LoRa TECHNOLOGY AND ITS IoT INTEGRATION IN AGRICULTURE: A BIBLIOMETRIC ANALYSIS

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Resumen

Introducción: El presente artículo es producto de la revisión "Tecnología LoRa y su integración IoT en la agricultura", desarrollada en la facultad tecnológica de la Universidad Distrital Francisco José de Caldas realizada durante 2019 y 2020.

Problema: En la actualidad la agricultura enfrenta desafíos y problemas como el calentamiento global, la escasez de agua y la demanda alimentaria. A causa de dichas dificultades se han venido desarrollando tecnología que facilitan el monitoreo de cultivos y granjas.

Objetivo: Resaltar las principales y más importantes características en común entre los artículos revisados, identificar las principales revistas que realizan publicaciones durante los años comprendidos entre 2015 y 2020.

Metodología: A partir de esto, se realizó una revisión sistemática en las bases de datos científicas en áreas clave de la agricultura, teniendo en cuenta los artículos publicados entre los años 2015 a 2020.

Resultados: Los resultados arrojaron 150 artículos de los cuales sólo 50 cumplieron los criterios de inclusión, Se excluyeron artículos de revisiones, metaanálisis y publicaciones en idiomas diferentes al español e inglés.

Conclusión: En esta investigación se discute y se analiza los dispositivos más usados dentro de la investigación, módulos LoRa, localizaciones exitosos y beneficios a nivel costos de la implementación de estos sistemas.

Originalidad: Mediante la metodología de revisión sistemática y herramientas bibliométricas como bibliometrix R permitieron identificar la información más relevante y los autores más citados.

Limitaciones: Existen muy pocos estudios a nivel local que involucran o implementen estas tecnologías.

Palabras clave: agricultura, agricultura inteligente, cultivo, Internet of things, Long range, riego.

Abstract

Introduction: This article is the product of the review "LoRa technology and its integration of IoT in agriculture", developed in the technological faculty of the Francisco José de Caldas District University, carried out during 2019 and 2020.

Problem: Today agriculture faces challenges and problems, such as: global warming, water scarcity and food demand. Due to these difficulties, technology has been developed, to facilitate the monitoring of crops and farms.

Objective: Highlight the main and most important characteristics in common between the articles reviewed, identifying the main journal publications between the years 2015 and 2020.

Methodology: Based on this, a systematic review was carried out in the scientific databases in key areas of agriculture, taking into account the articles published between the years 2015 to 2020.

Results: The results yielded 150 articles, of which only 50 met the inclusion criteria. Review articles, meta-analyzes, and publications in languages other than Spanish and English were excluded.

Conclusion: This research discusses and analyzes the most used devices in the research, LoRa modules, successful locations and cost benefits of the implementation of these systems.

Originality: By means of the systematic review methodology and bibliometric tools such as bibliometrix R, the most relevant information and the most cited authors, were possible to be identified.

Limitations: There are very few studies at the local level that involve or implement these technologies.

Key words: agriculture, smart farming, cultivation, Internet of Things, Long Range, irrigation.

1. INTRODUCTION

Agriculture is known as a system integrated by a natural ecosystem, which likewise is managed by human hand [1]. Also, agriculture incorporates activities that are developed in rural areas; currently viewed from a multifunctional perspective [2]. Similarly, within the cultivation of land concepts, such as: control of water, cultivation, harvest, among others [3] are integrated. In this way, the diffusion of the agricultural model promotes the modernization of productivity in agriculture, which brings together issues of food security and environmental impact [4].

Due to modernization, it is possible to tackle new problems, including: global warming, rapid population growth, and irrational use of water, making possible the development of studies focused on irrigation systems, aimed, among other things, at reducing water use and energy availability, with the target of guaranteeing access to basic drinking water for human beings and food production [5]. These goals require access to funding for innovative technologies, such as: Long Range (LoRa) and Internet of Things (IoT), which are affordable and easy to implement for small farmers to irrigate efficiently [6].

In order to increase the use of unlimited crop resources, it is necessary to integrate IoT techniques; specifically IoT sensors, which capture a large amount of data that helps the farmer in the productivity of their crops, the shrinkage of problems already mentioned above and the easy and wise use of pesticides [7]. These systems also allow prediction of diseases, to rationalize plant protection products and optimize irrigation, using data derived from IOT devices in the field [8].

The same way around, IOT technology has a presence in the agricultural industry, since it combines architectures and protocols, which allow the acquisition and analysis of large-scale data [9], the monitoring of temperature, soil pH and climatic conditions in crops [10]; and improve the control of the health of plantations in real time, sending information constantly [11].

There are a variety of characteristics in the field that IOT devices must face, among these difficulties are the size of crops and farms [12]. For this reason, currently manufacturers have focused on soil analysis, to develop suitable sensors and tools that monitor the characteristics of the terrain, allowing the determination of its nutrients and their deficiencies, in order to facilitate relevant actions in favor of soil quality [13].

In this way, it is possible to develop various types of sensors focused on the registration of different characteristics. Among these are georeferencing-based sensors, which record the depth and distance for sowing the seed and its movement, sending the information to the computer [14]. Likewise, fertilization based on IoT allows the evaluation of nutrients, facilitating the efficiency of fertilizers, reducing the impact on the environment and making use of aerial or satellite images that include the reflection of visible and infrared light from the vegetation to estimate crop health [15].

In irrigation systems, IOT field sensors allow different measurements to be carried out taking into account water scarcity and floods, compiling in turn, meteorological data and satellite images from sources [16], as well as farms or crops located in remote areas. IoT devices such as UAVs, spectral cameras and inexpensive sensors, allow to identify aspects such as growth in crops in real time and analyze consecutively the appearance of pests and diseases in crops, including climatic parameters through image analysis [17].

Likewise, LoRa technology for its part, integrates the group of LPWAN technologies (low-power wide-area network) which represent a new notion of communications, aimed at supplying the disadvantages of current wireless communication systems, such as: Bluetooth, Wifi, GSM and LTE [18], where the latest Low-Power Wide-Area Networks (LPWAN) and especially Semtech LoRa technology, offer a suitable connection response for IoT in remote areas, with a star topology and with a base station, which can deploy wireless communications [9].

Thus, LoRa technology has been developed to increase the effectiveness of IoT technology, since it increases the efficiency of wireless sensor network systems [19]. On the other hand, LoRaWAN is characterized by providing communications with excellent interoperability between smart sensors, without the need for fixed or complex installations, offering independence to the user and the programmer, allowing the deployment of IoT [20].

Likewise, LoRa can provide a good economic means of communication, since it can be used by the community and it is possible to focus on basic needs, in many cases in wild or mountainous regions and allow to take advantage of this topography to achieve online signals at very high speed [2]. Besides, it managed to carry out long-distance communications, achieving in favorable conditions, the propagation of the signal of several kilometers of range [21].

On the other hand, research dedicated to LoRa technology in the implementation of wireless industrial networks, is suitable for sensors and actuators in an industrial environment. It allows to consider the possibility of using LoRaWAN technology in difference with other classical wireless systems [22]. However, especially in the field of agriculture, Wireless Sensor Networks (WSN) and IoT technology that are used, allow the application of advanced agricultural solutions called Precision Agriculture [23].

Although there are several traditional communication technologies, in LoRa, the sensors emit a minimal amount of data with a long time through the air, and since most of these sensors are powered by batteries, long-range communication with low power is a current need [24].

Based on the relevance that IoT and LoRa devices have acquired in recent years, this study attempted to carry out a bibliometric analysis of the publications made on IoT and LoRa technologies in representative journals; with the purpose of investigating the current applications of these technologies in agriculture. Consequently, the specific objectives proposed were the following: a) Highlight the main and most important characteristics in common between the articles reviewed b) Identify the main journals that published during the years between 2015 and 2020; c) Recognize the most cited journals during the years between 2015 and 2020; d) Determine the authors with the highest number of publications relevant to the topic of interest during the years between 2015 and 2020; e) Highlight the countries with the most scientific production during the years between 2015 and 2020.

2. METHOD

Determining the methodology for selecting articles, some important aspects were taken into account. The following keywords were defined when starting the search: "Iot", "LoRa", "irrigation", "agriculture", "cultivation", "farm", "livestock", "smart agriculture".

Additionally, a search was carried out in the Scopus, IEEE, Sage, MDPI databases, in order to obtain articles on trends in IoT and LoRa technology and their relationship with characteristics in agriculture (321). Articles were selected using criteria, such as: year of publication between 2015 to 2020, publications that address IoT techniques to solve problems related to agriculture and publications with implementation data in real time.

Also, theoretical articles, systematic review, meta-analysis, languages other than English and Spanish, were implemented as exclusion criteria.

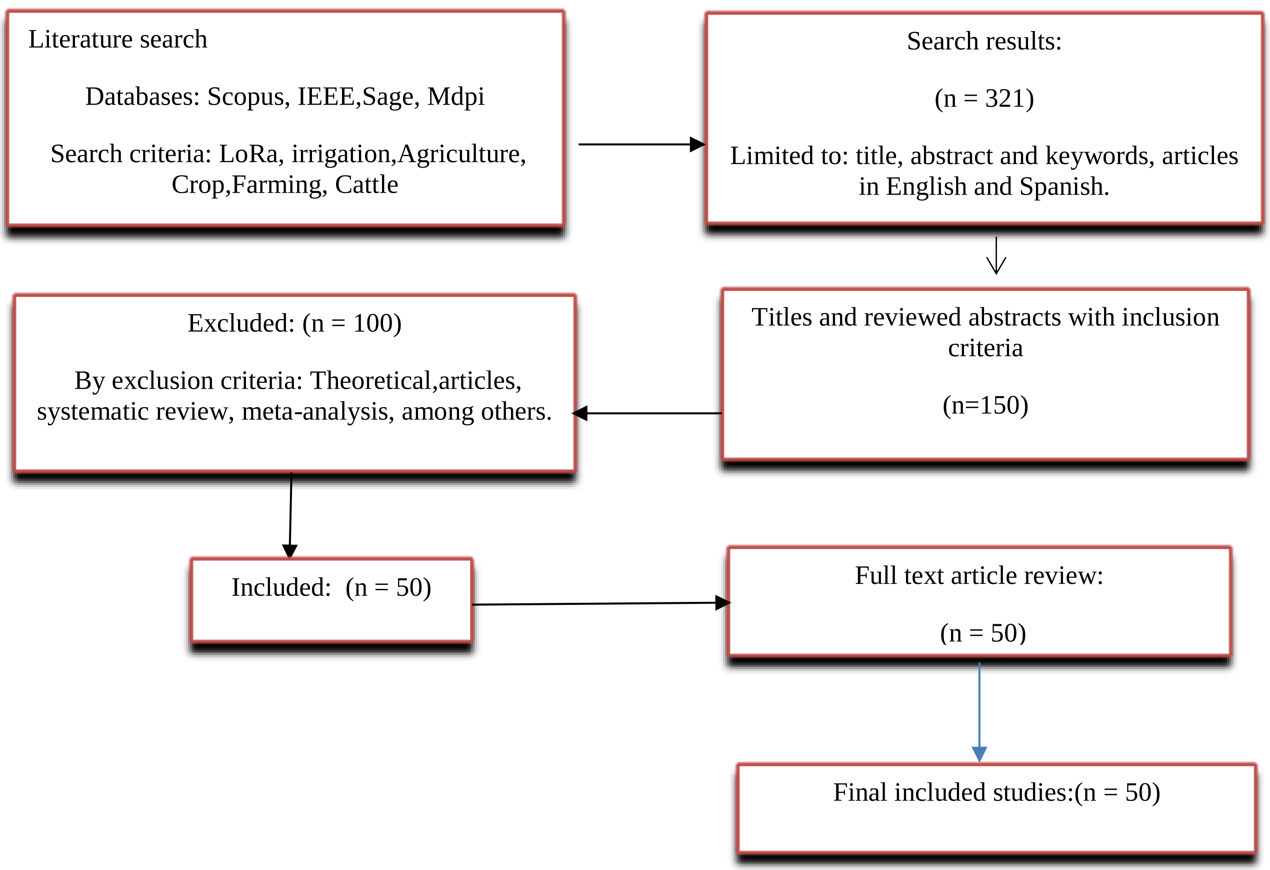

Figure 1 Revision selection method diagram.

Source: The authors

After applying various exclusion and inclusion criteria, 50 of 150 articles were selected to be reviewed, all of these articles were analyzed, discussed and classified.

3. INFORMATION ANALYSIS

The data of the articles were first analyzed by Bibliometrix R, which is the application of quantitative and statistical analysis to publications, like journal articles and their citation counts. Secondly, each article was integrated into a matrix elaborated in EXCEL that included a review of: Name of the article, argument of the problem, objectives, study variables, type of research, tools and devices, procedure, results, and discussion or analysis of results.

4. RESULTS

The following section will present the results obtained. In this, the most relevant data of the implementations that are addressed in the reviewed articles are integrated, and finally graphs are presented where the main journals, that make relevant and most cited publications are exposed; determining the authors with the largest number of relevant publications for the topic of interest and the countries with the most scientific production.

SENSORS

The main sensors that were included in the reviewed articles were those that are characterized by making measurements in different meteorological factors, such as: RFID, capable of measuring precipitation, temperature and humidity [25] and from another type, the DFRobot incorporated with ATMega328 microcontroller, programmed on an Arduino development board [26], photosensitive devices, which can measure solar radiation [27] and sensors based on solar panels, capable of measuring groundwater and spray losses [28].

On the other hand, are also included, NPK sensors wich enable the measurement of soil nutrients, like potassium and phosphorus, among others [29]; and capacitive sensors with materials, such as: graphite oxide, molybdenum disulfide, vanadium oxide and molybdenum oxide, which allow to capture humidity parameters with a higher level of certainty in the soil [30]. There is another variety of sensors capable of measuring the humidity below the soil at depths of 30, 60 and 90 cm [31] and multispectral ones, such as: the CGMD ASD FieldSpec HandHeld2 with optical light to measure the growth of crops, dielectric operating sensors with low-load storage such as the WaterScout SM100 useful for capturing parameters such as soil moisture [32].

Also included are USV sensors (unmanned surface vessels) that with MCU, Arduino and raspberry pi components; transmit information to sensor nodes that are capable of measuring the salinity of the water [33]. Similarly, other types of sensors such as UAV [34] and UABS were also included, which measure environmental factors allow knowing the growth of crops. Likewise, there are some focused on irrigation systems such as controllers connected to WNS [35] and sensors to measure the amount of water in an irrigation system [36].

For factors, like plant growth, there are infrared-based sensors capable of monitoring soil crops and chlorophyll quantity by capturing images and video [37]. For parameters, such as: the level of greenness that exist in the leaves, SPAD-502 Plus sensors using light intensities can measure this type of parameter [38]. In parameters such as the weight in plant mass, analog type sensors with characteristics like voltage measurement according to the plant mass that it has, it is useful to manage and determine the amount of nutrients necessary and later the relocation of the plant in another pot [39].

In the monitoring of agricultural end products in warehouses such as containers, BLE (Bluetooth Low Energy) type sensors that measure parameters such as temperature, present both power and low energy consumption [40].

Regarding the monitoring of livestock in large areas of territory, each of the previous devices together with LoRa modules, presented good data transmission in different time periods, such as: Heltec LoRa ESP32 [41], 3G gateways for long range [42], light telemetry transport protocols and ModBus communication protocols [43]; which characteristic is adequate frequencies for receiving the information. The ANT (WPAN) protocol for data collection integrating wireless transceiver modules [44]. Similarly, LPWAN FABIAN integrates a network protocol stack using an experimental configuration LPWAN technology designed for LoRa and its associated restrictions, such as: power consumption, low bandwidth [45], modules and XBEE-type transceivers incorporated with LoRa, which allow forming WSN type nodes capable of establishing wireless communications [46]. Another type such as Sigfox using the ATMEGA324P processor and RN2473 chip, is an alternative to incorporate with LoRa, for the measurement of different environmental parameters with long-range and low-power characteristics [47]. The inclusion of technologies such as the use of SMS together with GSM and WSN networks with different sensor nodes, perform different environmental measurements and indicate to the farmer by sending messages the way in which irrigation should be applied and keep him informed in time real on the variation of the state of the culture [48].

LOCATIONS

The main locations or lands where the technologies worked on in the reviewed articles were implemented, were mostly areas of East Asia in countries, such as: China, Indonesia, Bangladesh and India; where tropical climates are characteristic, and also other areas like the Middle East with more arid and drier climates. In turn, some implementations were included in European areas where the climate depends on the season and time of year. As for Latin America, in Colombia specifically, we worked in cold and temperate temperatures with higher altitudes where there are hills, mountains and plateaus. In these areas, the transmission of data in extensions of low latitude areas is more effective, if we take into account those of great latitude [49].

TYPES OF CROPS

The main types of crops where the technologies addressed in the reviewed articles were implemented were: rice crops, to monitor the temperature of the air and water in rice fields [50], greenhouse crops where parameters such as: thermal stress, temperature, humidity, gases, sound, wind intensity, pollution levels are taken into account [51]; crab cultures where water temperature and salinity are measured [52], vine crops in which the crop growth is measured using decametric maps, images provided from a satellite [53]; legume crops, like beans where moisture measurements were made at a distance underground when the water reaches a certain amount [54]; wheat crops where light measurements are made monitoring aspects such as the volume of the plant and the soil surface in different plots of the crop, in which follow-ups were carried out in the crop rows and the border of the plots [55]; banana crops, where factors like ambient temperature were monitored and among others, also irrigation control and use of fertilizers [56] and finally, cotton crops where factors such as water salinity, temperature and humidity are measured, evidencing precision in the collection information [57].

In hydroponic lettuce crops, factors of humidity, weight, and important components of the soil were monitored, obtaining as a result, relevant data that allowed to indicate if the plant is in optimal conditions [58]. In crops such as coffee, sugarcane and cocoa, factors such as the chlorophyll content in the plant are monitored in order to apply the correct amount of fertilizer [59].

SUCCESSFUL APPLICATION METHOD

The main procedures in the implementations of the technologies addressed in the reviewed articles were tea plantations, where sensors are installed in various blocks within the plantation, thus obtaining good performance in parameter measurements and data transmission from the plant. receiver side with LoRa modules [60].

On the other hand, in rice crops tubular MFCs were manufactured, the biosensors installed manually in the hoe of the upper soil of the rice before transplanting, the generation of electricity will arrive to indicate events and a long distance data transmission through LoRa and LoRaWAN protocols [61].

Furthermore, in terms of agricultural farms, sensor nodes were included within the farm, in order to collect meteorological data, thus intermediate sensors allow the distance to be extended to 750 meters [62], sensors are installed in the herds in the cattle collar, which allow taking different types of measurements and having control over the herds [63].

Similarly, in the management of irrigation pumps, a device consisting of two circuits was built, the first to turn the pumps on and off, and the second supervises and controls the work of the water pumps; this in order to reduce water waste in crops [64]. Likewise, the construction of a sensor-and-actuator-controller unit (SACU) allows to perform on and off functions of devices such as a water pump, thus reducing energy consumption [65]. In this way, regarding the implementation of several sensors, the collection of data from the nodes through LoRa has been seen effectively as it reduces costs in agriculture [66].

In addition, other types of image-based implementations and end nodes, are in charge of identifying the representative change of the monitored image and in this way updates the frame dividing the image into patches for the monitoring of agriculture, it is effective for growth of crops and pest and disease control [67].

In agricultural systems based on WSN networks and UAV nodes in data collection, it is quite effective in activities such as irrigation of crops, use of fertilizers and decisive stages in planting and harvesting. Furthermore, this system reduces dependency on IT infrastructures, which represents a higher cost for the farmer [68].

In arid territories, UAV devices were implemented using 8-wing drones, composed of cameras and thermal sensors, which were capable of examining images and the infrared level, identifying overlaps. The results of this implementation allowed the efficient identification of drainage zones [69].

In banana areas for the detection of pests and diseases, monitoring of the plants is carried out through the analysis and processing of images together with technologies such as GSM and SMS, thus allowing to avoid damage and losses in the plantations; which allowed to introduce improvements in the materials to be applied. [70].

In plantations, a monitoring system was implemented through cameras and meteorological sensor nodes, together with an intelligent decision system capable of monitoring the health status of the crops. This information is transmitted through applications to the farmer to apply the doses to the appropriate fertilizers and materials. [71].

In like manner, for citrus crops, a model based on sensor nodes was made, allowing the identification of diseases in the fruit, using camera-type sensors. The analysis of the images obtained, allowed in turn to obtain an efficiency level of 96% and helped farmers to detect diseases early. [72]

BIBLIOMETRIC ANALYSIS

In figure 2, we can show through a bar graph, the magazines Vs. the maximum number of publications in the years between 2015 and 2020. Among them, the IEEE things, whose main objective is the Internet of Things, comput electron agric, frontal information system, sensors and intelligent environment of ambient intelligence.

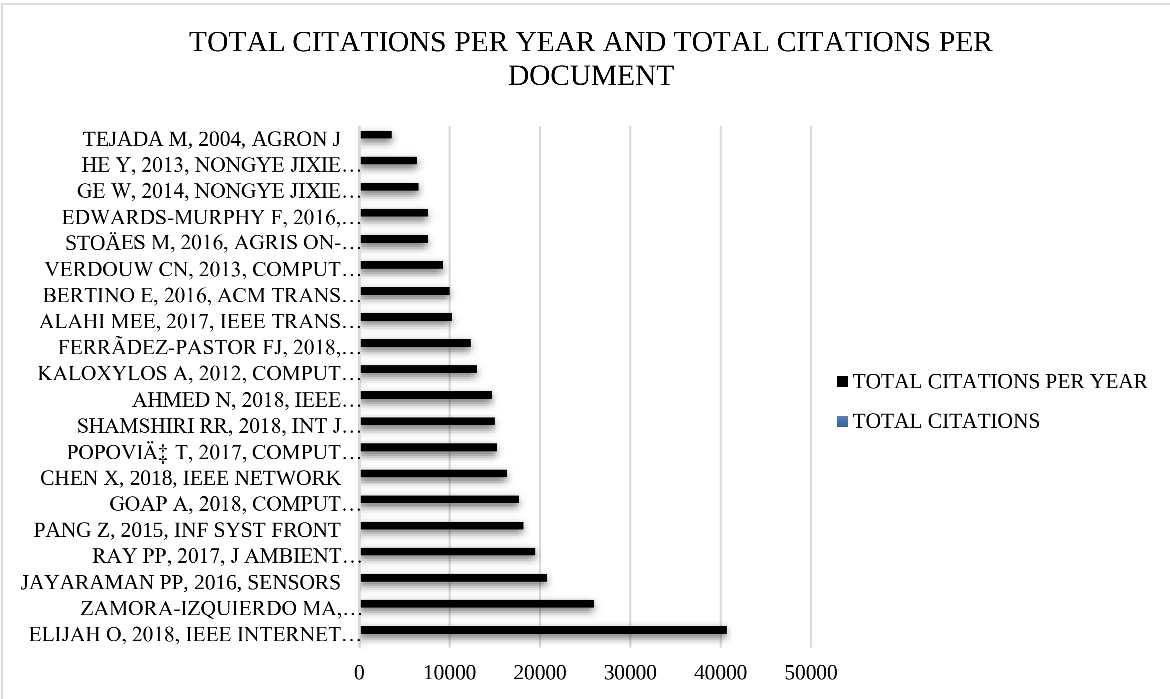

Figure 2. Summary of the main journals which have published during the years between 2015 and 2020.

Source: The authors

In figure 3, we can show through a bar graph, the journals Vs. the number of citations in the years between 2015 and 2020. Among them: Sensors, Computers and Electronics in Agriculture, Ieee Access, Nongye Gongcheng Xuebao / Transactions of the Chinese Society of Agricultural Engineering, International Journal of Recent Technology and Engineering.

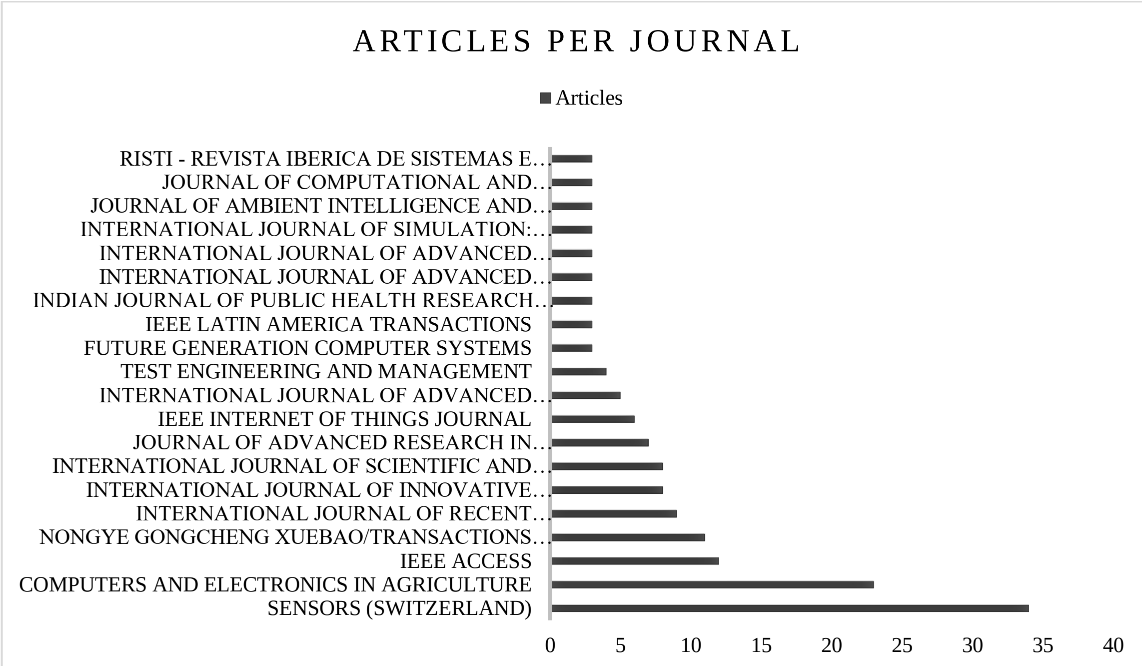

Figure 3. The most cited journals during the years 2015 and 2020

Source: The authors

In Figure 4, we can see a graph of grouped columns, which shows the authors with the highest number of publications during the years between 2015 and 2020, among them are Ayaz M, Abane, Arvantis, Li Y.

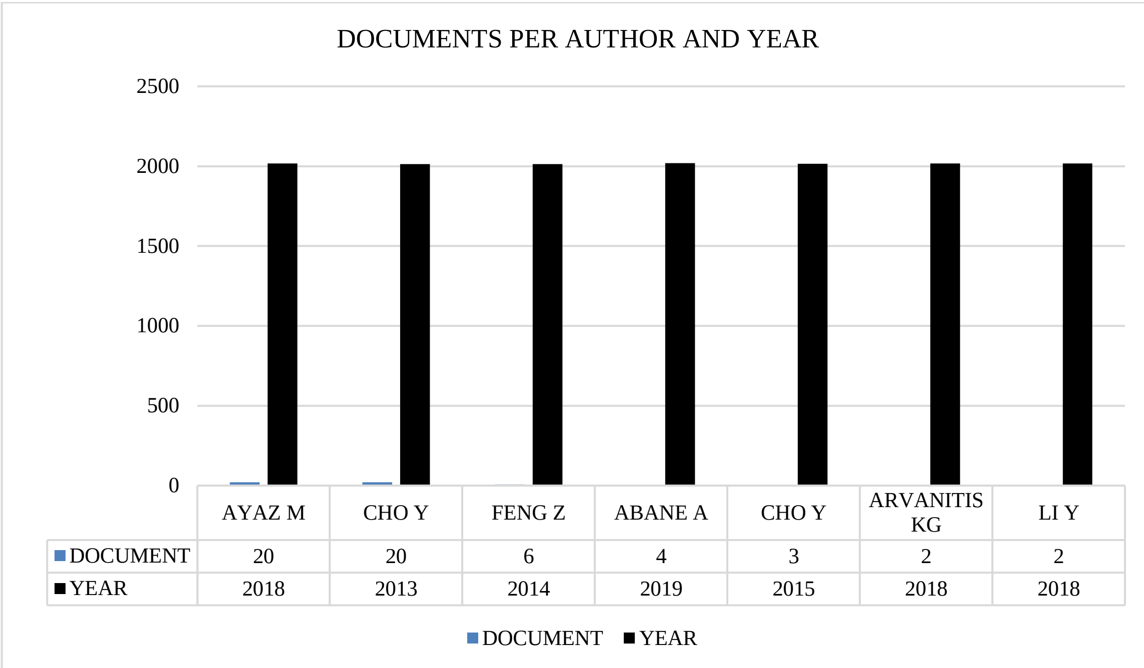

Figure 4. The authors with the highest number of relevant publications to the topic of interest, during the years between 2015 and 2020.

Source: The authors

In figure 5, the countries with the largest publications are shown in blue and the countries with no documents or publications in gray. The countries with the largest publications are: India, China, Spain, Italy and South Korea.

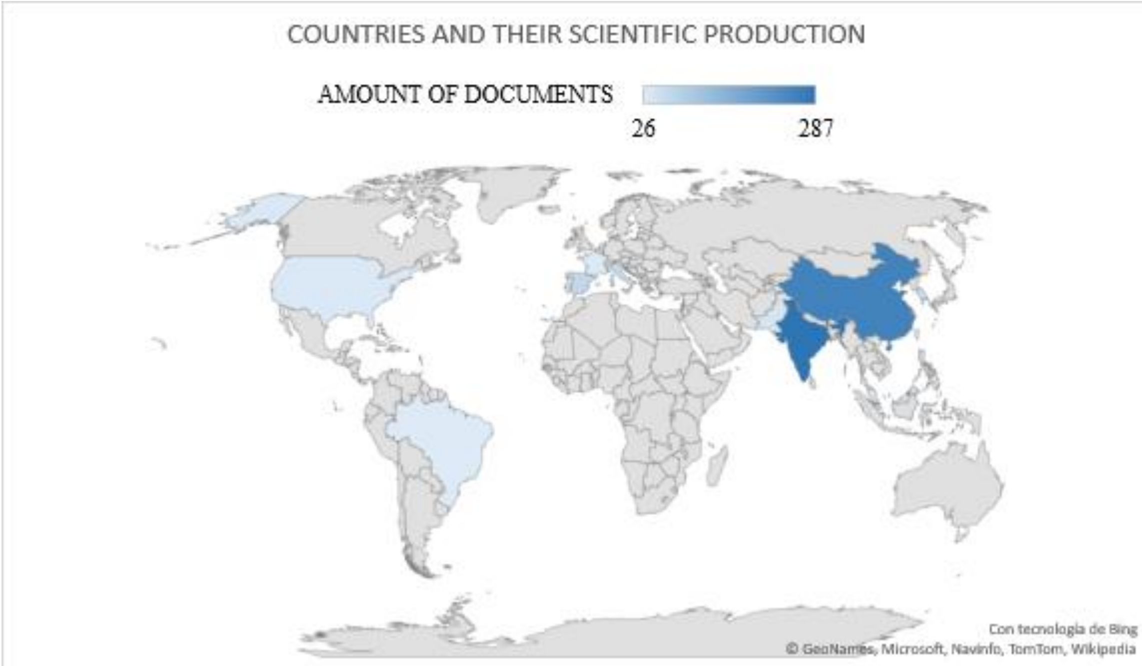

Figure 5. The countries with the most scientific production during the years between 2015 and 2020.

Source: The authors

5. DISCUSION

COST

Currently the cost of LoRa sensors, actuators and modules in the local trade, are inexpensive and affordable. However, by requiring the application of a solution with IoT and LoRa technologies in large areas, a large number of devices with greater capacity and quality are required, which meet the needs of the crop. For this reason, a greater economic investment can be generated, as a measure more sensors of the same type can be introduced as intermediaries that allow information to be captured between nodes and can be transmitted more easily, reducing investment by the farmer or owner of the crop.

SCALABILITY

Agricultural systems are extensive systems where is possible to integrate more devices through WSN networks, this allows to support a large number of devices and nodes. The restrictions that arise in the expansion of the sensor network are directed to the gateway, the network architecture and the middleware that allow communication between protocols [73].

ENERGY THROUGH RENEWABLE RESOURCES

Throughout the review of the solutions implemented with Iot systems, some used rechargeable and replaceable lithium batteries, solar panels that managed to reduce energy consumption, but have restrictions such as the environment, which affects effectiveness, since, in low sunlight, devices do not recharge properly. In other words, it replaces the interconnections by means of cathodes installed in the earth in crops such as rice; and thus manages to provide energy to the entire crop and feed all energy nodes [50]. This form of energy would be of great help in Colombia.

LOCALIZATION

In the implementations that were reviewed, the vast majority focused on crops such as rice and tea, which have the characteristic of being a tropical zone; and others such as vineyards, greenhouses, crab farms and herds, have the characteristic of belonging to warm and temperate zones; in these, the data transmission between sensor nodes was effective. In Colombia in crops such as potatoes, where the area is characterized by low temperatures and mountains, the data transmission in UAV sensors was not as good, due to the height above sea level and this type of Iot and LoRa systems are more efficient in crops such as corn and grapes [49].

6. CONCLUSIONS

Agriculture is a vital part of societies globally. Therefore, technologies such as LoRa and Iot have been coupled in the best way and it can be seen that these have been successfully implemented, in all techniques and in all areas of agriculture.

The different varieties of devices offer different uses in the subject of agriculture that have allowed to cover the food demand at global level reducing the excessive application of inputs such as water and others as chemical pesticides among others.

This study revealed how these technologies have generated great impact and multiple benefits to farmers and agriculturists in continents such as Asia and Europe. This type of technologies applied in Colombia are beneficial, since they are devices that are easily accessible in the market and would help the farmer to optimize agricultural processes and be aware of the changes that are occurring in the crop. However, at present there is partial internet coverage in Colombia. Otherwise, in which government programs in support of agriculture are strengthened and internet coverage is extended throughout the national territory, possibly throughout the country it would be possible to implement all kinds of devices and technologies that optimize resources, reflected in greater profits economic for agricultural producers of all sectors of national agriculture.

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