SLR Recommender Systems in Agriculture

Edinson David León

Determining the type, quantity, time, and frequency of applying nitrogen fertilizers is crucial to optimize economic resources and reduce the adverse effects on the environment. In consequence, the integration of intelligent systems has been proposed to manage the optimal application of fertilizers. In this context, recommender systems are software tools to assist farmers in the optimal application of fertilizers by integrating data from various sources, such as specialized knowledge bases, data sensors and climatic stations.

Planning

To study main recommender systems in agriculture and find technological gaps that limit their implementation in Colombia.

PICOC

- **Population:** Studies about recommender systems in agriculture, but focused on fertilizers
- **Intervention:** Sensors and Agronomic Model to gather data
- **Comparison:** Agronomic Models recommendations and agricultors' or experts' suggested applications of fertilizers
- **Outcome:** Accurate recommendations of fertilizers
- **Context:** Suggest fertilizers applications for cofee crops

Research Questions

1. What are the types of software tools to make recommendations or predictions in the field of agriculture?
2. What are the main crops in which these systems are used?
3. What are the main countries in which more research has been done in this area?
4. What are the data sources to make the recommendations and / or predictions?
5. What algorithms are implemented?
6. What are the most promising directions for future research?

Keywords and Synonyms

Keyword	Synonyms
Agriculture	Farming
Decision Support System	

Fertilizers	Nutrient
Nitrogen	NPK
Recommender System	Prediction System, Recommendation System

Search String

(("recommender system" OR "recommendation system" OR "prediction system" OR "expert system" OR "decision support system") AND (Farm* OR Agri* OR Nutri* OR fertili*))

Sources

- Mendeley
- Scopus (http://www.scopus.com)
- WoS (http://webofknowledge.com.acceso.unicauca.edu.co)

Selection Criteria

Inclusion Criteria:

- Articles containing recommendation systems, expert systems or prediction systems oriented to agriculture
- Articles published between the years 2011 - 2024
- Articles written in the English language
- Papers Presented at Satellite Conference Events

Exclusion Criteria:

- Articles from secondary or tertiary sources
- Articles that do not describe SR or prediction systems or expert systems
- Articles that do not explicitly describe the algorithms or techniques used to make recommendations / predictions in agriculture
- Artículos que no estén enfocados al contexto de la agricultura
- Short articles that only present abstracts or slides and that lack scientific information

Quality Assessment Checklist

Questions:

- Does it provide a comprehensive review of the current state of knowledge or existing related works?
- Does it present a diagram of the main architectural components?
- Does it show and describe the algorithms or pseudocodes used or at least clearly indicate the techniques used?

- Does it analyze the main findings and empirical results obtained?
- Does it clearly describe the evaluation carried out on the results obtained?

Answers:

- Yes
- Partially
- No

Data Extraction Form

- Year
- Country study
- Algorithm
- System type
- Crop
- Datasource
- Architecture
- Inputs
- Outputs

Conducting
Digital Libraries Search Strings

Scopus:

TITLE-ABS-KEY (("recommender system" OR "recommendation system" OR "prediction system" OR "expert system") AND (farm* OR agri* OR nutri* OR fertili*)) AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012)) AND (LIMIT-TO (LANGUAGE , "English"))

WoS:

ALL=(("recommender system" OR "recommendation system" OR "prediction system" OR "expert system") AND (Farm* OR Agri* OR Nutri* OR fertili*))

Imported Studies

- **Mendeley:** 207
- **Scopus:** 146
- **WoS:** 61

Data Extraction Form

Data Extraction Form

	Description	Type	Values
	Year	Integer Field	n/a
	Country study	String Field	n/a
	Algorithm	String Field	n/a
	System type	Select One Field	• AgronomicModelbasedRecommender • Decision Making • Decision Support • Prediction System • RS - CF • RS - Content B • RS - KB • RS hybrid • SystemExpert • SystemOther
	Crop	String Field	n/a
	Datasource	String Field	n/a
	Architecture	Boolean Field	n/a
	Inputs	String Field	n/a
	Outputs	String Field	n/a

Quality assessment

Title	Quality Score
Machine learning techniques for rainfall prediction using neural network	0.0
Prediction of irrigation event occurrence at farm level using optimal decision trees	18.0
A study on various data mining techniques for crop yield prediction	8.0

Application of Expert System with Web-Based Forward Chaining Method in Diagnosing Corn Plant Disease	11.0
Mobile based Expert System Application for improving productivity of crops in Agriculture for Tamilnadu, India.	0.0
Crop Suitability and Fertilizers Recommendation Using Data Mining Techniques	12.0
INTEGRATION OF EXPERT SYSTEM AND FUZZY THEORY FOR DIAGNOSIS WHEAT PLANT DISEASES	13.0
A generic methodology for developing fuzzy decision models	8.0
A Fuzzy Logic-Based Crop Recommendation System	16.0
AI Recommender System With ML for Agricultural Research	3.0
USE OF THE EXPERT SYSTEM-CROM IN APPLE ORCHARDS	8.0
U Nong Shu Cai Tong system - The Agricultural expert system based on U disk	8.0
Design of remote crops image capture and expert system in the Yellow River Delta	6.0
Development of Expert System for Selecting Tomato (solanum lycopersicum L.) Varieties	23.0
Agricultural Expert System Design Based on Bayes Theorem	15.0
Establishment and Validation of Nutrient Expert System for Radish Fertilization Management in China	16.0
Research on the expert system for sweet corn standard production based on heterologous data integration technology	5.0
GPC: An expert system based on multi-branch structure for grass pest control information	6.0
Improving Crop Productivity Through A Crop Recommendation System Using Ensembling Technique	13.0
IoT based farming recommendation system using soil nutrient and environmental condition detection	11.0
IRRIGATOR PRO: PROGRESSION OF A PEANUT IRRIGATION SCHEDULING DECISION SUPPORT SYSTEM	10.0
Rice crop management expert system with forwarding chaining method and certainty factor	9.0
Expert system for diagnosis of diseases of rice plants: Prototype design and implementation	18.0
Expert system for insect pests of agricultural crops	8.0
FPGA based effective agriculture productivity prediction system using fuzzy support vector machine	13.0

NIRS meets Ellenberg's indicator values: Prediction of moisture and nitrogen values of agricultural grassland vegetation by means of near-infrared spectral characteristics	13.0
Rain prediction using fuzzy rule based system in north-west Malaysia	18.0
Using daily data from seasonal forecasts in dynamic crop models for yield prediction: A case study for rice in Nepal's Terai	18.0
RSF: A recommendation system for farmers	23.0
Methodology of fertilizer recommendation based on yield response and agronomic efficiency for rice in China	16.0
Recommendation system for improvement in post harvesting of horticulture crops	11.0
Prediction of Frost Events Using Machine Learning and IoT Sensing Devices	20.0
Nitrogen Fertilization of No-Tillage Winter Cereals in the South-Central Region of Parana, Brazil	11.0
Syragri: A recommender system for agriculture in mali	25.0
Fertilizer recommendation system for melon based on nutritional balance [Sistema de recomenda{ç}{ã}o de fertilizantes para o meloeiro com base no balan{ç}o nutricional]	10.0
Fertilizers recommendation system for disease prediction in tree leave	18.0
Pest diagnosis system based on deep learning using collective intelligence	18.0
Ontology based expert system for pests and disease management of cotton crop in India	18.0
Rule Based Method in Expert System for Detection Pests and Diseases of Corn	18.0
Ontology Based Recommendation System for Predicting Cultivation and Harvesting Timings Using Support Vector Regression	21.0
Corn automatic irrigation expert system based on infrared temperature sensor and capacitive moisture sensor	13.0
Web based expert system for diagnosing disease pest on banana plant	11.0
Weather prediction based on fuzzy logic algorithm for supporting general farming automation system	16.0
KrishiMantra: Agricultural recommendation system	8.0
An expert system for integrating biodiversity into agricultural life-cycle assessment	8.0
An expert system for predicting orchard yield and fruit quality and its impact on the Persian lime supply chain	13.0
Automatic expert system based on images for accuracy crop row detection in maize fields	18.0
Automatic expert system for weeds/crops identification in images from maize fields	18.0

CitrusSprayEx: An expert system for planning citrus spray applications	23.0
AI Crop Predictor and Weed Detector Using Wireless Technologies: A Smart Application for Farmers	23.0
Internet of Things based Expert System for Smart Agriculture	18.0
Fuzzy logic tool to forecast soil fertility in Nigeria	10.0
In-season decision support tools for estimating sidedress nitrogen rates for corn in the Mid-Atlantic Coastal Plain	8.0
The designment of digital greenhouse expert system	6.0
Demand based crop recommender system for farmers	15.0
Challenges of devising nitrogen recommendation systems for open field vegetables	9.0
Improvement of Crop Production Using Recommender System by Weather Forecasts	18.0
Recommendation system for farmers	8.0
NUTRIENT RECOMMENDATION MODEL FOR CARROT CROP - FERTICALC CARROT	13.0
Nitrogen Fertilizer Recommendation for Paddies through Automating the Leaf Color Chart (LCC)	25.0
A novel ensembling technique for crop recommendation system using machine learning	18.0
Agricultural Recommendation System for Crops Using Different Machine Learning Regression Methods	20.0
Fertilizer recommendation system for coconut cultivation	20.0
Preliminary the diagnosis and Recommendation Integrated System (DRIS) norms for evaluating the nutrient status of apple	9.0
Narrowing yield gaps and increasing nutrient use efficiencies using the Nutrient Expert system for maize in Northeast China	10.0
Selection of wheat (Triticum aestivum) variety through expert system	9.0
Application of a logical reasoning approach based petri net in agriculture expert system	8.0
Mobile Interfaced Crops Diagnosis Expert System (MICDES): a case for rural Kenyan farmers	19.0
Cultivation of plants harnessing an ontologybased expert system and a wireless sensor network	18.0
Application of intelligent expert system on growth model of plant	3.0
Construction and application of the expert system of diagnosis for orchard pests and diseases	9.0

Application of modern information technologies on growth model of poplar	3.0
Assessment of a Markov logic model of crop rotations for early crop mapping	9.0
Automated high resolution mapping of coffee in Rwanda using an expert Bayesian network	15.0
An expert system using ontology as knowledge base for personalized rice cultivation suggestion	20.0
A web-based fuzzy expert system for frost warnings in horticultural crops	13.0
Fuzzy expert system for land valuation in land consolidation processes	21.0
CaneDES: A Web-Based Expert System for Disorder Diagnosis in Sugarcane	14.0
Development research on the expert system for the binary tree-based apple disease diagnosis	11.0
Modeling and simulation of a multi-parametric fuzzy expert system for variable rate nitrogen application	25.0
Nutrient expert (R) rice-an alternative fertilizer recommendation strategy to improve productivity, profitability and nutrient use efficiency of rice in Nepal	6.0
A site-specific expert system with supporting equipment for crop management	5.0
Design of distributed and collaborative agricultural expert decision system based on smart phone	5.0
Machine Learning Techniques for Predicting Crop Production in India	3.0
Land suitability assessments for yield prediction of cassava using geospatial fuzzy expert systems and remote sensing	18.0
Improved seasonal prediction of rainfall over East Africa for application in agriculture: Statistical downscaling of CFSv2 and GFDL-FLOR	13.0
Predicting within-field variability in grain yield and protein content of winter wheat using UAV-based multispectral imagery and machine learning approaches	18.0
LSTM-based cotton yield prediction system using UAV imagery	16.0
Smart yield accuracy prediction using linear regression and collaborative filtration	21.0
Development of a multimodel-based seasonal prediction system for extreme droughts and floods: a case study for South Korea	8.0
Rainfall prediction using generative adversarial networks with convolution neural network	25.0
Satellite Irrigation Management Support With the Terrestrial Observation and Prediction System: A Framework for Integration of Satellite and Surface Observations to Support Improvements in Agricultural Water Resource Management	9.0
Modeling the contributions of nitrogen mineralization to yield of corn	8.0

Prediction of canola and spring wheat yield based on the Canadian meteorological centre's monthly forecasting system	9.0
IoT based decision support system for agriculture yield enhancements	8.0
Agriculture Land Suitability Evaluator (ALSE): A decision and planning support tool for tropical and subtropical crops	16.0
Application of TOPSIS method in selection of design attributes of decision support system for fertilizer recommendation	8.0
Design and implementation of agricultural knowledge cloud service	5.0
Conceptualization of a framework of decision support system for agriculture in hilly region	11.0
Modular structure of web-based decision support systems for integrated pest management. A review	5.0
Will decision-support systems be widely used for the management of plant diseases?	6.0
The Automatic Agricultural Crop Maintenance System using Runway Scheduling Algorithm: Fuzzyc-LR for IoT Networks	21.0
Strategies for optimal fertiliser management of vegetable crops in Europe	9.0
Sensors Driven AI-Based Agriculture Recommendation Model for Assessing Land Suitability	25.0
Seasonal Predictability of Four Major Crop Yields Worldwide by a Hybrid System of Dynamical Climate Prediction and Eco-Physiological Crop-Growth Simulation	9.0
PulsExpert: An expert system for the diagnosis and control of diseases in pulse crops	23.0
Precision nutrient and conservation agriculture practices for enhancing productivity, profitability, nutrient-use efficiencies and soil nutrient status of maize (Zea mays) hybrids	6.0
Perspectives of a Farmer Digital Expert Assistant System	5.0
Multi-criteria rating using fuzzy ranking for improving soil recommendation system	8.0
Modeling the Hierarchical Fuzzy System for Suitable Crop Recommendation	16.0
Knowledge-based expert system for control of corn crops	16.0
An agricultural expert cloud for a smart farm	8.0
AgroConsultant: Intelligent Crop Recommendation System Using Machine Learning Algorithms	20.0
Agriculture based recommender system using IoT - A research	5.0
Agricultural recommendation system for crop protection	15.0

Behavior patterns related to the agricultural practices in the production of Persian lime (Citrus latifolia tanaka) in the seasonal orchard	6.0
An overview of fertilizer-P recommendations in Europe: Soil testing, calibration and fertilizer recommendations	5.0
Climate Recommender System for Wheat Cultivation in North Egyptian Sinai Peninsula	11.0
Smartphone Application for Diagnosing Maize Diseases in Egypt	8.0
Expert system design for diagnosis of diseases for paddy crop	20.0
Use of data mining in crop yield prediction	23.0
Soil Sensors Based Prediction System for Plant Diseases using Exploratory Data Analysis and Machine Learning	23.0
Knowledge-Based Expert System for Diagnosis of Agricultural Crops	13.0
Development of an expert system for personalized crop planning	25.0
M-DCocoa: M-agriculture expert system for diagnosing cocoa plant diseases	18.0
An effective identification of crop diseases using faster region based convolutional neural network and expert systems	20.0
Development of a model recommender system for agriculture using apriori algorithm	5.0
Papaya Disease Detection Using Fuzzy Na{{i}}ve Bayes Classifier	21.0
Big data analytics framework to identify crop disease and recommendation a solution	11.0
Development and implementation of an expert system for insect-pests management in pulses	0.0
Smart Crop and Fertilizer Prediction System	21.0
Expert system for coffee rust detection based on supervised learning and graph pattern matching	20.0
Rule-based expert system for detection of coffee rust warnings in colombian crops	19.0
Neural Network (NN): An expert system based technique for forecasting the sell quantity of chemical fertilizer data	9.0
Agricultural Irrigation Recommendation and Alert (AIRA) system using optimization and machine learning in Hadoop for sustainable agriculture	25.0
Web-Based Expert System to Detecte Chili Desease Using Rule Base Reasoning Approach	3.0
Expert System Diagnosis Corn Pests and Diseases Using Certainty Factor Method	8.0
Expert systems diagnosing of banana pests and diseases use case-based reasoning method with android	6.0

Improving the Performance of Sigmoid Kernels in Multiclass SVM Using Optimization Techniques for Agricultural Fertilizer Recommendation System	16.0
Expert system for disease diagnosis in cocoa plant using android-based forward chaining method	8.0
Crop recommendation system for precision agriculture	17.0
Detecting Corn Plant Disease with Expert System Using Bayes Theorem Method	8.0
Coconut Disease Prediction System Using Image Processing and Deep Learning Techniques	15.0
Irrigation monitoring and prediction system using machine learning	15.0
Agricultural crop predictor and advisor using ANN for smartphones	18.0
Contextual multi-armed bandit strategies for diagnosing post-harvest diseases of apple	6.0
Banana ripeness detection and servings recommendation system using artificial intelligence techniques	8.0
Expert system for diagnosis mango diseases using leaf symptoms analysis	15.0
Soil Toxicity Prediction and Recommendation System Using Data Mining in Precision Agriculture	14.0
Ontology Based System for Pests and Disease Management of Grapes in India	8.0
e-RICE: An Expert System using Rule-Based Algorithm to Detect, Diagnose, and Prescribe Control Options for Rice Plant Diseases in the Philippines	25.0
An NLP hybrid recommendation system in crop selection for farmers	15.0
Decision support system based site quality evaluation for plantation	11.0
A Machine Vision-Based Maturity Prediction System for Sorting of Harvested Mangoes	25.0
A new Expert System for greenness identification in agricultural images	23.0

Data Extraction

La Figura. 1 muestra los años de publicación de los trabajos.

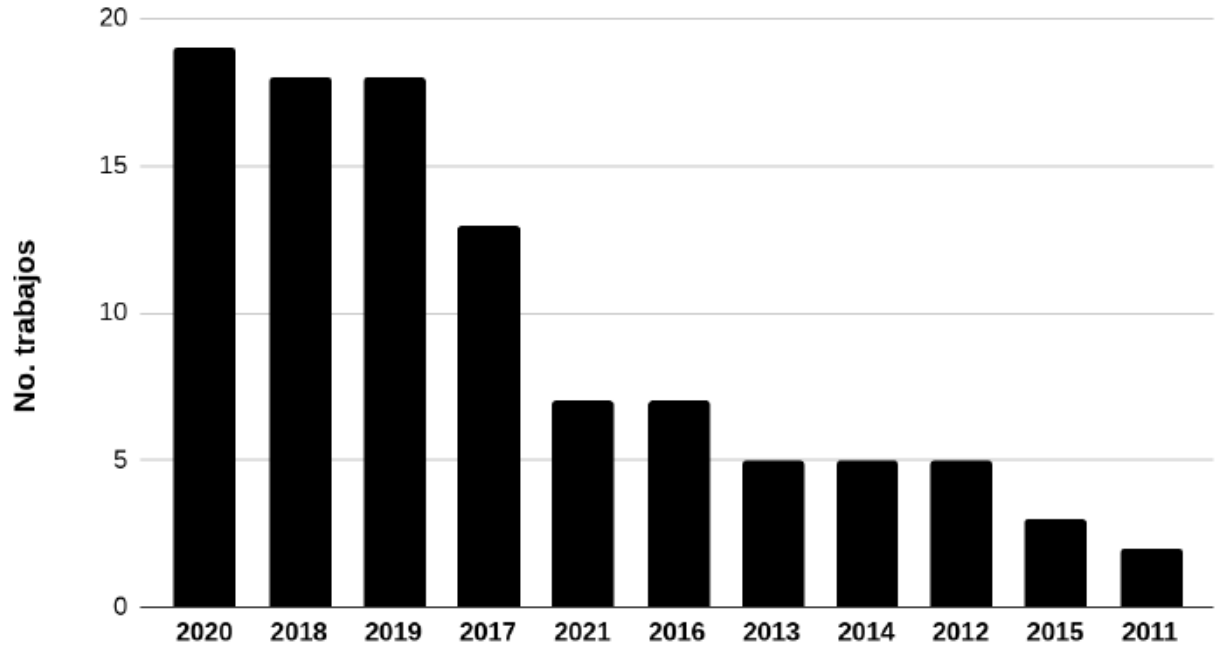

Figure 1. Extraction of the years of the related works.

The figure shows that most of the decision support systems papers found in the RSL have been developed in the last 5 years, indicating an increase in agricultural research aimed at improving farmers' practices. Figure 2 shows the results for the study countries.

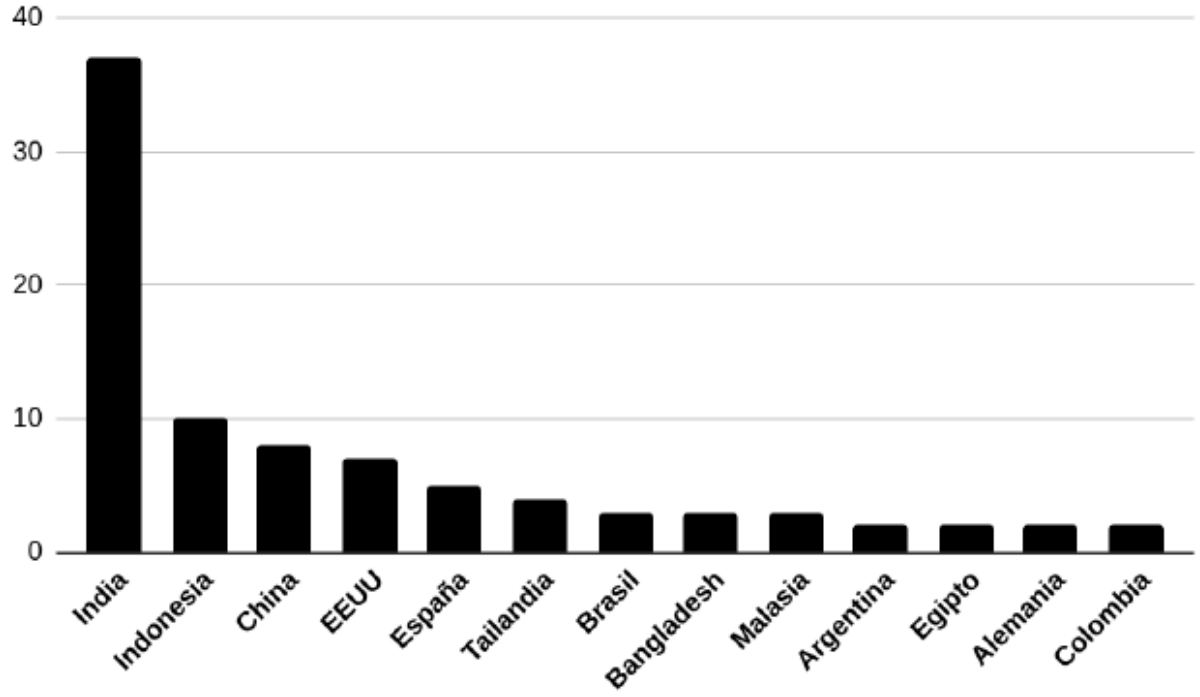

Figure 2. Extraction of the study countries from related works.

This figure shows that studies of this type of systems (experts, recommendation, prediction, etc.) in agriculture are frequent in existing agricultural powers, such as India, China and the USA. It is also observed that there are very few studies in the South American region, which indicates that it is a little-explored field in agriculture in the region. Figure 3 shows the most common algorithms used.

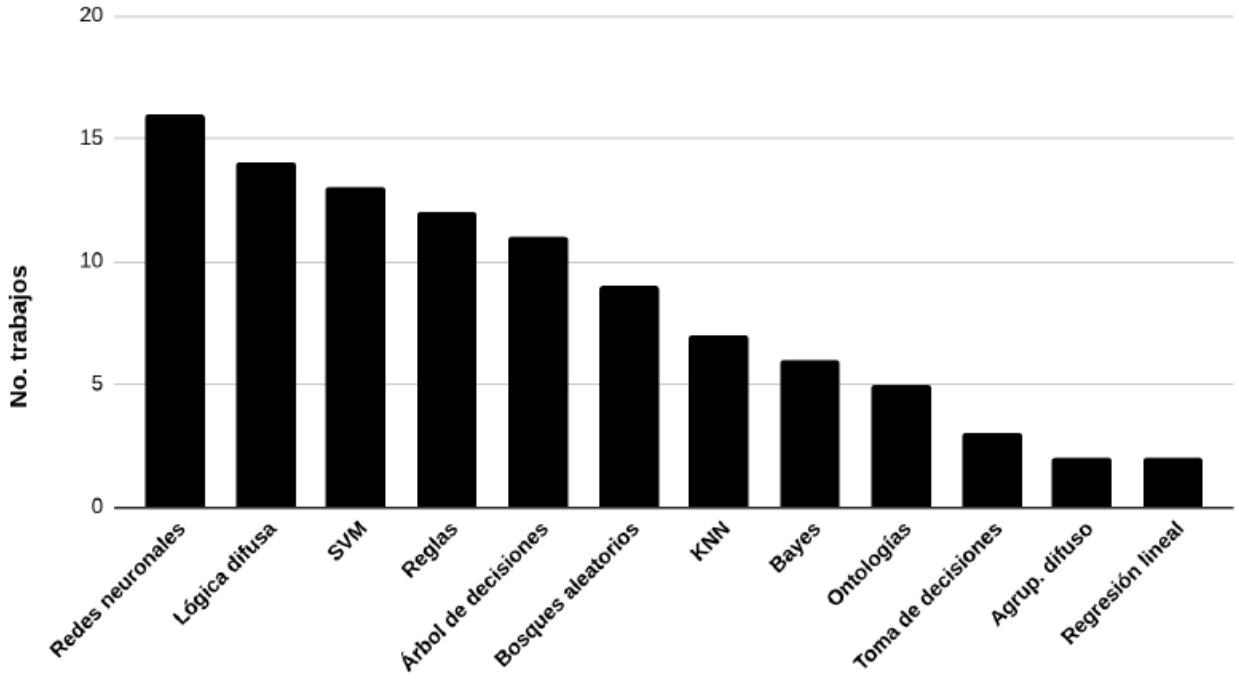

Figure 3. Extraction of the algorithms used in the related works.

Figure 3 shows that the main algorithms used are the most common supervised machine learning algorithms available. Including the k-nearest neighbors algorithm, which was used in this work. It is also observed that more than 20 works use expert-related techniques for the development of their system, validating the importance of having expert information in agricultural studies. Figure 4 shows the types of systems found in the RSL.

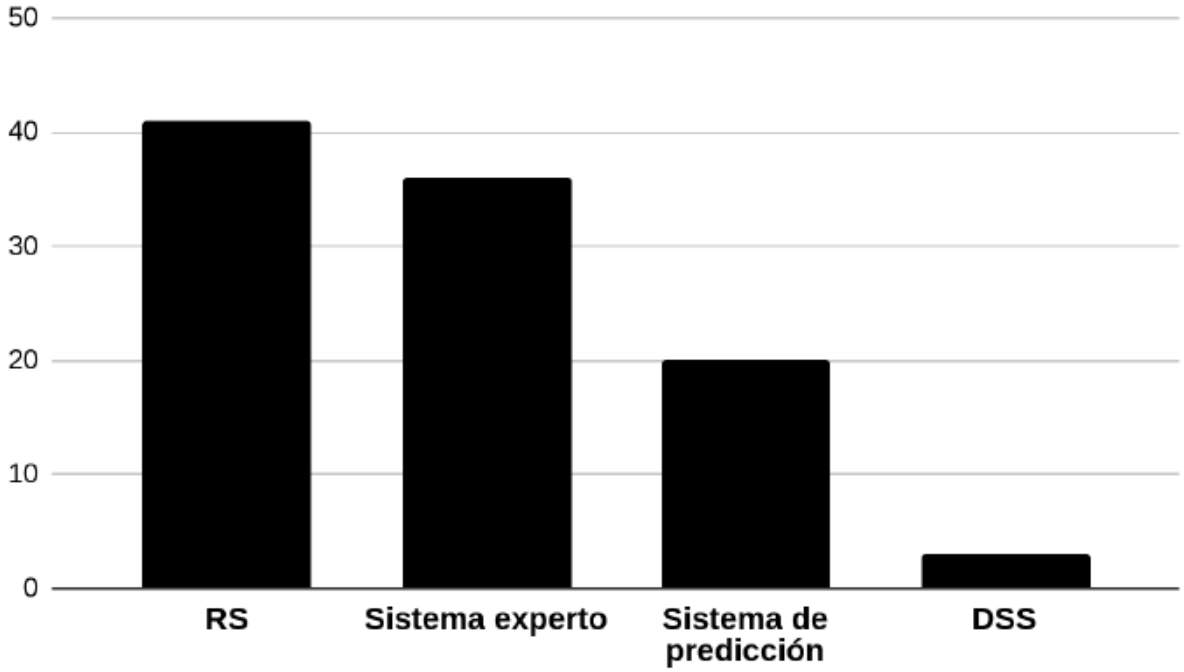

Figure 4. Types of systems found in related works.

It is observed that RS and expert systems are the most worked on in this field, since providing recommendations to farmers and taking into account expert information is what most helps to improve the care and management of crops. Figure 5 shows the most common variables found in the 102 papers.

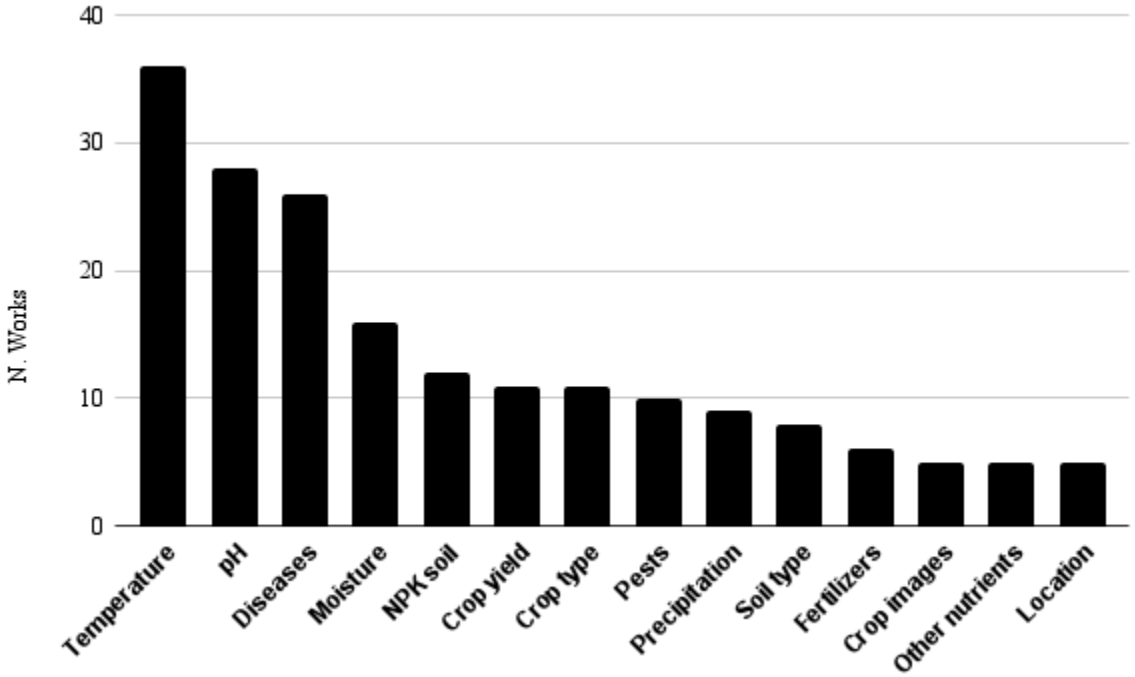

Figura 5. Extracción de las variables de entrada más comunes utilizadas en los trabajos relacionados.