health and welfare. Remote monitoring can not only detect changes in feeding behaviour and signs of disease, but can also be used to model and predict the outcome of changing conditions and check responses to vaccination. For horses, a sensor-carrying belt attached to the animal may detect unusual behaviour which may be a sign of disease.

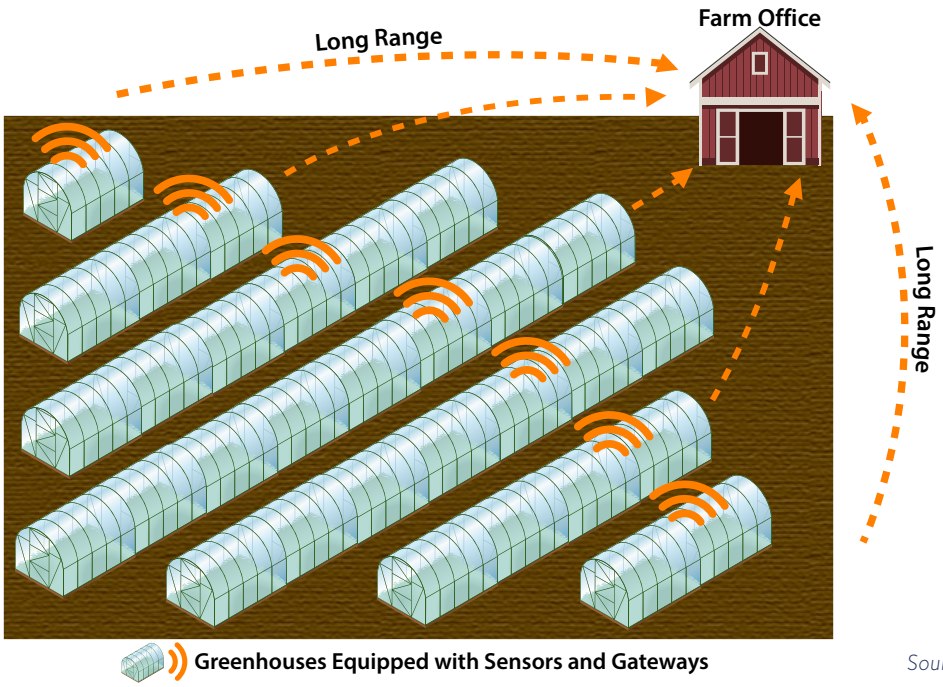
In-door Horticulture – Cultivation of High Value Fruit, Flowers and Vegetables

Greenhouses need frequent monitoring in order to ensure that any failure is detected immediately and a range of conditions are constantly under control. Indicators such as solar radiation, temperature, humidity and air quality, presence of mildew or pests have always to be within the necessary ranges. Continuous sensing and communication of data sensed with the farm management system are essential in those cases.

Of particular concern in this type of cultivation are fungal diseases such as oidium and mildew. They are part of a group of phytopathogenic fungi that cause diseases in plants and both have similar symptoms. In fact, mildew fungi is causing losses of up to 80% in the Spanish vineyard zone of Jerez (Andalucía) in 2016. Rainfall, fog, heat and the absence of dry wind are all conditions that have exacerbated this problem.

These fungi are always present in leaves, but only develop when particular conditions are allowed to develop (usually high heat, humidity and little wind). IoT allows the prediction, with mathematical models, of when diseases like these are likely to strike, allowing farmers the opportunity to pro-actively apply phyto-sanitary products before an outbreak. To control the potential over-use of phyto-sanitaries the European Union is starting to enforce the use of data to justify applications.

Figure 1.2 - Smart Agriculture Connectivity for Greenhouse Grown Plants



Source: Beecham Research

The farming contexts described above can coexist in large companies empowering the concept of smart farming as an intelligent and connected space. In the same farm, we can have small-sized field farming solutions, precision livestock monitoring solutions and in-door horticulture solutions. The farm management information system becomes the unified brain of all the smart applications in the farm.

The Benefits and the Return on Investment in Smart Farming Applications

The current deployments of smart farming applications are revealing several benefits for farming activities such as:

- Understanding the factors that govern crop growth and yields, hence improving yields and reducing crop losses through disease or adverse weather.
- Saving costs by limiting the use of fertilisers, pesticides and other consumables needed for production, by applying only when necessary. Some national and international regulations limit the use of fertilizers so farmers have to know their waste to schedule the usage[3].
- Optimising the use of water to reduce waste in order to save resources and therefore costs which affect an already low-margin business like farming.
- Offering a better quality of life and reducing hard labour to attract young generations of farmers. Re-population in rural areas needs human resources dedicated to agricultural activity, to that end, it is vital that technological investment allows the best quality of life possible. Reducing time and physical labour in the care of farms.
- Precise scheduling of harvesting. To obtain the greatest benefits from crops, farmers need to know when the plot is ready to be harvested. In this way, farmers can plan for the each yield.

" Farm owners and managers are attracted by the amount of measurements that sensors can take and how capable predictive and management systems are."

Post-harvest and similar techniques could be helpful in the food supply industry, optimising processing, reducing costs and limiting spoilage as product makes its way to the consumer. The Return on Investment (RoI) in precision farming systems can be quantified in terms of actual numbers. In fact, the market starts to show case studies in which the RoI is real. Section 3 of this paper will show that.

The qualitative benefits for farmers are multiple, including savings of not only time and money, but also savings related to the environment. Using sensor technology means that chemical spraying must occur only when absolutely necessary. Other applications may alert farmers in case of dry soil and other conditions that may require attention or human intervention. In other words, everything about the use of data and analytical systems can be used to inform decision making, in order to make better use of the farmer's land and resources.

Farmers may ask, what financial value can be placed on a better understanding of how crops behave in the field? They require hard evidence of actual RoI before providing cash and time to implement these new technologies in their businesses. Farm owners and managers are attracted by the amount of measurements that sensors can take and how capable predictive and management systems are.

Small grants are also available from public sources such as European Union projects, with input from research and academic institutions, which aim to provide proof of concept; this understanding affords the confidence needed to unlock further funding. In 2015, the UK government announced plans to invest £10 million in a new Centre for Agricultural Informatics, Metrics and Success.[4]

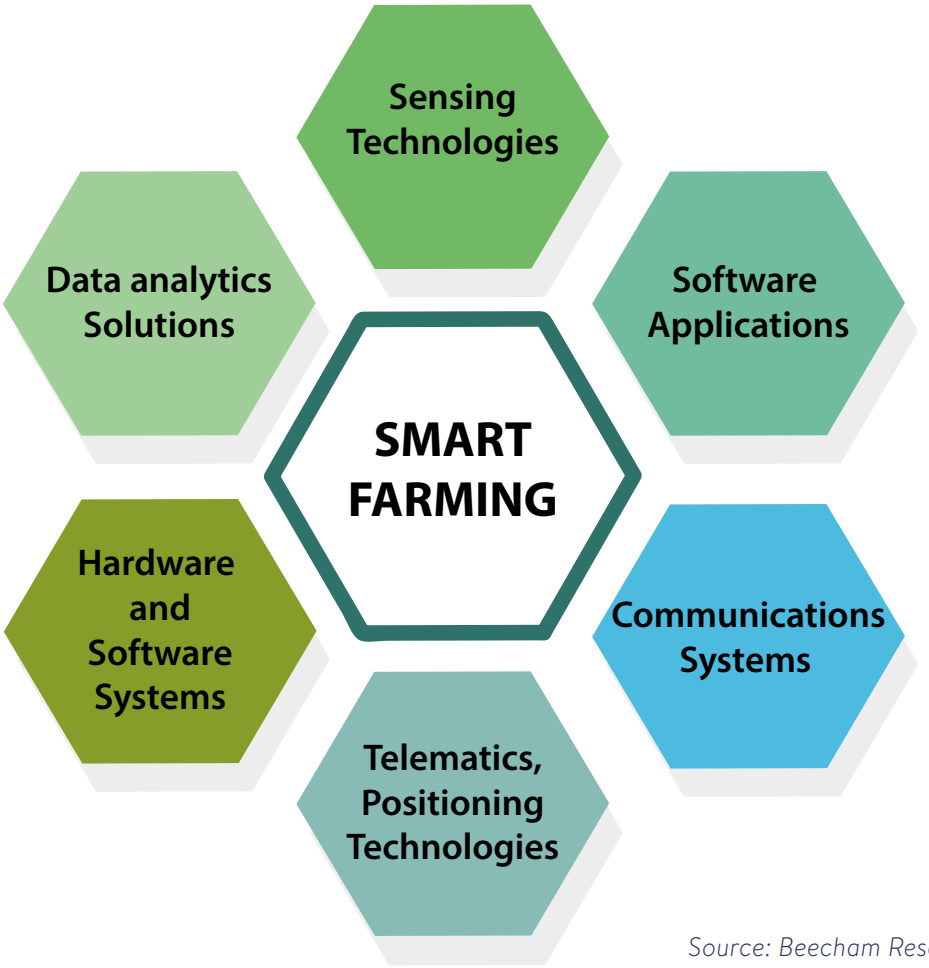
[3] Spanish and European Regulations for fertilizing products - http://www.magrama.gob.es/es/agricultura/legislacion/Legislacion-productos-fertilizantes.aspx

[4] Centre for Agricultural Innovation - https://www.gov.uk/government/publications/centres-for-agricultural-innovation/centres-for-agricultural-innovation

OVERVIEW OF SMART AGRICULTURE TECHNOLOGIES

The set of technologies involved in the design and deployment of smart agriculture solutions is very diverse and multi-disciplinary. Figure 2.1 shows that set.

Figure 2.1 - Overview of Smart Agriculture Technologies



Source: Beecham Research

> " Sensing technologies underlie all smart argiculture activities. For all imaginable application types, data is the fundamental building block. "

This diversity implies also that smart agriculture solutions involve different market players such as communication service providers, agriculture vehicle and equipment manufacturers, software developers, data analytics and sensing technology providers.

The paper will briefly discuss a subset of the smart farming technologies illustrated in Figure 2.1. These technologies together contribute to four fundamental steps in smart agriculture projects; data sensing, data acquisition, data transmission and data processing.

Sensing Technologies and Data Acquisition

Sensing technologies underlie all smart agriculture activities. For all imaginable application types, data is the fundamental building block, whether the data comes from a soil sample or a satellite correction signal.

For example, data points collected can highlight both spatial and temporal variability within a field. Many factors can contribute to this variability; understanding the effect each factor has can only be measured and managed using statistical analysis of the data.

Sensors technologies have a variety of application, including for soil quality sensing, animal sensing, tank and silo level monitoring. The layout of sensors and devices in the field is tailored to the type of data needed. Informed choices have to be made as to:

- Where the sensors and gateway are located and how many are needed at the site
- How frequently data is collected
- The size of the data - payload
- Whether a power supply is needed (battery, solar power).

Modes of Connectivity

In all the agricultural applications where remote monitoring is used, the data sensed and gathered by sensors are then sent to the farm management information system through a variety of communication modes. Wireless communications – from 2G to 4G – is the most preferable mode. However, the availability and reliability of cellular connectivity in rural environments can be very weak. Therefore, data communications via satellite can be an option. However, the cost of satellite can be prohibitive, particularly for small and medium-sized enterprises. In addition to that, certain farming applications require the need of long-battery life devices working on low-data rate. In that scenario, even 2G connectivity can be expensive when available. The new range of LPWAN (Low Power Wide Area Network) is seen as a potential substitution of cellular connectivity in long battery life, long range connectivity scenarios and affordable rates (between 2 and 14 Euros per year). Crop and pasture management are two applications that are currently served via LPWAN networks, but, there are many others in farming contexts that can be served via LPWAN[5].

> “ The new range of LPWAN (Low Power Wide Area Network) is seen as a potential substitution of cellular connectivity in low-data rate, long battery life, and long range connectivity scenarios.”

In addition to connectivity at WAN level, several medium and short-range forms of connectivity are used in mesh-networks. The typical example is a mesh-network of sensors gathering data and then communicate that data to the gateway which is located in the same physical space. The gateway will then communicate with the farm management system via a WAN network. The technologies used for mesh-networks are very diverse from Bluetooth connectivity to peer-to-peer wireless systems.

Farm Management Information System

The data sensed and acquired is then sent to the back office system, often known as Farm Management Information System (FMIS). The FMIS brings together data from farming activity connected to each other, also to a raft of historical data such as weather events, climate, economics, product information and specifications, machine settings etc. The FMIS will analyse all this together in order to take the correct decision. This is what the Internet of Things is all about, connecting systems so as to allow an integrated, multidimensional view of farming activities, enabling deeper understanding on how the whole ecosystem works. Precision farming would become ‘decision farming’.

> “ Precision farming would become ‘decision farming’.”

[5]Beecham Research. 2016. An Introduction to LPWA Public Service Categories: Matching Services to IoT Applications. *http://www.beechamresearch.com/download.aspx?id=1049*

It is important to note that technology alone is not enough to derive the best benefits from precision farming. The farm management information system, which analyses the data sent, must be custom designed for the application. The software engineers need input from people with specialist knowledge about the product in question, veterinary surgeons, plant scientists, pest scientists and other agriculture specialists is vital to ensure that the technology is applied in the optimal way, systems are developed to collect and analyse the right data for purpose, and the results understood.

> **" The farm management information system, which analyses the data sent, must be custom designed for the application."**

In the marketplace there are several players providing elements of the process described. There are then others able to offer elements for all the steps. Libelium belongs to the latter group. The remaining part of this chapter will introduce Libelium and then their offer for smart agriculture.

INTRODUCING LIBELIUM

Libelium designs and manufacturers hardware for wireless sensor networks. It also provides software solution development kits that enable system integrators and solution providers to deliver IoT solutions with minimal time to market. Libelium allows the implementation of wireless networks for a wide range of IoT systems including smart parking systems, urban monitoring, waste management, environment, security & emergencies and smart farming applications among others.

Waspmote, one of the key products of Libelium, is an advanced mote for Wireless Sensor Networks. It operates in ultra low power and is able to connect any sensor (more than 110 different ones), using any wireless technology sending data to any Cloud platform.

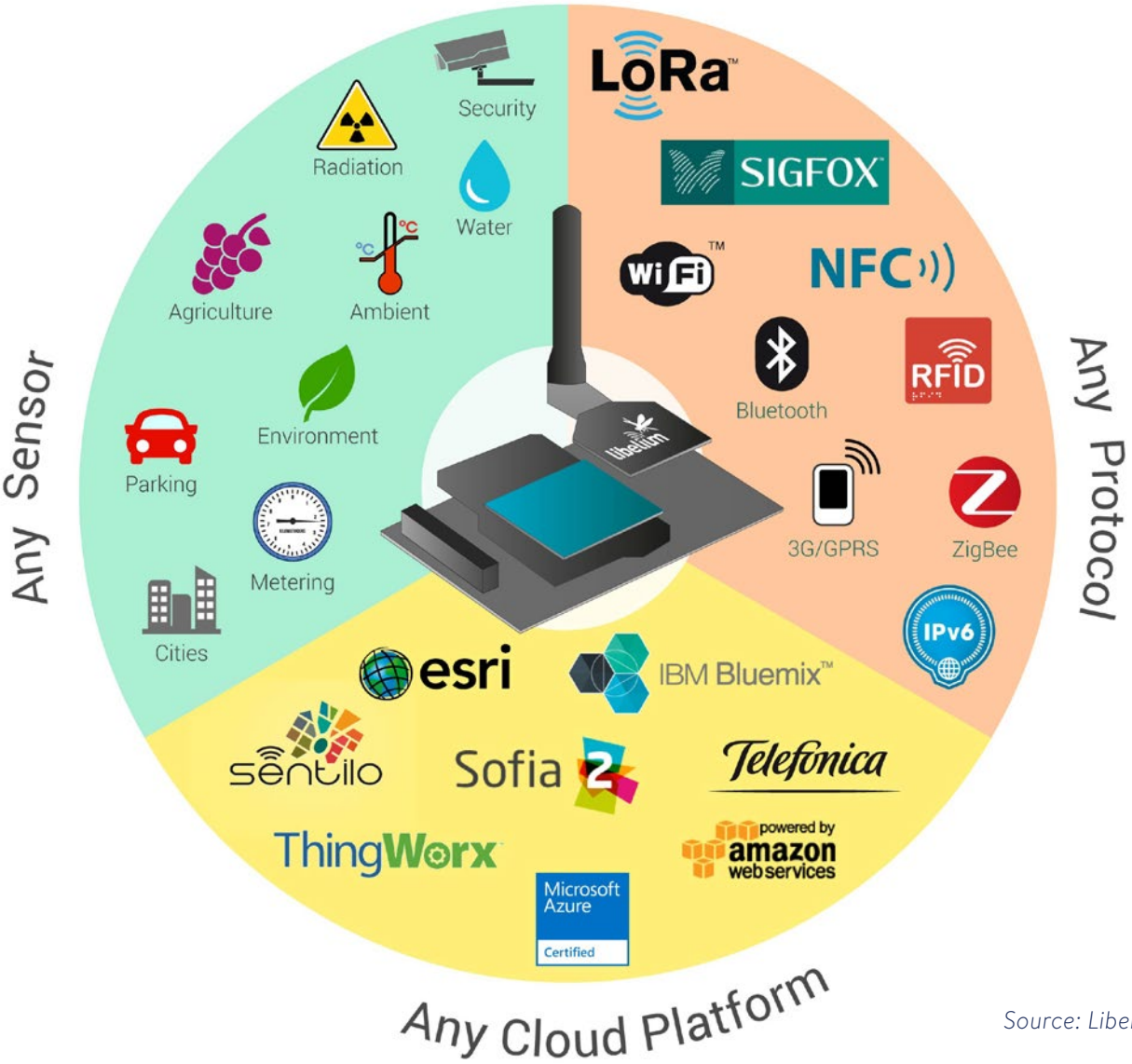
Waspmote's Plug & Sense!, shown in figure 2.2, is the encapsulated line of Waspmote. It is designed to allow users to easily deploy scalable wireless sensor networks with minimal maintenance costs. It provides a robust waterproof enclosure with specific external sockets to connect the sensors, such that new sensors nodes can be easily attached by screwing them into the bottom sockets.

Figure 2.2 - Waspmote Plug & Sense!

Source: Libelium

The interoperability of Libelium technology enables connections with any type of device, any type of connectivity, and any type of cloud-based platform as shown in figure 2.3. Thanks to the horizontality of the Waspmote platform, an endless number of projects can be developed with Libelium technology.

Figure 2.3 - Libelium Interoperability



Source: Libelium

LIBELIUM TECHNOLOGIES FOR SMART AGRICULTURE

Considering the steps of data sensing, data acquisition, data communication and data processing for smart farming applications, here the whitepaper discusses how Libelium technologies provide all the elements for smart agriculture implementations. Libelium's Waspmote provides everything that is needed to collect, forward and store data collected from remote sensors.

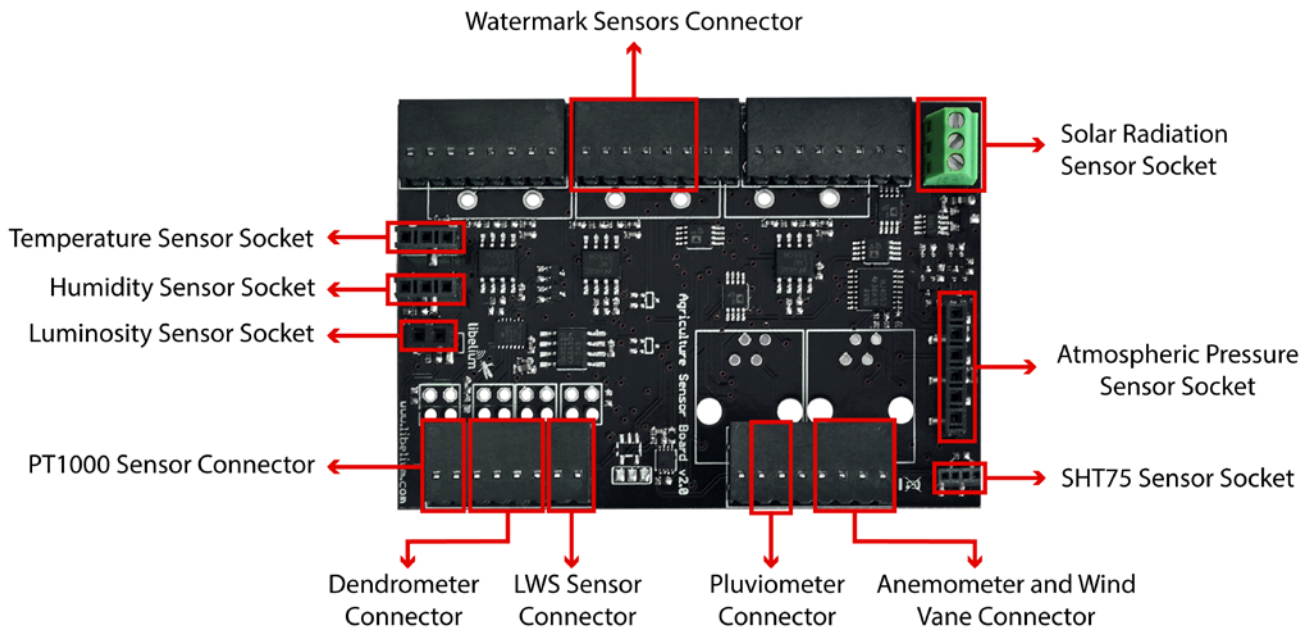
> " Libelium's Waspmote provides everything that is needed to collect, forward and store data collected from remote sensors. "

Data Collection

The data collection phase consist of sensors, devices and gateways. Sensors differ in type and amount of data they are collecting, intervals of collection, and power source – e.g. battery or solar. Libelium's Waspmote Agriculture 2.0 Board (see Figure 2.4) collects multiple environmental parameters for

a range of agricultural applications, from analysing plant growth to weather observation. For this reason, sensors are configured to collect data for various applications. Types of data collected include air and soil temperature and humidity, luminosity, solar visible radiation, wind speed and direction, rainfall, atmospheric pressure, leaf wetness and fruit or trunk diameter measurement (dendrometer).

2.4 - Waspmote Agriculture 2.0 Board



Source: Libelium

The main applications for Waspmote Plug & Sense! Smart Agriculture are precision agriculture, irrigation systems and greenhouses. Figure 2.5 shows a Waspmote mounted on a post, measuring airborne parameters. Libelium Waspmote Plug & Sense! allows to control the amount of sugar in grapes to enhance wine quality, as well as to control micro-climate conditions to maximize the production in greenhouses.

The three levels of depth of the soil moisture sensor are helpful to reduce waste of water by selective irrigation in dry zones. On the other hand, controlling humidity and temperature levels in hay or straw can prevent fungus and other microbial contaminants.

Figure 2.5 - Waspmote Powered by Solar Panel

Source: Libelium

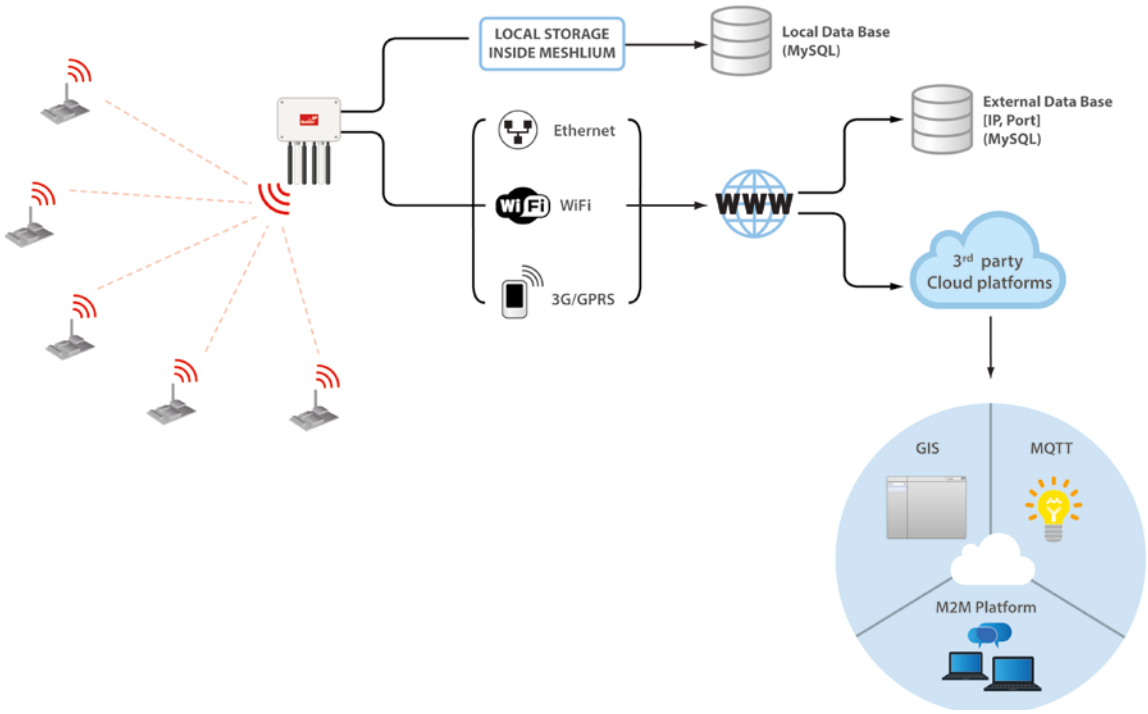
Libelium has also developed a Plug & Sense! application model for Smart Water which is suitable for potable water monitoring, chemical leakage detection in rivers, fish tank and aquaculture monitoring, remote measurement of swimming pools and spas and levels of seawater pollution. In Precision Farming is applied specially to control and monitor irrigation systems.

Sensor probes can be easily attached by screwing them into the bottom sockets of the platform. Developers can add new sensing capabilities to existing networks, to cater for changes in requirements; likewise sensor probes may be easily replaced in order to ensure the lowest maintenance cost overall of the sensor network. Libelium's preconfigured sensor devices make deployment easier, so as to also ensure minimum maintenance costs.

Data Communications, storage and processing

The Libelium architecture is network agnostic. In fact, Waspmote supports the following radio interfaces: XBee-ZigBee, LoRaWAN, Sigfox, WiFi, Bluetooth Low Energy, GPRS and all cellular connectivity from 2G to 4G. Therefore, the distances supported range from 100 metres (Bluetooth) to 100 km (cellular connectivity). Figure 2.6 shows a schematic of the total Libelium connectivity architecture, from data collection to forwarding to storage to the Cloud and M2M analytical platform.

Figure 2.6 - Libelium Meshlium Connectivity Options



Source: Libelium

Meshlium is a multi-protocol router which works as the Gateway of the Waspmote Sensor Networks. It can contain 6 different radio interfaces: WiFi 2.4GHz, WiFi 5GHz, 3G/GPRS, Bluetooth, XBee and LoRaWAN. As well as this Meshlium can also integrate a GPS module for mobile and vehicular applications and be solar and battery powered.

> " Libelium has partnered with several cloud software solution providers to offer ready interoperability with systems such as AWS, Microsoft Azure, ESRI, IBM Bluemix, Indra, ThingWorx & others."

A ready-to-be-deployed Smart Agriculture Solution

Libelium launched on March 2016 The IoT Marketplace[6], a one-stop click-and-buy-store, offering complete Internet of Things solutions ready to deploy smart applications including hardware, software and cloud connection. Libelium has partnered with several cloud software solution providers to offer ready interoperability with systems such as AWS, Microsoft Azure, ESRI, IBM Bluemix, Indra, ThingWorx and others. The kits includs a number of components, but also the necessary documentation and Libelium technical support in order to enable companies to develop their own applications.

One of the aims of the company is to facilitate the access to develop new IoT solutions for Agriculture market with an out-of-the-box kit that enables to monitor environmental parameters in farming, vineyards, greenhouses or golf courses. Developers and System Integrators use this kit to make Proof of Concepts to test business cases before going for massive deployments. Libelium Smart Agriculture Vertical Kit allows to control different parameters such as soil moisture, temperature, humidity, leaf wetness or atmospheric pressure.

[6] The IoT Marketplace of Libelium. *https://www.the-iot-marketplace.com/*

OVERVIEW OF THE LIBELIUM SMART AGRICULTURE PROJECTS

Libelium is involved in a very wide range of IoT projects, including all types of agriculture in many countries. In all of these, Libelium's Waspmote Plug & Sense Smart Agriculture is deployed in different configurations, in order to collect data appropriate to the application. Libelium's Meshlium serves as a gateway to store and forward the data to the cloud.

Here we will discuss examples of horticulture and one example of water management. Water management is an important adjunct to farming, which also ties in with environmental management which is becoming increasingly important in areas adjacent to farmland.

Figure 3.1 - Some Examples of Libelium Smart Agriculture Projects

NAME & TYPE OF PROJECT	PARTNERS INVOLVED	DATA COLLECTION	VISUALISATION MECHANISM	RETURN ON INVESTMENT
VINEYARD HEALTH MONITORING Switzerland	Dolphin Engineering with University and government funding input from scientific research institutes, engineers, vintners, disease experts	Sensors from Waspmote Plug & Sense! Smart Agriculture monitor air temperature, humidity, leaf wetness and rainfall	**PreDiVine** dashboard displays messages with predicted dates of insect pest activities; this allows the growers to make ready and apply insecticides precisely when needed	Improved grape quality, management, lower costs; advice on just-in-time intervention; extend system to other areas
VINEYARD HEALTH MONITORING Slovenia	Elmitel with help from European private and public start-up accelerators	Sensors from Waspmote Plug & Sense! Smart Agriculture that collect environmental data including temperature and soil humidity	Elmitel's eViti application combines Elmitel Sensing and Libelium technology for a complete Cloud-based solution for managing vineyards.	Growers are more confident as to the best time for spraying; as a result, spraying has been reduced by around 20 percent from the previous season
OLIVE TREE MONITORING Italy	Team Dev working with Assoprol Umbria, a consortium of Italian olive producers	Through Waspmote Plug & Sense! Smart Agriculture specific weather conditions in each plot such as temperature, humidity, rainfall, atmospheric pressure, wind direction and speed, soil moisture and leaf wetness were measured	Waspmote Plug & Sense! Sensor Platform is connected by Meshlium to a cloud service of ArcGIS Online, an ESRI geographic platform, that collects all data and geolocates them in maps. Software creates the model of fly diffusion based on weather conditions	Better control of olive fruit fly pest through understanding of growing and environmental conditions; technology investment recovered in the course of one year
TOBACCO PLANTS MONITORING Italy	TeamDev in partnership with farmer association	Sensors from Waspmote Plug & Sense! Smart Agriculture collect key parameters including ambient temperature, humidity, rainfall, atmospheric pressure, wind direction, wind speed, soil moisture or leaf wetness	Waspmote Plug & Sense! Sensor Platform is connected by Meshlium to a cloud service of ArcGIS online, an ESRI geographic platform, that collects all data and geolocates them in maps. All data converge in a software for mananaging tobacco's crops which is part of AGRICOLUS suite	Project provided guidance as to how to adapt conditions for growing tobacco in Europe, as well as growing to comply with EU regulations to reduce toxicity to smokers

NAME & TYPE OF PROJECT	PARTNERS INVOLVED	DATA COLLECTION	VISUALISATION MECHANISM	RETURN ON INVESTMENT
COCOA PLANTATION MONITORING Indonesia	Singapore-based solution provider in conjunction with various researchers and scientists located remotely. The project was part of Indonesia's Sustainable Cocoa Production Program	Temperature, humidity, photo-synthetically active radiation (PAR) and soil water potential were monitored through Waspmote Plug & Sense! Smart Agriculture	Because Internet connectivity in the rural site was unreliable, the collected data were sent to the Cloud for off-site researchers and collaborators to visualise and analyse the data from the on-going experiments	Project showed multiple benefits including such as reducing visits to remote site, developing pest resistant cocoa, rehabilitation of old trees and counteracted deforestation
STRAWBERRY PLANT MONITORING Italy	Famosa, specialist in crop management, worked with farmers growing strawberries in greenhouses	Sensors from Waspmote Plug & Sense! Smart Agriculture collect temperature and soil water content	The Web service portal esiFarm is the solution that combined collection and monitoring of parameters; both were connected via wireless system	Some of the benefits were losses reductions and better fruit quality; savings of money and energy; reducing water daily supply up to the 30% after planting and around the 15% during harvesting; more rapid time to market and constant production made possible stable pricing of the fruit
ENVIRONMENTAL IMPACT IN WASTEWATER IRRIGATION AREA Australia	AJ Bush Meat Manufacturer commissioned Pacific Environment to provide sensor network in a wastewater irrigation area	Soil moisture was measured through Waspmote Plug&Sense! Smart Agriculture and electrical conductivity, temperature and dissolved oxygen through Waspmote Plug & Sense! Smart Water	EnviroSuite software platform comprising monitoring, forecasting and reporting tools converted data into information as to what was happening in the soil and waterways	The real time system enabled effective management of operations and adherence to compliance processes The investment was recovered in 18 months, through reduced grab monitoring, improved labour efficiencies and laboratory costs and waiting time

ILLUSTRATING LIBELIUM IMPACT ON AGRICULTURE - CASES OF EXCELLENCE IN SMART AGRICULTURE

> " Because of their high value, losses are proportionately high, and likewise savings from reduced spoilage are also high. "

Seven case studies will be illustrated in this section. Six of them describe applications for monitoring high value crops. Farms and greenhouses are generally small compared with large arable fields. Because of their high value, losses are proportionately high, and likewise savings from reduced spoilage are also high. The last case study will look at the need of monitoring wastewater irrigation system to measure the quality of water.

MONITORING VINEYARD HEALTH

Background and Aims

In the vineyard, diseases and pests adversely affect wine grape production and cause major economic losses annually. Whilst traditional treatments are available, these incur additional costs for growers and are largely inefficient.

Dolphin Engineering is a young startup company hosted at the Incubator of the University of Lugano in Switzerland, with the help of some funding from the Swiss government. It focuses on monitoring the micro-climate conditions of crops in order to predict plant diseases.

Implementation Details

Dolphin Engineering's PreDiVine decision support system (DSS) is designed to predict the evolution of some of the most serious diseases, and also suggest "just-in-time" and targeted treatments needed to keep vineyards healthy and profitable. The system uses Libelium's Waspmote Plug & Sense! Smart Agriculture to collect the data which is an indicative of the micro-climate conditions it monitors, e.g. air temperature, humidity, leaf wetness and rainfall. PreDiVine's viewable dashboard displays messages with predicted dates of insect pest activities; this allows the growers to make ready and apply insecticides precisely when they are needed.

The system is now being deployed elsewhere in Switzerland. Dolphin Systems has integrated risk predictions for other vineyard diseases like downy - and powdery mildew into the DSS.

Results and Lessons Learned

Just like manufacturing industry, when used as a decision support system PreDiVine makes possible the continuous improvement of vineyard management policies and practices. The system is dynamic, learning from the outcomes of actual conditions and in-field activities and observations.

Further, because the PreDiVine system combines scientific research with vineyard management, the start-up has established relationships with renowned research institutions and universities in Italy and France, fostering collaboration and knowledge sharing.

Elsewhere the company has found that wineries were eager to be involved in a project where they would have ongoing access to environmental data, and therefore be able to make more informed decisions.

> " Connecting Libelium sensors to Elmitel's IoT platform on its cloud infrastructure took only a few days."

VINEYARD MONITORING IN SLOVENIA

Background

Elmitel is a software company based in Slovenia. Founded in 1994, it specialises in the set-up, planning and deployment of telecommunications and electrical networks. The company is composed of young engineers who are also agronomists, sommeliers and wine growers, offering multidisciplinary skills.

Initiation of development of the Libelium Vineyard Management Software

The company sought some early growers who were interested in the technology and jointly set up the pilots with them. As regards the business case, Elmitel had previous experience with business/start-up development. It has also been involved with European private and public start-up accelerators, which provided additional mentoring and coaching on business development.

Development of the solution

Elmitel was already familiar with Libelium's technology; it had discovered Libelium when researching the IoT marketplace and had begun working with Waspmotes as a technology platform as part of its R&D activities, whilst researching the opportunities afforded by IoT to technology companies like themselves.

Hence connecting Libelium sensors to Elmitel's IoT platform on its Cloud infrastructure took only a few days. Whilst the initial development began at full pace in December 2014, the company is still progressing in its development of its vineyard management software.

Installation details
eVineyard combines Elmitel Sensing and Libelium technology for a complete Cloud-based solution for managing vineyards. Elmitel provides the entire package to the vineyard owners.

Installing the Waspmote nodes took only half an hour per node, to dig a hole in the soil and fix the node. Initially customers consisted of small wineries, but larger producers are also using the solution in a small area.

Customer benefits
Growers are more confident as to the best time for spraying; as a result, spraying has been reduced by around 20 percent the previous season. The company has also found that wineries are eager to be involved in projects where they would have ongoing access to environmental data, and therefore be able to make more informed decisions.

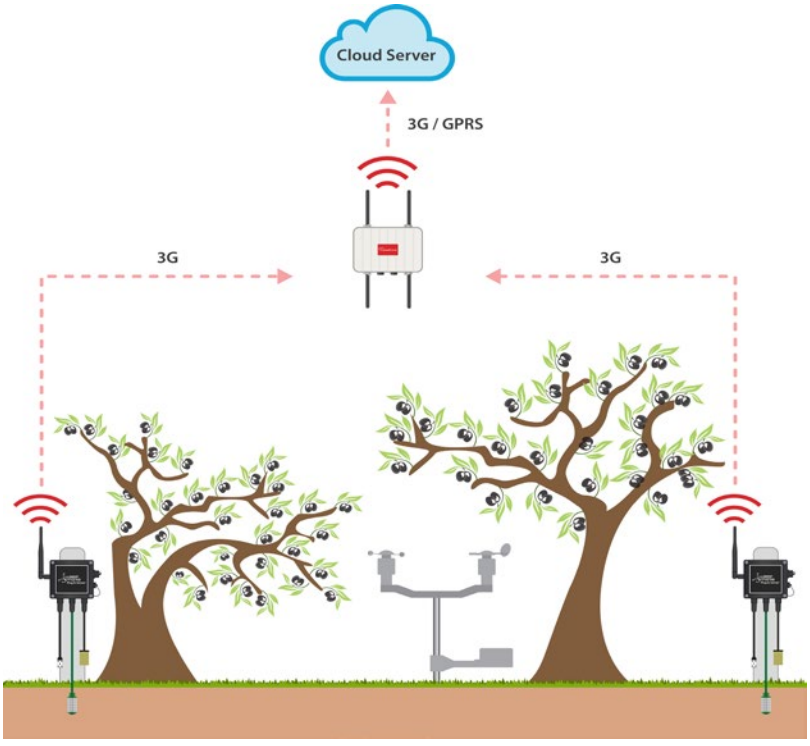
Elmitel benefits
Elmitel's vineyard management software in combination with Libelium's hardware is now installed outside of Slovenia. The solution is being accelerated by EU accelerator, where it has become one of the top ten among roughly 300 initial projects.

MONITORING OLIVE GROVE

Background and aims
Olive producers are an essential part of the agricultural sector in southern Europe where they represent a significant share of the agricultural economy. Average olive oil production in the EU in recent years has been 2.2 million tonnes, representing around 73 % of world production. Spain, Italy and Greece account for about 97% of EU olive oil production, with Spain producing approximately 62% of this amount[7].

The olive fruit fly Bactrocera Oleae is a serious pest for olives causing major losses of the crop. Moreover oil from the infested fruit has a higher acidity and lower shelf life compared with that extracted from non infested fruit.

Figure 3.2 - Weather Monitoring Schema for Olives Groves



Source: Libelium

[7] European Commission, Directorate-General for Agriculture and Rural Development , July 2012. http://ec.europa.eu/agriculture/olive-oil/economic-analysis_en.pdf

Implementation details

TeamDev, an Italian software company, has developed a decision support system based on weather data collected by Libelium's Waspmote Plug & Sense! Sensor Platform. The company has been working with Assoprol Umbria, an organisation of Umbrian olive producers, to develop a Web-based platform to collect information about the presence of olive fruit fly and to support a timely action and a defense plan.

> " Spain, Italy and Greece account for about 97% of EU olive oil production"

Results and lessons learned

Data from the Waspmotes is used to create a predictive model of fly diffusion based on weather conditions in each olive grove. This allows growers to devise timely protective measures against the pest.

MONITORING STRAWBERRY PLANTS

Background and aims

Strawberries are a high value soft fruit crop. It is important that the time between picking and selling is kept as short as possible, as the fruit does not keep well.

> " These parameters have to be constantly maintained within optimum ranges, in order to avoid losses of up to 80 percent of the fruit."

Strawberries grown in greenhouses are sensitive to two main factors: air temperature and water supply. Both these parameters have to be constantly maintained within optimum ranges, in order to avoid losses of up to 80 percent of the fruit.

Implementation details

Famosa, an Italian software developer, chose Libelium's Waspmote Plug & Sense! Smart Agriculture to create a solution for strawberry growers. The system collects data from greenhouse sensors and forwards it to Famosa's web-based esiFarm monitoring system.

> " The farmer can instantly check its status on his mobile phone & receive alerts when sensitive thresholds are reached. "

Air temperature and soil water content sensors placed near the plants allow the crop to be monitored on a continuous basis. The farmer can instantly check its status on his mobile phone and receive alerts when sensitive thresholds are reached.

Results and lessons learned

Growers save both money and energy by reducing the water supply by up to 30% after planting, and by around 15% during harvesting.

The company estimates that the use of the system results in significantly less fruit lost. As a result growers can maintain a constant production level of around 40 t/Ha. The resulting constant quality standards attained increase the loyalty of the consumer, and allow the growers to charge a uniform price throughout the harvesting period: around 3.5-4.5 euro/kg for product sold direct.

MONITORING TOBACCO PLANT

Background and aims

Among the climatic factors that can affect the tobacco crop's quality and quantity, those that have particular importance include air and soil temperature, availability of water in soil, relative humidity of air, duration and intensity of lighting. For this reason, is important to monitor those parameters throughout the entire crop's growth cycle.

Italy is one of the leading producers of tobacco within Europe[7], and Italian growers are experimenting with cultivating the crop in new areas of the country. The aim is to develop growing practices that will yield a product of higher quality, whilst at the same time respecting the environment and making best use of the soil and the climate. This includes producing a product with reduced amounts of the chemical substances that could be toxic for smokers.

Implementation details

With the support of a farmers association, TeamDev, an Italian software company has deployed a computer-based management system which collects and analyses information regarding local weather conditions. By understanding the factors that govern tobacco plant growth and management of the crop, growers can understand climate peculiarities in each of the areas above, and also control the growth environment.

> " Italian growers are experimenting with cultivating the crop in different areas of the country."

Libelium Waspmote Plug & Sense! Smart Agriculture sensors are used to collect the data to input to the system. The parameters measured include ambient temperature, humidity, millimetres of rainfall, atmospheric pressure, wind direction, wind speed, soil moisture and leaf wetness. All this data is forwarded to the crop management system.

Libelium's Sensor Platform is connected through 3G with Libelium's Meshlium gateway, thence in turn to the ArcGIS Online cloud platform. ArcGIS is a geographic platform from ESRI which collects all data and defines geolocation in maps. Data from each Waspmote is sent hourly to the system in near real time.

> " The system builds predictive models which allow the farmer to take timely remedial action only when necessary."

Users can monitor the crop information remotely by computer or mobile device via a Web interface; this displays each parameter value, its maximum and minimum in near real time. What is more, the system builds predictive models which allow the farmer to take timely remedial action only when necessary.

Results and lessons learned

The Information derived is used to support decisions about agricultural operations like sowing or harvesting, advising on timing for treatments, and building predictive models describing the spread of pests. This information may also suggest ways to improve cultivation techniques, essential for improving tobacco quality in accordance with European standards.

MONITORING COCOA PLANTS

Background and aims

According to the International Cocoa organization, world cocoa consumption is on the rise due to people in developing markets acquiring a taste for chocolate. It estimates that demand will exceed supply by 2020 by a potential million ton deficit.

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Moreover, according to the World Cocoa Foundation (WCF), Indonesia is the third largest cocoa producer in the world and this cash crop is strategically important to the country. 80-90 percent of cocoa production comes from small, family-run farms, typically 2-4 hectares (5-10 acres) in size.

[7] European Commission, Agriculture and Rural Development, Raw Tobacco - http://ec.europa.eu/agriculture/tobacco/

> “ 80-90 percent of cocoa production comes from small, family-run farms, typically 2-4 hectares (5-10 acres) in size.”

Indonesian cocoa farmers however face a number of challenges. Factors contributing to the decline in cocoa production include the effects of climate change, ageing trees prone to pests and disease, and lack of scientific knowledge about the crop. Moreover the cocoa farms and research stations are located in far-flung areas that previously required experts to travel for days in arduous conditions to access the field and collect the data.

Remote monitoring is allowing agronomists to address these problems. By understanding the factors that affect crop behaviour, researchers, plant scientists and agronomists can devise a set of best breeding and agronomic practices, through laboratory and field-based experiments in the cocoa fields.

Implementation details

As part of Indonesia’s Sustainable Cocoa Production Program (SCPP), a ‘Smart Cocoa Research Station’ was built at a remote site to monitor the crop in the field, in order to discover ways of adapting local cocoa production practices for a changing climate. The project brought together experts from Australia, France, Indonesia, U.K. and the U.S; it involved correlating real time measurement of environmental factors with scientific observations and manual data collection from tobacco plants equipped with near field communication (NFC) tags.

Singapore-based IoT solution provider, in conjunction with a client organisation, built a computer-based system to collect environmental data from the site. Libelium Waspmote Plug & Sense! sensors were selected for data collection as they were deemed to provide best protection against the harsh outdoor conditions of this deployment. A total of 50 Waspmote nodes were installed within range of the cocoa research facility, transmitting data continuously to the Libelium Meshlium gateway, thence stored then forwarded to the Cloud. The parameters measured included temperature, humidity, photosynthetically active radiation and soil water potential. In addition Libelium developed a new, customised Waspmote sensor board to collect soil volumetric water content and soil electrical conductivity data for the project.

> “ By understanding the factors that affect crop behaviour, researchers, plant scientists and agronomists can devise a set of best breeding and agronomic practices.”

Because Internet connectivity from the site is not reliable and to guard against data loss, a local server system was also deployed as an interim solution to store information from the field data collection. The software company developed a screen-based dashboard that allowed managers to remotely visualise sensor, environmental, and NFC data by on-site and off-site researchers.

Results and lessons learned

The Smart Cocoa research station now tracks the cocoa tree diseases that blight output, including the cocoa pod borer (CPB) insect, vascular streak dieback (VSD) and blackpod. The information has contributed to:

- The development of pest-resistant cocoa clones
- The learning and sharing of techniques to rehabilitate old or unproductive trees
- The prevention of deforestation, important for sustainability and climate concerns
- The understanding of fungal root diseases particularly in humid farms
- The creation of field schools for farmers to help established best practices to break the infection cycle and prevent infestation.

WASTEWATER IRRIGATION MONITORING

Background

Pacific Environment is an environmental technology and consulting company based in Australia, with a client base world-wide. The company is composed of staff with expertise in a number of areas, including economists and scientists. The client, AJ Bush (Manufactures) Pty, a meat rendering company based in Australia sought the assistance of Pacific Environment to undertake a series of modelling and monitoring studies, in response to an Environmental Protection Order issued by the Queensland Department of Environment and Heritage Protection.

Organic wastes from such facilities pose significant environmental management challenges. The management of soil moisture in wastewater irrigation is essential for the protection of groundwater from nitrate contamination.

Initiation of development of the project

The project area covers approximately 500 hectares, of which about 160 hectares will be irrigated with treated wastewater from cattle farming.

The team became aware that a real-time monitoring platform would enable AJ Bush to effectively manage their wastewater irrigation, without impacting the receiving environments of soils, groundwater and nearby creeks.
The solution only took a few weeks to develop, given that Pacific Environment knew what sensors were needed, the best location for the sensors to collect the necessary data, and had its decision support system to transform raw data into environmental and operational intelligence.

> " AJ Bush estimates it will be making significant savings in reduced lab fees & related sampling costs, as well as maximising the amount of wastewater that they irrigate on their land. "

Development of the solution

The decision support part of the solution was based on Pacific Environment's EnviroSuite, a proactive environmental management system that combines real-time monitoring and predictive modelling with high resolution weather forecasting and automated data analysis. The sensors network was sourced from Libelium's Plug & Sense. The client purchased all the components of the solution from Pacific Environment.

Libelium's Plug & Sense! Smart Water sensor network was installed in the wastewater irrigation area. This comprises sensors that measure electrical conductivity, temperature and dissolved oxygen.

Through the real-time monitoring of water quality, the sensor network provides an early warning system for potential surface water contamination. The plan is to install additional sensors for the measurement of nitrate, pH and flow in real-time.

Installation details

Starting in early 2016, Pacific Environment's field scientists installed the sensors and related communications equipment, with some assistance from AJ Bush personnel. To date, the team have installed equipment, initially to assess any site specific teething problems (e.g. curious cows), and to verify the stability and reliability of the data and communications. They envisage that to install the entire 160 hectare site would require two people one calendar month to install.

Customer benefits

The system has the potential to significantly reduce the cost of environmental reporting and compliance, in the broad range of human activities that affect both surface and ground water.

The projected payback for investment in the hardware is approximately 18 months. From then on, AJ Bush estimates it will be making significant savings in reduced lab fees and related sampling costs, as well as being able to maximise the amount of wastewater that they irrigate on their land. The other notable benefit is mitigating their environmental risk by not polluting groundwater and surface water resources with nitrate, in accordance with the Queensland government's environmental protection mandate.

> " The management of soil moisture in wastewater irrigation is essential for the protection of groundwater from nitrate contamination."

Pacific Environment benefits

For the company, this was a pioneering project in its use of a real-time monitoring intelligence platform as an operational and environmental management tool for wastewater irrigation.

Figure 3.3 - Libelium sensors and EnviroSuite Agriculture Model being installed at AJ Bush

4 | CONCLUSION

Over the past 15 years, farmers have started using computers and software systems, mainly for organising their financial data and keeping track of commercial relationships. In the more recent years, farmers have started using digital technologies for monitoring crops, livestock and all elements of the farming process. Farming is becoming a very data-intensive sector; information comes from different devices located in the farm, sensors, farming machineries and weather stations.

The availability of vast amount of data, the ability of analysing data and making decisions are revolutionising the agriculture sector, transforming it in one of the most receptive and dynamic to technological innovation. These improvements have been deployed in farms with different extensions, which cultivates a wide range of crops, from large farms, farming research centres to small and medium-sized farms and greenhouses. The main reason is that the RoI and the benefits of technological investments are measurable for farmers.

Objectives and Drivers of the Smart Agriculture Revolution

This attitude towards technological innovation is making the Smart Agriculture revolution real for farmers. Helping them to understand the huge possibilities that Precision Farming has in their daily work. The overall aim is to have a complete view of all the steps in the production chain, the transactional activities with other stakeholders involved and supporting transparency in the value chain. This objective is driven by some key factors:

- Product safety
- Labour welfare
- Nutritional responsibility
- Plants and animals health
- Local and global market presence
- Sustainability
- Productivity
- Cost and waste reductions

Smart Agriculture. Data Sensing – Data Communications – Data Storage and Processing

From a technological perspective, Smart Agriculture is based on four key steps: data sensing, data communications, data storage and processing. In other words, the farmers have to design a robust ubiquitous network of sensors, to be able to combine all the data and analyse it in order to achieve the objectives discussed before.

Farm Management Information Systems (FMIS) also become a fundamental block. The predictive capabilities of an FMIS are also very critical because these techniques enable farmers to make better decisions at the right moment and prevent future risks or damages in farms. In light of all this, there is a necessary need to have an integrated solution that involves sensor networks, machine to machine communications, data analytic, management systems and applications development with predictive models. The number of applications in farming is then very vast. Here some examples:

- Yield measurement systems
- Extraneous and foreign bodies identification
- System for milk quota
- Collaborative spraying
- Plant disease monitoring and forecasting for spraying
- Weather monitoring and actions in that situation
- Remote machine control and diagnostic
- Greenhouse management
- Automated stable management and monitoring
- Livestock disease monitoring
- Livestock monitoring in the field and virtual fencing
- Increasing production through livestock biology monitoring

Traditionally, agronomists might have "feelings" about the progression of their crops from season to season, but this is not not objective data to enable them to determine which are the best ways to cultivate. With the IoT and applying Big Data technologies, the farmer has historical data to link which years produced the best yeilds (either in volume and/or quality) with the inputs of each season, allowing geater insight into why the harvest in a given year was so good.

Sensing Companies in Smart Agriculture – The Case of Libelium

In order to offer a Smart Agriculture solution as described above, the skills and the type of companies involved are very diverse. An essential building block for a Smart Agriculture solution is the sensing technology company. There are several approaches and propositions in the marketplace. Some of them are limited to the provision of sensors and networks with just an integration option or cloud solution so that developers have to decide everything before deploying the project, with no option to make any change in the future. Libelium gives the choice to change any time the communication protocol or the cloud solution and offers a horizontal platform where others sensors can be easily add. Interoperability is the differentiating feature of the company giving all customers the capability to customize their monitoring and control systems. The white paper has discussed several case studies showing how a based Libelium solution has contributed to the development of very successful stories in different agriculture applications. That has enabled Libelium to be a leading player in sensing solutions for agriculture.

Waspmote Plug & Sense! Smart Agriculture allows the monitoring of different key parameters that affect crops. Soil moisture and temperature, humidity, leaf wetness, solar radiation, atmospheric pressure, stem, fruit and trunk dendrometers, anemometer, wind vane and pluviometer sensors which allow farmers the ability to control and plan outcomes. For example the amount of sugar in grapes, which affects the wine quality, or the growing cycle of specific crops, and the control of micro-climate conditions, to maximize the production of fruits and vegetables in greenhouses and prevent diseases. The three levels of depth of the soil moisture sensor are helpful to reduce waste of water by selective irrigation in dry zones. On the other hand, controlling humidity and temperature levels can prevent fungal and other microbial contaminants and diseases.

A ready to be deployed solution: Smart Agriculture Kit

With The IoT Marketplace, Libelium offers a comprehensive model that integrates the four key steps for Smart Agriculture: data sensing, communications, storage and processing. The company has followed that route becoming a key player in the Precision Farming market. The Libelium Smart Agriculture Kit is a ready-to-be-deployed solution composed of three Waspmote Plug&Sense! units.

The IoT Marketplace is the operational tool for these partnerships, bringing together a number of specialsed players in the Smart Agriculture value chain, such as cloud-computing, data analytics and agri-tech solution providers. This approach will also enable Libelium to empower its presence in the Smart Agriculture market. It is complex due to the diverse set of applications, but it is getting a lot of momentum among the agri-tech community and the IoT community.

Organisations can exploit that momentum if they collaborate bringing different skills together. Libelium is doing that through The IoT Marketplace. There will be growth in the high-value crop farming, in precision livestock farming, and in smart fishing and aquaculture.

Connected agriculture vehicles will also be top of the agenda and not only from the point of technological features, but also introducing service-based models such pay-as-you-use data models. The overall Smart Agriculture market is growing. Sensing and data management services are fundamental elements of that. Therefore, a company such as Libelium can have an important role in that growth.

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www.beechamresearch.com

info@beechamresearch.com

@BeechamResearch

libelium 10 YEARS

TEN YEARS POWERING THE IoT REVOLUTION

Libelium designs and manufactures hardware for wireless sensor networks and a complete software development kit (SDK) so that system integrators, engineering, and consultancy companies can deliver reliable Internet of Things (IoT), M2M, and Smart Cities solutions with minimum time to market. Waspmote—Libelium's wireless sensor platform—is modular and ready to integrate with key Cloud systems (AWS by Amazon, Azure by Microsoft, B-Scada, DeviceLynk, Devicify, Element Blue, Esri, IBM Bluemix, IoTSens, Sentilo, Sofía2 by Indra, Solvver, Telefónica, Thing+, ThingWorx), and low-energy IoT connectivity protocols (LoRa, MQTT, Sigfox).

Over 2,000 developers from 115 countries in companies ranging from startups to universities to large international corporations have adopted Libelium's technology for projects in five continents. Commercial deployments based on Waspmote include applications as varied as parking, traffic congestion, environmental monitoring, water quality and precision agriculture.

Recently, Libelium has been considered a baby unicorn company in technological sector in Spain by Financial Times. Established in 2006, Libelium is privately held and has headquarters in Zaragoza, Spain.

To find out more get in touch here:

www.libelium.com

@Libelium

www.the-iot-marketplace.com

@IoT_Mktplace

sales@libelium.com