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Prototype Knowledge Based System for Land Suitability Prediction for Coffee Production in Afaan Oromoo

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Abstract

Agriculture is one of the world's most important activities that support human life. It includes crop production, horticulture, agricultural engineering, forestry, animal husbandry and fishery science. Among crop production, coffee production is paramount because millions of small producers rely on coffee for living in various countries. However, factors such as selecting suitable land for coffee plantation affects coffee production. In Ethiopia, 25% of foreign exchange is from coffee, of which more than 64% comes from Oromia Regional State. The main objective of this study was to develop a prototype knowledge based system for land suitability prediction for coffee production in Afaan Oromoo. To develop the proposed system, experimental research design was used. The study sites were Ministry of Agriculture, Jimma University College of Agriculture and Veterinary Medicine, Gomma and Mana Agricultural Offices. Data was collected from study sites using systematic sampling technique. Moreover, interview and document analysis were employed as data collection methods. Visual prolog v7.3 software was used for the system development. As a result, the developed system can help professionals, land managers, investors and farmers to identify suitable land for coffee production because it can categorize the suitability of land for coffee plantation into high, moderate or marginally suitable in Afaan Oromoo, an official language of Oromia Regional State. The system can contribute significantly to increase coffee production and quality and thus we recommend the implementation of this system.

Key words: *Coffee Production, Afaan Oromoo, Land Suitability, Knowledge Based System, Oromia*

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Axareeraa

Qonni wantoota dhala namaatiif barbaachisoo ta'an kan addunyaarra jiran keessaa isa baa'yee murteessa ta'edha. Qonni midhaan oomishuu, abaaboo omishuu, injineeriingii qonnaa, kunuunsa bosonaa, kunuunsa horiifi saayinsii qurxummii dabalata. Biyyoota garaagaraa keessatti qonnaan bultootni miliiyoonan lakka'aman buna oomishuu irratti waan boba'aniif, oomisha biqiltootaa keessaa buna oomishuun baay'ee beekamaadha. Haata'u malee, sababootni kan akka lafa mijataa buna oomishuuf ta'u filachuun oomisha isaa irratti dhiibbaa fida. Biyyi Itoophiyaa jijjiirraa maallaqa biyya alaa %25 kan argattu bunarraa yommuu ta'u, isa keessa %64 kan caaluu Oromiyaa keessatti kan oomishamudha. Kaayyoon gooroo qorannoo kanaa lafni tokko buna omishuuf hangam ga'aa akka ta'e murteessuuf kan gargaaru musaaja (tool) beekumsa irratti hundaa'e (Knowledge-based system) Afaan Oromootiin qopheessuudha. Musaaja kana hojjechuuf malli shaakala (experimental) jedhamutu hojiirra oole. Iddoon qorannoo Ministeera Qonnaa, Kolleejjii Qonnaafi Yaala Beeladaa Yunvarsiitii Jimmaa, Waajjira Qonnaa Gommaafi Mannaati. Mala iddattoo sirnaawaa (systematic sampling) jedhamuun ogeessotni iddoo qorannoo irraa kan filataman yoo ta'u, af-gaaffiifi sakkata'a barrulleen (document analysis) maloota ittin odeeffanoon walitti qabamanidha. Musaajicha hojechuuf Visual Prolog V 7.3 gargaaramne. Akka firii qorannoo kanaatti musaajichi qophaa'e ogeessootni, hoogantootni lafaa, investaarootnifi qonnaan bultootni, lafa bunaaf ta'u addaan baasuuf kan gargaaruu ta'a. Musaajichi qophaa'e kunis, Afaan hojii naannoo Oromiyaa, Afaan Oromootiin buna omishuuf baay'ee mijataa, giddugaleessummaan mijataa, hanga tokko mijataafi mijataa miti jedhee murtee (decision) nikenna. Musaajichi omishaafi qulqullina bunaa dabaluuf ga'ee olaana qaba. Kanaaf, hojiirra ooluu qaba jenna.

Jechoota ijoo: *Buna oomishuu, Afaan Oromoo, mijaa'ina lafaa, musaaja,Oromiyaa*

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1. Introduction

Agriculture is one of the world's most important activities that support human life. From the beginning of civilization, man has used land for agriculture. The land resources regeneration is very slow while the population growth is very fast, leading to competition for resources. In addition, how, where and when to cultivate a given crop are the main issues that farmers and land managers face day to day (Mokarrametal, 2010). The information technology opens a new door for agricultural researchers, extensions workers and farmers to make effective and efficient related to agricultural problems (Diyya and Sree, 2014). Artificial Intelligence is a subset of IT, which gets attention to support intelligent decision making on different complex decision of which Knowledge based system (KBS) is one.

Even though there are many KBSs in other domains, there are few KBS applications developed for agriculture sector. Some of KBSs applications in this sector are crop production management, pest management, diagnostic systems, overall planning systems as well as economical decision making. The other application of KBS in agriculture is to determine the quality of land for agricultural uses and it was intended as a decision and planning support (Elsheikh, 2013).The principal purpose of land suitability evaluation is to predict the potential and limitation of the land for crop production .The development of

Agriculture Land Suitability Evaluator (ALSE) allows for standardizing a framework for characterizing geo-environmental conditions relevant for production of major crops (Pan and Pan, 2012).This is vital task of land evaluation to identify the levels and geographical patterns of biophysical constraints.

The Ethiopian economy is highly dependent on coffee because it contributes more than 25% of the country's foreign exchange earnings. Of this, the lion share comes from Oromia Regional State, the origin of *Coffee Arabica*, because more than sixty four percent (64%) of coffee is from this Region. The language spoken in Oromia is known as Afaan Oromoo, a Cushitic language family which is spoken by more than 50 million people in all parts of Ethiopia, and East Africa countries like Kenya, Somalia, Egypt and Tanzania. This language is the third widely spoken language in Africa next to Arabic and Hausa (https://scholar.harvard.edu/erena/oromo-language-afaan-oromoo) and it is an Official language of Oromia Region. Therefore, developing such system in Afaan Oromoo plays great contribution for coffee production and as a consequence it can improve Ethiopian economy.

Coffee is an important commodity in the world economy. Unfortunately, coffee productivity and quality are still quite low (Derwin, 2013). In addition, it is difficult to sell poor quality coffee in the world market. It is obvious that developed countries want to buy good-quality coffee at a good price and they do not pay much for coffee of poor quality. So, farmers should produce good coffee beans. According to FAO (2015), to produce coffee beans of good quality the grower must choose a good site for the plantation which is challenging in world of today with disturbed ecosystem. In such dynamic world, IT can play a great role to run with current situation. However, there are only few systems developed so far on agriculture like paste management and crop diagnosis and treatments.

In Ethiopia, there is no system developed to date which can support professionals and farmers to decide a suitability crop land especially for coffee plantation yet. Thus, this study was initiated with the main objective to develop prototype knowledge based system that provides expert advice for land suitability prediction for coffee production in Afaan Oromoo.

2. Methodology

For this study, experimental research design was used by inserting the facts and rules into inference engine of Prolog tool and changes the order of facts and rules again and again until it works as expected. The rules were represented in production rule (IF …THEN.).

Study site and sampling technique

The study site was Jimma Zone, Oromia Regional State, Ethiopia. The reason for selecting the site for the study is that relatively coffee is well cultivated in Jimma Zone; Gomma and Mana woredas. Besides, knowledge domain experts were selected systematically from Ministry of Agriculture, Jimma Agriculture and veterinary Medicine, Gomma and Mana Agricultural Offices.

The sampling technique for this study was systematic sampling whereby knowledge domains were selected based on their knowledge of coffee and land management from the selected institutions and offices.

Data collection method

Tacit and explicit knowledge types were used to develop the prototype system. The explicit knowledge was collected by using document analysis whereas the tacit knowledge was collected by using in-depth interview. Interview questions were developed to collect domain knowledge about how to select suitable land for coffee production.

Implementation Tool

The development of the prototype was done by using visual prolog v7.3 programming environment. This programming tool facilitates human knowledge or expertise for decision making. The reason to use visual prolog programme is because of its flexibility and expandability. Moreover, it is open source programming language.

3. Knowledge Representation and Modeling

Knowledge representation

Knowledge representation is the way knowledge is encoded. Based on its nature, different types of knowledge require different kinds of representations. The knowledge representations mechanisms are often based on logic, rule, and frame, case and semantic net. One of the most popular approaches is production rule, sometimes called IF-THEN rule. For instance:

IF condition THEN action

IF premise THEN conclusion

F proposition p1 and proposition p2 are true THEN proposition p3 is true

Knowledge representation can be considered at two levels: knowledge level at which facts are described, and symbol level at which the representation of the objects, defined in terms of symbols, can be manipulated in the programmes. A good representation enables fast and accurate access to knowledge and understanding of the content. The fundamental goal of knowledge representation is to facilitate inference (conclusions) from knowledge. The issues that arise while using knowledge representation techniques are many. Some of these are explained below. The following are some of coffee land suitability by production rule in Afaan Oromoo presented below followed by English translation.

Table 1: knowledge representation for Coffee land suitability

No	In Afaan Oromoo	In English
1.	Yoo hangi roobaa>1300mm, olka'iinsi lafaa 1500-1800m, gosti biyyee gurraacha, hangi ho'insaa 22-25^{0}C ta'e Buna oomishuuf baay'ee mijataadha	If rainfall>1300mm, Elevation between1500-1800m, Soil Type=Nitosols, Temperature between 22-25^{0}C. Then **Highly Suitable.**
2.	Yoo hangi roobaa 1100-1300mm, olka'inssi lafaa 1500-1800m, gosti biyyee gurraacha, hangi ho'iinsaa 22-25^{0}C ta'e Buna oomishuuf giddugaleessummaan mijataadha.	If rainfall between1100-1300, Elevation between 1500-1800, Soil Type=Nitosols, Temperature between 22-25^{0}C. Then **Moderate Suitable**.
3.	Yoohangiroobaa>1300mm, olka'iinsi lafaa 1100-1300m, gosti biyyee nitosols, hangi ho'iinsaa 22-25^{0}C ta'e Buna oomishuuf giddugaleessummaan mijataa dha.	If rainfall>1300, Elevation between 1100-1300, Soil Type=Nitosols, Temperature between 22-25^{0}C. Then **Moderate Suitable**.
4.	Yoo hangi roobaa>1300mm, olka'iins lafaa 1500-1800m, gosti biyyeea crisols, hangi ho'iinsaa 22-25^{0}C ta'e Buna oomishuuf giddugaleessummaan mijataa dha.	If rainfall>1300, Elevation between 1500-1800, Soil Type=Acrisols, Temperature between 22-25 ^{0}C. Then **Moderate Suitable**.
5.	Yoo hangi roobaa>1300mm, olka'iinsi lafaa 1500-1800m, gosti biyyee nitosols, hangi ho'iinsaa 18-22^{0}C fi 25-28^{0}C ta'e Buna oomishuuf giddugaleessummaan mijataa dha.	If rainfall>1300, Elevation between 1500-1800, Soil Type=Nitosols, Temperature between 18-22 &25-28 ^{0}C. Then **Moderate Suitable**.
6.	Yoo hangi roobaa 1100-1300mm, olka'iinsi lafaa 1200-1500m, gosti biyyee crisols, hangi ho'iinsaa 18-22^{0}C ykn 25-28^{0}C ta'e Buna oomishuuf giddugaleessummaan mijataadha.	If rainfall between1100-1300, Elevation between 1200-1500, Soil Type=Acrisols, Temperature between 18-22 &25-28^{0}C**. Then Moderate Suitable.**
7.	Yoo hangi roobaa 800-1100mm, olka'iinsi lafaa 1200-1500m, gosti biyyee acrisols, hangi ho'iinsaa 18-22^{0}C ykn 25-28^{0}C ta'e Buna oomishuuf hanga tokko mijataa dha.	If rainfall between 800-1100, Elevation between 1200-1500, Soil Type=Acrisols, Temperature between 18-22 &25-28 ^{0}C. Then **Marginally Suitable**.
8.	Yoo hangi roobaa 1100-1300mm, olka'iinsi lafaa 900-1200m, gosti biyyee acrisols, hangi ho'iinsaa 18-22^{0}C ykn 25-28^{0}C ta'e Buna oomishuuf hanga tokko mijataa dha.	If rainfall between1100-1300, Elevation between 900-1200, Soil Type=Acrisols, Temperature between 18-22 &25-28 ^{0}C. Then **Marginally Suitable**.
9.	Yoo hangi roobaa 1100-1300mm, olka'iinsi lafaa 1200-1500m, gosti biyyee luvisols, hangi ho'iinsaa 18-22^{0}C ykn 25-28^{0}C ta'e Buna oomishuuf hanga	If rainfall between1100-1300, Elevation between 1200-1500, Soil Type=luvisols, Temperature between 18-22 &25-28 ^{0}C.

	tokko mijataadha.	Then **Marginally Suitable**
10.	Yoo hangi roobaa 1100-1300mm, olka'iinsi lafaa 1200-1500m, gostibiyyeeacrisols, hangi ho'iinsaa 15-18^{0}C ykn 28-30^{0}C ta'e Buna oomishuuf giddugaleessummaan mijataadha.	If rainfall between1100-1300, Elevation between 1200-1500, Soil Type=Acrisols, Temperature between 15-18 &28-30 ^{0}C. Then **Moderate Suitable**
11.	Yoohangiroobaa 800-1100mm, olka'iinsi lafaa 900-1200m, gostibiyyeeluvisols, hangiho'iinsaa 15-18^{0}C ykn 28-30^{0}C ta'e Buna oomishuuf hangi tokko mijataadha.	If rainfall between 800-1100, Elevation between 900-1200, Soil Type=Luvisols, Temperature between 15-18 &28-30 ^{0}C. Then **Marginally Suitable**.
12.	Yoo hangi roobaa< 800mm, olka'iinsi lafaa <900m, hangi ho'iinsaa 0-15^{0}C ta'e Buna oomishuuf mijataamiti.	If rainfall between 0-800, Elevation between 0-900, Soil Type=All others, Temperature between 0-15 ^{0}C. Then **Not Suitable.**
13.	Yoo hangi roobaa< 800mm, olka'iinsi lafaa 900-1200m, gosti biyyee luvisols, hangi ho'iinsaa 15-18^{0}C ykn 28-30^{0}C ta'e Buna oomishuuf mijataa miti.	If rainfall between 0-800, Elevation between 900-1200, Soil Type=Luvisols, Temperature between 15-18 &28-30 ^{0}C. Then **Not Suitable**.
14.	Yoo hangi roobaa 800-1100mm, olka'iinsi lafaa <900m, gosti biyyee luvisols, hangi ho'iinsaa 15-18^{0}C fi 28-30^{0}C ta'e Buna oomishuuf mijataa miti.	If rainfall between 800-1100, Elevation between 0-900, Soil Type=Luvisols, Temperature between 15-18 &28-30 ^{0}C. Then **Not Suitable**.
15.	Yoo hangi roobaa 800-1100mm, olka'iinsi lafaa 900-1200m, hangi ho'iinsaa 15-18^{0}C ykn 28-30^{0}C ta'e Buna omishuuf mijataa miti.	If rainfall between 800-1100, Elevation between 900-1200, Soil Type=all others, Temperature between 15-18 &28-30 ^{0}C. Then **Not Suitable**.
16.	Yoo hangi roobaa 800-1100mm, olka'iinsi lafaa 900-1200m, gosni biyyee luvisols, hangi ho'iinsaa 0-15^{0}C ta'e Buna oomishuuf mijataa miti.	If rainfall between 800-1100, Elevation between 900-1200, Soil Type=Luvisols, Temperature between 0-15 ^{0}C. Then **Not Suitable**.

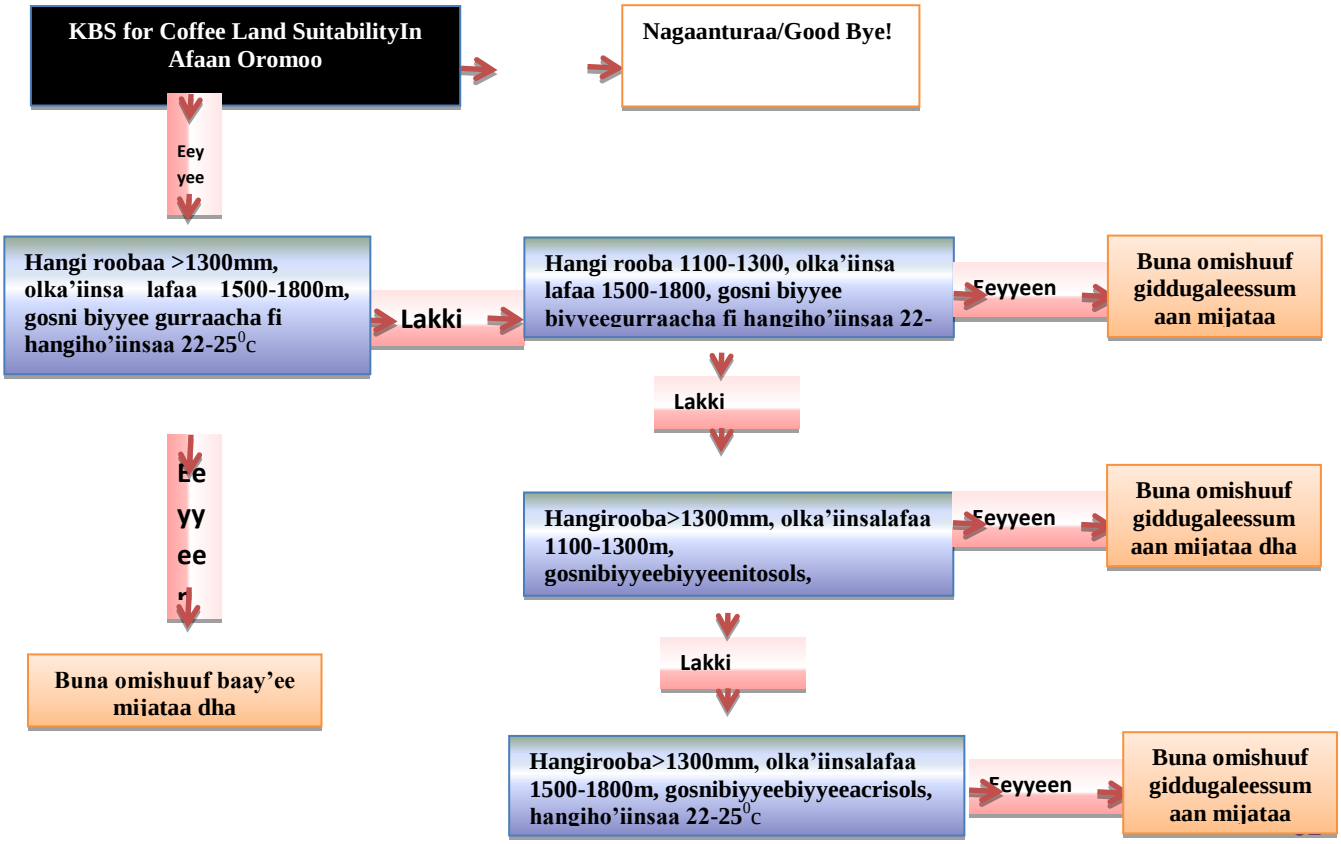
Knowledge Modeling

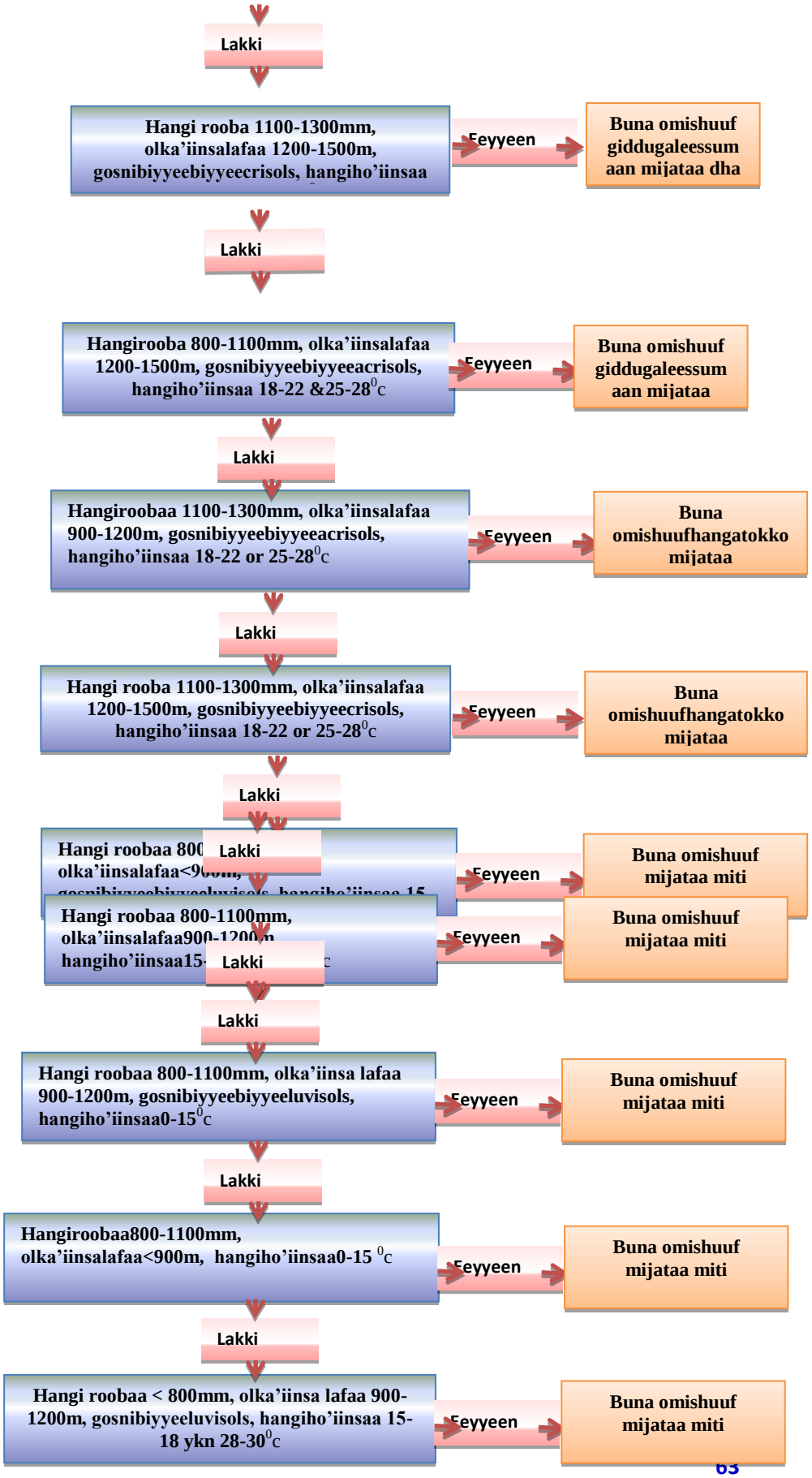
Conceptual modeling is the abstraction of a simulation model from the part of the real world (Stewart, 2010). Abstraction implies the need for simplification of the real system and for assumptions about what is not known about the real system. The final two items that the conceptual model must describe are the assumptions and simplifications of the model (Robinson, 2008). Assumptions are made either when there are uncertainties or beliefs about the real world being modeled. Simplifications are incorporated in the model to enable more rapid model development and use, and to improve transparency.

The conceptual model may remain conceptual, *i.e.*, a model in the head of the modeler until it is formally developed. Some conceptual models are informal when the systems for which the conceptual models are developed are small and clear. The knowledge model of an application provides a specification of the data and knowledge structures required for the application. The most productive conceptual frameworks are often those that bring in ideas from outside the traditionally defined field of study, or that integrate different approaches, lines of investigation, or theories that no one had previously connected.

KBS construction methods typically provide tools for knowledge analysis in the form of the so called conceptual models of knowledge or simply knowledge models. A knowledge model provides an implementation, independent of specification of knowledge in an application domain. Typically, a knowledge model provides formats for writing down both static domain knowledge (rules, classes, relations) as well as reasoning strategies in which this domain knowledge is used to solve a particular problem.

Most of the knowledge is unstructured and often in tacit form. The knowledge engineer tries to understand both tacit and explicit knowledge acquired and then used decision tree to construct the conceptual model. Usually, conceptual models are designed by system analysts or other professionals for particular domains. The prototype system conceptual model is developed by the researcher depending on acquired knowledge from domain expert and depending on the facts that are collected from different explicit knowledge journals, articles, books and manuals and the tacit knowledge is collected from the domain experts. Depending on the acquired knowledge the researcher constructed conceptual model of how to predict coffee land suitability as presented in figure 1 below.




Lakki
Hangi rooba 1100-1300mm, olka'iinsalafaa 1200-1500m, gosnibiyyeebiyyeecrisols, hangiho'iinsaa
Eeyyeen
Buna omishuuf giddugaleessum aan mijataa dha
Lakki
Hangirooba 800-1100mm, olka'iinsalafaa 1200-1500m, gosnibiyyeebiyyeeacrisols, hangiho'iinsaa 18-22 &25-28^{0}C
Eeyyeen
Buna omishuuf giddugaleessum aan mijataa
Lakki
Hangiroobaa 1100-1300mm, olka'iinsalafaa 900-1200m, gosnibiyyeebiyyeeacrisols, hangiho'iinsaa 18-22 or 25-28^{0}C
Eeyyeen
Buna omishuufhangatokko mijataa
Lakki
Hangi rooba 1100-1300mm, olka'iinsalafaa 1200-1500m, gosnibiyyeebiyyeecrisols, hangiho'iinsaa 18-22 or 25-28^{0}C
Eeyyeen
Buna omishuufhangatokko mijataa
Lakki
Hangi roobaa 800
Lakki
Eeyyeen
Buna omishuuf mijataa miti
Hangi roobaa 800-1100mm,
Eeyyeen
Buna omishuuf mijataa miti
Lakki
Lakki
Hangi roobaa 800-1100mm, olka'iinsa lafaa 900-1200m, gosnibiyyeebiyyeeluvisols, hangiho'iinsaa0-15^{0}C
Eeyyeen
Buna omishuuf mijataa miti
Lakki
Hangiroobaa800-1100mm, olka'iinsalafaa<900m, hangiho'iinsaa0-15 ^{0}C
Eeyyeen
Buna omishuuf mijataa miti
Lakki
Hangi roobaa < 800mm, olka'iinsa lafaa 900-1200m, gosnibiyyeeluvisols, hangiho'iinsaa 15-18 ykn 28-30^{0}C
Eeyyeen
Buna omishuuf mijataa miti

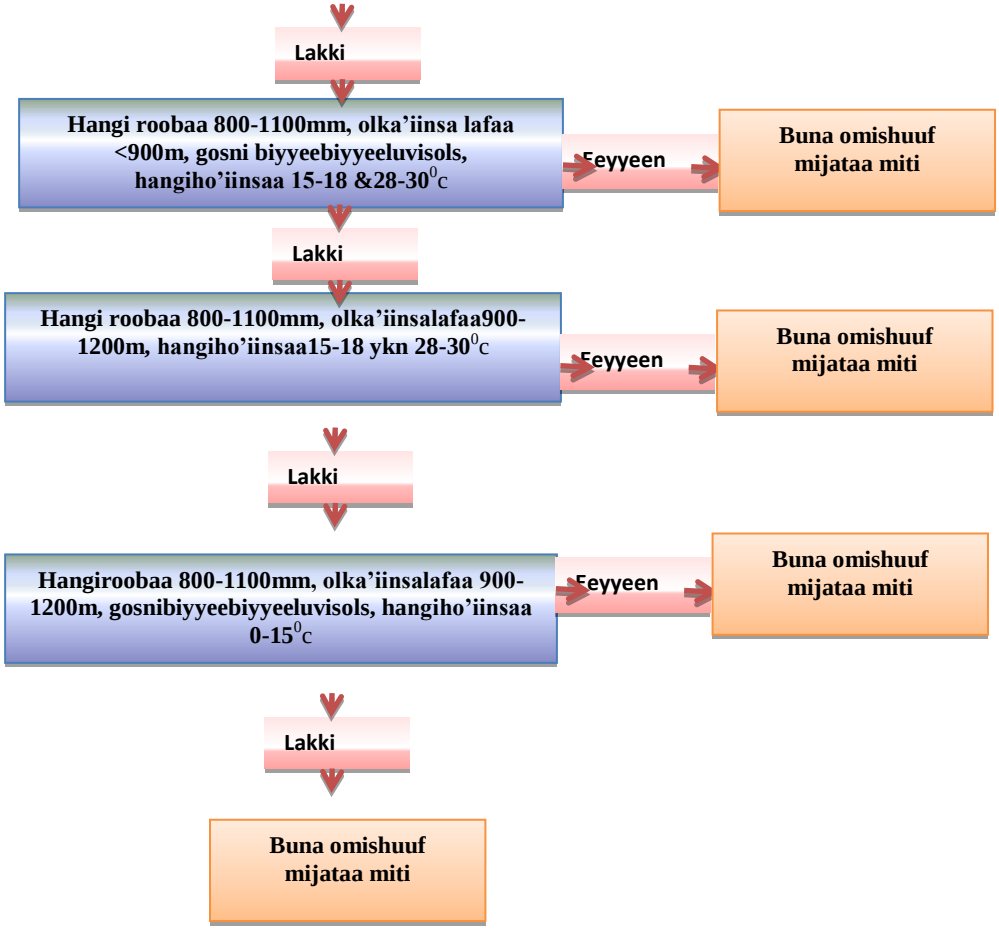


Figure 1: Conceptual Model of Land Coffee Suitability

4. Implementation and experiment

The main objective of this study was to develop knowledge based system for coffee land suitability analysis based on geo-spatial characteristics in Afaan Oromoo. At the end a prototype system which can identify a specific land in to highly suitable (*baay'ee mijataa*), moderately suitable (*giddugaleessaan mijataa*), marginally suitable (*hanga tokko mijataa*) and not suitable (*mijataa miti*) was developed. A system developed by Kalogirou (2002) for land evaluation using an Intelligent Geographical Information System which supports rural planners with the first view of the land suitability for cultivation of certain crops according to the FAO methodology indicates such system helps farmers by identifying land for crop cultivation. Another system developed by Elsheikh et al. (2013) strength that such system is useful for decision makers to determine the quality of land for agricultural uses and is intended as a decision and planning support. It was an intelligent system for assessing land suitability for different types of crops (e.g. mango, banana, papaya, citrus, and guava) in tropical and subtropical regions based on geo-environmental factors. In addition, a Web-Based Decision Support System for Evaluating Soil Suitability for Cassava Cultivation was developed by Adewale&Ajibola (2017) and the developed system was esteemed a prospective tool for farmers, soil laboratories and other users in predicting soil suitability for cassava cultivation.

The major functions of the developed system were discussed as follows. As it is shown in figure 2 the developed system can predict the specific land into highly suitable (*baay'ee mijataa*). This is by using knowledge acquired from different sources and feed into Prolog tool.

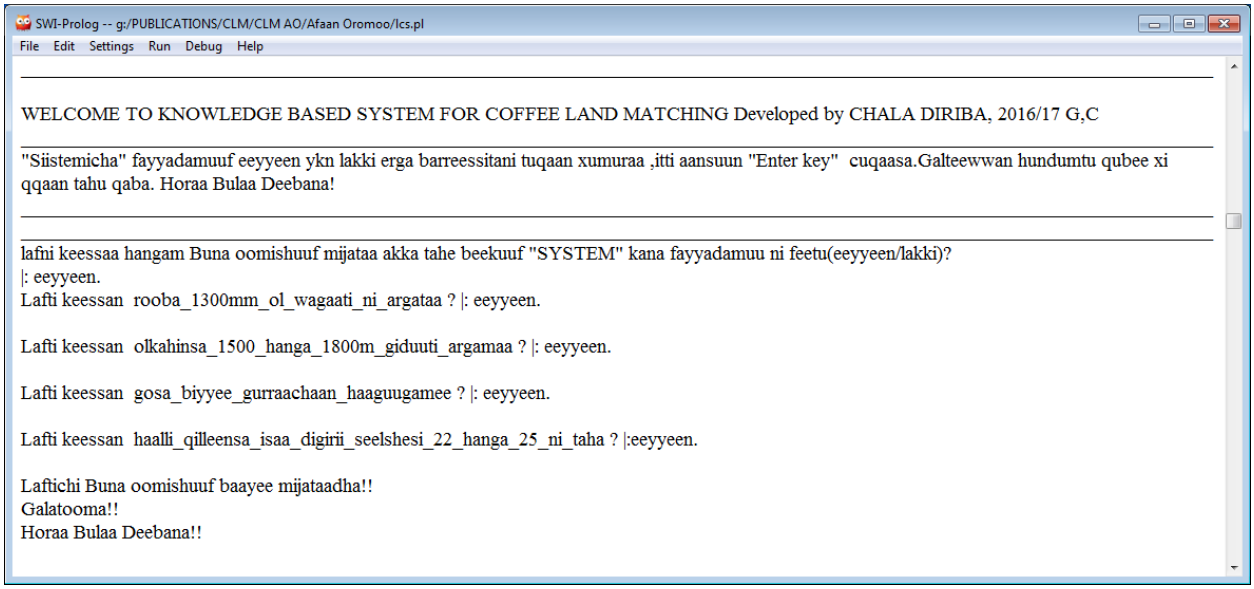


Figure 2: Identifying land into highly suitable for coffee production

In addition, the system can identify the land into moderate suitable (*giddugaleessa*) for coffee production in Afaan Oromoo. It was presented in the figure 3.

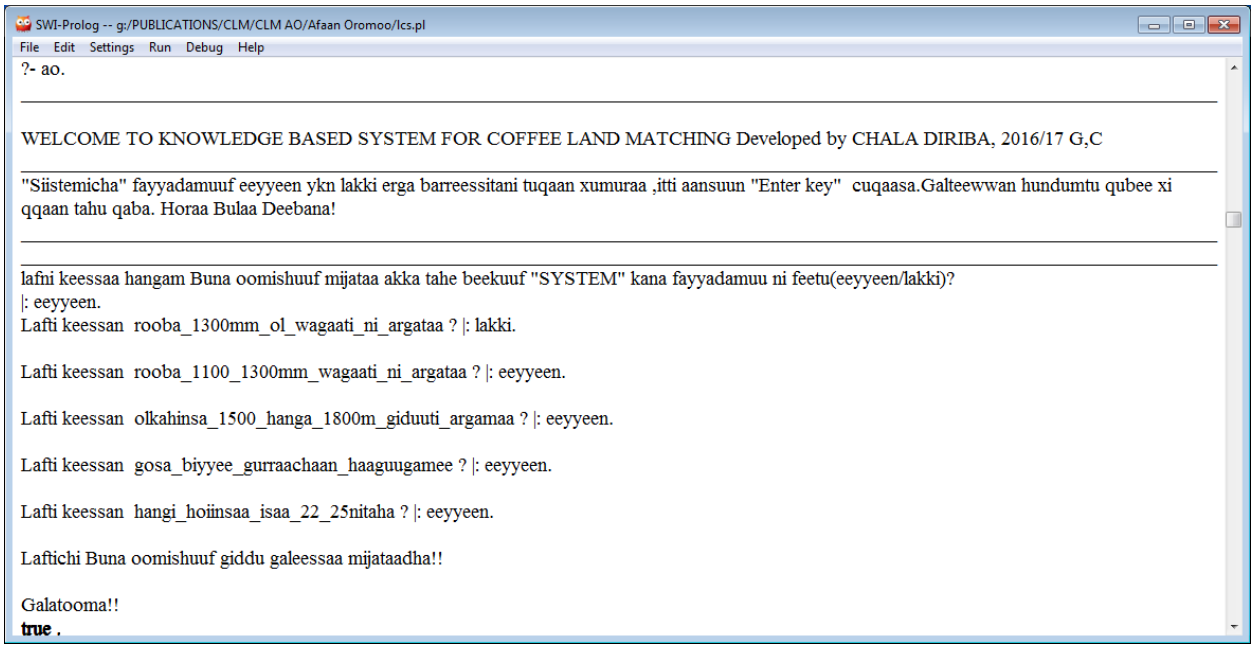


Figure 3: Identifying land into moderate suitable for coffee production

Moreover, the prototype system can determine land into marginally suitable (*hanga tokko mijataa)* for coffee cultivation as shown in figure 4 below.

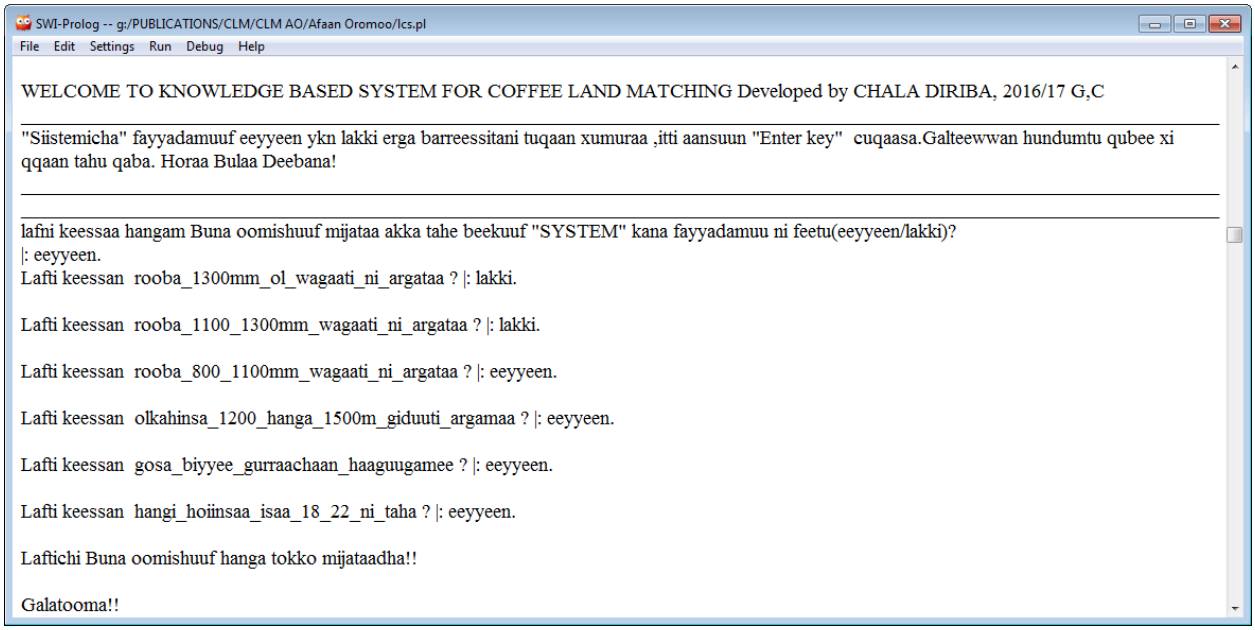


Figure 4: Identifying land into marginally suitable for coffee production

Furthermore, the developed system can identify if the land is not suitable (*mijataa miti*) for coffee production at all as depicted in figure 5.

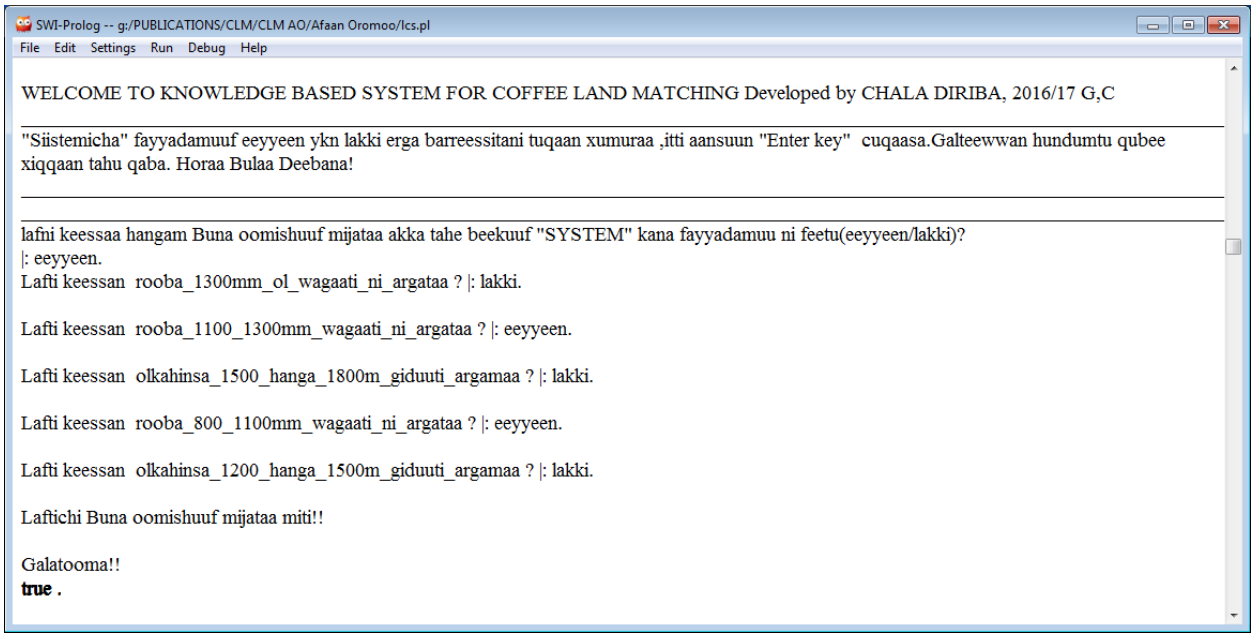


Figure 5: Identifying land into not suitable for coffee production

5. Conclusion and Recommendation

Crops production, specifically coffee production is a back bone of of Ethiopian economy because it is the main export item. Moreover, coffee is vital to the cultural and socio-economic life of Ethiopian people. Because of some problems such as selecting appropriate land for coffee, the quantity and quality of coffee produced is significantly affected. In addition, to the knowledge of the researchers, there is no intelligent KBS developed in

Afaan Oromoo, a language spoken and used as official language in Oromia Region. Therefore, the developed system can support professionals and coffee producers to identify suitable land for coffee plantation as the developed system can categorize the land unit in Afaan Oromoo into high, moderate, and marginally suitable for coffee plantation.

This study focused on geo-spatial characteristics (temperature, rainfall, elevation and soil) and thus other researchers can add chemical requirements and social economic parameters. In the future scholars can generate more rules by collecting more knowledge for domain experts because it is difficult to entirely acquire tacit knowledge. The other further work would be using other tool rather than Visual Prolog 7.3 which may solve problem of prolog user interface. Moreover, developing KBS for coffee land suitability identification through integrating scientific and indigenous knowledge that can identify specific land as of its suitability level for coffee plantaion.

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