Journal of Theoretical and Applied Information Technology
15th December 2022. Vol.100. No 23

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

ONTOLOGY BASED KNOWLEDGE MODELLING FOR INDONESIAN RICE VARIETIES

SOFI DEFIYANTI[1], AHMAD ASHARI[2], DANANG LELONO[3]

[1] Faculty of Computer Science, Universitas Singaperbangsa Karawang, Karawang, Indonesia

[2,3] Dept. of Computer Science and Electronics, Universitas Gadjah Mada, Yogyakarta, Indonesia

E-mail: [1]sofi.defiyanti@unsika.ac.id, [2]ashari@ugm.ac.id, [3]danang@ugm.ac.id

ABSTRACT

Knowledge is an asset for every organization, including knowledge about new superior varieties of rice developed by the Agricultural Research and Development Agency of the Ministry of Agriculture of the Republic of Indonesia. Until 2021, as many as 120 new superior varieties of rice have been published, but knowledge of the improved varieties developed is only limited. Many varieties cause farmers to be confused in determining the rice varieties to be planted. So that a knowledge model is needed that can formalize knowledge about rice varieties, one way is to develop a rice variety ontology model. We propose the **Ont**ology **Var**ieties **Rice** (OntVarRice), an ontology of new superior rice varieties in Indonesia, by following the MethOntology methodology, which consists of a specification, conceptualization, formalization, and implementation of the ontology. OntVarRice includes 32 classes, 16 object properties, 7 data properties, 167 individuals, and 2430 logical axioms implemented using OWL. Evaluation and validation using HermiT to test consistency and coherence, and Description Logic query (DL query) is used to verify the knowledge built based on the answers to competency questions. OntVarRice as a knowledge-bases model can improve agricultural practices to make optimal decisions because OntVarRice stores and models knowledge about new superior rice varieties in the form of a complete picture of the concept of new superior rice varieties that can maximize variety selection, yield potential, production quality, pest, and disease resistance.

Keywords: *Ontology Deployment, Varieties, Rice, Knowledge-Based, Agriculture*

1. INTRODUCTION

Knowledge is an essential asset for any organization. Knowledge will continue to increase and change along with the process of socialization, externalization, internalization, and combinations thereof. This critical asset is easy to lose for many reasons, so it will have a very significant effect on the organization, especially on a person's expert knowledge. Inheritance of improper can cause the knowledge to be reduced or distorted so that it cannot be inherited perfectly.

Knowledge can be disseminated easily using an ontology model written in OWL format. Ontology is a conceptualization that represents objects that attract attention and represents the relationship between objects. In addition, ontology is based on logic to allow conclusions and verify the consistency of knowledge by computers. So, knowledge modeled in the form of an ontology will support interoperability and can be used as input for a decision support system.

An ontology represents a method for formally expressing a shared understanding of information that can play a significant role in representing and reusing knowledge semantically [1], [2]. Ontology has become a relevant model for representing knowledge in many fields of science, such as medicine, biomedicine, bioinformatics, food, and more. Ontologies can also improve recommendation models. Ontologies also provide a means of capturing and transforming human knowledge into understandable and explicit formats. Thus developing an ontology is often regarded as the starting point of standardization and formalization of the knowledge domain [3], [4]. Ontologies have been used in many scenarios in different application areas for knowledge-based integration. As a result, much semantic data related to the domain is published [5].

Research organizations in agriculture, especially on rice germplasm, take a long time to get results. It takes about 5-10 years to achieve reliable research on superior rice varieties. With research characteristics that take a long time and involve multidisciplinary research, it is very vulnerable to loss of knowledge. A special method is needed for its storage to maintain the knowledge that has been generated. One approach that can be used to store knowledge explicitly is to use an ontology model. Knowledge-based storage with an ontology model will be helpful for sustainable knowledge [4].

Indonesia has more than 120 certified rice varieties. Almost all farmers grow rice without knowledge of rice varieties [6]. Each variety has different attributes, such as disease resistance, pest resistance, cropping recommendations, and yields depending on how farmers cultivate their agriculture, one of which is the selection of appropriate rice varieties to obtain maximum production results. Lack of information about rice varieties causes farmers to plant the same variety so that what is expected in the form of increased production does not occur. The use of superior rice varieties that can produce high yields, are responsive to fertilization and resistant to pests and diseases accompanied by improved irrigation and cultivation techniques have been proven to increase productivity, efficiency and food sufficiency [7].

This research focuses on developing an ontology model to record knowledge about superior rice varieties into a knowledge base. This ontology model will be a tool for storing and disseminating knowledge. It is hoped that this will solve the problems that occur.

We make the ontology of agricultural domains related to rice varieties. Semantic technology is integrated into the project to provide a formal representation that allows the accurate definition of concepts. Reasoning techniques are used to conclude the best rice varieties to plant. The contribution of this work is a knowledge-based ontology, namely Ontology Varieties Rice or OntVarRice, which is used to support the recommendations. The knowledge bases are filled with data on rice varieties collected from the Ministry of Agriculture of the Republic of Indonesia.

OntVarRice is an ontology that describes the knowledge structure of the domain of rice varieties based on data collected from the Ministry of Agriculture. OntVarRice shares knowledge through conceptual design that allows the reuse of modeled knowledge.

2. THEORETICAL BACKGROUND AND RELATED WORKS

2.1 Ontology

Ontology is a formal artifact designed to represent knowledge related to a specific or generic domain in terms of relevant concepts, relationships between these concepts, and examples of these concepts [8]. Ontology in computer science is defined to represent a domain of knowledge explicitly about a concept by giving meaning, properties, and relations to the concept so that it is collected in a knowledge domain and forms a knowledge based. Another understanding of ontology that comes from computer science is that ontology defines a common vocabulary for researchers who need to share information activities in the domain [9].

The basic components of an ontology are classes (represented in taxonomic order), relations (used to link between domains), axioms (used to model statements that are always true), properties (used to describe general characteristics of instances of a class or to link between classes), and instances (specific data representations).

2.2. Protégé

Protégé is an open-source platform developed by Stanford University for Biomedical Informatics Research center in collaboration with the University of Manchester, which provides a set of tools for users to build domain models and knowledge-based applications with ontologies. Information related to Protégé can be found at https://protege.stanford.edu/ including tutorials and the Protégé user community. Protégé is a tool that is used to build an ontology based on the results of the design. The ontology design built using protégé will produce resources like RDF or OWL. Protégé is java-based, extensible, and provides various plug-ins that make it more flexible in ontology development. Plug-ins are separately developed software models that add more functionality to existing software [10]–[14]. Examples of Protégé plug-ins are DL-Query, SPARQL, and SWRL. These plug-ins are used to retrieve information in the ontology [15][16]. HermiT, Pellet, Ontop are plug-ins that are used for reasoners and validation to check the consistency and coherence of the ontology. OntoGraf dan OWLViz are plug-ins used to display ontologies in a visual form.

The Protégé plug-in used in this research are:

- **DL-Query** is a query language used to get information in the ontology. DL-Query uses a notation that is close to natural language, making it easier to find information [17].
- **HermiT** is a reasoner that can automatically detect consistency and coherence in ontologies and identify subsumed relationships between classes [18].
- **OntoGraf** provides support for interactively navigating each relationship in the ontology. The supported relationships are classes,

subclasses, individuals, and object properties [19].

2.3 Related Works

Ontologies can represent knowledge in a specific domain and allow semantic interoperability by being linked to other external data sources. Compared to database schemas, ontologies can provide the possibility to present knowledge with richer and more explicit semantics. Domain ontologies can enable reasoning and query knowledge-based on specified classes, properties, and relations. Ontology technologies can improve coordination and interaction between different communities and computer applications by facilitating knowledge capture, storage, integration, and querying. In addition, ontologies can support decision-making processes that traditionally rely on individual experience and knowledge of relevant domain experts and managerial personnel [3]. The domain is therefore machine readable and can provide a shared understanding of the representation of information to the community as well as allow for the automatic processing of knowledge in the domain [10].

Table 1. Related Works Rice Ontology

Domain	Reference
Pests and Diseases	[20] [21], [22], [23] [24] [25] [17] [26] [27][28]
Fertilizer	[27] [29]
Rice	[30] [31] [28] [32]
Rice Production Process	[33] [34][35][36][37] [29][28]
Rice Anatomy	[38]
Rice Research Policy	[39]

Ontology modeling has been developed for many agricultural domains, both general in nature, such as plants ontology to specific ones, such as citrus ontology, dates ontology, etc. The rice domain is no exception, as shown in Table 1 regarding the literature study on the rice ontology that has been done. From the table, several domains have been carried out, such as the domain of pests and diseases in rice, fertilizer, production processes, anatomy, and policies for rice research. However, knowledge representation that focuses on the selection of rice varieties is not widely carried out, even though the selection of varieties is the beginning of the process of rice cultivation.

The problem that occurs is that the number of rice varieties that have been developed causes the dissemination of information and knowledge about the description of new superior varieties of rice that is not well distributed so that farmers plant the same variety every growing season. This causes an increase in rice production that could not be more optimal. The ontology of rice varieties can represent knowledge about the domain. In addition, ontologies can also improve the results of the recommendation model with a shared understanding of the information contained in them [1]. The development of OntVarRice can be a knowledge base for recommending new superior varieties of rice planted by farmers.

3. ONTOLOGY DEVELOPMENT METHODOLOGY

OntVarRice development is served with the MethOntology development methodology. MethOntology is one of the methodologies for building ontologies other than On-to-Knowledge, OntoClean, DILIGENT [40], Ontology Development 101[9], DOGMA [41]. MethOntology is the most popular method used to build ontologies from scratch, reuse other ontologies or to re-engineer ontologies [42][43]. This research uses MethodOntology for ontology engineering in modeling the knowledge-based of rice varieties which has four main steps: specification, conceptualization, formalization, and implementation. Figure 1 shows the overall phase in OntVarRice's development.

The specification aims to determine the purpose and scope of ontology development. The specification also includes the feasibility of targeting potential platforms and applications where the ontology will be deployed and integrated. At this stage, a series of competency questions are determined to be able to represent relevant and appropriate knowledge in the ontology.

Conceptualization is concerned with the organization of knowledge acquired during knowledge acquisition activities. Conceptual design maps relevant information into a conceptual model. At this stage, the knowledge acquired at the specification level is organized into concepts or classes, attributes, relationships, formal axioms, rules, and individuals.

Formalization and Implementation are realized in OWL by using Protégé software to implement the ontology.

Evaluation, verification, and validation of the formed ontology is needed to correct errors, refine or update the ontology that is built.

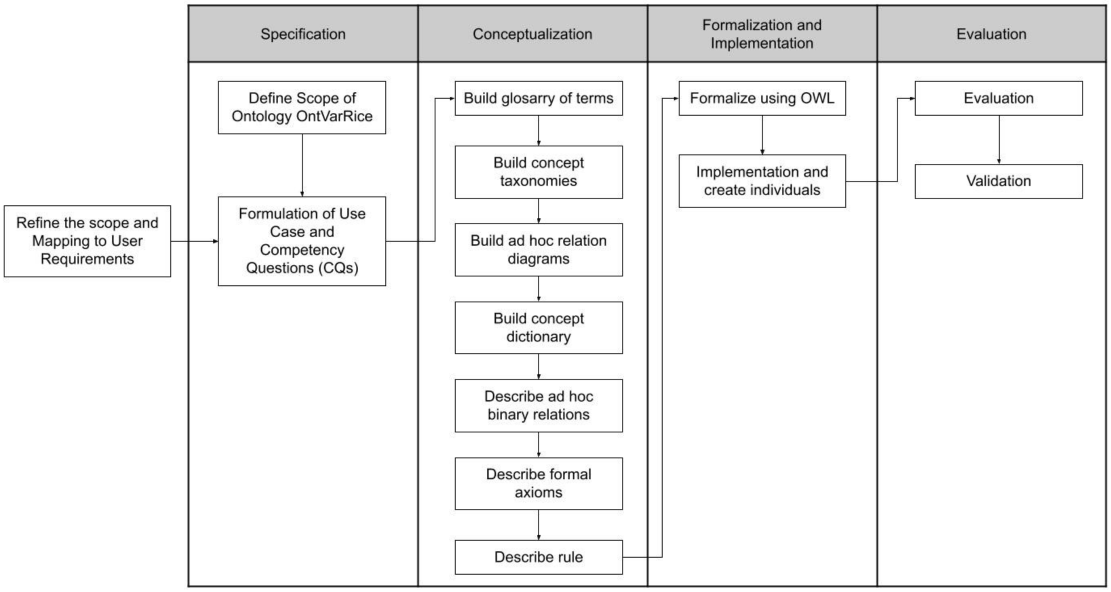

Figure 1. The Workflow Of Ontology Development Ontvarrice

4. RESULT AND DISCUSSION

4.1 Ontology Specification

The ontology specification stage determines several points that must exist in OntVarRice. OntVarRice is a reference model representing knowledge about superior rice varieties which can later be used for decision support systems. The scope of OntVarRice is limited to the description of new superior varieties of rice issued by the Ministry of Agriculture of the Republic of Indonesia. Implementation using Web Ontology Language (OWL) via Protégé. OntVarRice will be used by professionals in agriculture, especially rice (e.g., germplasm researchers, agricultural extension workers), rice farmers, and software developers, especially in agriculture. OntVarRice has the purpose of using it as a knowledge-based about new superior varieties of rice that can be used for recommendations for selecting rice varieties, a knowledge-based that can be used for developing decision support systems in agriculture, and a knowledge-based to support the learning process.

At this stage, competency questions (CQ) are also determined. Competency questions (CQ) are used to achieve the expected goals. If the ontology that is built can answer the entirety of the CQ that has been formulated correctly, the ontology that has been built has achieved the expected goals [44][45]. Table 2 contains competency questions (CQ) that must be answered by the designed ontology.

Table 2 Subset Of Cqs Of Ontvarrice

No.	Competency questions
1	What varieties have the texture of rice A?
2	What varieties have an average yield of B?
3	Which varieties are resistant to disease X
4	What varieties are resistant to Y pests?
5	What varieties have a plant life of Z days?
6	What varieties have A shedding?
7	What varieties have a potential B yield?

4.2.2 Build Concept Taxonomies

The concept of taxonomy in this study was built using a top-down process or from general to specific. Concepts or classes are selected from a list of terms determined in the previous stage. Then the taxonomy is arranged, looking at the relationship or relationship between each existing class. For example, the OntvArRice class has a Paddy class with subclasses: Group, Pest, Disease, Variety, and Size. As shown in Figure 2 in the class structure, a Thing is always defined as the initial concept in building a knowledge domain.

4.2.3 Build Ad-hoc Relationship

After the taxonomy concept is built, then proceed with creating an Ad-hoc relationship. At this stage, the relationship type in the term table is used to connect each concept that has been created. In creating a relationship, it is necessary to consider each type of relationship. Figure 3 depicts a fragment of the ad-hoc binary relation diagram of the built ontology model.

Table 3. Glossary Of Terms And Concepts In Ontvarrice

Name	Description	Type
Rice varieties	Groups of plants with each other have the same characteristics.	Concept
Group	Classification of rice types based on their ecosystem.	Concept
Plant Age	Age of variety from spreading to physiological maturity	attribute
Plant shape	The appearance of the plant grass stands is based on the angle formed between the tiller stems with an imaginary line in the middle of the clump and perpendicular to the ground surface.	Attribute
Plant height	Height from ground level to the tip of the longest panicle.	Attribute
flag leaf	The last leaf to emerge from the stem, the leaf angle measured from the point of attachment of the flag leaf to the panicle stalk.	Attribute
Grain shape	The results of observations on the length and width of the grain.	Attribute
Grain color	Palea and lemma colors when the grains ripen.	Attribute
Threshing Grain	A measure of whether the grain falls out easily when the panicle is grasped by hand.	Attribute
Lodging	The position of the plant stands on the entire plot measured at the ripening phase of the grains.	Attribute
Rice texture	The physical-chemical properties of the rice texture are characterized by amylose content, which is one of the physicochemical properties of rice.	Attribute
Glycemic Index (GI)	Food grades according to their effect on blood sugar.	Attribute
Weight 1000 grains	The weight of 1000 grains content at 14% grain moisture content.	Attribute
Average yield	The average yield of milled dry grain with a moisture content of 14% at various test locations.	Attribute
Yield potential	The highest yield ever achieved in a particular area.	Attribute
Disease	A condition in which plant cells and tissues do not function normally.	Concept
Pest	Animals that interfere with plants and cause crop yields to not grow and develop optimally.	Concept

4.2.4 Build Concept Dictionary

The next step is to create a concept dictionary where each domain is listed with the instance attributes and the class attributes and relations that exist in that class. Table 4 shows the OntVarRice model concept dictionary.

4.2.5 Describe Ad-hoc Binary Relation

After completing the stages of making a concept dictionary, the next step is to describe the relationships used in detail. This stage is an ad-hoc binary translation where each relation that will be used in the ontology is created. The example of the relation in Table 5 HasDisease means having rice plant disease.

4.2.6 Describe Formal Axiom

In this activity, all the required axioms are listed in detail. In MethOntology, formal axioms have structures such as axiom names, axiom descriptions, axiom expressions, concepts, and variables used. Table 6 contains the formal axioms of OntVarRice.

4.2.7 Describe Rule

The rules needed to create an ontology with the MethOntology must be identified and explained in the form of a "rules table". The rules identified in this table are the same as those defined in the previous stage of formal axioms. Information such as names, natural language descriptions, concepts, properties, binary relationships, and variables should be described. In the MethOntology method, the "if-then" pattern is used to describe the rules. Rules are created based on the nature of the ontology concept by the author in consultation with experts. They are included in the Protégé software so that concepts with related rules in natural language are separated from other concepts.

The rules on OntVarRice are used to support the provision of knowledge about each type of superior variety, both regarding pests, diseases, or physical descriptions of rice plants. In the depiction of the rule, a rule table is created which contains the name of the rule, description, expression, concept, and variable used. Table 7 describes the name of the rule, which is about the texture of rice from superior varieties.

Table 4. Concept Dictionary

Concept	Relation
Pest	HasPest HasResistance
Disease	HasDisease HasResistance
Measurement	HasMeasurement
Group	IsGroup HasGroup
Varieties	HasPhysique HasShape HasFlagLeaf HasLodging HasThresingGrain HasResults HasGrainShape HasRiceTexture HasGrainColor

Table 5. Ad-Hoc Binary Relation

Relation	Source Concept	Cardinality (Max)	Target Concept	Inverse Relation
HasPest	Varieties	M	Pest	IsAPest
HasDisease	Varieties	M	Disease	IsADisease
IsAGroup	Varieties	1	Group	Has Varieties

Table 6. Sample Of Formal Axiom

Axiom Name	Pest Type
Description	Identify types of pests and their resistance to pests.
Expression	If Rice Varieties X Then Pest Resistant Y
Concept	Varieties Pest
Adhoc Relation	HasPest

Table 7. Sample Of Rule Table Ontvarrice

Rule Name	Rice Texture
Description	Describe the texture of the rice owned by superior varieties
Expression	If Varieties (?a) Then Texture ketan Else if Varieties (?a) Then Texture Sangat Pulen Else if Varieties (?a) Then Texture Pulen Else Pera
Concept	Varieties
Ad-Hoc Relation	HasRiceTexture
Variable	A

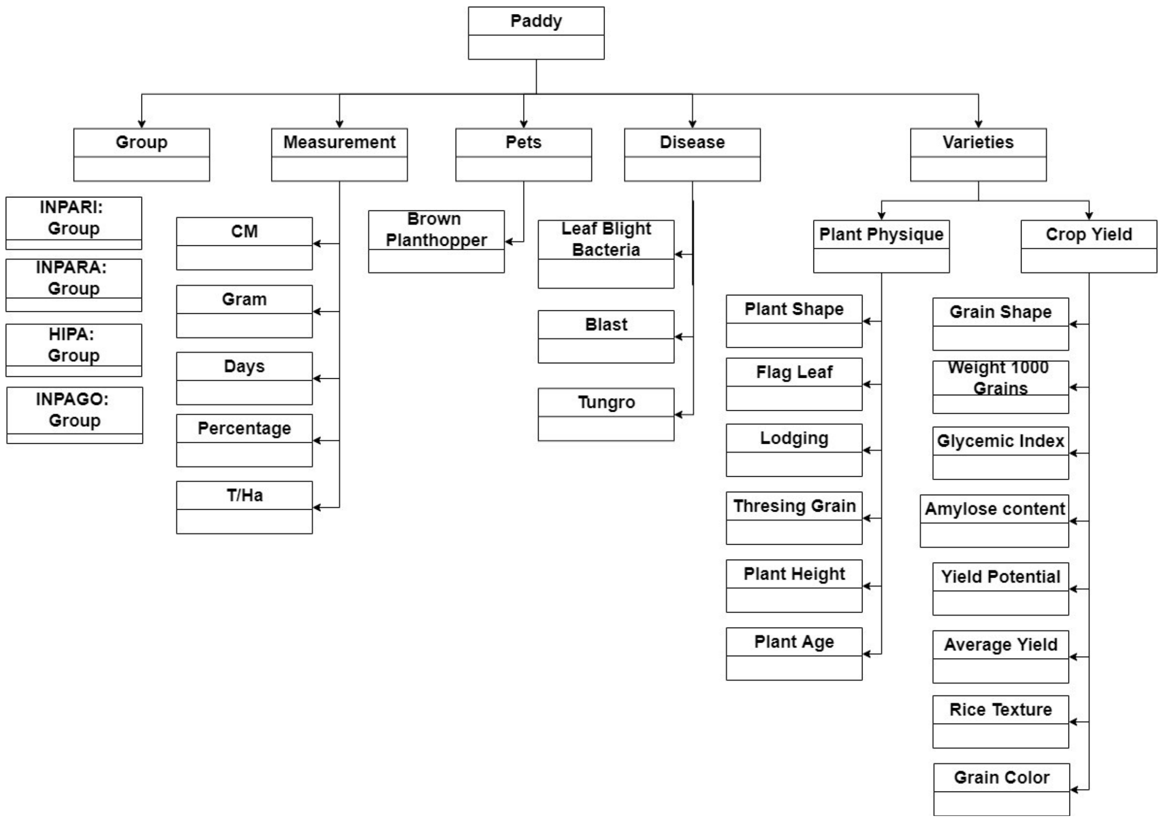

Figure 2. Concept Taxonomies Of Ontvarrice

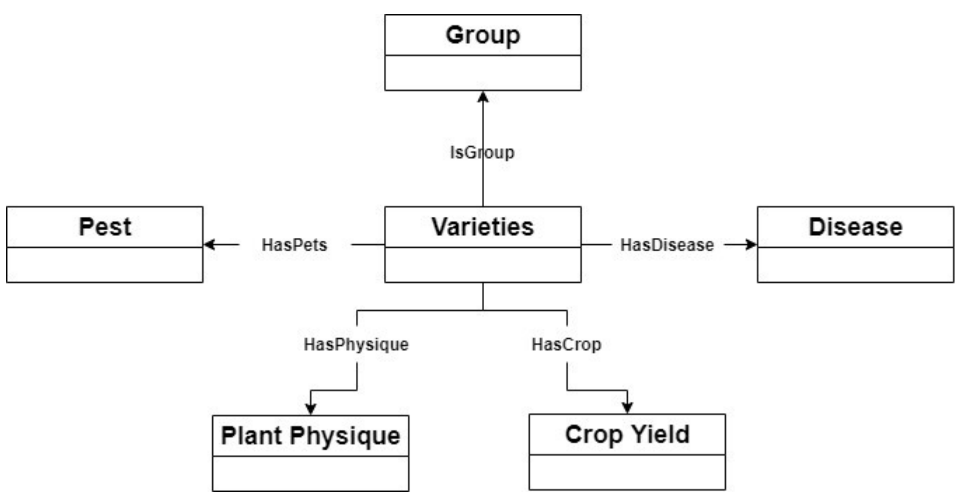

Figure 3 Ad-Hoc Relations

Journal of Theoretical and Applied Information Technology
15th December 2022. Vol.100. No 23

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

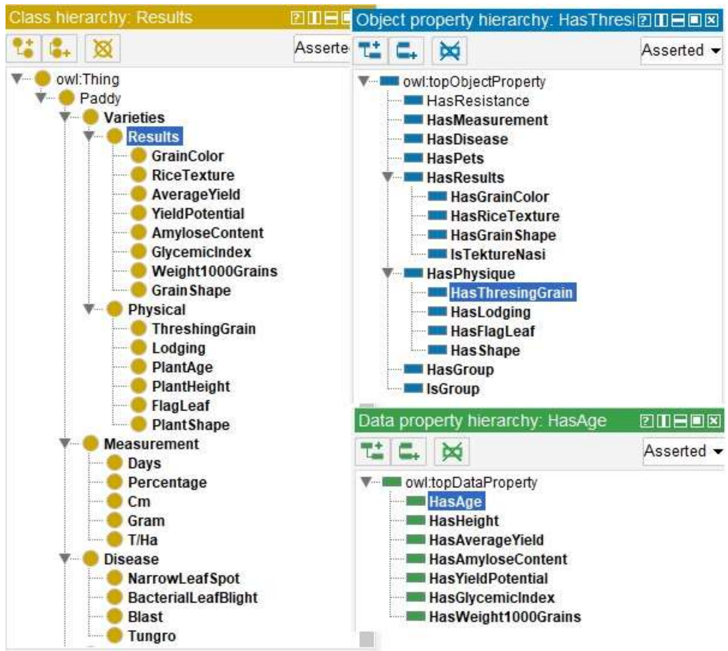

Figure 4. Implementation With Protégé

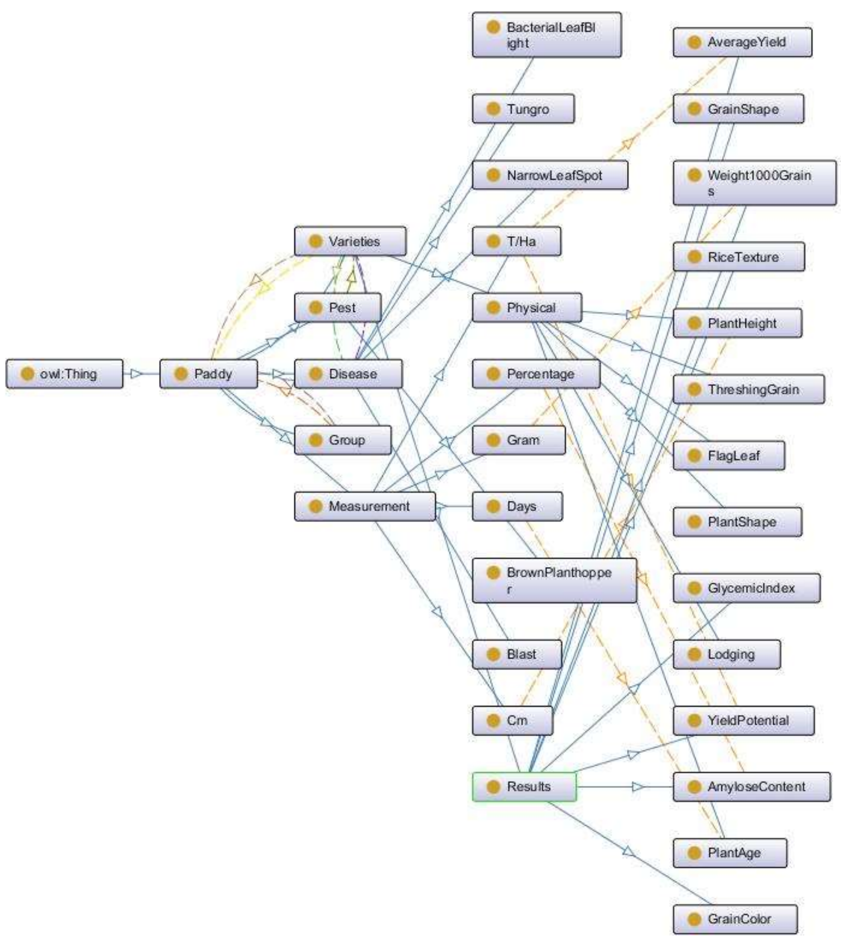

Figure 5. Ontvarrice Ontograf

Journal of Theoretical and Applied Information Technology
15th December 2022. Vol.100. No 23

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

4.3 Ontology Formalization and Implementation

This study used protege software to formalize existing ontology, which OWL/RDF supports. Ontology formalization begins after the conceptualization stage. Ontology expressions through the language of representation are carried out with formalization.

OntVarRice implementation in OWL using the Protégé editor version 5.5 based on the design that was carried out in the previous stage. The result of the implementation is a form that can be read by the computer. Figure 4 shows the implementation of the design in the form of classes, subclass, property objects, and property data on OntVarRice. OntVarRice includes 32 classes, 16 property objects, 7 property data, 167 individuals, and 2430 logic axioms that are implemented using OWL.

OntoGraf is used as an understanding of concepts, property, and individuals formed in OntVarRice in the form of visualization. By using OntoGraf will be seen the link between classes or between individuals. Figure 5 illustrates the details of the linkages between classes and subclass on OntVarRice. The straight blue line shows the subclass, and the dotted line describes the object's property.

4.4 Ontology Evaluation and Validation

Evaluation of the ontology model can be done by innate reasoning from Protégé applications to determine consistency and coherence. The evaluation is carried out with HermiT 1.4.3.456. HermiT aims to determine the consistency of ontology and identify the hierarchical relationship between classes. Testing with HermiT is carried out on classes, object property, data property, and repeatedly if ontology OntVarRice is built. Consistency and coherence of OntVarRice have been tested with HermiT reasoner and showing no problems because it does not error when running reasoner. Figure 6 shows the results of HermiT when verifying OntVarRice.

Figure 6. Reasoner Hermit 1.4.3.456 When Verifying Ontvarrice

The validation of the conceptual model was carried out to determine the effectiveness of the ontology. Validation is carried out by using the CQ domain test approach that has been carried out at the specification stage. This validation is carried out to ensure that the built ontology answers the competency questions in Table 1. DL-Query is used for the validation process on OntVarRice because it was developed with OWL. Table 8 shows that OntVarRice can answer all competency questions that have been created.

The first query in accordance with the competency questions that have been formulated in the initial stage is about the texture of rice. Figure 7 illustrates the results of DL Query for the first question about the texture of rice. The results of this query illustrate the truth of the captured knowledge and the requirements set during the specifications stage.

Table 8. Answering Competency Questions With Dl Query

Competency Questions	DL Query
Varieties that have the texture of rice A?	HasRiceTexture value A
Varieties that have an average result B?	HasAverageYield some xsd:float[>=B]
Varieties that are resistant to disease C	HasResistance value Disease_Resistant and HasDisease some C
Varieties that are resistant to pests D?	HasResistance value Pest_Resistant and HasPest some D
Varieties that have the age of the plant E Day?	HasAge some xsd:integer[>E]
Varieties that have a loss f?	HasThreingGrain value F
Varieties that have the potential of G results?	HasYieldPotential some xsd:float[>=G]

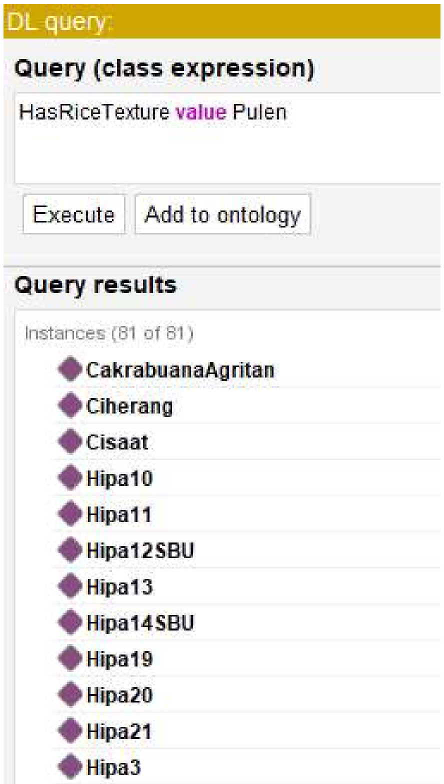

Figure 7. Dl Query For Rice Texture

4.5 Discussion

Increased demand for food is balanced with a smart agricultural ecosystem aimed at increasing crop yields, optimizing plant growth, and improving plant quality. Therefore, this research focuses on knowledge about superior rice varieties in Indonesia. Knowledge of new superior varieties of rice consists of several factors in it such as diseases, pests, potential results, and so on. These factors allow farmers to make optimal decisions for agriculture.

Based on knowledge about the new superior rice varieties in Indonesia, the ontology OntVarRice model has been successfully developed following the MethOntology method implemented in OWL through Protégé. With OntVarRice, the selection of new superior varieties can be easily made based on the desired conditions, such as selection based on rice texture, yield potential, or resistance to pests or diseases using DL query. OntVarRice includes 32 classes, 16 property objects, 7 property data, 167 individuals, and 2430 Logic Axioms.

OntVarRice is designed to store and model knowledge about new superior varieties in Indonesia. OntVarRice provides a complete picture of pests, diseases and results obtained by these varieties. OntVarRice was built using an ontology modeling because it allows to connect and meet the requirements of unstructured, semi-structured or structured data formats without the need for standardization. Ontology cuts the process of identifying, increasing the results of classification to compile important information [47].

Knowledge from OntVarRice can be taken and used to make intelligent decisions regarding the recommendations of new superior varieties by integrating with external interfaces such as decision support systems. Mechanical learning techniques can also be integrated with the ontology model to support system predictions and analysis using the classification, grouping and identification techniques of associations will present the ability in an ontology-based system. The final service and application quality depends on the quality of the knowledge-base that is usually built from the ontology model [48]. OntVarRice is the first step to introducing the ontology model that can be integrated with the machine learning or decision support system to bring intelligence to agriculture, especially rice in Indonesia. OntVarRice is possible to get insight into the parameters of selecting superior rice varieties that will be planted to get optimal results. Configuration of parameters in the selection of new superior varieties of the correct rice allows rice plants to grow healthy, high harvests thereby increasing agricultural productivity.

The evaluation was carried out using a HermiT reasoner to test consistency of OntVarRice, and it was found that ontology OntVarRice is consistent. Validation is carried out using DL Query to test the completeness of the knowledge formed on OntVarRice with the parameters of competency questions and their answers as in Table 8 and Figure 7.

The fundamental difference between our research and previous research is that the ontology we have built has a particular domain: new superior rice varieties in Indonesia. In addition, OntVarRice provides a complete description of new superior varieties of rice that have been issued by the Ministry of Agriculture and Forestry of the Republic of Indonesia. OntVarRice was built to build a decision support system in the form of recommendations for new superior rice varieties. Ease of adding new superior rice varieties as instances by simply adding instances to the class of varieties and attributes related to their configuration.

5. CONCLUTION

The wide varieties of rice developed by the Ministry of Agriculture of the Republic of Indonesia have confused farmers in determining which varieties to plant. A lack of information about rice varieties causes farmers to plant the same variety, so

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

the increase in production is not optimal, OntVarRice was developed to solve this problem.

OntVarRice has been successfully developed according to the MethOntology method implemented in OWL through Protege. OntVarRice includes 32 classes, 16 object properties, 7 data properties, 167 individuals, 2430 logical axioms, and no inconsistencies exist in the built ontology.

OntVarRice is used to store essential knowledge and has been validated by answering competency questions regarding new superior rice varieties consisting of several factors such as disease, pests, age, shape, height, flag leaf, grain shape, grain color, threshing grain, lodging, rice texture, glycemic index, the weight of 1000 grains, average, and potential yields. These factors allow farmers to make optimal decisions for agriculture. With OntVarRice, the selection of new superior varieties of rice can be easily made based on the desired conditions, such as rice texture, yield potential, or resistance to pests or diseases.

OntVarRice has several limitations; its development is not based on a consolidated top-level ontology and does not consider interoperability between ontologies.

Knowledge of OntVarRice can be retrieved and used to make intelligent decisions regarding farm operations with a decision support system. Then the next job is to make system recommendations based on OntVarRice by utilizing machine learning or decision support systems. Additionally, a suitable graphical user interface should be implemented to allow easier access to OntVarRice.

REFERENCES:

[1] D. McKensy-Sambola, M. Á. Rodríguez-García, F. García-Sánchez, dan R. Valencia-García, "Ontology-based nutritional recommender system," *Appl. Sci.*, vol. 12, no. 1, hal. 1–17, 2022.

[2] P. Manika, E. Xhumari, A. Ktona, dan A. Demiri, "Application of ontologies and semantic web technologies in the field of medicine," *CEUR Workshop Proc.*, vol. 2280, hal. 24–30, 2018.

[3] X. Xing, B. Zhong, H. Luo, H. Li, dan H. Wu, "Ontology for safety risk identification in metro construction," *Comput. Ind.*, vol. 109, hal. 14–30, 2019.

[4] P. Delir Haghighi, F. Burstein, A. Zaslavsky, dan P. Arbon, "Development and evaluation of ontology for intelligent decision support in medical emergency management for mass gatherings," *Decis. Support Syst.*, vol. 54, no. 2, hal. 1192–1204, 2013.

[5] T. Ozacar dan O. Ozturk, "Karyon: A scalable and easy to integrate ontology summarisation framework," *J. Inf. Sci.*, vol. 47, no. 2, hal. 255–268, 2021.

[6] S. Yudi *dkk.*, *Description of New Superior Varieties of Rice*. 2021.

[7] S. Noviyanti dan D. Sulistyowati, "Adoption of Innovation Using New Superior Varieties of Rice Field (Oryza sativa L.) in Cilaku District, Cianjur Regency, West Java Province," *J. Inov. Penelit.*, vol. 1, no. 4, 2020.

[8] H. Wardhana, A. Ashari, dan A. Kartika, "Review of Ontology Evolution Process," *Int. J. Comput. Appl.*, vol. 179, no. 25, hal. 26–33, 2018.

[9] N. F. Noy dan D. L. McGuinness, "Ontology Development 101: AGuide to Creating Your First Ontology," 2001. [Daring]. Tersedia pada: http://www.ksl.stanford.edu/people/dlm/papers/ontology101/ontology101-noy-mcguinness.html.

[10] J. V. Fonou-Dombeu, N. Naidoo, M. Ramnanan, R. Gowda, dan S. R. Lawton, "OntoCSA: A Climate-Smart Agriculture Ontology," *Int. J. Agric. Environ. Inf. Syst.*, vol. 12, no. 4, hal. 1–20, 2021.

[11] K. Desmond Mogotlane dan J. V. Fonou-Dombeu, "Automatic Conversion of Relational Databases into Ontologies : A Comparative Analysis of Protege Plug-Ins Performances," *Int. J. Web Semant. Technol.*, vol. 7, no. 3/4, hal. 21–40, 2016.

[12] L. Mesmer dan A. Olewnik, "Enabling supplier discovery through a part-focused manufacturing process ontology," *Int. J. Comput. Integr. Manuf.*, vol. 31, no. 1, hal. 87–100, 2018.

[13] O. Jessie, M. A. Abdulgabber, dan S. C. Liew, "IPFJRO: The development of image processing ontology," *J. Theor. Appl. Inf. Technol.*, vol. 96, no. 9, hal. 2604–2614, 2018.

[14] A. Khamparia, B. Pandey, dan V. Pardesi, "Performance analysis on agriculture ontology using SPARQL query system," *2014 Int. Conf. Data Min. Intell. Comput. ICDMIC 2014*, hal. 1–5, 2014.

[15] Y. Gutiérrez, D. Tomás, dan I. Moreno, "Developing an ontology schema for

enriching and linking digital media assets," *Futur. Gener. Comput. Syst.*, vol. 101, hal. 381–397, 2019.

[16] N. Malik, D. Hijam, dan A. Sharan, "Ontology based knowledge representation : Case study from agriculture domain," *Int. J. Knowledge-based Intell. Eng. Syst.*, vol. 25, hal. 97–108, 2021.

[17] W. Jearanaiwongkul, C. Anutariya, dan T. Racharak, "applied sciences An Ontology-Based Expert System for Rice Disease Identification and Control Recommendation," *Appl. Sci.*, vol. 11, 2021.

[18] L. Bunnell, K. M. Osei-Bryson, dan V. Y. Yoon, "RecSys Issues Ontology: A Knowledge Classification of Issues for Recommender Systems Researchers," *Inf. Syst. Front.*, 2019.

[19] D. L. Nuñez dan M. Borsato, "OntoProg: An ontology-based model for implementing Prognostics Health Management in mechanical machines," *Adv. Eng. Informatics*, vol. 38, no. October, hal. 746–759, 2018.

[20] W. Jearanaiwongkul, C. Anutariya, dan F. Andres, "An Ontology-based Approach to Plant Disease Identification System," *ACM Int. Conf. Proceeding Ser.*, no. December, 2018.

[21] A. Goldstein, L. Fink, O. Raphaeli, A. Hetzroni, dan G. Ravid, "Addressing the 'Tower of Babel' of pesticide regulations: An ontology for supporting pest-control decisions," *J. Agric. Sci.*, vol. 157, no. 6, hal. 493–503, 2019.

[22] K. Lagos-Ortiz, J. Medina-Moreira, C. Morán-Castro, C. Campuzano, dan R. Valencia-García, "An ontology-based decision support system for insect pest control in crops," *Commun. Comput. Inf. Sci.*, vol. 883, hal. 3–14, 2018.

[23] M. Zhitomirsky-Geffet dan C. Z. Mograbi, "A New Framework for Collaborative Ontology Construction for an Agricultural Domain from Heterogeneous Information Resources," *J. Agric. Food Inf.*, vol. 19, no. 3, hal. 203–227, 2018.

[24] L. Peng dan L. Zhang, "The study of the knowledge model based on event Ontology for the occurrence of paddy stem borer (scirpophaga incertulas)," *Commun. Comput. Inf. Sci.*, vol. 159 CCIS, no. PART 2, hal. 371–376, 2011.

[25] A. Kawtrakul, P. Tippayarak, F. Andres, dan S. Ujjin, "Personal warning service for pest management using a crop calendar and BUS model," *7th Int. ACM Conf. Manag. Comput. Collect. Intell. Digit. Ecosyst. MEDES 2015*, hal. 242–249, 2015.

[26] W. Jearanaiwongkul, C. Anutariya, dan F. Andres, "A Semantic - Based Framework for Rice Plant Disease," *New Gener. Comput.*, vol. 37, no. 4, hal. 499–523, 2019.

[27] A. Kawtrakul, "Development of an Information Integration and Knowledge Fusion Platform for Spatial and Time based Advisory Services : Precision Farming as a Case Study," *2014 Annu. SRII Glob. Conf.*, hal. 241–248, 2014.

[28] A. Kawtrakul, M. Suktarachan, N. Khantonthong, A. Thunkijjanukij, dan P. Saint-Dizier, "Rich lexical knowledge based Q&A System for ubiquitous knowledge service," *CEUR Workshop Proc.*, vol. 674, 2010.

[29] H. Afzal dan M. K. Kasi, "Ontology-based knowledge modeling for rice crop production," *Proc. - 2019 Int. Conf. Futur. Internet Things Cloud, FiCloud 2019*, hal. 343–350, 2019.

[30] Y. Kou, Z. Ruixue, dan G. Xian, "Research on Construction of Agricultural Domain Knowledge Service Platform Based on Ontology," *IFIP Adv. Inf. Commun. Technol.*, vol. 452, hal. 565–574, 2015.

[31] M. P. Polson dan S. Eswara, "Ontology Creation and Semantic Web for Paddy," *Int. J. Comput. Appl.*, vol. 41, no. 9, hal. 18–22, 2012.

[32] A. Kawtrakul, R. Amorntarant, dan H. Chanlekha, "Development of an expert system for personalized crop planning," *7th Int. ACM Conf. Manag. Comput. Collect. Intell. Digit. Ecosyst. MEDES 2015*, hal. 250–257, 2015.

[33] A. Thunkijjanukij, A. Kawtrakul, S. Panichsakpatana, dan U. Veesommai, "Ontology development: A case study for thai rice," *Kasetsart J. - Nat. Sci.*, vol. 43, no. 3, hal. 594–604, 2009.

[34] A. Thunkijjanukij, "Developing rules and criteria for rice ontology construction," *Int. J. Metadata, Semant. Ontol.*, vol. 4, hal. 54–64, 2009.

[35] A. Thunkijjanukij, S. Panichsakpatana, A. Kawtrakul, dan U. Veesommai, "Rice Production Knowledge Management : Criteria for Ontology Development," *Thai J.*

Agric. Sci., vol. 42, no. 2, hal. 115–124, 2009.

[36] A. I. Walisadeera, G. N. Wikramanayake, dan A. Ginige, "An ontological approach to meet information needs of farmers in Sri Lanka," *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 7971 LNCS, no. PART 1, hal. 228–240, 2013.

[37] A. I. Walisadeera, G. N. Wikramanayake, dan A. Ginige, "Designing a farmer centred ontology for social life network," in *DATA 2013 - Proceedings of the 2nd International Conference on Data Technologies and Applications*, 2013, hal. 238–247.

[38] L. Cooper *dkk.*, "The plant ontology as a tool for comparative plant anatomy and genomic analyses," *Plant Cell Physiol.*, vol. 54, no. 2, hal. 1–23, 2013.

[39] M. Buranarach, P. Porkaew, dan T. Supnithi, "A Decision Support System Development to Support Rice Research Policy Planning using an Ontology- based Framework," no. 2, 2010.

[40] H. S. Pinto, S. Staab, dan C. Tempich, "DILIGENT: Towards a fine-grained methodology for DIstributed, Loosely-controlled and evolvInG Engineering of oNTologies," *Front. Artif. Intell. Appl.*, vol. 110, hal. 393–397, 2004.

[41] M. Jarrar dan R. Meersman, "Ontology engineering - The DOGMA approach," *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 4891 LNCS, hal. 7–34, 2008.

[42] O. Corcho, M. Fernández-López, dan A. Gómez-Pérez, "Methodologies, tools and languages for building ontologies. Where is their meeting point?," *Data Knowl. Eng.*, vol. 46, no. 1, hal. 41–64, 2003.

[43] M. F. Lopez, A. Gomez-perez, dan J. P. Sierra, "Building a Checical Ontology Using Methontology and the Ontology Design Environment," *IEEE Intell. Syst.*, hal. 37–46, 1999.

[44] S. Babalou, E. Grygorova, dan K. Birgitta, "How good is this merged ontology ?," in *European Semantic Web Conference*, 2020, hal. 13–18.

[45] E. Femi Aminu, I. O. Oyefolahan, M. Bashir Abdullahi, dan M. T. Salaudeen, "A Review on Ontology Development Methodologies for Developing Ontological Knowledge Representation Systems for various Domains," *Int. J. Inf. Eng. Electron. Bus.*, vol. 12, no. 2, hal. 28–39, 2020.

[46] R. Mohemad, N. Fadila, A. Mamat, N. Maizura, M. Noor, dan A. C. Alhadi, "The development of an ontology model for early identification of children with specific learning disabilities," *Int. J. Electr. Comput. Eng.*, vol. 9, no. 6, hal. 5486–5494, 2019.

[47] R. Abbasi, P. Martinez, dan R. Ahmad, "An ontology model to represent aquaponics 4.0 system's knowledge," *Inf. Process. Agric.*, no. xxxx, hal. 1–19, 2022.

[48] C. Zhang, G. Zhou, dan Q. Lu, "Decision support oriented ontological modeling of product knowledge," *Proc. 2017 IEEE 2nd Inf. Technol. Networking, Electron. Autom. Control Conf. ITNEC 2017*, vol. 2018-Janua, hal. 39–43, 2018.