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Ontology Driven Context-Specific Information for the Cassava Farmers

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Abstract: Limited access to complete cassava processing information has affected the motivation to farm and the quantity of Cassava harvested annually in Nigeria. Some of this vital information is found mostly in tacit knowledge of the experience farmers, in manual records at the agricultural extensions, Federal government ministries/agencies, States agriculture department leaflets, on radio and television agricultural programs. Limited access to cassava information is mainly due to the unstructured and diverse format, lack of awareness by the farmers, whom mostly are based in the rural settings. Thus, the need to provide important cassava and other agricultural information to the farmers cannot be overemphasized. To enable cassava farmers to meet their goal of bountiful yield and quality production; cassava knowledge should be provided both in a generic and context-specific manner. One way to address this limited access and information sharing on agriculture is to develop Cassava ontology which specifically addresses entire cassava processes. The proposed ontology will integrate local characteristics regarding culture, language, climate, market and cassava plant varieties The farmers desire for context-specific information prompted the design for a knowledge base for cassava crop. This study presents a database with contextual information and ontological approach designed to meet information needs of the cassava farmers. Presently, no Cassava ontology or any other related tubers have been constructed in Nigeria. We believe this study would guide the construction of other crop knowledge base, in Nigeria and the domain of agriculture.

Key words: Agriculture, cassava, ontology, knowledge, technology

INTRODUCTION

Research has shown that agriculture plays a significant role in the economy of several countrie's and Nigeria is no exception. The cassava farming in Nigeria is a source of livelihood for many rural populations which accounts for a little over 60% of the total population (Adekunle *et al*., 2004). Every so often, we hear unpleasant news about the cost of farm produce skyrocketing due to wrong seed types, lack of essential agricultural information which trickles down to a poor harvest. Thus, data flow on agriculture, particularly on cassava must be strengthened to attain quality yield and increased output in all agricultural produce which would contribute to Nigeria GDP. Countless concerns must be addressed and overcome to achieve a successful agricultural information flow from experts, extension researcher's government agencies to rural farmers.

Some of these concerns relate to which information is essential? How do we identify and gather such information? Where do we store this information? What method can we use to deliver this valuable information? How do we simplify the information to meet farmer's needs? Importantly, how do we get information promptly to the farmers in different regions? Interaction with the cassava growers shows that occasionally, farmers need information such as the best cultivars, pest and diseases management, application of fertilizers and pesticides; weather updates, pre and post harvesting best practices, farming machinery, market prices and much more to enable a proper decision on phases of cassava farming cycle.

Studies by Ekanayake and Adeleke (1996) and Adekunle *et al.* (2004) shows that some of the needed information is scattered and are obtainable from various sources, such as in the mass media the government ministry of agriculture and FAO website. Other sources are the research extension websites, food and agriculture organization leaflets, indigenous farming communities, tacit and embedded knowledge trapped within the farmer. Moreover, bulks of this information are kept in the various unstructured text, video and audio formats; the inappropriate and unsuitable delivery methods makes it difficult to reach the farmers.

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Contextualized approach: There is quite a few definition of context; we selected Dey (2001), the operational definition of context because it is closely related to the focus of this paper and the meaning we desire. Dey (2001) defined context as: "Context can be any information which could be used to describe the state of an entity. Any object which is considered pertinent to the interaction between a system user and an application, along with the user and the applications" (Dey, 2001).

The above definition clearly describes the context and it can be used to explain the circumstances of a participant, in this case, a farmer in an interactive way. When farmers talk with farmers, they usually applied the implicit situational material, or context, to illuminate the topic of discussion and expand the scope of their conversational band width. This is what we found necessary to develop data repository with a contextual emphasis.

According to research by Dumais *et al*. (2004), a notable drawback of current retrieval models is that information regarding context and the user is mostly ignored. Retrieval theory suggested that context changes will affect the type of information retrieved, either by interference, hindering, or second-learned information (Rosas, 2006). A study by Fafchamps and Minten (2012) emphasizes the need for contextualized information for farmers, argued the effectiveness of this approach to farmer's productivity and income since the information provided in a context-specific system would be more relevant to the farmers need. Another study by Smith and Mizumori (2006) shows that contextual information can play a significant role in learning and memory. Research shows learned information usually becomes connected with the context in a way that the viewpoint can prompt the pertinent memories and behaviors. Thus, due to incompleteness and complexity of data; the relationships amongst several concepts and the need to have information and knowledge represented in a comprehensive, structured manner, we have selected a contextualized approach to developing a cassava centered knowledge base.

A cassava crop context-specific would enable the presentation of information centered on a predefined connotation. Thus, context-specific knowledge base derived from farmers concerns, generated from farmers focus group data, experience, observational data and other established taxonomy would be of significant service to farmers.

Centered on reviewed literature, we agreed that cassava farmers need relevant information to their context, instead of general diverse information. For example, a cassava farmer needs information that would be pertinent to the crop situation such as, seed, soil, weed management, application of fertilizer and other pre and post-harvest information. Relevant plant information would be appropriate to the cassava farmer's needs and could facilitate the better decision-making process. This study realized that context-specific information is precious to the cassava farmers for successful harvest; therefore we must develop an innovative way to deliver relevant agricultural information to the cassava farmers using a context-specific technique.

Knowledge management for cassava plantation: A study by Li *et al.* (2012) presented and argues the need for using Knowledge Management (KM) modeling and related techniques to solve and hand le complex real-world problems. Knowledge management has been positioned by scholars as a challenge and deliberated as one of the most critical success factors for competitive advantage in the future. The first indication for cassava knowledge base is that knowledge, without a doubt dignified as an asset and should be preserved as such which includes all required conditions for generating, gathering, managing and distributing acquired knowledge. In agricultural market, for a farmer to become successful crop supplier, the product offered should be of a stand ard well packaged and provide related information for alternate uses and product preservation methods to end users in contrast to similar crops.

Research by Jones (1989) presents knowledge acquisition procedures as, organizational structure analysis, the understand ing of business processes and application of KM business strategies. The study considers the analysis of crop structures, pre and post-harvest processes along with KM techniques as essential factors to explore the importance of cassava knowledge acquisition. At various stages of interacting with the farmers, we found communication to be a key challenge because most of the farmer's action is what we consider tacit or inferred knowledge. We believed that development of a context-specific knowledge requires, amongst all things, that effective communication is essential, in addition to unstructured scattered information of various format. We, therefore agreed that a cassava context-specific has a significant role in the development of a shared understand ing of knowledge-base to minimize communication challenges.

Research by Cakula and Salem (2013) shows that several system developers are focusing on the use of ontology-based, context-specific for the index, comparison evaluation, expansion of result and query processes optimization. Ontology-based knowledge has gradually been moving its trends from Artificial-intelligence field to the desktops of context-specific domain experts. Critical context-specific functionality is to provide unambiguous intelligent interpretation over knowledge assets. Context-specific database can equally be used for indexing, querying and referencing over non-context-specific data sources and systems.

The uses of context-specific are beginning to gain ground in many information systems both to a large, Small and Medium Size Enterprises (SME). The context-specific approach now serves as a backbone for the Semantic Web plus in many e-activities domains such as e-Agriculture, e-Banking, e-Business, e-Government, e-Health and e-Learning to name a few (Cakula and Salem, 2013; Henricksen and Indulska, 2006). As noted, context-specific popularity application has been almost in all distinct areas, at different levels but it has not extended to the cassava domain which inspired this study.

Cassava contextual information: In this study, we explained context-specific approach and how we intend to design the knowledge base to provide context-specific information to the cassava farmers.

Nigerian cassava farmers would realize a greater benefit if a cassava context-specific is developed with easy access. This study targets cassava farmers, agricultural information specialist, researchers, agricultural institution, instructors, everyone and businesses allied with cassava crop. To clearly identify cassava context, we extracted domain specific information with the aid of the following:

- Cassava farmers in selected southern and southwestern states of Nigeria
- Cassava crop experts from four universities in southwest Nigeria
- Group discussion, interviews and questionnaires (both structured and unstructured)
- Books and research articles on cassava varieties
- FAO report on Cassava
- Online authoritative data sources (Federal and State Ministry of Agriculture)
- News media (metrological data, television, radio and newspapers)

Analysis of the gathered information provided us a clearer picture of the cassava farmers information need, to enable better decision-making process at all phases of cassava life cycle.

We separated collected information into two categories; such as; dynamic information and static information. The dynamic information that changes so frequently, such as; consists of consumer behavior, profitable market locations, market prices, varieties are grown in other regions, agricultural loan rates and other products services. While the static information, provides information that changes over an extended period such as soil selection, weather, cassava seed types and properties; fertilizers application, pesticides and disease management; and post-harvest issues to name a few. The following questions were used to extract relevant information which narrates the worries of most cassava farmers:

- What type of cassava is suitable for planting?
- Which is the best cultivar?
- Between organic and inorganic fertilizers which is best for cassava?
- For the best result, when is a good time to apply fertilizer?
- What are common cassava crop diseases?
- How do you manage these diseases?
- How do you protect cassava crop from diseases?
- How do you identify a particular disease type?
- When is the best time for planting
- What is the cassava crop life cycle?
- What is the best harvesting approach?
- How do you preserve harvested cassava?
- What are other uses of cassava apart from food?
- Is irrigation necessary for cassava?

We received different responses to the above questions which we attributed to the:

- Farm size (this could be garden or commercial farmers which can be either, small-scale, medium-scale and large-scale farmers)
- Seed preferences (such as high yielding cassava varieties, insect and disease resistance crop and crop types which are bio, chemical and or organic fertilizer friendly)
- Farm location (i.e., rainfall, temperature, elevation, sunlight, wind, climate zone and humidity)
- Stages of cassava life cycle (such as Soil preparation, field layout, planting, fertilization, irrigation, weed control, pest control, disease control, other cultivation practices and harvesting (Adekunle *et al*., 2004)

The complete analysis of the cassava life cycle shows that that soil selection, cultivars selection andplanting at the right time are all noteworthy phases for a successful harvest. Thus, to help the cassava farmer improve in the overall decision-making process for maximum yield, we identified the following stages based on farmers information needs acknowledged earlier:

- Step 1: Farm location
- Step 2: Soil preparation
- Step 3: Select cassava varieties
- Step 4: Stems cutting and preparation
- Step 5: Planting time
- Step 6: Techniques for planting and correct spacing
- Step 7: Weed control
- Step 8: Herbicide
- Step 9: Fertilization
- Step 10: Intercropping
- Step 11: Pests and diseases control
- Step 12: Harvesting
- Step 13: Processing and marketing (Fig. 1)

Farm location: Cassava can be grown in all agro-ecological areas, especially in a deep loamy soil with good drainage. It is advised that a farmer avoids stony and clayey soils for it yield poor crops. Thus, for a healthy return, the cassava farmer needs to consider soil type, vegetation, topography, soil physical properties and land history.

Soil preparation: Poor soil preparation will result in increased weed struggle and deprived plant establishment. To achieve desirable yield, besides the depth of water table and soil type, cassava farmers needs to practice a good tillage mechanism to conserve soil moisture, organic matter and reduce erosion in sand y areas. The land should be prepared to increase soil contact with cassava stem cuttings. An improved mixture of topsoil in hard soil areas and use of mounds or ridges in waterlogging areas is recommended for better establishment.

Selecting cassava varieties: Research by Ay *et al.* (1983) shows that there are about 41 varieties of cassava (Manihot esculenta) held at various research centers including International Institute of Tropical Agriculture (IITA). Some of these varieties are valued and evaluated for their size of yield, disease and pest tolerance and cooking quality. To achieve a desirable return, the farmer should select the right variety. A variety with highest yield in a particular farm site and environs should be chosen. This research discovered that many high-performance varieties are available from IITA. The IITA identifies the stand ard improved varieties with the

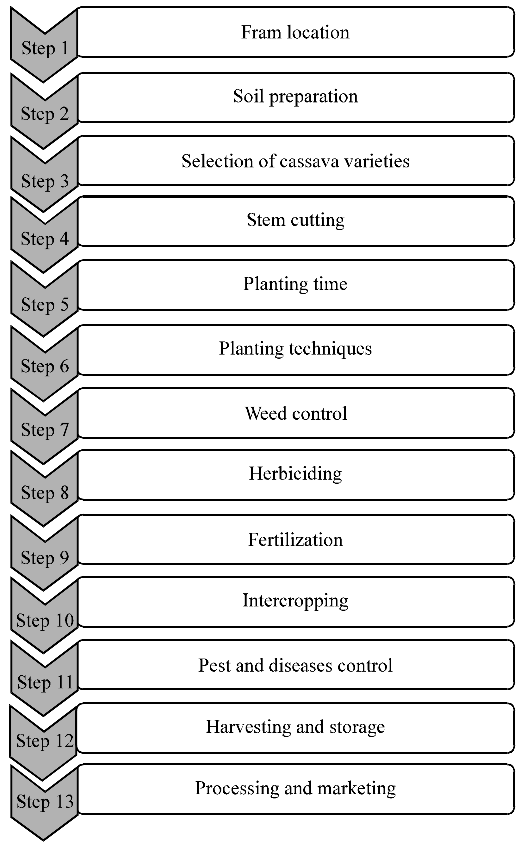

Fig. 1: Indentified casava farmings

highest performance in Nigeria as #30572 and #4(2)1425; capable of yielding 20-35 tons per acre, with 12 month maturity date, moderately tolerate pest and other cassava diseases. Some of the characteristics of best cassava varieties are:

- Early maturity and fast growth
- Good yields
- Tolerate diseases and pests
- Meet consumers stand ard
- Store up to 18 month in the ground

Stems cutting and preparation: Is another significant step for a successful harvest; stems should be selected from healthy, vigorous cassava plant with minimal leaf and stem damages from pests and diseases. The best categories of stems are derived from plants between 7-14 months old. A farmer should cut stems from hardwood portion of the cassava plant and not from bottom portions. Hardwood is recommended because it sprouts better, especially when hand led properly to avoid damages and bruises to the nodes. Importantly, the cut stems should be treated with broad-spectrum insecticide and fungicide to prevent infections.

Planting time: In Nigeria, the majority of the farmers are seasonal planters. Thus, it becomes necessary to follow local cassava farming calendars based on the rainy seasons to ensure good cassava establishment and healthy sprouting. Cassava cultivation in the dry season is not encouraged, particularly, where the water table is too low or near the end of the raining season. However, with proper irrigation system and access to the knowledge base, a cassava farmer can plant year round without annual limitation.

Techniques for planting and correct spacing: unsuitable planting techniques could lead to small roots, challenging and poor harvest. Subject to soil types, cassava stem may be inserted into the ground vertically, horizontally and or at an angle. Vertical planting is necessary for sand y soil; it enables water reserves for the deeper lying roots; the farmer may choose to bury the stem horizontally for more stem production which is many but smaller in sizes. Moreover, the farmer could just be interested in more roots, in which case the stems would be planted in an angle. Correct spacing is also critical, perhaps, the farmer plan to intercrop, then the proper spacing of 1×1.5 m or 1×1 m for the single crop is required. Unnecessary wide spacing gives room for increased weed competing for nutrients that would have benefited the cassava crop, thereby yielding a poor harvest.

Weed control: Weed competition for water, nutrients, space and light diminishes crop development and harvest size. To mitigate this preventable competition, farmers must be proactive by weeding early, applying any of the following methods; either, manual weeding, mechanical, intercropping to suppress weeds (not too efficient without weeding) and application of weed control chemicals.

Herbiciding: Research of Okigbo (1978) shows that planting cassava crop on poor soil, matures poorly and is infected by diseases and pests. Thus, the application of pre-emergent herbicide to control weeds is necessary for the vegetative (1-3 months of growth) stage of cassava life cycle. The scholars suggested that application Paraquat and Glyphosate at the initial stage as a pre-planting herbicide against fallow vegetation and latter as post-emergence to kill competing weeds, but farmers have to use the shield to safeguard first crops from chemical attack.

Fertilization: Studies by Adekunle *et al*. (2004) and Seesahai and Manmohan (2008) posit that soil should be tested to ascertain the type rate of fertilizer that would be suitable. The scholars suggested that when soil test are omitted, farmers should apply NPK 12:24:12 or 15:15:15 within 6 weeks at the rate of 336 kg ha^{-1} and application of type 16:8:24 at 16 weeks of crop planting. The researchers also suggested applying a mixtures of fertilizers such as Muriate of Potash Calcium Nitrate and Triple Super Phosphate at 25-37 kg ha^{-1} P, 114-209 kg ha^{-1} N and 240-335 kg ha^{-1} K within 6 and 16 weeks after planting. The report concluded that fertilizing cassava plants 14-16 weeks after planting enriches tuber bulking. Fertilizing cassava comes in many varieties, for the small-scale farmers, organic manures from cattle and chicken work equally fine. Applicable with organic fertilizers, soil analysis is required to help determine the quantity of fertilizer to be applied.

Intercropping: The rationale for intercropping is to reduce soil erosion, reduce weed competition, reduce risks and better land utilization, cassava can be intercropped with legume and maize, cassava planted on the heap or the crest, while corn or bean is planted on the ridge or heap. Most small scale cassava farmers, consider sole planting of cassava as an inefficient use of limited land space.

Pests and diseases control: Diseases and pests attack, contributes to reduction, growth and size of cassava yield. Common diseases attacking cassava are root rot, African Cassava Mosaic Virus (ACMV), Cassava Anthracnose Disease (CAD) and Cassava Bacterial Blight (CBB).

Others are thrips and mites, mealy bug, cassava shoot fly, chinch bugs, super elongation disease, variegated grasshoppers and cassava bacterial blight. The good news is that cassava pests and diseases can be avoided and controlled, by avoiding crops suffering from complex pests and diseases; isolate and burn diseased plants to reduce disease spread. Moreover, cassava pests and diseases can be controlled with the applications of Systemic insecticides when infestations are heavy; insect growth regulators and miticide during the dry season. According to a number of cassava farmers interviewed, most agreed that the best way to avoid and control pests is:

- To grow varieties, that is resistance to these pests
- Treat stems with fungicides and pesticides before planting and during the development stage
- At post-harvest, all stems and roots with pest contamination or disease symptoms should be destroyed
- Avoid using planting materials with fungus patches, leaf with chlorosis, shoot tip dieback, cankers and streaks on the stems
- Weed regularly use of cassava pests natural enemies

Harvesting: Preferably, cassava farmers harvest in the dry season but cassava crops are harvested all year round at maturity. Maturity varies from one variety to another and can be harvested within seven months and three years of planting. Commercial cassava farmers sometimes delay harvesting until processing and market conditions are favorable. For starch production, the longer cassava stays on the ground, the better, because tuber and starch rapidly increase in size and quantity. It is advisable to harvest as soon as maturity, especially, if the yield is meant for consumption.

Processing and marketing: Cassava consists of 65-70% water with a shelf life of only 2-3 days after harvest. These tubers need to be processed into various food types and or consumed immediately to avoid deterioration, preserve quality and reduce cost. Cassava quickly gets spoiled and transporting it in a raw form can be costly. Hence, the initial stages of processing harvested cassava take place on the farm and these products shelf life are longer than the cassava tubers itself. The results of this process are consumable goods such as lafun, gari, fufu to name a few without use for the agribusiness sector or use as raw materials for industrial finished products.

In reality, cassava can be processed into some industrial marketable products. These products include starch, chips, flour, pellets, adhesives, alcohol, textile, ethanol, wood and other materials for the livestock feed and soft drinks industries. Cassava is tradable in the foreign markets, either as food or raw material for additional processing into other valuable auxiliary products. Targeting multiple purpose use of cassava would potentially increase earning for these farmers and others in the value chain of cassava production, for the industrial market.

The Nigerian cassava growers are mostly subsistence farmers, who use this crop as a substitute source of income. The truth is that cassava has excellent potential for revenue generation if these farmers have access to cassava knowledge base such as the one proposed by this research.

The stage a farmer is in the cassava life cycle above, help determines the type of information required by the producer. For example, when selecting a Cassava variety for planting, the farmers are most interested in diseases and pests control. At this point, we recommend a suitable type with no and or limited pest and disease problems. Also, suggests a control mechanism for types of diseases that is susceptible to the selected type.

Analysis of farmer's information needs, suggested that farm location, cassava cultivars and planting techniques are essential factors required when imparting cassava knowledge and related information to farmers Thus, this important information becomes part of the cassava, context model. This study believes cassava information relating to the context model would be sufficient for farmer's information cravings.

Context-specific ontology: The purpose of this study, a Context-Specific Ontology, considered as a unique database type which focuses on cassava related properties; "that store's information concerning expertise of a particular domain". Aimed at providing precise information to search queries, well-defined relationships, reasoning support, inference mechanism and robust semantic capabilities; a Cassava ontology can support queries efficiently than a non-context-specific agriculture ontology.

Gruber (1995) defined ontology as "an explicit description of a conceptualization". At present, there is few agricultural ontology; developed to provide general information to assist farmers in problem-solving and decision making using computers, cell phones and other hand held gadgets. Some of these systems provide general information about pest and diseases, weather forecast and fertilizer application to crops. As noted, these systems are more of a generalist and not adequate to fulfill the cassava farmer's need for information in timely routine. We have confidence that creating a cassava context-specific knowledge base would be more resourceful than a general agricultural ontology (Garforth *et al*., 2003).

The context-specific ontology would provide a structured view of crop information and a repository of concepts for the cassava domain. A context-specific KB would facilitate question answering, knowledge aggregation, knowledge sharing and information retrieval as it relates to a particular crop, in this case, cassava (Gruber, 1995).

Currently, there are some authoritative and well-established vocabularies in the agriculture domain, such as the Food and Agriculture Organization (FAO) AGROVOC Thesaurus. Although, a Thesaurus can be useful in the construction of domain ontology, it has limitations such as in the usage of vocabularies, semantic ambiguity in descriptions and poorly defined connotation of relationships.

Presently, there are notably rice and soil science ontologies in the agricultural domain (Thunkijjanukij *et al*., 2009). The rice ontology provides information for rice production encompassing cultivation to harvesting. The Thai Rice ontology was designed to facilitate knowledge acquisition which provides unambiguous intelligent interpretation of Rice production life cycle and to enable better decision-making process at

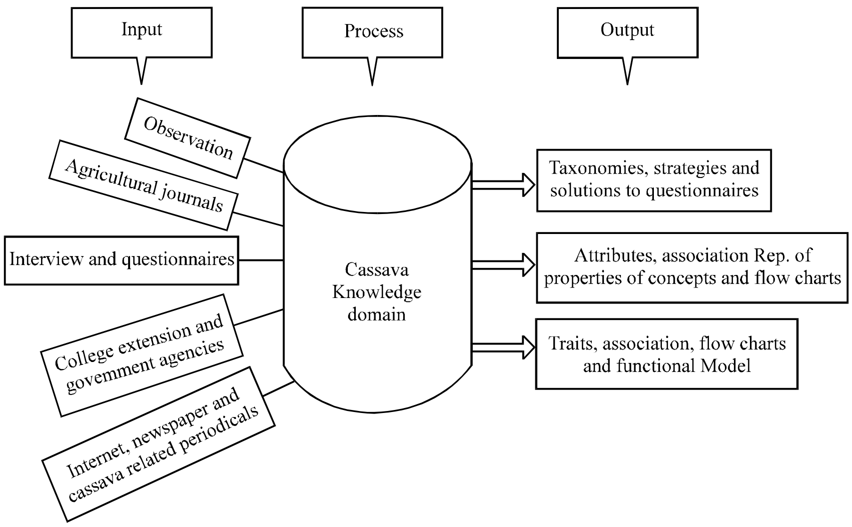

Fig. 2: Cassava knowledge discovery techniques

all phases. Besides the rice and soil ontologies, our study did not find any agricultural ontology designed to represent farmer information needs in the context of cassava knowledge. This research gap prompted the need for this study, to develop Cassava ontology for farmers which exemplified information desires according to grower background. This study intends to help individual farmer's access contextual and relevant crop information.

Cassava ontology approach: The aim of this study is focused on information acquisition, extraction and retrieval which characterizes the knowledge cassava farmers seek to manage farming activities. Cassava comes in many varieties with different types of problems throughout the life cycle. Thus, to present information in context; we must identify the right ontology design method. To provide solutions relating to identified problems, we collected data from both primary and secondary sources such as data on cassava life cycle, challenges encountered by the cassava farmers, experts in extensions and agriculture departments and secondary data from peer reviewed agricultural journals, the Internet, Newspapers and cassava related periodicals (Fig. 2).

Discovering cassava knowledge is an extensive process of converting a lower level data into a higher level knowledge which includes pre-processing, data mining and post-processing (Frietas, 2003). Applying the above techniques, we extracted several concepts from observation, interviews with the farmers, use of questionnaires, agricultural journals, extensions, Internet and government agencies. The concepts were then categorized into cassava varieties, life cycle, stem preparation, techniques for planting, weed control, herbicide, fertilization, intercropping; cassava pests and diseases management; harvesting, processing and storage.

Research by Gruninger and Fox (1995) shows that there is no particular methodology to design ontology. Ontology is designed based on intended artifacts, description of the objects and task. We select First-Order Logic (FOL) method to develop Cassava ontology for farmers; FOL provides a mechanism to tackle the disadvantages of terminological vagueness in the domain by describing meaningful, rigorous and scientific terms (Szykman *et al*., 2000).

MATERIALS AND METHODS

Cassava context-specific methodology: This Cassava ontology development starts with the definition of farmer's problems and questions itemized above. The ontology represents proficiency inquiries using its axioms, terminologies and definitions. To characterize information as it relates to the cassava farmer's context; skill questions are formulated for this purpose. These skill questions established by covering entire information of the cassava life cycle, problems and associated constraints provided by the farmers would help determine the scope of this Cassava ontology and ascertain the contents.

Descriptions of terms and constraints are interpreted and specified using a set of axioms in first-order logic. To answer some of these proficiency questions, axioms are required for better understanding. Sometimes, added

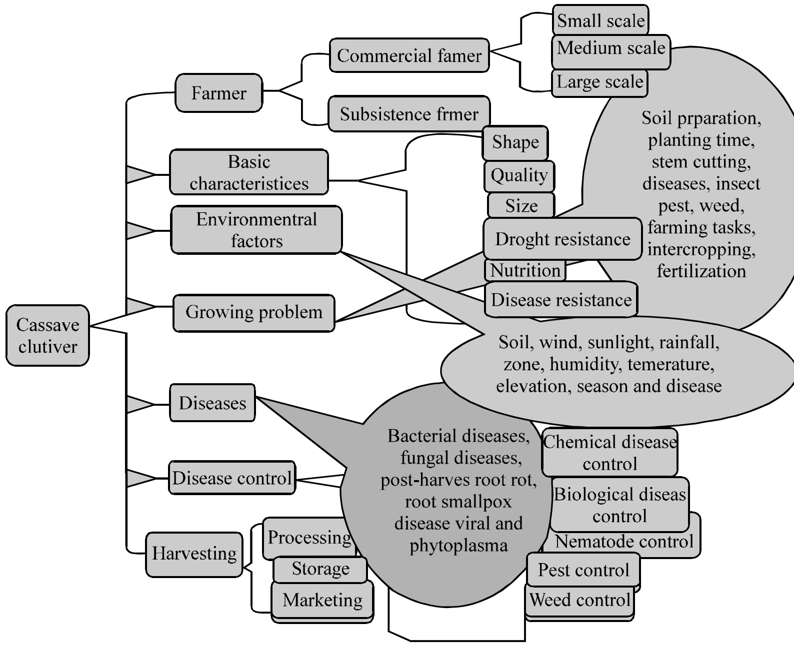

Fig. 3: Structure of cassava context-specific ontology

concepts, axioms or relationships are necessary to provide increased representation to formal proficiency questions and solutions. At this point, we redefined all simple competence questions with proper and stand ard terminology. For example which cassava varieties are less susceptible to cassava bug and disease? The answer to this query can be modeled to proficiency questions. This answer would then be retrieved from the Cassava ontology or knowledge base populated with instances. Importantly, this Cassava ontology can be organized by linking the farmer's context and construe responses to queries focused on context. Figure 3 shows a segment of implemented cassava context-specific ontology

The extracted knowledge from the cassava farmers is formalized into a mental model with associating taxonomies. Ontology can be constructed by reusing an existing one or designing a new one from the beginning. Research by Reddy and Kumar (2010) suggests that if developing a new ontology is the option, it can be constructed using a manually-produced by experts, automatic technique and or semi-automatic technique. In this study, on entire cassava production life cycle, we selected manual construction method due to the uniqueness of the study and the ontology was designed from a new beginning.

Today, there are several tools and languages for ontology development. However, appropriate tool for ontology development that is capable of capturing an entire cassava plantation life cycle would have been better for Cassava ontology but it is currently not available. In the absent of such tool, it was necessary that we develop the Cassava ontology manually, despite the fact that to manually create ontology could be a time consuming and tedious task.

RESULTS AND DISCUSSION

Testing the validity of the Cassava ontology is recommended. Validating content and construction correctness is important. The content focuses on the definitions, relationships amongst concepts, concept properties; hierarchical structures of concepts and information constraints of the Cassava ontology. Also, we used proficiency questions to evaluate the ontology, making sure it meets the farmer's cassava requirements. We invite cassava experts to validate the ontology by examining the relevance, correctness and inconsistencies of the components if any. Based on feedbacks and recommendations from the experts, the contents would be refined accordingly. To model cassava context-specific ontology, we adopted the following seven steps described by Noy and McGuinness (2001) for ontology construction.

Step 1: Define scope and domain: we have clearly defined the intent of this study which covers context-specific knowledge for Cassava ontology. It aimed, at helping cassava farmers, by providing access to essential information for the entire cassava crop processing.

Step 2: Reusing existing ontology: presently, no ontology covers whole cassava plantation process for reusing. Thus, it was necessary to construct a new one.

Step 3: Itemize significant terms of the ontology: Significant terms, concepts and properties of the crop are defined. Most of the concepts are extracted using the cassava knowledge discovery techniques in Fig. 2.

Step 4: Outline class and the class hierarchy: gruber, (1995), stated several approaches to assembling taxonomy. We have outlined classes and subclasses using the top-down approach as shown in Fig. 3 (Superclasses are in top level).

Step 5: Outline class properties (slot): we defined class features because not all Classes and its hierarchy have the essential semantics relating to its domain. Since, some classes have data properties with primitive data types, while multiple properties encompass other user objects.

Step 6: Define property constraints: we have defined various kinds of constraints which could reduce and or affects the crop values such as disease and or environmental issues.

Step 7: Creating instances: the last step here is to create classe's instances after concepts, their taxonomy and attributes have been defined. Comparable to object oriented environment where instances of the classes are objects that interacts with the real world as noted in Fig. 3 (instances of cassava and associated properties).

CONCLUSION

Cassava farmers in Nigeria need essential and relevant information to make best decisions for a bountiful harvest. Presently, the major problem for the cassava farmers is their inability to access agricultural knowledge-bases with cassava context. Accordingly, we believe information requirement of the cassava farmers ought to be contextualized with regards to all the questions and concerns the farmers presented in this research. As evident in this study, we have identified context connected to the entire cassava life cycle for the Nigerian farmers, summed up as farm location, cassava varieties, techniques for planting, pests, diseases and weed control; fertilization, harvesting and processing. Also, we have designed an ontological method to meet the cassava farmer's information requirements using selected First-Order Logic (FOL). The first-order logic approach was necessary to characterize cassava information in context, FOL features and the proficiency questions made it easier to provide support for farmer's queries in context.

Finally, we present a different ontological method to organize cassava domain knowledge using context efficiently. We believe domain knowledge structured in this mode, would facilitate a better decision-making process; identification and selection of best practices agricultural methods which would result in improved cassava life cycle and ultimately quality and quantity yield. With this methodology, relationships, concepts and constraints with different circumstances can be added to the knowledge repository which makes the ontology richer in cassava knowledgebase, improves the farmer's experiences, potential for industrial production and ultimately increase in farmer's revenue, the stand ard of living and agriculture GDP contribution.

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