A Prediction Model of Smart Agriculture Based on IoT Sensor Data: A Systematic Literature Review

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Abstract—**In recent years we have faced drastic climate change which have affected various areas of life but especially those of agronomy. The most critical factor for grape quality and quantity is climate changes. Sensing devices are helping different sectors, especially in agriculture, the data are transferred throw Internet protocols and the field is known as Internet of Things. The fact of collecting IoT sensor Data from SmartAgriculture and SmartCity sensors is known as "smart agriculture" which consists of activities such as monitoring of cultivation, identification of diseases, define the period of time for fertilization of agriculture products, etc. This paper presents a systematic literature review to identify main researches in this field and further developments. According to prior observation of published research conducted since 2018, we are focusing our research on studies that have been published in areas that are relevant to smart agriculture; data mining for smart agriculture; predictive algorithms for smart agriculture; predictive model of smart agriculture on IoT sensor data and smart agriculture and IoT technologies. The number of papers in this field is huge for this reason is very important to conduct a review to see current development and find key components for future works.**

Keywords-Internet of Things, Artificial intelligence, data mining, IoT sensor data, smart agriculture.

I. INTRODUCTION

Climate change, consumer needs, expanding demand, and persuading young people to become farmers and accept and learn new technologies are all huge difficulties that agriculture is facing today. In viticulture and wine production, climate is probably the most critical factor that influence the quality of grape. By using climate data from the Kosovo Hydrometeorological Institute, data from institute of viticulture and specific sensors for collecting data, data mining, visualizing data in real time and do prediction for the quality and yield of grape are the key factors that lead to decision making in this area.

Agriculture is no exception to the rule that data is power. Farmers can learn more about their land and how it behaves by using data. Artificial intelligence, data mining and other data analysis techniques are utilized in systems that collect and analyze data. Collecting data, mining and analyzing them in order to make decision related to agriculture will benefit not just farmers and governments, but also scholars who will be able to use the data produced for future studies. Furthermore, it will enable decision making for farmers and business in this field.

By smart agriculture [10, 11, 12] we mean the use of digital techniques to recreate, govern and optimize production processes. Digital transformation encourages human intervention in agriculture and helps reduce the workload, carry out specific measures, to calibrate the use of chemical products of soils and crops, in addition to guaranteeing and increasing crops.

The aim of this paper is to analyze the existing research in this field and specify the main goals for future work. As

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such, the methodology used in this paper will seek to analyze and resolve the relevant research questions that arise.

The following in second section is presented the methodology we use for this research. In the third part a classification schema of this research is presented. The fourth section present the results based on some research question. At last is conclusion and future works.

II. METHODOLOGY

The main aim of this systematic literature review is to determine and answer the main question we have for this area. Search is done in four main topics which is related to our field of research as:

- Smart agriculture;
- Data mining for smart agriculture
- Predictive algorithms for smart agriculture;
- Predictive model of smart agriculture on IoT sensor data

For each of this research topics a large number of papers was shown in result but we select they which are of our interest. The idea is to extract a comparative table related to different parameters and extract the list of algorithms which are used for prediction in smart agriculture IoT sensor data and which models for this purpose are proposed before. Also, we analyze the question why smart agriculture is the future and what are the processes that take place on a farm using smart farming?

TABLE I. SEARCH STRING

Search string	No. of papers in result	No. of papers we choose
Smart agriculture;	490	18
Data mining for smart agriculture	108	10
Predictive algorithms for smart agriculture;	71	12
Predictive model of smart agriculture on IoT sensor data	48	13

A. Research Questions and Search Strategy

The aim of this paper is to analyze publications that have tackled predictive algorithms for smart agriculture based on some research questions such as:

- Why Smart Agriculture is the future?
- What are the processes that take place on a farm using smart farming?
- What are the predictive algorithms used by authors?
- Which of the authors propose a model for prediction in smart agriculture?

Based on the search string we provide in table 1 we have searched the most credible digital libraries as IEEE-Xplore, ACM, SpringerLink, ResearchGate, EBSCO host, etc. The larger number of papers is when the topic is more general as in our case where the search query is just smart agriculture, when the topic is more focused on our research area the number of papers is smaller. From the result we get we just pick up the paper how are related to smart agriculture and propose a model for prediction in IoT sensor data. The filtering also is done are chosen papers how describe and use of algorithms for prediction in smart IoT sensor data in the field of agriculture. The selection also is done the algorithms for prediction needs to be in the field of data mining. As a result, we select just 52 papers out of 717 paper we read.

III. CLASSIFICATION SCHEMA

The classification schema is presented in three columns (figure 1): the main field of interest related to smart agriculture, a methodology which need to be conducted in order to propose a model for prediction in smart agriculture IoT sensor data and algorithms which are used for prediction in smart agriculture IoT sensor data. Based on this research we have identified a list of algorithms that we will use for further testing and propose a model for prediction in smart agriculture. Our research is based on three main methodologies as data mining methods for prediction in smart agriculture by using artificial intelligence.

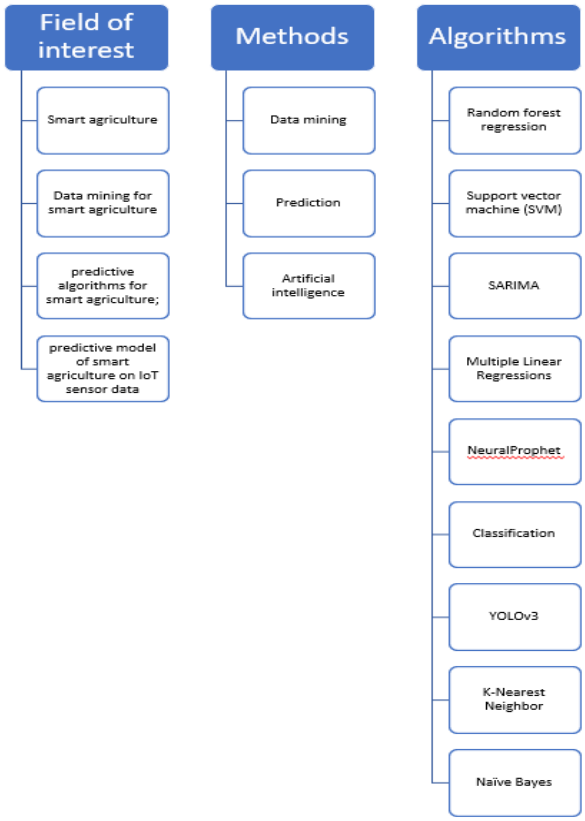

Figure 1. Classification schema

IV. RESULT

The selected papers during this research are classified into four categories related to the main research topics we present in table 1. Based on this classification we answer the four-research question we have specified in this study.

We have analyzed 52 papers in total for four main research topics in the period of time 2018-2022. Based on the table 2 we can see that the larger number of papers are published in period of time 2020-2021 this mean that this field is actual for following researches.

TABLE II. NUMBER OF PAPERS PER YEAR

Year	Number of papers	%
2018	5	9.26
2019	7	12.96
2020	16	29.63
2021	15	27.78
2022	9	16.67

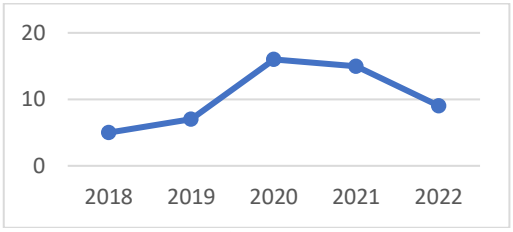

Figure 2. Number of papers per year

A. *Why Smart Agriculture is the future?*

Smart Agriculture is a fairly new term and most farmers are not aware of what exactly lies behind it. This section will describe the exact concept of smart agriculture and why it is the future of agriculture [10, 52].

The term smart agriculture refers to the use of technologies such as the Internet of Things, sensors, location systems, robots and artificial intelligence on farms [10, 52]. The ultimate goal is to increase the quality and quantity of the harvest.

Some examples of technology used in smart agriculture are:

- Precise watering and proper nutrition of plants;
- Management and control of temperature in the greenhouse;
- Sensors for soil, water, light, humidity, temperature management;
- Software platform;
- Location systems – GPS, satellites, etc.;
- Communication systems – based on mobile connection;
- Robots;
- Analytics and optimization platforms.

The connection between all these things is the Internet of Things, where it is a mechanism for the connection between sensors and machines resulting in a complex system that manages the farm based on the received data. Thanks to this system, farmers can monitor the processes on their farms and make strategic decisions remotely - tablet, phone or any other mobile device without being present in the fields.

To have a strategy for smart agriculture will help farmers to make decision and improve the food production [12]. FAO [12] estimated that if the present production and consumption rates continue, agricultural production should increase 60% by 2050 to meet the needs of food of world's population. Because the climate has changes is important to integrate Information and communication technologies (ICT) to protect food production.

Also, the authors in this paper [13] as others authors [11, 12] say that the food production in the future need to increase because the population will increase too. This is challenging in recent years because of the climate changes for this reason incorporating technologies will help farmers to protect their agricultural products. Incorporating IoT sensors is a must. IoT provides us automation and control of the objects that are used on a regular basis through the internet from any place on the globe [13]. The system that is proposed in this paper is composed from sensors which collect data for soil moisture, temperature & humidity, then these sensors are connected to NodeMCU including Wi-Fi module ESP8266-12E. The data from sensors are send in Blynk cloud using a bridge throw Wi-Fi. The app of Blynk can be used for monitoring this data collected from sensors. This paper present one IoT prototype for smart agriculture with low cost to implement it.

The authors in this paper [16] presents the latest trends in IoT smart agriculture applications, also the open-source software for smart agriculture is presented. The issues and challenges that are faced with this open-source software also are shown. In this paper are presented the main challenges in smart agriculture as: hardware and devices, networking, infrastructure, signal interference, data security and organizational challenges.

The authors in this paper [17] also mentioned that smart agriculture is very important for cultivation of agricultural products with high quality and quantity. Smart agriculture also is known as smart farming or precision farming which is a field that use IoT sensor data and information technologies to help farmers take decision in different situation. In this paper also are presented the challenges, strength and weaknesses with sensor equipment used for collecting data from farms.

The process of pre-processing of data is very important in the field of agriculture known as data sensing in smart agriculture. The authors [18] present a strategy for smart agriculture to identify inaccurate condition based on machine learning in order to increase the validity of sensing data.

The author [19] is this paper show that application of technology in smart agriculture have also positive impact in the economy by increasing the revenues. They present the fields where smart agriculture is applied as detection of pest also for food safety, etc.

The economy in many countries depends from agriculture, China is one of them where the low labor cost enables to be one of the countries with the most developed agriculture. Many of them use IoT technologies to increase quality and quantity of products [20]. In this paper [20] it is discussed how to combine smart agriculture with IoT technologies in China. They propose method intelligent agriculture system based on heterogeneous networking technology.

The smart agriculture is now in many sectors of food production. In this paper [21] the authors present the importance of applying smart agriculture in cotton production management. They describe the advantages for using smart agriculture in this sector.

The authors [22] in this paper show also how important is smart agriculture and IoT in India. They presented one

automated system for crop monitoring of the agriculture lands.

The smart agriculture is very interesting area nowadays. This paper [23] show how children can develop smart agriculture IoT based system to monitor temperature and humidity without programing language and computer. They use 3D printer to print the necessary equipment and use iPhone throw QR code scanning they develop such system.

The authors in this paper [24] show a smart agriculture system for home where the different quantities of soil and air conditions are measured. The proposed system uses ESP-32 device to connect sensors, then the sensor data throw Wi-Fi are sent to mobile application. The system generates real-time report about the environments and plants.

In this paper [25] is presented the use of Fog computing in smart agriculture because it enables tracking in real time the data generated by sensors and enables prediction in real time.

There are many applications used in smart agriculture and IoT. The authors [26] in this paper present the software and hardware used to develop a smart agriculture model. The use MQTT Cloud to store data, LoRaWAN Network to monitor remotely the sensor data.

B. What are the processes that take place on a farm using smart farming?

The smart agriculture integrates different task in order to get a desired result. Different authors [39-51] in their papers presents the steps that need to be taken in order to deal with smart agriculture as:

- Data collection- Sensors are installed in all parts of the fields and transmit data on air, soil moisture, etc.
- Diagnosis- The collected data is analyzed by the system and in the end, it produces a result for the status of the monitored object or process. Possible problems are also identified.
- Decision making- Based on the problems presented earlier, the software platform or even a person managing the platform decides on the actions to be taken.
- Actions- Actions that have been identified earlier have been completed. A new measurement of soil, air, humidity is performed by the sensors and the whole cycle starts again. The result from this smart agriculture process is precise and under control 24/7, ultimately saving on all the main resources used – water, energy, fertilizers, time spent by strategic people, time spent by qualified human resources shorter.

C. What are the predictive algorithms used by authors?

There are different researches [27-37] which propose the use of different data mining algorithms for prediction in IoT sensor data for agriculture. These algorithms fall into data mining techniques for predicting smart agriculture data. The main algorithms proposed by them are:

- Multiple Linear Regressions
- Linear regression;
- Decision tree;
- Classification;
- K-Nearest Neighbor
- K-means Clustering
- Apriori Algorithm
- Naïve Bayes algorithm
- DBSCAN,
- PAM,
- CLARA,
- Chameleon,
- Neural network
- Machine Learning Techniques
- Deep Learning,
- YOLOv3,
- Support vector machine (SVM)
- Random forest regression

For more details which paper which algorithms have proposed you can find in table below.

TABLE III. PREDICTIVE ALGORITHMS PROPOSED BY RESEARCHES

[27]	[28]	[29]	[30]	[31]	[32]	[33]	[34]	[35]	[36]	[37]
Nearest Neighbors based Data Filter	Multiple Linear Regressions and Linear regression Decision tree	Classification Decision Tree, Random Forest, Neural Networks, Naïve Bayes, Support Vector Machines and K-Nearest Neighbor	1. K-means Clustering 2. Apriori Algorithm 3. Naïve Bayes algorithm	DBSCAN, PAM, CLARA, Chameleon, regression techniques	Neural network	Machine Learning Techniques supervised algorithms and regression model	Multiple Linear Regression, K-Nearest Neighbors, Support Vector Machine, and Random Forest	machine learning or time series forecasting	Deep Learning, YOLOv3, Pests and Diseases, Smart Agriculture, Unmanned Aerial Vehicle (UAV), Artificial Intelligence (AI), Internet of Things (IoT), The Artificial Intelligence of Things (AIoT)	multiple linear regression, K-nearest neighbor (KNN), Support vector machine (SVM) and random forest regression

But also, we have done research related to which are algorithms for prediction in smart agriculture IoT data. There are also several researches in this specific topic and we are going to present next.

The authors in this paper [39] propose one architecture for prediction in smart IoT data. They use two algorithms in different cases, Linear regression and SVM were if the output is required to be determined, they propose to choose the SVM, but if the output is needed to be slightly smooth, is better to choose the LR. They use cloud for collecting and analyzing the data, also MySQL database is used and Raspberry PI. The proposed architecture gives a message to farmers if there are found diseases.

A new approach [40] for predicting disease manifestation using weather data with the help of extreme learning machine. The proposed model helps identifying the problems in order to reduce the economical lose. They use prediction of disease for potatoes.

Another methodology is proposed [41] for prediction. It can predict the temperature, precipitation, wind speed and evapotranspiration based on the field location and day. They use machine learning algorithms as Linear Regression, Decision Tree, Random Forest and Neural Networks. But best efficiency, after cross-validation achieve Random Forests and Decisions Trees.

The other authors in their paper [42] also propose a model for recommending the best crop to grow based on soil and the region's weather characteristics, and another for the forecasting of the hourly average air temperature. They use different algorithms as Random Forest which show the best metrics as a classifier and it is compared to K-Nearest Neighbors (KNN), Decision Tree, Naive Bayes, Logistic Regression, Convolutional Neural Network, and Feed Forward Neural Network. They conclude that classic machine learning algorithms performs well for small datasets for that reason they use also Facebook Prophet which was more accurate (R2 = 0.81, RMSE = 3.74) than their proposed LSTM architecture.

In this paper [43] the author proposes a model to predict air temperature in green house system by using NN-based prediction algorithm. This mean that prediction of air temperature is not applicable just for smart agriculture but also in other areas.

Decision tree algorithms are showed very successfully when we have to deal with large amount of data as they came from IoT sensors. In this paper [44] is proposed a model for prediction in smart farming by using Decision Tree algorithm of the Scikit-learn library of python. The research is done for Bok choy product in Indonesia.

A review of existing works in prediction for smart agriculture is presented in this paper [45]. Also, here the authors propose a model for prediction in smart agriculture based on machine learning (ML) for IoT sensor data.

In this paper [46] is presented a monitoring system called SEnviro for smart agriculture. They explain all the components of this architecture in this paper. Also they created a web based user interface where the user can see the data from the monitoring process and can be alerted when something is not going well.

The authors in this paper [47] propose one IoT-based smart agriculture system which have multiple function as detection, quantification, ripeness checking, and detection of infected vegetables. They use machine learning method-convolutional neural network (CNN), circular Hough transformation (CHT), color thresholding, and color segmentation methods.

The authors in this paper [48] propose a model for crop productivity and drought predictions for smart farming. The proposed method combines different algorithms and use PART classification techniques. The proposed method is named WPART. The proposed system is composed from four stages: first collect the data from IoT system, then the second stage preprocesses data, the third stage uses the Wrapper feature selection approach to analyze the environmental indicators, and select the effective indicators of the farming system, and at last the is used PART supervised machine learning algorithms are used to predict the drought depending on the selected features [48].

In this paper [49] the author proposes a low-cost monitoring system in smart farming using flying IoT, which mean they use drones to collect data and based on this data as next research they will develop algorithm for prediction.

Prediction in smart agriculture is a main task in order to advice farmers for taking right decision related to their crops. The same task is done also in this paper [50] where is proposed a revolutionary wireless mobile robot based on the IoT. They use Decision Trees for prediction and also, they use Kalman filtering for prediction.

The authors in this paper [51] propose a method for reduction of data collected from sensors in node level by using prediction and reduction algorithms. They achieve an 88% data reduction. They use machine learning data reduction algorithm (MLDR) and the Pearson Data Correlation and Prediction algorithm (PDCP).

D. Which of the authors propose a model for prediction in smart agriculture?

One important part of our research is to find what models are proposed for prediction in smart agriculture based on IoT senso data. We found out that the model proposed are composed from different phases starting from data collection to visualization and prediction. Was important in some papers are analyzed the key factors which indicates the data to have anomalies during the collection phase. The researchers are done for different agro products but our interest was grape. Many of researches which was related to grape products are done in Italy region and France which are well known for wine culture. From all paper we select related to the research field just 20 of them out of 52 have proposed a model for prediction in smart agriculture. The paper which proposes a model are shown in table below:

TABLE IV. NUMBER OF PAPERS WHICH PROPOSE A MODEL FOR PREDICTION IN SMART AGRICULTURE PER YEAR

Year	Paper reference number	Number of papers per year	%
2018	[6], [34], [48]	3	15
2019	[1], [40], [41], [42]	4	20
2020	[7], [18], [25], [37], [39]	5	25
2021	[2], [5], [26], [35], [36] [44]	6	30
2022	[3], [10]	2	10

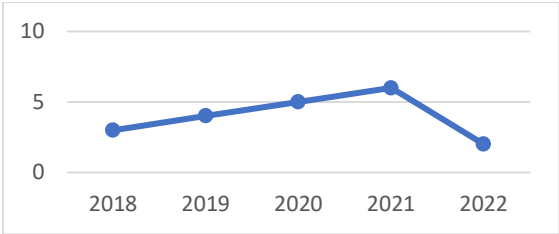

Figure 3. Number of papers which propose a model for prediction in smart agriculture per year

V. CONCLUSION AND FUTURE WORKS

This research is based on many researches in four specific fields which give a clear view about the existing researches in this field. From this view we can conclude that smart agriculture is one emerging field for research because of rapid climate changes and the negative impact that have in the quality and quantity of agriproducts.

Smart Agriculture is a fairly new term and most farmers are not aware of what exactly lies behind it. The term smart agriculture [14, 15, 53] refers to the use of technologies such as the Internet of Things, sensors, location systems, robots and artificial intelligence on farms [10, 52]. The ultimate goal is to increase the quality and quantity of the harvest.

Because the world is facing with climate changes in one side and the population growth by the other side [4, 8, 9, 42, 52] is very important to use data mining techniques in agriculture to predict the quality and quantity of agriproducts.

From this research we have identified the algorithms used for prediction on IoT smart agriculture data and the existing models for prediction in smart agriculture.

To advance our research in this field we conclude that we need to:

- Propose a model for prediction of quality and quantity of grape based on IoT sensor data from agriculture. This proposal will help farmers to take decision and improve the process of grape processing and grape sterilization.
- Select the prediction models and algorithms used by other authors, and to compare them and select the best to compose the new model which is better than existing.
- Propose a web-based platform for visualizing the data in real time where the farmers will be able in real time to monitor the weather parameters as temperature, air humidity, air pressure and the land humidity.

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