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Ontology Based Knowledge Management Portal for Coconut Plantation Care

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Abstract— **Coconut (Cocos nucifera) is one of Sri Lanka's most significant plantation crops. Different coconut tree parts are used for numerous activities. Decision making is critical in the treatment method of coconut plantation. So, ontology modelling will help in decision making to diagnose causes and treatment methods easily. It is designed and developed to support agriculture engineers, coconut planters, and researchers. The ontology model is designed by using the Delphi method. Data was collected from research papers, articles, coconut research institute's websites, and through the discussion with farmers, agriculture experts, and coconut research officers. The ontology model is evaluated and validated by tools OOPS! Evaluation editor, DL query & SPARQL Query, and ontology experts. Future work is planned to develop a knowledge management system for the coconut plantation care.**

I. INTRODUCTION

In Sri Lanka, the three main crops are tea, coconut, and rubber. There are several issues caused in the coconut cultivation some of them are climatic changes, accessing the technology and pest and disease damages. The key objective of this research is to uplift the production of coconut and productivity, and to establish a sustainable coconut cultivation by providing necessary information about the treatment and facilities to coconut growers island-wide through an efficient extension & advisory service.

As a residential crop and a commercial crop, it currently covers more than a million acres of land on the entire island. Generally, the Coconut Cultivation Board has limited number of Coconut Development Officers to provide new technical information and services to coconut growers and in this modern world there are several young agripreneur, youngsters who shows their interest towards to grow the income earning plants like coconut, and they don't have enough knowledge about the coconut plantation, In case when we consider the agricultural department staffs or coconut research officers there are very few amounts of aged experienced persons and they don't have enough experienced knowledge about that coconut cultivation. When considering theoretically educated persons, it is better to have well experienced senior experts who have practical knowledge in the field of coconut plantation. So, to overcome the problem by segregating the whole knowledge of those people experiences and understanding this system is planned to provide for the coconut plantation interested growers.

These are the motivation points that are the basis for the idea of this research. There are several articles, blogs, and books it describes the coconut-based plantation issues and solutions, but there are no sectors mentioned the coconut-based plantations. In Srilanka, there are no any researches carried out for ontology-based plantation solutions in the field of coconut plantation.

Basically, ontology is a Semantic Web that represents information more meaningfully for humans and computers alike. It allows automated annotation, discovering, publishing, advertising, and composing of services as well as the description of materials and services in machine-readable form.
Ontology is the foundation of the Semantic Web, and served as the basis for development. So, the web becomes machine-understandable rather than machine-readable. Ontology is a vital method for defining the semantics and providing resources on the Semantic Web a uniform, understandable framework. In other words, the web is transformed from machine-readable to machine-understandable. In fact, Ontology is a key technique with which to annotate semantics and provide a common, comprehensible foundation for resources on the Semantic Web. These key technique makes to understand the basic concept in the field of Ontology-based knowledge management portal [1].

The validity of an ontology will prevent applications from employing inconsistent, incorrect, or repetitive data, improving the quality of the information. Ontology evaluation and validation are hence essential. However, there was no precise mechanism for assessing this ontology. Depending on the objective, aspect, and ontology being validated [2].

This study develops ontology-based knowledge management portal for coconut plantation users. A complete study was done on both the problem domain (coconut plantation diseases and treatments) and ontology-based application protégé Ontology editor 5.5. Then developed the ontological approach for coconut plantation diseases, and follow the KM portal when completing all steps in ontology development. Finally developed a useful knowledge management system in coconut plantation care for the farmers and others who are involved in the coconut plantation.

The following questions are considered as the research gaps for the selected topic or the analysis of the selected topic. There are much of research questions that need to be analyzed on the topic of "Ontology-based knowledge management portal for coconut plantation and care".

The following research questions lead to this research.

•**RQ1**.What is the current status of knowledge management and decision-making in diagnosing the treatment method for diseases caused in a coconut plantation?

•**RQ2.**How to improve the knowledge management and decision-making in diagnosing the treatment method for diseases caused in a coconut plantation?

•**RQ3.**How to provide the solution for knowledge management and decision making to diagnose the treatment method for diseases caused in a coconut plantation that can be evaluated?

This paper discusses the proposed ontology model for the ontology knowledge management portal in the treatment method of coconut plantation care.

Protégé Ontology Editor 5.5 was used to create the coconut plantation care ontology. The coconut domain implements all concepts and relationships using the Web Ontology Language (OWL). Using the FACT++ Reasoned of Protégé ontology editor 5.5, the developed ontology is evaluated. The ontology model is validated by ontology experts, and the domain is validated by domain experts. By using Reasoned, DL queries are used to verify the validity of the ontology, and SPARQL queries are used to evaluate the proposed ontology.

Ontology-based knowledge management portal for coconut plantation care is one of the applications of the knowledge management portal for coconut plants. It is important for almost all coconut planters, agripreneur, farmers, and agriculture department staff. Because it`s difficult to take a decision making while selecting or identifying diseases in a coconut tree and caring for proper treatment methods. An ontology-based knowledge management portal is needed to improve more valuable knowledge about coconut diseases and their proper treatment methods. From the research findings, most of the knowledge management on coconut plantations has not been developed by ontology. But several researchers have proved that an ontology-based domain is developed with other sectors where domain knowledge has produced more valuable results [3].

The main objective of this research is to design an ontology model for the coconut plantation care and evaluation & validation of developed ontology. This research aims to contribute to the treatment method in the coconut plantations in coconut research institute by developing an ontology-driven solution that organizes, describes, and helps decision making clearly in the domain. Agripreneur also can get knowledge by developing an ontology driven solution that describes all the diagnosing causes and treatment methods from the top to the base level. This would help the researchers to reuse the ontology for future works.

The paper has been organized as follows. The first section describes an introduction to the whole research. It consists of the introduction, purpose of the study, statement of research, the significance of the study, definitions, delamination, limitations, assumptions, and contribution of the study. The second section is the literature review. This contains the details of the previous work in the areas of ontology and the knowledge management portal. The third section elaborates on the research methodology to develop the knowledge management system. The fourth section presents results and discussions. This section elaborates on all the results obtained from this study and the evaluation that was carried out to check the performance of the knowledge management system. Section five contains the conclusion about the knowledge management portal and indicates the future work to be done with the knowledge management portal.

II. LITERATURE REVIEW

In recent times, several types of research have been involved in the analysis of identifying the diseases in the coconut with image processing, machine learning, and deep learning techniques [4]. In [5] authors discuss the major pests and the minor pests which cause diseases in the coconut and mention that coconut mites, black beetle, coconut caterpillar, and red palm weevil are the major pests that are indigenous. Also, they mentioned that usual diseases like leaf bright, and stem bleedings are less important than pest diseases, thus it causes great economic losses in this field.

T. Kumara et al [6] identified that there are mainly three most significant and harmful pests which attack the coconut trees often in Sri Lanka. They are red palm weevils, coconut black-headed caterpillars, and rhino beetle and they usually live in major coconut cultivation areas. Bioecology is a study method that can be used to analyze the current status and the management of these pests. Early detection of these pests is the most significant and critical part of coconut production. In [7] authors discuss the early pest detection from crops using image processing and computational intelligence. They found that small whiteflies, relatively small, cause severe crop damage. Therefore, as an initial step, they counted the pests on the leaves to identify how many insects are there on a leaf. The two different algorithms were implemented in their studies, the RMI and the proposed algorithm, and comparing both, ended up with above 98% success in addition, numerous studies have been conducted to discover the coconut management system by employing various expert systems, deep learning systems, and machine learning methodologies to solve the issues.

In the semantic web, ontologies are one of the most powerful tools for representing knowledge and making decisions. Ontology, which is machine-interpretable, is used to represent domain knowledge [2]. It can be used to create a common conception that makes it easier to store, communicate, retrieve, make decisions, and display knowledge. There are classes, persons, and relationships between them in the ontology model. Object properties and data properties are used to illustrate relationships. Restrictions are employed to improve the authenticity of relationship depiction.

Phoksawat, Kornkanok; Ta'a, Azman; Mahmuddin, Massudi researched Intercropping in Rubber Plantation Ontology for a Decision Support System in 2019 [3]. They wanted to develop a decision-making system for individual farmers who wanted to grow rubber trees. They wanted to achieve the maximum income and lowest cost through the system, which used semantic web technology to allow farmers to access knowledge at all times and lower the risk of growing crops while also assisting the decision support system (DSS) to become more intelligent. They contribute

to the field of knowledge management by using ontology to identify plants that are acceptable for specific farmers. Aside from that, besides being useful in DSS by offering options with accuracy, it also reduces the complexity of the problem by reducing decision variables and condition variables in the multi-objective optimization model of DSS.

To address this issue, Jearanaiwongkul, W., Anutariya, C., and Andres, F. researched disease identification in plants in 2018 and presented several systems and methodologies for recognizing plant diseases. However, the majority of them are more concerned with image-based pattern identification than with plant disease irregularities. In other words, they haven't used ontology to detect plant disease semantically. Current procedures make it difficult for farmers to identify disease labels that are relevant to the semantics of an affected plant. The authors [8] introduced an ontology-based strategy to simulate plant diseases and demonstrated their method by developing a rice disease ontology.

According to the research done in [9] they discussed the User Centred Ontology for Sri Lankan Farmers Study, where they use some methodology such as the Delphi Method, Modified Delphi Method, and OOPS. This research was conducted to validate the validity of the ontology. Also, they used a web-based tool as part of their methodology. An online knowledge base with a SPARQL endpoint was created to exchange and reuse domain knowledge that may be queried depending on user context. Additionally, they offer a method for building a database of agricultural knowledge to respond to user inquiries while taking into account the context in which those queries are made at different stages of the farming life cycle.

There are some methods commonly used by experts to validate the ontology in terms of quality & accuracy. Delphi method, and Modified Delphi method; These are more effective methods as it gives agility, minimize the time required, it can maintain the enthusiasm of participants throughout the processes, and facilitate dialogues and collaborations among the participants that encourage in creating new ideas and OOPS! Web based tools are some of them. And there are some concepts used to evaluate ontology. One is verification methods that are ensuring the structure of ontology and validation methods that examine their real-world applicability.

The research in [10] was conducted on an overview of Knowledge Management (KM), including its purpose, definition, components, KM assets, problems, and processes in any organization. It also included a description of how ICICI OneSource has implemented the KM program to support the company's Business process outsourcing goals. Both information sharing and re-use must be promoted and rewarded at both the individual and corporate levels. Measuring and rewarding knowledge performance is the most effective way to accomplish this. Success in Knowledge Management requires long-term strategic commitment and a business culture that encourages knowledge performance.

Ontology is used in knowledge representation for the security and protection of critical infrastructure. The ontology in this case provides vulnerability classification as well as links to other security concerns. The ontology developed for this purpose is to describe interdependencies among particular assets, vulnerabilities, threats, and safeguards [2].

Knowledge based or domain ontologies are mainly used for sustainable knowledge management as well as more intelligent decision support, which can be used for collecting, consolidating, storing, and sharing experiences [11]. Ontologies provide aggregation and use of knowledge items and sub-processes and give a way to move from a document-oriented view of knowledge management to a content-oriented view. Ontologies effectively address domain problems by providing a worldview and a shared understanding of a domain [12].

III. METHODOLOGY

In the literature review, a few techniques were employed to create ontology modelling, including the Grüninger and Fox methodology [13] and the Delphi method [1]. We used the Delphi approach to obtain greater accuracy and flexibility. The process for creating an ontology model of coconut plantation care is shown in Fig. 1.

The Delphi method was used for data collection in this field. An extensive literature survey and expert collaboration were used to get relevant data. Two farmers with extensive knowledge of agriculture (mainly on Coconut plantation), three agripreneur, and an expert on ontology engineering took part., and the books and websites provided by the coconut research institute were used to get the domain knowledge in coconut plantation care. Aside from that, we verified whether or not the data gathered from the experts were accurate by utilizing reliable sources supplied by the experts. All the information was organized into the proper classes, and individuals were integrated. Farmers and agripreneur received all the information that was categorized and integrated. Domain specialists evaluated such specifics, revised them again iteratively, and made all the necessary corrections.

By using the ontology modelling knowledge, Ontology is designed using Protégé Ontology Editor 5.5. After that, the Ontology model is evaluated by OOPS! Evaluation Editor. All the pitfalls were identified and also rectified by the researcher, FaCT++ reasoned is used for reasoning and DL Query is used to check the correctness of the ontology modelling and relationships. SPARQL Queries are also used to check the ontology model. Finally, ontology experts validated the ontology model, and corrections were rectified [2].

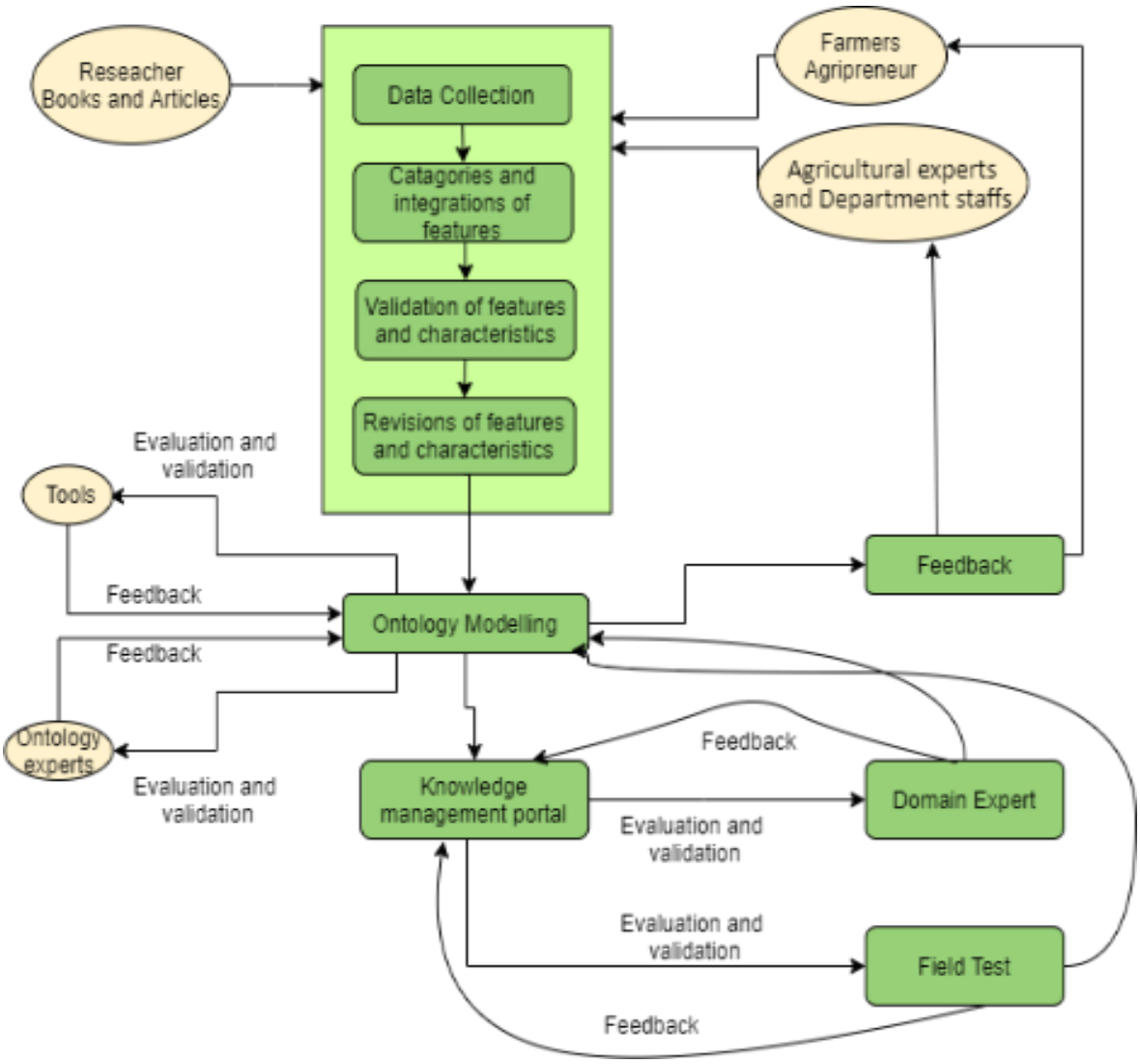

Figure 1: Methodology for Ontology Modelling

Figure 2 describes the high-level classification and the relationships of the knowledge management portal for coconut plantation care which has the main part of the ontology development. Developed the High-level hierarchy for coconut plantation care using classes as the main functions which are involved in a coconut plantation. For each disease, causes, symptoms, prevention, and treatments classes created instances are important. Created the relationship between classes and also between instances in object property. And also created the data property as the data type for each individual. After that created the relationship between each instances using Object property assertions. Using the reasoner checked whether the developed ontology is running perfectly or not. If the ontology is working properly check it using an online validator for getting more fit falls of the developed ontology.

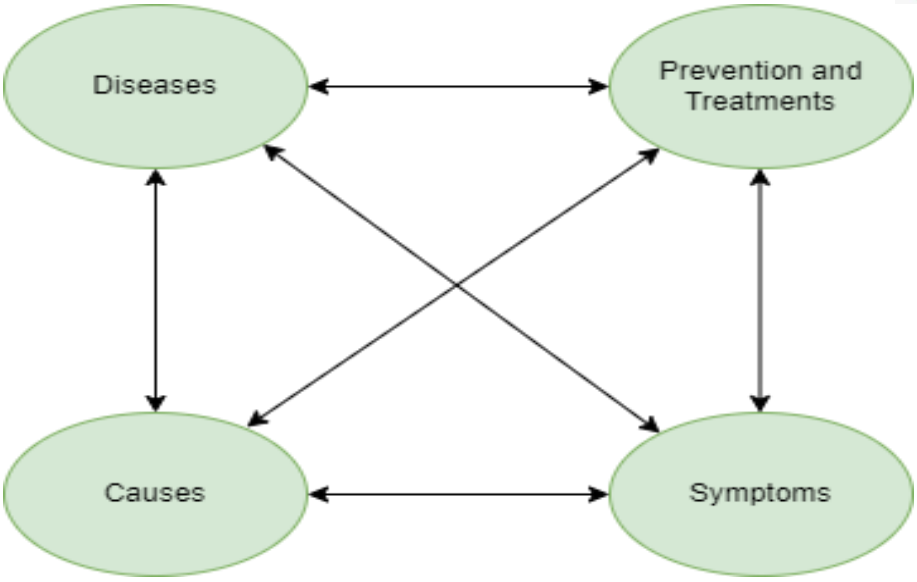

Figure 2: High level classifications and relations

IV. RESULTS AND DISCUSSIONS

In Sri Lanka, farmers face issues accessing vital information needed for their farming activities due to a lack of targeted delivery methods, unstructured and varied formats, etc. Currently, many systems are available to assist farmers in knowledge management by providing essential information, which includes weather forecasts, pests, and diseases, fertilizers needed, etc., through various devices. But these systems are not holistic and address only specific issues.

To tackle all these issues, the ontology was used to provide a structured view of domain knowledge and act as a key concept. The ontology represents a richer data model than a normal one, where there are well-defined relationships and precision. For the Sri Lankan context, the ontology for coconut plantation care that is proposed includes components such as prevention and treatment, symptoms, diseases, and causes. By using this developed ontology, coconut planters can get high-quality production, increase productivity, improve post-harvest handling, and better identify agricultural methods and technologies. This ontology can be further developed to provide a richer knowledge base to upgrade coconut plantation fields. In addition, the proposed logic-based ontological approach (user-centered ontology for coconut planters) was created to model the actual representation of the domain and its challenges of it in coconut plantations.

To implement the ontology, Protégé ontology development environment and Web Ontology Language (OWL) were used. To improve and refine the ontology, two internal evaluation procedures were used: Protégé implementation and SPARQL endpoint. Because it involves the system's users, this system is completely human-centric in the design and development process so that the system will meet their needs and that they will utilize the system in their routine decision-making. That's why farmers collaborated with agricultural entrepreneurs and coconut research officers throughout the design and development process.

OOPS! Evaluation results show the pitfalls in the evaluation of developed ontologies. Errors are categorized into critical, important, and minor errors. Defining the wrong relationships and defining multiple ranges, in domains or properties are some examples of critical error which needs to correct the pitfall. It affects the inconsistency of the ontology model. Missing disjointness and no license or properties are some of the important errors that are not critical for ontology function, but it is important to correct this pitfall. Creating unconnected ontology elements, missing annotations, and inverse relationships that are not explicitly declared are some of the minor errors.

When we checked the OOPS evaluation results in Pitfall Scanner, all the critical bugs were fixed in the proposed ontology model. Missing annotations, missing disjointness, merging different concepts in the same class, and an inverse relationship that is not explicitly declared are some of the minor errors that do not require correction; however, correcting these errors improves the appearance of the ontology.

The proposed ontology method was successfully developed using protégé ontology 5.5. and part of the developed ontology shown in Fig 3. Both the evaluation and the validation were executed separately. The FaCT++ reasoner is used to verify the accuracy and caliber of the developed ontology. OOPS! The critical, major, and minor pitfalls were all discovered by the ontology editor, and they were all fixed. The OOPS! Evaluation results of the created ontology are displayed in Figure 4.

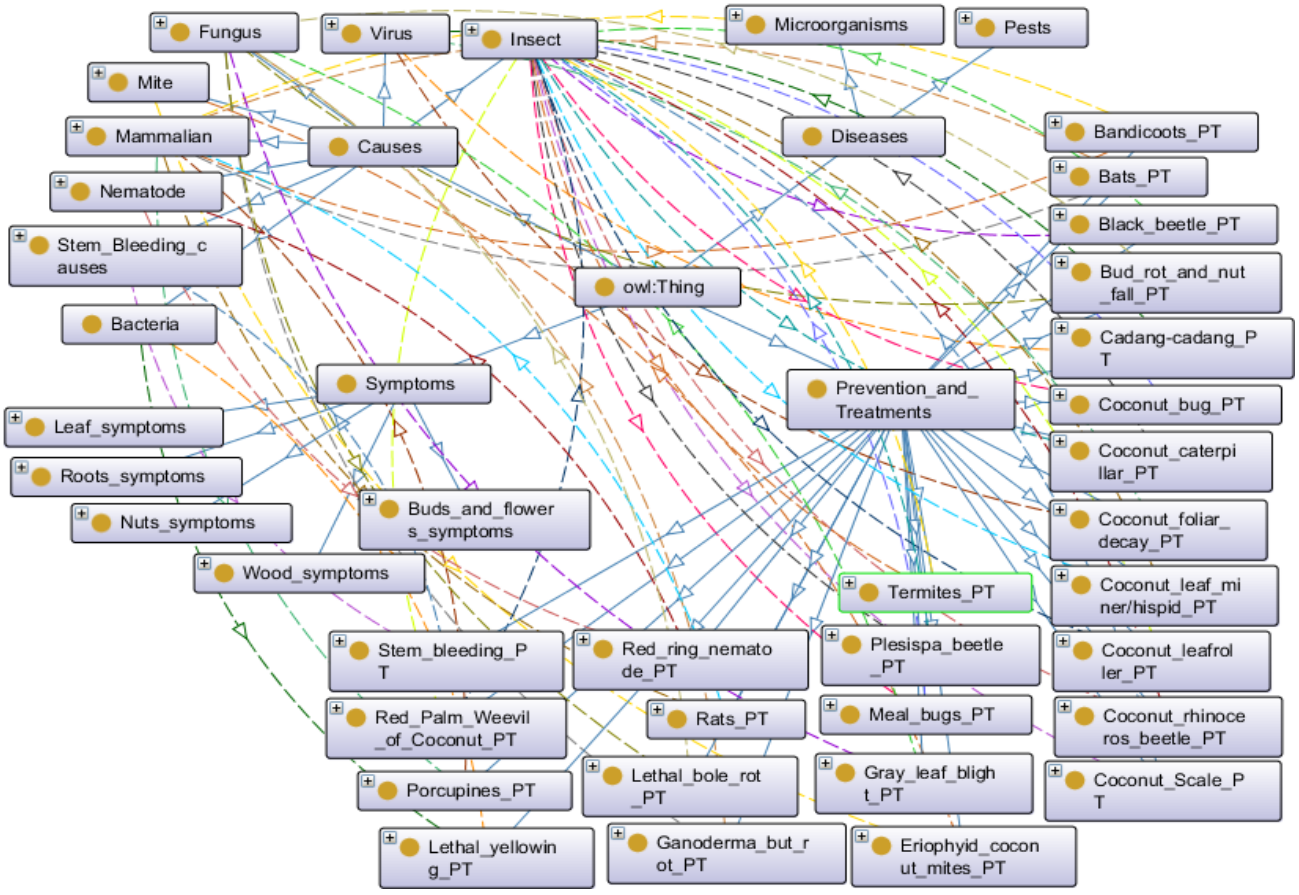

Figure 3: Part of the ontology's Ontograf

Evaluation results

It is obvious that not all the pitfalls are equally important; their impact in the ontology will depend on multiple factors. For this reason, each pitfall has an importance level attached indicating how important it is. We have identified three levels:

- **Critical** : It is crucial to correct the pitfall. Otherwise, it could affect the ontology consistency, reasoning, applicability, etc.
- **Important** : Though not critical for ontology function, it is important to correct this type of pitfall.
- **Minor** : It is not really a problem, but by correcting it we will make the ontology nicer.

[Expand All] | [Collapse All]

Results for P04: Creating unconnected ontology elements.	4 cases | Minor
Results for P07: Merging different concepts in the same class.	8 cases | Minor
Results for P08: Missing annotations.	488 cases | Minor
Results for P11: Missing domain or range in properties.	57 cases | Important
Results for P12: Equivalent properties not explicitly declared.	1 case | Important
Results for P13: Inverse relationships not explicitly declared.	1 case | Minor
Results for P22: Using different naming conventions in the ontology.	ontology* | Minor
Results for P30: Equivalent classes not explicitly declared.	4 cases | Important
Results for P41: No license declared.	ontology* | Important

Figure 4: Ontology Pitfall Scanner Evaluation Results

V. CONCLUSION

Coconut plantation care is an experience-based and knowledge-intensive activity, which mainly depends on the experience and knowledge of the coconut experts and farmers as well. With this developed ontology coconut planters can get high quality production, increase productivity, improve post-harvest handling, and better identification of agricultural methods and technologies and this can be developed to provide a richer knowledge base to upgrade the coconut plantation field.

This research is about the decision-making of the partners who have a problem and go further with diagnosis and treatment using this ontology model. We confidently believe that our ontology-based coconut plantation care can help the coconut planters, agripreneur and coconut plantation experts, and other active researchers in this field to improve not only knowledge management and also decision support and experiences. In the future, the developed ontology model will be extended to the knowledge management portal and support the farmers, agripreneur, and coconut research officers.

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