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Design and Development of Smart Communication Systems based on Olive Tree Information for Smart Agriculture

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تصميم وتطوير أنظمة اتصالات ذكية قائمة على معلومات شجرة الزيتون للزراعة الذاكية

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Abstract

Data for smart agriculture is derived from various sources, including meteorological and geological maps, as well as a wide range of sensors and mobile devices (such as smart tractors , drones and smartphones). Fixed sensors are often used in crop fields to monitor soil moisture and mineral composition, whereas sensors built into mobile agricultural equipment can detect water stress , pest attack , or disease .Once the data has been collected locally for the farm, it is aggregated/pre -processed locally on low - cost edge nodes before being transferred to the cloud infrastructure . Context-aware data collection allows the mobile collector to adapt its strategy dependent on the context of the domain under observation . Process - based crop models are algorithms that dynamically describe (typically in daily time steps) the evolution of a crop from planting to harvest based on its surroundings . An integrated systems proposal is developed in this study to use information and communication technologies to design systems that aid in improving and managing olive tree cultivation in a more intelligent and effective manner, based on collecting and analyzing information related to the olive tree, such as the state of growth, humidity, the need for fertilization, irrigation and the condition of Diseases and pests using wireless sensors and artificial intelligence. The proposed system for the application of smart agriculture in the cultivation of olive trees is based on wireless measurements and sensors that can identify the environmental and climatic conditions, as well as the reproduction of pests that affect olive trees and based on these measurements, artificial intelligence is used to predict tree growth rates and issue recommendations that determine the best methods to develop irrigation and fertilization systems, as well as early warning systems.

Keywords: Smart agriculture, Olive sustainable production, IoT, GIS; precision olive growing.

الملخص

تستمد بيانات الزراعة الذكية من مجموعة متنوعة من المصادر، بما في ذلك خرائط الأرصاد الجوية والخرائط الجيولوجية ، بالإضافة إلى مجموعة واسعة من أجهزة الاستشعار والأجهزة المحمولة (مثل الأجهزة الذكية والطائرات بدون طيار والهواتف الذكية) غالبا ما تستخدم أجهزة الاستشعار الثابتة في حقول المحاصيل لمراقبة طبيعة التربة والتركيبة المعدنية ، في حين إن أجهزة الاستشعار المدمجة في المعدات الزراعية المتنقلة يمكنها اكتشاف الإجهاد المائي (ضغط الماء) ،وهجوم الآفات، أو الأمراض. بمجرد جمع البيانات محليا للمزرعة ، يتم تجميعها مسبقا ومعالجتها محليا بتكلفة منخفضة قبل نقلها إلى البنية التحتية ، يسمح جمع البيانات المدركة للسياق للمجمع المتنقل بتكثيف إستراتيجيته اعتمادا على سياق المجال الخاضع للمراقبة، نماذج المحاصيل القائمة على العماليات هي خوارزميات تحدد بشكل ديناميكي (عادة في خطوات زمنية يومية) تطور المحصول من الزراعة إلى الحصاد بناء على البيئة المحيطة به.

تم في هدي الدراسة تطوير مقترح أنظمة متكاملة لاستخدام تقنيات المعلومات والاتصالات لتصميم أنظمة تساعد في تحسين و إدارة زراعة شجرة الزيتون بطريقة أكثر ذكاء وفعالية ، بناء على جمع وتحاليل المعلومات المتعلقة بشجرة الزيتون ، مثل حالة النمو و الرطوبة ، والحاجة إلى التسميد والري ، وحالة الأمراض والآفات ويمكن أن يتم ذلك باستخدام أجهزة الاستشعار اللاسلكية وأجهزة تحليل بيانات تعمل بالذكاء الاصطناعي .

النظام المقترح لتطبيق الزراعة الذكية في الزراعة أشجار الزيتون يعتمد على قياسات لاسلكية وأجهزة استشعار يمكنها التعرف على الظروف البيئية و المناخية وكذلك تكاثر الآفات التي تصيب أشجار الزيتون وبناء على هذه القياسات تم التوصل إلي الذكاء الاصطناعي و يستخدم لتنبو، بمعدلات نمو الأشجار وإصدار التوصيات التي تحدد أفضل الطرق لتطوير أنظمة الري والتسميد وكذلك أنظمة الإنذار المبكر .

الكلمات المفتاحية:- الزراعة الذكية ، الإنتاج المستدام للزيتون ، انترنت الأشياء ، نظم المعلومات الجغرافية ، زراعة الزيتون بدقة .

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1 – Introduction

Smart agriculture is an essential and vital development in agricultural development policy because it tries to create a sustainable rise in agricultural production while adapting to the new realities imposed by weather patterns. According to the World Bank, the implementation of smart agriculture is a guarantee of reducing costs and boosting production by using less water in light of climate change, water limitations and scarcity of arable land, resulting in a 50% increase in crop productivity. As a result, success will be reached in the process of field irrigation and fertilization in the near future.

In an environmentally friendly manner, with increased agricultural production [6].

1 – 1 - The Concept of Smart Agriculture

Smart agriculture is a management concept that focuses on providing the agricultural business with the infrastructure to harness sophisticated technology, such as big data, the cloud and the internet of things (IoT), to track, monitor, automate and analyze activities. A notion of Smart agriculture was emerged from software engineering and computer science, with the incorporation of computing technologies and the transmission of data from agriculture, within an overall context of almost ubiquitous computing. These computing elements are embedded in items and are linked to each other and the internet.

Smart agriculture is defined as those agricultural techniques and practices that aim to improve agricultural productivity and do not pollute the environment or contribute to pollution. A smart agriculture approach is one that aims to grow and improve the agricultural system. It is based on modern agricultural methods and mechanisms that increase productivity and quality without depleting natural resources, such as good agricultural practices, biodynamic and organic farming systems and biological and organic fertilization, which in turn rely on biological and organic fertilization to improve agricultural lands. And the natural resources of the fields, as well as increasing the ultimate agricultural product's quality [7;6].

Climate-smart agriculture is a method of assessing which production systems, supporting institutions and policies are best adapted to respond to the difficulties of climate change in specific areas. At the same time, they want to boost production and/or income. Climate-smart agriculture is one of 11 institutional areas for resource mobilization under FAO's Strategic Objectives. It is consistent with FAO's vision of sustainable food and agriculture and contributes to FAO's goal of making agriculture, forestry and fisheries more productive and sustainable". Then, environment-smart agriculture is a concept that helps lead measures to restructure and reconfigure agricultural systems in order to successfully promote development and ensure food security in a changing environment . Climate-smart agriculture strives to achieve three primary goals:an improvement in agricultural output and income that is sustainable over time[23].

Adaptation and resistance to climate change; and, if practicable, reduction and/or elimination of greenhouse gas emissions.

There are two types of smart agriculture: aquatic and organic, aims to the use of the least amount of land and water to acquire the best yield from the target crops in order to accomplish sustainable agricultural output while preserving natural resources for future generations. Smart agriculture also decreases hazardous petrol emissions while adapting to future climate changes [6].

1 – 2 – The Development of Smart Agriculture

During the 2010 Hague Conference on Agriculture, Food Security and Climate Change, FAO proposed the concept of climate-smart agriculture (CSA) as a concept that contributes to the achievement of sustainable development goals .

It addresses the issues of food security and climate change while integrating the three pillars of sustainable development (economic , social and environmental) [6].

Smart agriculture necessitates a significant transformation in the way water, soil, fertilizers and other agricultural resources are managed. Nuclear techniques can be used to track and measure the movement and dynamics of carbon, water and nutrients within various agro-ecosystems in order to improve smart agricultural practices, radioisotopes are being used to track the movement and dynamics of carbon, water and nutrients in agro ecosystems in order to evaluate the effects of conservation agricultural measures, to investigate the stability and turnover of soil organic matter and to determine the fate of nitrogen and chlorine in crop residues. They are also used to investigate land degradation and soil erosion in order to better target soil and water conservation and management practices [3;4].

Creating climate-smart agricultural practices that not only help to adapt to and reduce climate change, but also have the potential to boost food production. Better management of natural resources such as land, water, soil and genetic resources is essential to boost agricultural output and resilience. Conservation agriculture, for example, can bring various benefits, including reduced soil erosion, improved soil water retention and nutrient availability for crops, enhanced organic matter formation in the soil and higher crop and animal productivity [12;14].

1 – 3 – Smart Agriculture Systems

Smart farming systems, with their real-time management and high level of automation, have the potential to significantly increase productivity and food safety.

1 – GIGABYTE IoT Gateway Agricultural System

To increase agricultural efficiency through technology, the GIGABYTE system was created as a smart agriculture system to help farmers better regulate the crop-growing process.

With environmental sensors, monitoring systems and equipment controllers receiving data such as sunlight , temperature, and humidity in the front – end environment , the GIGABYTE "IG-3815" Smart IOT Gateway System also uses computing and wireless technologies such as WIFI/ZigBee/LoRA to collect those data or control signals are sent to the front – end equipment to maintain the growth environment . Furthermore, the gathered data can be transferred to a GIGABYTE cloud storage device (Virtual Store Appliance: H261-H61) and analyzed using big data.

The database can be used by users to get information on the growth environment of each crop batch and then compare and analyze the crops to reach the ideal growth environment for the plant.

GIGABYTE IoT Gateway Agricultural System, ZigBee wireless technology , MCU boards, and sensors that can manage the environment to offer the plant with the best possible growing environment [18;19].

Collecting, storing, and analyzing greenhouse environmental data can improve the plant development environment with frontal sensors and specific environmental optimization equipment. IoT Gateway collects data and sends control signals to front-end equipment using EDGE computing and embedded ZigBee. After managing the (fan, water, light, and shade cloth), the data is collected in a back-end database for transfer to big data analysis. Previously, the farmer had to be present at all times to monitor the crop, patrol the water, fertilize and keep an eye on the day. Farmers can now employ IOT Gateway eco-box technology to reduce agricultural losses. Boost output, smart agriculture IoT technologies are intended to assist in crop field monitoring by using sensors and automating irrigation systems. As a result, farmers and affiliated businesses can readily and conveniently monitor field conditions from anywhere.

2 – Integration of Internet of Things (IoT) and Long Range (LoRa) Technologies with Programmable Logic Controllers (PLCs)

This system makes use of a low – cost, low – power, large-scale wireless sensor network based on Internet of Things (IoT) and long – range (LoRa) technologies . Internet of Things (IoT) and Long Range (LoRa) technologies are coupled in this system with Programmable Logic Controllers (PLC) , which are commonly used in industry and agriculture to operate numerous processes, devices, and machines using Sematic IOT2040 [17;22].

The system also incorporates a newly developed web − based monitoring tool hosted on a cloud server , which analyses data from the farm environment and allows visualization and remote management of all connected equipment . A Telegram robot is added to automatically converse with users via mobile messaging app. Figure (1) illustrated architecture of the two mentioned smart agriculture systems.

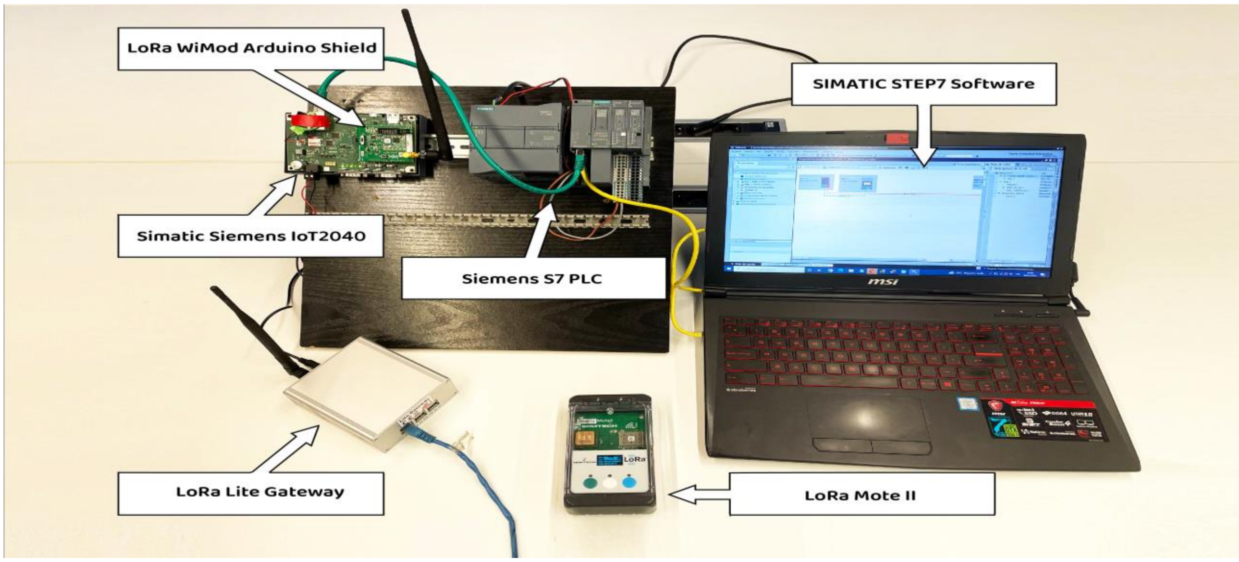


Fig. 1. The farm is connected to a LoRa gateway, which exchanges data with users via a cloud server in a smart agricultural system architecture .

1 – 4 – Principles of Smart Agriculture

1 – Sustainably maintain and increase productivity

The global shift to smart agriculture is critical not only for preventing future food security crises, but also for contributing to the economic and agricultural revitalization of rural areas plagued by hunger and poverty.

2 – Adaptation and resilience

Agricultural systems must be altered in order to be resilient to climate change . Changes in practise , such as modifying the crops or livestock raised , the adoption of new technologies and the use of climate or weather data to inform future decisions are all examples of adaptation

3 – Mitigation

Mitigating resource input and improving efficiency typically go hand in hand with lowering emissions . The greater the reduction in GHG concentrations in our atmosphere , the less likely extreme climate scenarios will be in the future, and the easier it will be to adapt to climate change . Another important component of mitigation is carbon uptake in plants and soils, which can help to reduce CO_2 levels in the atmosphere .

1 – 5 – Smart Agriculture Success Factors

The success of smart agriculture is affected by the following factors [3;13].

1- Technology: Smart agriculture relies on modern and advanced technologies such as smart sensors, photo analysis and communication and networking technologies.

2- Agriculture data: Smart agriculture needs to collect accurate data about branches, crops, weather conditions, soil and water, which are available in digital warehouses and serve as a source of vital information.

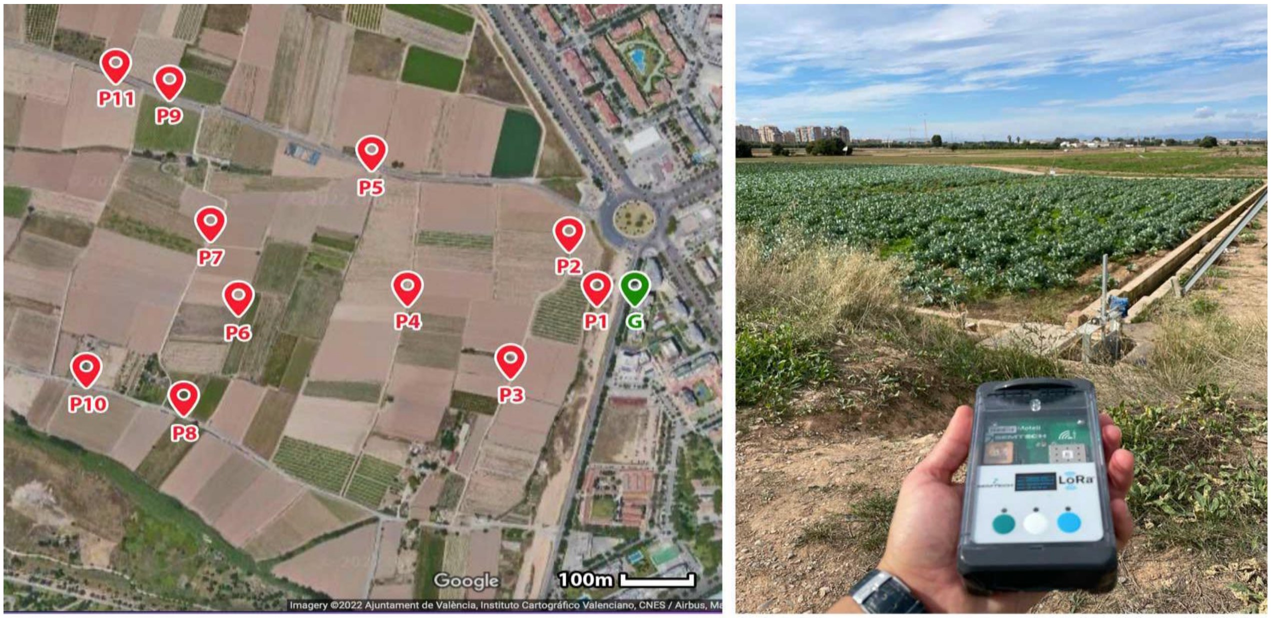
3- Advanced Analysis: As agriculture data is collected, it is analyzed using statistical analysis techniques, data science and artificial intelligence to identify strengths and weaknesses and provide methods to improve them.

4- Smart management: To improve the performance of smart agriculture, you need smart management. This includes responsibilities for providing vital data, preparing periodic reports and monitoring electronic transactions to arrange operations more efficiently.

5- Saving investments: Smart agriculture requires high investments in hardware, applications, training and analysis to achieve more benefits and positive results for farmers and consumers.

1 – 6 – The importance of Remote Sensing and Artificial Intelligence in Smart Agriculture Applications

The implementation of smart agriculture or smart irrigation systems began in the 1990s in industrialized countries throughout the world with the use of geographic information systems, GPS and remote sensing techniques. North America, Germany, England, Belgium and China were the first countries in the globe in this field. Figure 2 showed Example of different measurement locations using the GPS application on mobile phones.



(a) (b)

Fig. 2. Example of different measurement locations using the GPS application on mobile phones.

Implementation of the Smart Agriculture system, including the smart irrigation system, smart fertilization and the prediction system for battling agricultural pests with the artificial intelligence system aims to rationalize agricultural water consumption and reduce the haphazard use of chemical fertilizers and pesticides.

The application of current technology such as remote sensing, geographic information systems, IoT and artificial intelligence systems in smart agriculture aims to improve crop management efficiency from land preparation to harvesting operations.

Crop monitoring and their quality is determined, pests are identified and appropriate quantities of fertilizers and pesticides and timings for its use, as well as irrigation dates, as the availability of appropriate information at the right time for those in charge of managing the farm achieves the highest efficiency of agricultural management by making the appropriate decision at the right time, which contributes to raising regarding the required quantities and additives of fertilizers, insecticides and irrigation water at the stated time and location [18].

The smart irrigation system comes first, which is regarded one of the wings of smart agriculture to maximize the utilization of water resources. The smart irrigation system is a high-tech technology that relies on measuring the ground moisture level in the soil via planting precise gadgets and sensors, the actual plant inside the field or using a mobile application. Where the land irrigation system is opened and closed by a message received through mobile phone using sensors or a sensor planted in the ground that records the amount of moisture in the soil and this message sends the farmer an order [18,19].

However, before implementing the smart irrigation system on the farm, a comprehensive database that includes soil type, soil content of plant nutrients, crop composition and the farm's geographical location must be created so that integrated management can be carried out from the start of planting to the harvest season. Furthermore, my farm's database is linked to the database of geographic information systems.

1 – 6 – 1 – Importance of IoT

IoT is a network of networked devices that securely exchange information and resources when a connection to the Internet is made. The Internet of Things outperforms all other traditional networks in terms of less direct human interaction, a broader perspective, and extendable qualities [20].

The development of new, appealing features and functionalities as well as the simplification of the design to make IoT devices smarter and more affordable are the makers' top priorities, not their security. Because of insufficient security measures, there have actually been a lot of cyber–attacks on IoT devices recently. In fact, both the number of assaults and IoT devices is steadily rising [8 ;9]).

Only a small number of specified instruction sets may be processed by IoT devices due to their limited memory and processing capability. The inability to do so prevent them from being able to record, monitor and analyze communication between IoT devices [8;16] .

Climate–smart agriculture is built on three fundamental pillars:

1 – The first pillar: economic; it consists of boosting agricultural output and income in a sustainable manner.

2 – The second pillar is the social pillar, which consists of adjusting to and strengthening resilience to climate change.

3 –The third pillar: Reducing and/or eliminating greenhouse gas emissions Climate Change [6].

Climate-smart agriculture (CSA) is characterized by the World Bank as an integrated approach to managing landscape, arable land, livestock, forests, and fisheries that addresses the interconnected concerns of food security and climate change.

Climate-smart agriculture aims to guide agricultural management in the face of climate change and achieve food security while simultaneously mitigating climate change and contributing to other sustainable development goals. Thus, climate-smart agriculture as a strategy assists farmers in reducing susceptibility, increasing adaptive capacity, and dealing with subsequent hazards [23].

2 –The Application of Smart Agriculture in the Cultivation of Olive Trees

In this part, an integrated systems proposal is developed to use information and communication technologies to design systems that help in improving and managing olive tree cultivation in a more intelligent and effective manner based on collecting and analyzing information related to the olive tree, such as the state of growth, humidity, the need for fertilization, irrigation and the condition of Diseases and pests using wireless sensors and artificial intelligence data analysis devices.

The proposed system for the application of smart agriculture in the cultivation of olive trees depends on wireless measurements and sensors that can identify the environmental and climatic conditions and the reproduction of pests that affect olive trees, and based on these measurements, artificial intelligence is used to predict the growth rates of trees and issue recommendations that determine the best methods to develop irrigation and fertilization systems and early prediction of pests and diseases before damage to the crop occurs.

The idea of designing and developing smart communication systems based on olive tree information for smart agriculture is based on two axes:

1 - Measuring weather factors such as temperature and humidity that affect the growth rates of trees and the reproduction of insect pests and measuring the direction and speed of winds, the amount of rain, solar radiation and other weather factors that affect the growth of the olive tree.

2 - Using artificial intelligence software to analyze the data collected on the condition of trees.

Artificial intelligence in olive cultivation is concentrated in three main categories: agricultural robots, soil and crop synchronization and predictive analytics, which are achieved through the farmer's use of sensors and soil sampling, which are stored within data to analyze the soil situation, treat pests and reach the best crops suitable for the soil.

It employs artificial intelligence to analyze data in order to determine the need for fertilization of olive trees and their stages of growth, as well as to detect diseases using the information stored for each tree on the application and a proposal appears to the farmer for pesticides or fertilization solutions.

2 – 1 – Smart Fertilization of Olive Trees

Several remote sensing (RS) technologies and platforms have been widely used in studies of olive cultivation during the olive growing cycle, yielding valuable insights into olive development and production. Future research will likely focus on processing RS data in addition to using air and ground vehicles for data collection.

Precision agriculture is increasingly being used in olive groves as a new method for managing agricultural diversity with the aim of providing plants with the right amount of inputs while minimizing losses or surpluses by developing a methodology on a GIS platform using GEOBIA algorithms to build maps and recipes for the use of variable rate nitrogen fertilizers (VRT) in orchards. Olive to determine the fertilization plan for each tree by applying its nitrogen balance, taking into account the variability of nitrogen in the soil, leaves, production and actual biotic and spectral conditions [10].

The general nutritional state of the trees is measured by calculating the concentration of nutrients for leaves that demonstrate a deficiency in a specific nutrient to define the health status of olive trees. The threshold value represents the nutrient concentration limit that defines the olive tree's nutritional state [21].

A standard olive tree fertilization system employed by hundreds of experienced olive growers comprises applying 8–15 lbs. (4–7 kg) of N–P–K 11–15–15 fertilizer to each adult tree once or twice a year. In non–irrigated trees, the best time is in the autumn and winter. The majority of studies have associated the concept of "smart" with controlled and/or slow release of nutrients. Some papers attributed the adjective "smart" to fertilizers that are able to release their nutrients over a longer period compared to conventional fertilizers. Smart nitrogen fertilization was used to significantly reduce nitrogen losses and store the excess of this element for future use by olive trees [15].

The nitrogen content of the soil can be connected to production quantities. For example, if an olive tree requires 100 nitrogen units and the soil stock is 30 nitrogen units, we discover that the farmer in traditional agriculture adds 100 nitrogen units, but in the smart farming system, a number can be added by sensing the soil content of nutrients, particularly nitrogen. Nitrogen units required through nutrient mapping, i.e. supplying 70 nitrogen units instead of 100 nitrogen units based on prediction and sensing of soil stock of plant nutrients, which leads to rationalization of chemical fertilizer use [13].

Smart agriculture provides precisely measured water, fertilizer and pesticides to plants, resulting in increased yield and high quality.

In particular, from an environmental standpoint, the reduction of dispersed nitrogen reduces the process of loss by leaching, resulting in pollution of surface and groundwater.

The first classification of smart fertilizers: each sort of smart fertilizer can have one or more operational mechanisms and be composed of one or more nutrients. Table 1 showed types of smart fertilizers used in the cultivation of olive trees and the purpose for which each type is used.

Table 1. Types of smart fertilizers used in the cultivation of olive trees

Number of nutrients	**Smart fertilizers Types**	**Operational mechanisms**
Single nutrient	Nanofertilizers	Controlled release
Multiple nutrient	Composite materials	Bioactivation
	Bioformulation	

Figure 3 showed Nutrient release pattern of conventional fertilizer, recommended curve of nutrient release and olive trees nutrients demand.

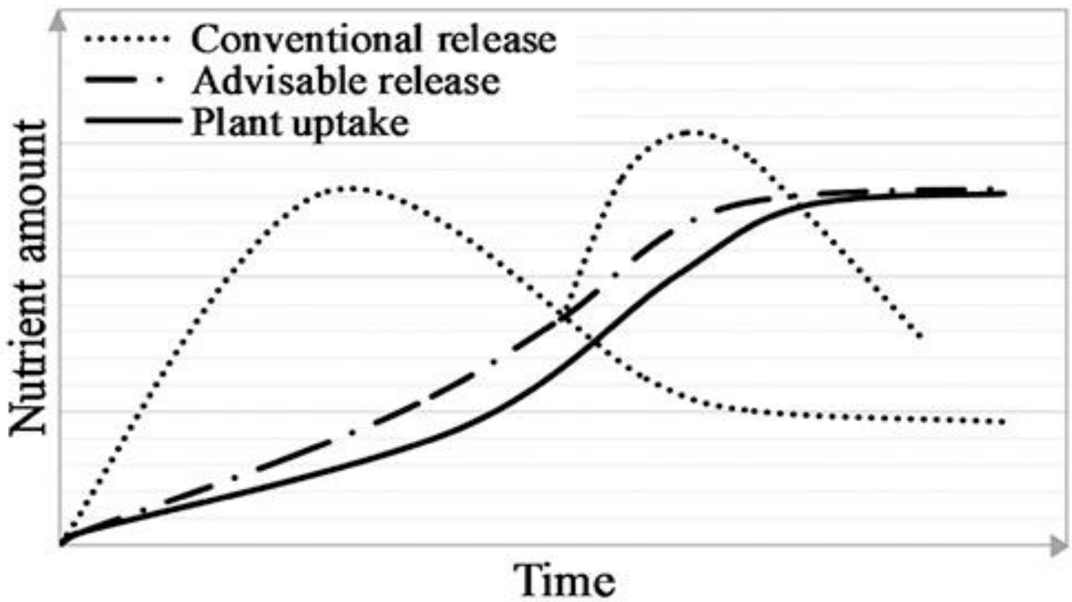


Fig. 3. Nutrient release pattern of conventional fertilizer (dotted curves), recommended nutrient release curve (dot–dashed curve) and olive trees nutrients demand.

2 – 2 – Smart Irrigation of Olive Trees

Remote sensing techniques also provide insight into the ideal crop combinations on the reclaimed lands, allowing the best crops appropriate for cultivation in a given location to be selected. The water needs of olive trees can be estimated using satellite images based on irrigation water characteristics and these irrigation needs can be calculated using information provided by the images about soil moisture and surface temperature and the images can also determine if there is a type of stress resulting from irrigation or fertilization, or soil problems such as salinity [11].

It can be detection the depth of groundwater and the percentage of salinity in the water using portable gadget that detects by measuring the water resistance to the rays it emits; the higher the water resistance, the more the proof that the salinity is high.

Irrigation systems use a panel control unit, electronic valves, and irrigation pumps equipped with sensors for measuring soil moisture to carry out the irrigation process automatically according to the specified program, based on measuring the soil moisture level, eliminating the need to calculate irrigation standards based on agricultural meteorological data, which farmers are not good at [5;2].

Wireless sensors are utilized to measure parameters in an Intelligent Farming System for sustainable agriculture, allowing the amount of water required by the olive trees to be determined in real time . Data acquired from olive groves is processed by sophisticated algorithms , including Machine Learning algorithms, to compute the evapotranspiration model of olive trees and determine when to begin watering . In such cases , commands to start and stop irrigation are conveyed to actuators [1].

2 – 3 – Smart Control of Pests and Diseases Affecting Olive Trees

Artificial intelligence is used to identify diseases and harmful pests in olives, as its accuracy in identifying disease has reached 98%, and it can be used as a weapon against insects through sensors that monitor the farm, the movement of plant maturity, reaching ideal maturity and adjusting light to speed up or slow down the pace of ripening [17].

IoT technology based on smart phones notifies and alerts farmers to reduce the spread of diseases and potential pests, reducing crop losses, managing lighting and remote environmental control, the use of artificial intelligence has allowed us to minimize the use of pesticides by up to 80%and the use of robots has helped to lower production costs while maintaining good quality [2;22].

The use of agricultural robots to survey and analyze data in real time for infected trees, allowing the farmer to diagnose the problem and provide the farmer with a plan for the necessary crop treatment. Figure 4 showed different applications of autonomous mobile robots used in smart agriculture.

Fig. 4. Autonomous mobile robots used in smart agriculture.

3 – Conclusions

Wireless sensors are utilized to measure parameters in the Smart Permaculture Agriculture System, allowing the quantity and quality of fertilizers, in addition; the amount of water required by olive trees will be computed in real time. The data collected from the olive groves is processed by advanced algorithms, including machine learning algorithms , to assess the nutrient content of the soil and predict the evapotranspiration of the olive trees, allowing it to detect when watering should begin . In such instances, commands to start and stop irrigation are given to the actuators. The current study aimed to design and develop smart communication systems based on olive tree information for smart agriculture by using information technologies.

And communications to design systems that help in improving and managing the cultivation of the olive tree in a more intelligent and effective way, by collecting and analyzing information related to the olive tree such as the state of growth, humidity, the need for fertilization and irrigation and the status of diseases and pests. This can be done using wireless sensors and AI-powered data analyzers.

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