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Cloud-Based Top-Down and Bottom-Up Approach for Agriculture Data Integration

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Abstract: The big data revolution and the growth of information technology have had a profound influence on many areas of our life. Many farms today employ precision farming techniques and capture enormous volumes of data. Making the most of these datasets for decision support requires integrating data from several sources, doing analysis rapidly, and generating conclusions based on the results. In order to analyse agricultural data from several sources, this study presents a framework that utilises cloud-computing. This approach is more scalable, adaptable, cost-effective, and easy to maintain than existing alternatives. Based on extensive interviews, surveys, and literature reviews, the framework offers a workable architecture for cloud-based services for data integration, analysis, and visualisation. This skeleton architecture was used to construct many programmes; as we learned more and faced tougher problems, we tweaked the plan to make it work better. We demonstrate the framework's value with several example applications. Each use case has its own specific requirements for data integration; therefore, it makes use of a different set of services from the suggested architecture.

Keywords: *Agriculture, Big Data, cloud computing, data analysis, data integration, data visualisation, decision support systems.*

1. Introduction

Precision farming techniques have significantly increased as a result of the usage of IT and big data in agriculture. (also known as Agriculture 3.0). Sensors, satellites, and other technologies are used by a wide variety of agricultural information systems (IS) to gather information, such as soil moisture, nitrogen concentrations, and temperature gradients between the ground and the air. In addition, databases spanning many years are increasingly becoming accessible, allowing researchers to examine data trends across time. These advancements have led to a "data overflow" problem, For effective data retrieval and analysis, the article emphasises the significance of cognitive storage and processing abilities. Another issue is that many farms still use incompatible data management systems, meaning they are missing out on opportunities to enhance the quality of their decision-making tools.

Information gathered and analysed from many sources is crucial for better agricultural decision-making. For example, in addition to weather, topological terrain, irrigation, and agricultural yield data, information on beehive treatment, plants growing in the area of the hive, and honey production levels might be useful for making management decisions. Integrating data is a great first step toward better decision making, but it is not sufficient on its own. Users also need quick and simple access to the data and the ability to make actionable conclusions.

A major deficit in the capacity to combine data from different agricultural resources was already apparent in the early days of recent years. The large amounts of data generated by precision agriculture constitute a "data overflow" concern. They emphasise the need of standardised data transfer and tools for managing and analysing information. There have been subsequent presentations of other strategies for integrating and managing agricultural data.

In order to analyse agricultural data from several sources, this study presents a framework that utilises cloud-computing. This approach is more scalable, adaptable, cost-effective, and easy to maintain than existing alternatives.

The framework establishes a practical architecture of cloud-based services for the purposes of data integration, analysis, and visualisation. Users can take use of the framework's included services, or they can utilise those services as a foundation to create their own. It should be noted that the framework is meant to include and process data from both new and current external databases, while making use of existing software services whenever practical.

Numerous applications and demonstrations of the framework's effectiveness are provided. Each use case has its own specific requirements for data integration; therefore, it makes use of a different set of services from the suggested architecture.

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The study makes use of cloud computing, which has benefits including cheaper prices, on-demand computational capabilities, flexibility, and outsourced IT infrastructure management, to analyse and aggregate agricultural data from diverse sources. This is especially crucial in agriculture, where farmers sometimes lack the tools for digitalization and vast amounts of data must be monitored and analysed since data is constantly being collected.

The research approach, design science, requirement analysis stage, background knowledge on cloud computing and data integration techniques are all included in the article. Along with two use cases and a functional framework to illustrate its use and many features, it also offers a full analysis of the results. The conclusions are discussed in Section 4.

2. Literature Survey

The study's two key goals are:

In order to improve farm management and decision-making, it would be useful for farmers to have access to a framework outlining a cloud-based services architecture. The infrastructure services allow for the development of novel agricultural offerings.

Explain how you may use cloud computing to integrate and analyse data in the agricultural sector. Here, we provide two programmes that might serve as examples when developing novel data-integration services.

Our research strategy was motivated by the design science paradigm [1]. Based on 1) Through a study of the literature, unstructured interviews with Indian farmers, and agricultural research, a framework for cloud-based services for agriculture was created.

Based on the requirements of diverse farms, a framework is created for various farm situations. On top of the framework, cloud-based services are developed, with illustrations shown for each situation.

- Developing a system to compile data from many sources on the RPW's geographic distribution and display it on a map.
- The development of an ontology-based pest control DSS.
- Models can optimise irrigation schedule, estimate yield, and predict disease by using data from sources including soil and plant sensors and weather stations.
- Abeehive management system that keeps track of treatment data for all of the beehives is essential for analysing productivity in connection to treatments and bee genetic lines.
- We built a dashboard that aggregates data from several sources and presents several key performance indicators (KPIs) pertinent to farming in order to better help farmers in making educated decisions.
- A major field crop farm is now putting a cloud-based farm management system into place.
- Development of an agricultural machinery selection aiding system.
- Making a smartphone app to gather and analyse complaints of insect damage from a broad population.

Due to space limitations, we will only be able to cover the first two conceivable uses. An ETL process that involves data collection, transformation, and loading into a single database is shown in the first use case (RPW). The second example (DSS for pest control) exemplifies knowledge management and reuse while highlighting the Semantic Web's and ontologies' possibilities. (Irrigation recommendation), we see how machine learning technology combined with data fusion can forecast how much water should be utilised for irrigation.

As we developed applications and services to fulfil the required use cases, we improved and extended the framework.

Following this is an introduction to the issue of data integration, followed by detailed explanations of how to do a needs assessment and make use of cloud computing for agricultural purposes.

2.1. Needs Assessment

As mentioned above, the first framework was developed with the use of interviews and surveys to gather information on farmers' and experts' needs from a variety of agriculturally-related agencies. In all, 117 farmers were polled [2]. In the polls, farmers were asked whether or not they were currently using certain agricultural treatments, whether they were familiar with them but had no intentions to employ them, and whether or not they were familiar with them at all. Different application-specific responses are shown in Figure 1's frequency distribution. With these results in mind, it's evident that many agricultural applications are crucial for farmers right now.

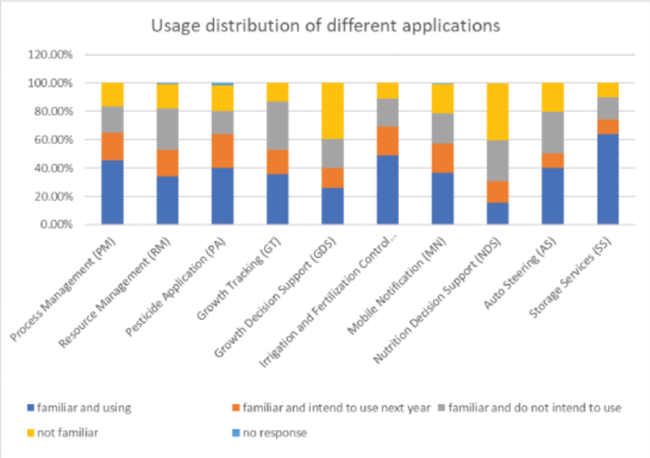

Fig 1. Proportions of the population that have used, are familiar with, or intend to use a certain app.

According to [2]'s research, by conducting interviews with farmers and specialists from different agricultural organisations, we were able to compile the following broad areas of functionality required in agricultural software.

- There is an urgent need for individualised management and decision-making resources for rural professionals.
- The interface of a system should be easy to use and flexible enough to accommodate different sorts of users. Software with a basic interface is ideal for those with less technical knowledge.
- Automated and straightforward software is required for efficient data management. The user should be able to simply add and programme new automated operations into the system.
- Moreover, the user should have complete control over the processing and analytic parameters. Advanced users may want to try out new methods.
- It's essential to have specialised knowledge, particularly rule-based expertise, to adapt systems to particular environments and take into account users' abilities, habits, and preferences. (such as risk profiling, for instance).
- More standardised, top-notch computer systems are urgently required to cut down on learning time and effort and guarantee excellent technological performance.
- We have read research on cloud-based agricultural systems and precision agriculture, as well as extra needs like:
- Assist with cordless, unobtrusive spying [2].
- The interface is offered in the farmer's native tongue, and the same information may be supplied in other systems, native languages. [3].
- storage capacity [7].
- Multiple types of information must be measured or gathered to give useful decision assistance. Measuring data (together with timestamps) is better collected over time than it is collected quickly and then forgotten.
- The text promotes the use of open data standards, interfaces, and protocols for easy interoperability with other software applications and data sources, both locally and remotely over the internet, which is essential for facilitating compatibility with more antiquated systems and decentralised architectures. [5].
- The capacity to support a sizable and growing number of users and data sources [6].
- Meta-data support for data portability across programmes; this feature allows for easier sharing of information across programmes.
- Cost Effective.

2.2. Services using Cloud Computing

On-demand self-service, which enables users to provision resources as needed, broad network access, which encourages the use of a variety of client platforms, including smartphones, tablets, and personal computers, and elastic resource provisioning, which enables resource access over the network are all features of cloud computing.

As a result of these features, cloud computing offers several advantages. As a first step, cloud computing makes it possible for customers to pay for computing resources and services on an as-needed basis [3], [7]. This reduces or eliminates the need for customers to make large initial expenditures in computer hardware and software. The second advantage is that it enhances the scalability and responsiveness of programmes to altering business requirements by making computer resources accessible swiftly (within minutes). In addition, virtualization and other cloud-specific parallel processing technologies (like Spark and Hadoop) boost application performance [4].

Users may access networked computers from any place by outsourcing IT infrastructure management to external cloud service providers, which can lower IT maintenance costs and remove the need for internal IT staff. [4].

While infrastructure-as-a-service (IaaS) offers processing, storage, and network resources on demand for software deployment, software-as-a-service (SaaS) is the cloud-based deployment and operation of software. Platform-as-a-Service (PaaS) enables programmers to create and deploy software using the IDEs, libraries, APIs, and tools provided by cloud computing, which is rapidly being investigated for use in the agricultural sector.

With the use of precision agricultural technology, farmers and scientists may gather enormous volumes of data on variables such as crop production, topographical characteristics, moisture content, and temperature, allowing efficient reaction to unforeseen conditions.

The majority of farmers, however, do not have access to powerful computers, which restricts their capacity to analyse this data online.

Farmers without the resources to invest in IT infrastructure can benefit from cloud computing services, which offer on-demand access to agricultural data, faster processing, and thorough analysis, including details on disease transmission, pest control, weather information, and best practises.

In order to help farmers make educated choices, the study provides a cloud-based framework for creating SaaS applications with an agricultural emphasis. This framework combines data from many sources, does analysis, and graphically shows results.

2.3. Tools for Data Integration

The suggested architecture unifies data from several sources, including relational databases (where data are obtained using SQL), no-SQL databases (such as those based on JSON), CSV files, This section contains background knowledge on HTML files on the Web, which are less prevalent but vital, and ontologies and triplestores, which are required for implementing the second use case.

An ontology is a precise, computer-readable description of domain knowledge. Formal, computer-interpretable ideas known as ontologies specify domain entities, properties, and links. [9] They are increasingly used as a foundational tool in knowledge management systems, DSSs, and other intelligent systems to describe domain information.

An ontology is a formal description of domain knowledge that computers may use to make inferences about the world. For instance, the insect Red mite may be controlled using Agriron's active component, abamectin. [9] If the ontology states that a pesticide is successful if one of its compounds is effective against that bug, then this conclusion may be drawn. The foundation of knowledge bases for DSSs and expert systems may be formed via ontologies.

With the use of ontologies, databases and application programmes may work together without exchanging data structures. This makes it possible to automatically extract and aggregate data from two applications or websites that share the same taxonomy. The ideas presented in one app can be transferred to the corresponding ideas presented in the other app.

Last but not least, ontologies enable the reuse of specialised knowledge. When an ontology is made available to the public, it may be utilised by applications across numerous industries. An further advantage of ontologies is that they may be joined to create a more thorough ontology of a domain [8]. A few of open ontologies that have found application in agriculture include AGROVOC [6] and DBpedia. The United Nations' Food and Agriculture Organization (FAO) publishes a multilingual thesaurus called AGROVOC, DBpedia, an important ontology, adopted from the well-known Wikipedia, gives definitions and features of agricultural subjects in 17 different languages, making it simple to combine material from different languages. As a result, it provides access to billions of unique words (Things) and cross-references to several other dictionaries.

When it comes to building out the so-called Semantic Web, ontologies are a must. The Semantic Web, also known as the Web of Data or the Web of Linked Data, is a set of standards developed by the World Wide Web Consortium (W3C) to provide a formal representation of the information available on the World Wide Web, facilitating data sharing and reuse in various contexts.

HTML pages, which can be read by both people and machines, currently make up the overwhelming majority of online content. Machines can only do a keyword search of these papers and cannot understand the text itself. The Semantic Web project aims to fix this problem by using ontologies to make text in online publications machine-readable. Ontologies offer a formal vocabulary to describe the relationships between digital information and physical things (i.e., instances of classes). Standard ontologies make it possible to combine different Web-based data sets into a single database, such AGROVOC and DBpedia, which may then be used to improve communication across diverse agricultural efforts on the Semantic Web.

The World Wide Web Consortium's (W3C) guidelines and tools enable the Semantic Web. A paradigm for publishing and exchanging data, the Resource Description Framework (RDF), is extended by the Web Ontology Language (OWL) to support ontologies with richer semantics and knowledge inference. RDF data stored in international triplestores may be retrieved using the all-purpose query language SPARQL. Triplestores[10] are a specific type of graph database designed specifically for storing and retrieving RDF. Triples, which have a subject, a predicate (or verb), and an object, are used to hold the RDF data.

3. Results and Methodology

The framework's structure was developed after the data collected via questionnaires and interviews was thoroughly analysed. This skeleton architecture was used to construct many programmes; as we learned more and faced tougher problems, we tweaked the plan to make it work better. This section describes the top layer of the functional architecture as well as two more application scenarios that are incorporated into it.

A. System Design for a Framework

The framework architecture is depicted in Figure 2 with its four-tiered structure of functional services.

Relational databases, triple stores, XML files, papers, etc. are all part of the Data Layer's collection of data storage technologies. At this stage, data can be made either accessible to the public or kept confidential Only the farm's employees have access to the data it collects. Our second-layer IoT data extraction services are augmented by third-party Web services that grant access to external databases and sensors.

- The process of data ETL include gathering, converting, and loading data from numerous sources before storing it in a centralised system with a range of services.
- Provides SQL query services for accessing relational databases.
- SPARQL may be used to query triplestores as an ontology query language.
- Creators and shapers of ontologies.
- Services for managing access to information in accordance with users' roles and permissions inside an organisation.
- Data may be automatically extracted from many sources, cleaned, and fed into a centralised database using any number of existing ETL solutions, both commercial and bespoke.
- Providers of IoT data gathering services, with a focus on soil and remote sensing devices.

The Data Analysis Layer provides a variety of services for processing data and presenting findings in a form that facilitates decision making. Among the many available offerings are:

- Businesses that offer GIS services for spatially analysing agricultural data.
- In order to better inform suggestions and projections, several businesses now provide data mining services. Clustering of data is another service provided by machine learning algorithms Learning models, such as regression, classification, and clustering, identify related data and treat them appropriately to forecast the goal value of an observation, such as the predicted yield of a field, and categorise observations, such as pest photos or land plots.
- Business intelligence (BI) services use data acquired and combined at data access and integration levels to provide real-time analysis and clever visualisations.These kinds of services are invaluable to ranchers and farmers, allowing them to construct dashboards with more intelligence and effectiveness.
- Deep learning and other approaches are used by image processing services to automatically analyse pictures, such as satellite photography, to comprehend their qualities or meaning.

The Applications Layer is a group of SaaS applications that provide assistance to farmers. At this stage, applications are constructed on the infrastructure laid out in Levels 1-4.

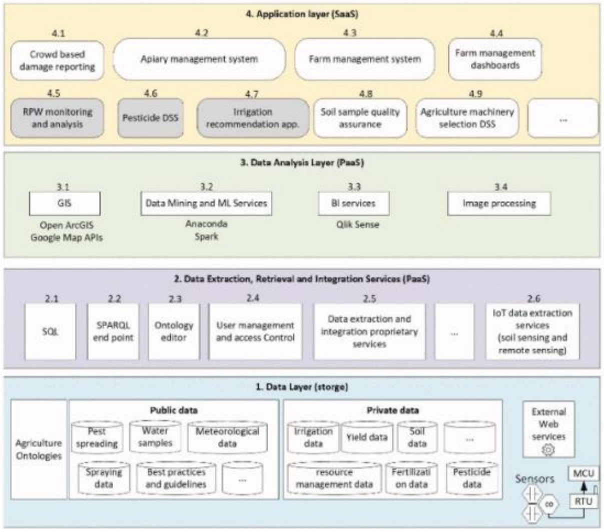

Fig 2. This is a schematic showing how the future service infrastructure is planned out.

B. Example(s) of Application

1) Monitoring and analysing data on the spread of the red palm weevil (RPW)

This use case is intended to demonstrate how data from many sources may be integrated to monitor an issue's development.

Snout beetle Rhynchophorusferrugineus (RPW) is a serious danger to Indian palm farms. The fast growth of RPW has increased the number of unhealthy trees, presenting hazards to both safety and the economy. Two organisations in India have been looking into the matter, but because of their disparate databases, it is difficult to provide a thorough analysis. In order to assist stop the spread of RPW, this use case attempts to provide a cloud-based solution that integrates data from these organisations with analytical tools that are visual and map-based.

The following requirements for the envisioned service were uncovered through interviews with many RPW monitoring groups.

- The RPW distribution shouldn't just be shown by area, but rather at the national level, hence data from several information systems should be merged to demonstrate this. Specify the infected palm tree count and the number of RPW caught and released.

- The service shouldn't interfere with the numerous procedures an organisation uses to accomplish its goals.
- The service should include tools for statistical analysis, such as data aggregation and filtering, as well as the ability to see the combined data on a map.
- Global, always-on access to information is a must.
- Due to planned actions to improve awareness of and encourage public reporting of sick trees, the system must be scalable and capable of managing additional data and bandwidth.

Through an ETL process, the service will combine data from diverse sources, enabling visualisation and analysis without altering current practises. Due to consumer needs and a lack of inter-firm collaboration, this strategy is favoured. Instead of developing a comprehensive information system that covers user interfaces and data input processes, the service focuses on data integration since it is quicker and less expensive to do so.

You'll need to take care of a visual representation of the combined data as part of the answer. To achieve this objective, we employ ArcGIS. ArcGIS from Esri (Esri.com) is a GIS that can be used to create and alter maps that depict information on the planet's topography [11]. After the mapping process is complete, researchers have many options for examining the aggregated data on the spread of RPW.

The solution architecture is comprised of the following parts:

- The consolidated database, depicted as the Data layer in FIGURE 2, requires the use of a relational database management system for its administration (RDBMS).
- The Data Extractor service (component 2.5 in FIGURE 2)is a Java software that collects data on RPW distribution using Web services, storing it in a unified database in CSV and JSON formats from different databases.
- • The creation of new maps and the modification of existing ones is made easier by ArcGIS Online, the web-based ArcGIS desktop GIS programme (see section 3.1 in FIGURE 2). In contrast to the offline version, which requires installation on client servers or rented cloud infrastructure, it enables users to share their maps with others. ArcGIS Online is accessible to users who pay as they go. Maps may be made using ArcGIS Online and the many data layers included in the data warehouse. The user has the freedom to dynamically select which layers to display from the complete set of database tables and views.
- Converting data from the centralised database to a comma-separated value format (CSV) for use in ArcGIS mapping applications (see component 4.5 of FIGURE 2). Thus, we developed some code to retrieve the required data from the centralised database (through SQL - part 2.1 in FIGURE 2) and save it as CSV files on the cloud server. The software may export global and yearly summaries of palm trees, palm tree health, palm tree sickness, traps, and captures as comma-separated value (CSV) files. It was decided to automate the program's daily execution, thus the corresponding batch file was created and uploaded to the cloud server. Layers on the map are dynamic, reflecting updates to the related CSV files.

In Fig. 3, we can see how all the different components of the suggested design are linked together.

- The Data extractor service (3) receives real-time updates from two sources:
- The data is a comma-separated values (.csv) file from the Eden farm1 (1.1).
- The Agriculture Research Organization's data is provided via a web service that delivers the data in JSON format (1.2).
- It is possible to immediately import static data from Plant Protection and Inspection Services (2) into the central repository.
- The Data Extractor collects information from many sources and deposits it into a centralised database (4)
- The storage capacity of the unified database is increased by a wide variety of triggers.
- Database to ArcGIS Converter, the fifth component, transfers data from the centralised database into the ArcGIS format (6).
- ArcGIS Online is a data monitoring and analysis tool (7).
- Furthermore, users can make direct connections to the database from remote locations and run queries.

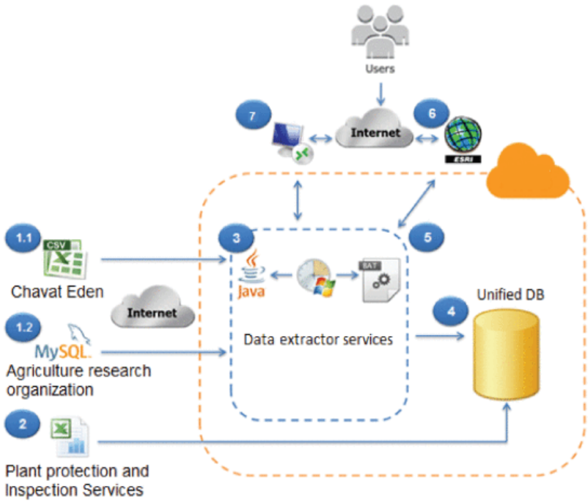

Fig 3. Description of the proposed methodology used.

With SQL Server serving as the primary database, the product is currently accessible on the AWS cloud. It is hosted on Amazon Elastic Compute Cloud. Machine instances with the user-selected operating system, programmes, libraries, and data are started using the EC2 infrastructure service.[4] Using an Amazon Aurora DB instance in a VPC[12] and providing data extraction services as Lambda functions are two alternative deployment techniques..[13] When it comes to scalability, performance, and availability [14], go no farther than Amazon Aurora, a serverless relational database management system (RDBMS) that maintains data across several DB instances.Data from many sources must be combined in a single ArcGIS database using the comma-separated values (CSV) format.

2. Insecticide Application Decision Support System

This use case aims to demonstrate the integration of online data to develop a DSS for pest control.

A farmer must consider the pesticide's effectiveness, the pesticide's safe application, and the pesticide's cost when determining which pesticide to use to combat an insect that is damaging his crop. Farmers find it challenging to acquire information and make decisions since pest control data is often housed in many places and languages. An ontology-based Web system for pest control is recommended as a solution to this problem in order to handle the various pesticide regulations in the nations where crops are sold. enhancing efficiency and effectiveness. By employing a common terminology, this system would facilitate the coordinated presentation of data from many web resources.

Better decision support for farmers can help them use pesticides responsibly and in accordance with the regulations of the countries to which they export their goods.

The most efficient pesticides should be recorded by the pest-control DSS so that they may be used to exterminate the many pests that cause harm to agricultural products. It must take into consideration the maximum residue limit (MRL) for a given pesticide in the given nation, the number of days prior to harvest during which that pesticide may be applied, and the amount of pesticide that may be used on a given crop before reaching dangerous levels. Given that this information is dispersed across several resources and languages, an ontology seems like the best way to bring it all together.

It is hoped that the ontology will serve as the foundation for a Web service that may be used by farmers, the PPIS pesticide recommendations, and anyone involved in pest control.

Reusing ontology ideas from other ontologies and publishing the ontology to the Semantic Web are both necessary. Consequently, it must be formalised in accordance with Semantic Web standards.

In [15], we detail the steps taken to develop this ontology as well as its final product. Figure 4 represents the user's web browser; it communicates with web server. A SPARQL Server's triplestore now provides access to the ontology. When the results of a user's query are returned to them, the browser presents them to the user.

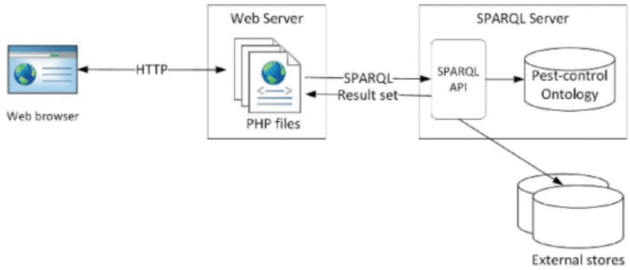

Fig 4. A diagram of the DSS used to spray for insects.

Apache Jena Fuseki Server originally kept the ontology in a triplestore, however Amazon Neptune provides a scalable, manageable deployment alternative for PHP applications that can be set up using Amazon's Elastic Container Service.

The application serves as an example of how Semantic Web ontologies may be used to reuse ideas across different databases. It creates hierarchical menus of crops and pests using pest pictures from DBpedia and AGROVOC, showing how concepts are connected online. so that we can quickly locate the pest or crop for which we are looking.

In conclusion, the two examples presented above demonstrate the framework's utility.

4. Conclusion

Using cloud computing, the system combines and analyses agricultural data from numerous sources, boosting the scalability, flexibility, cost-effectiveness, and maintainability of solutions. Incorporating, analysing, and visualising data is simplified with the use of the framework's predetermined cloud-based service infrastructure. The first layer is the Data layer, Data including insect spreading data, weather data, water sample data, linked data, and document files are stored in the second layer. In order to provide effective data management and retrieval, it also comprises services like IoT, data extraction, and unique data extraction and integration service.Several use cases have been used to demonstrate the framework and assess its efficacy. This study focuses on two such use cases, each of which is based on a different set of services from the proposed architecture and reflects a different set of data integration requirements. Take the case of an India programme designed to monitor the spread of RPW as an illustration. This example shows how an ETL process may use a GIS service for data integration and how online data can be utilised with a decision support system to help with pesticide consumption. Additionally, sensor data analysis and plot-specific watering recommendations may be done using ML models.

Some cloud-based frameworks [16[The proposed framework] attempts to give a thorough description of the functional aspects required for data integration and analysis, while as much as possible abstracting particular technologies. This practical information comes from both the ground up and previous books. (through actual experiences of applying the framework to real-world use cases) and the top down (via a comprehensive literature analysis, interviews, and surveys). We believe the framework's features will be adequate for developing the vast majority of cloud-based agriculture apps.

Our efforts double the original worth. To begin, more scenarios needing multi-source data integration can benefit from the proposed architecture and its implementation, as indicated by the two use examples. The framework encourages farmers to work together and makes it possible to integrate data across agricultural systems. Secondly, our research adds to the body of knowledge on how cloud computing can be used to unify different types of agricultural data. The proposed approach utilises cloud computing for the integration of data. When it comes to cloud computing and storage, customers may "pay as they go," eliminating the need to fork over a large sum of money up front for costly gear and software. Since cloud-based solutions allow for the nearly immediate addition of resources like processor speed, data storage space, and network throughput, they are more adaptive and expandable as well. Cloud computing offers advantages beyond the pest control and sensor-based irrigation sectors by enabling customers to outsource IT infrastructure maintenance to other vendors. It may incorporate information from agricultural information systems, including plant disease monitoring, satellite crop yields, and weather predictions, improving overall effectiveness and efficiency., it is vital to have a system that can scale to accommodate growing data volumes while being cost-effective and easy to use. Keep in mind that farmers can already be using agricultural cloud services (SaaS) that facilitate data collecting and decision making. These services often have their own application programming interfaces (APIs) that facilitate integration. By integrating and using current services, cloud computing may considerably help in the development of new agricultural data integration services, improving farmers' capacity to share data and facilitating supply chain cooperation. The ability to integrate data is a major factor in this. Several common farming situations might benefit economically from this ([17], [18]). The design of cloud-based agricultural services may provide network effects that raise the platform's value for all users. The framework will generate new agricultural services, data products, and information as more people join and utilise it. The rise of cloud-based agricultural services is anticipated to increase their use and advantages for farmers and stakeholders. Positive feedback is anticipated to contribute to this growth.

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