Using indigenous knowledge to model land suitability for crops in Amuru district, northern Uganda

Article *in* African Journal of Food Agriculture Nutrition and Development · November 2019

DOI: 10.18697/ajfand.87.17555

2 authors:

Expedito Nuwategeka
Gulu University

Nyeko Martine
Gulu University

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2019; 19(4): 14805-14828 DOI: 10.18697/ajfand.87.17555

USING INDIGENOUS KNOWLEDGE TO MODEL LAND SUITABILITY FOR CROPS IN AMURU DISTRICT, NORTHERN UGANDA

Nuwategeka E[1*] and M Nyeko[2]

Expedito Nuwategeka

*Corresponding author email: exnuwategeka@gu.ac.ug, nuwategeka@gmail.com

[1]Gulu University, Faculty of Education and Humanities, Geography Department, P.O. Box 166, Gulu, Uganda

[2]Gulu University, Faculty of Agriculture and Environment, Department of Bio systems Engineering, P.O. Box 166, Gulu, Uganda

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

ABSTRACT

Locally-generated agricultural land management models may be more effective in achieving sustainable agricultural production and environmental management because they operate within the eco-cultural context of the farmers, therefore easily useable. The present study uses locally generated indigenous knowledge to model the suitability for cultivation of maize, rice and beans and compares the results obtained with those of a modern scientific land suitability model in Amuru district, northern Uganda. Geo-referenced indigenous knowledge-based land suitability data was collected from farmers' fields using a Global Positioning System handset, questionnaires and focus group discussions were also used to develop an indigenous knowledge-based agricultural land resource database. The Analytical Hierarchical Process method was applied to sort the data to determine the relative importance of the various indigenous land evaluation parameters. For the modern scientific land suitability evaluation data set, a land resource database with climate and soil physical and chemical parameters was developed to model the scientific land suitability evaluation. The two data sets were analyzed using Automated Land Evaluation System software based on the principles of the FAO framework for land evaluation. Two spatial land suitability models were generated for the two data sets. The two spatial models were matched using ArcGIS software applications to obtain land suitability comparisons. Results produced more than 70% agreement between the indigenous and the modern scientific evaluations. The evaluation for maize and rice produced 75% agreement. Both scientific and indigenous land evaluations for maize and rice showed that the two crops almost have similar land use requirements. On the other hand, land suitability comparisons for beans produced 71% level of agreement. It is concluded that locally generated land evaluation systems based on farmers' indigenous knowledge are comparable to modern scientific ones, and may be relied upon where technical land evaluations are not readily available or useable by rural indigenous farmers.

Key words: indigenous knowledge, modelling, geographic information system, land suitability evaluation

DOI: 10.18697/ajfand.87.17555

INTRODUCTION

Land suitability, the fitness of a given type of land for specified kind of land use [1] has been conducted using various evaluation methods like the Land Capability Classification (LCC) developed in the United States in 1930s, the Canadian Land Inventory, and the conventional Food and Agriculture Organization framework [4]. Apart from the broad methods, specific computer-based land evaluation models like Automated Land Evaluation System (ALES), the Mediterranean Land Evaluation Information System (MicroLEIS), and Agricultural Productivity Simulation Model (APSIM) have been developed. In this paper, we use the ALES model. These are integrated systems for land data transfer and agro-ecological land evaluation [2]. The Models can be used to predict crop yields under different management strategies, as well as individual land qualities that are important components of yield, such as moisture supply, nutrient supply, and radiation balance.

In addition to the above-mentioned land evaluation methods and models, indigenous knowledge, that is, the accumulated knowledge, skill, understanding, and technology of local people derived from their direct interaction with the environment and passed on through generations [3] also forms part of land evaluation methods. Because land evaluation involves the study and interpretation of land forms, soils, vegetation, and climate in order to identify and make a comparison of promising kinds of land use, ideally, every region or territory should develop its own evaluation system that takes care of the varied nature of the landscape. However, in recognition of the resource constraints in developing location-specific land evaluation systems especially for the developing countries, the FAO has developed an international framework on which any local land evaluation can be modelled [4].

Applying statistical analyses to produce models in land evaluation is one of the ways to model traditional indigenous knowledge. Therefore, using local knowledge on land suitability evaluation, parameters may be ranked and input in an equation of the nature $Y=Ø(X_1, X2, Xn) + \mathcal{E}$, where Y may be the parameter being evaluated, X_n corresponds to the selected land characteristics and $\mathcal{E}$ measures the residual. Although the mathematical form of $Ø$ may not be known, this function can always be approximated within an experimental context by a polynomial equation [5].

Additionally, parametric systems can allocate numerical value on the most significant land characteristics, and then account for interactions between such significant factors expressed through a simple multiplication or an addition of single-factor indices [5]. It is, therefore, possible to run simple correlation and multi-regression analyses to determine the importance of one parameter in land evaluation relative to the others. Such a system for multiplying soil productivity parameters was developed by Storie in 1933 [6]. In a similar way, indigenous knowledge parameters for assessing land suitability can be treated as the Storie index when modeling land suitability.

Indigenous knowledge in land suitability evaluation is capable of being modeled to provide solutions for land use planners in the era where top-down development

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

interventions are receiving criticism from rural development practitioners; that they ignore local environmental management practices, and this may be partly responsible for the collapse of imported western scientific development models after projects close [7]. In Amuru district of northern Uganda, like most areas in developing countries, local farmers have developed an indigenous land suitability evaluation system based on observable environmental phenomena like soil colour, indicator plants, and soil organisms [8]. The objectives of the present study were to generate an agricultural land suitability evaluation model based on farmers' indigenous knowledge, and to compare it with one based on the conventional scientific agricultural land suitability evaluation data set. The output of the paper may form a hybrid agricultural land suitability evaluation model which may be more useable to local farmers than the conventional formal scientific evaluations.

MATERIALS AND METHODS

Study area

The study was conducted in Amuru district in northern Uganda (Figure 1). Geographically, the district is located between 31°4'3"E to 32°3'4"E and 2°7'8"N to 3°6'3"N. The main physiographic units are plains characterized by some rock outcrops on isolated residual hills. The soil types in the area are leptosols, acric ferralsols and eutric regosols. Annual rainfall ranges between 1000-1200mm [9]. Small scale subsistence agriculture is the dominant form of crop husbandry, the major crops being maize, sesame, beans, upland rice, pigeon peas, millet and cassava. Because indigenous knowledge develops in a particular cultural area and context, data was collected from among the Acholi ethnic group in Amuru and Pabbo sub Counties because the two sub Counties exhibit a relatively homogenous Acholi population than other sub Counties, which have an urban influence (hence a cultural mixture).

Data collection

A total of 52 farmers were interviewed using questionnaires to determine the indigenous knowledge parameters used in general land suitability evaluation for only maize, upland rice and beans, the three being the most widely grown in the area. In order to build an indigenous-knowledge-based spatial model for land suitability covering all the soil types in the study area, an indigenous knowledge-based land resource database was built by collecting Global Positioning System point data for 24 farmers' crop fields.

DOI: 10.18697/ajfand.87.17555

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

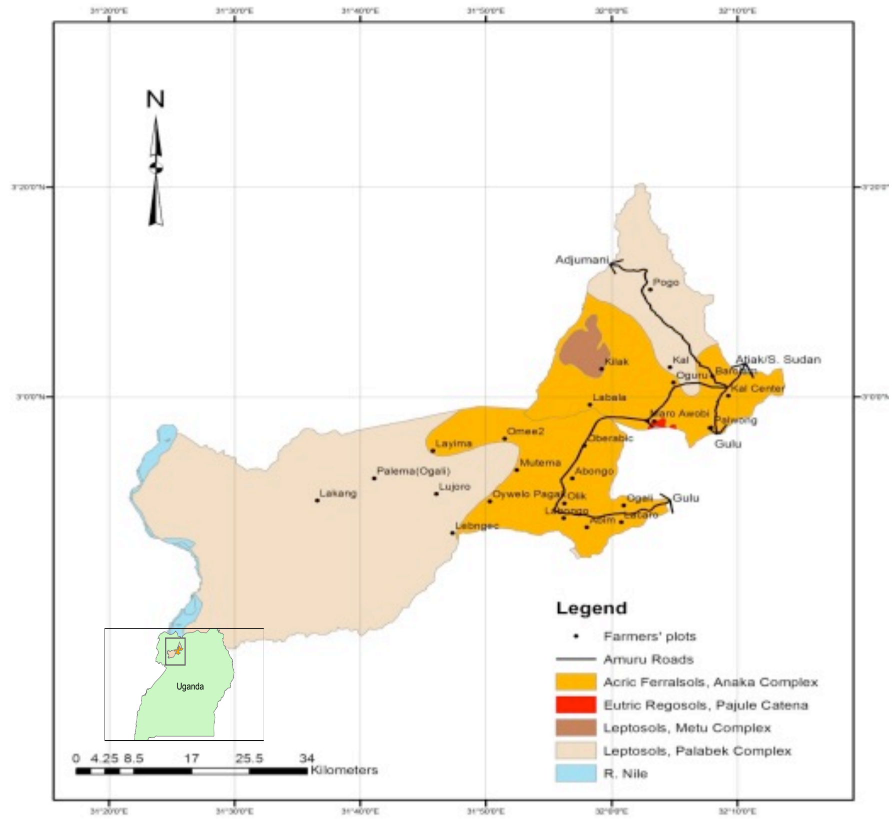

Figure 1: Study area
Source: Soil Memoirs for Uganda, 1967

Modeling land suitability based on indigenous knowledge

Land suitability modeling based on indigenous knowledge used Geographic Information System tools. Data entered in a GIS database included GPS position of the plots, Land Characteristics (LC), Land Utilization Types (LUTs) and Land Management Units (LMU). Land Characteristics included the indicator plants for suitable land, soil colour, indicator soil organisms, natural vegetation density, vegetation species diversity, growing season and soil compactness (See Table 2). Land Utilization Types were rain fed maize, rice, and beans. Land Management Units were the aggregated farmers' crop fields. Automated Land Evaluation System (4.0) software was used to analyse the data to generate land suitability. In this paper, we often refer to the output from the ALES software as the "scientific suitability". Maximum limitation method was used to construct severity level decision trees in ALES based on the diagnostic factor ratings generated from the LCs (see Table 1). Data for indicator plants and soil organisms contained a variety of items, and in order to objectively determine the diagnostic factor ratings for each of them, the Analytical Hierarchical Process (AHP) method was used. Basing on the fundamental scale of absolute numbers [10], expert farmers ranked the different indicator plants and soil organisms using pair-wise comparison matrices for each of the LUTs. Therefore, each

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 19 No. 4 November 2019 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

of the indicator plants and soil organisms was assigned a rank depending on its relative importance in influencing land suitability for all the three respective LUTs.

Finally, Land Use Requirements (LURs) of each LUT were matched with LQs of each LMU to obtain final suitability ratings. The suitability ratings were based on the Satty scale of absolute numbers [10]. Suitability classes were constructed as S1=highly suitable, S2=moderately suitable, S3=marginally suitable and N=not suitable. A point map was then generated for each of the LMUs using ArcGIS (10.1) software.

Modelling land suitability evaluation based on the modern scientific data set

A soil map for Amuru and Pabbo sub Counties comprising physical and chemical soil properties like depth, pH, organic matter, phosphorous, nitrogen, potassium, cation exchange capacity and base saturation was obtained from the soil memoirs for Uganda [17]. Soil data was analyzed using ALES, where each soil mapping unit was treated as an independent LMU with its own LCs (*See Table 3*). Land Use Requirements for the three LUTs were generated through literature review [14, 18] as presented in Tables 4, 5, and 6. The final suitability classes were similar to the ones in the indigenous evaluation discussed in section 2.3.

Climate data for annual monthly rainfall from 1980 to 2010 and daily minimum and maximum temperatures from 1991 to 2009 for Gulu station, which is about 30km from the study area was used. MS Excel 2007 was used to analyse temperature and rainfall data. We provided growing season rainfall and temperature to ALES using data from the Department of Meteorology.

Table 3. Land mapping units and qualities with severity levels used for physical suitability assessment.

Codes for LC and severity levels: d= deep, vi= very insufficient, s= sufficient, i= insufficient, n= neutral, a= acidic, vad= very adequate, mad= moderately adequate, ad= adequate, vl= very low, ina= inadequate. N=Nitrogen, P= Phosphorous, K= Potassium, Ph= Soil reaction, %Base= base saturation, CEC= cation exchange capacity, OC= organic carbon.

The soil and climate data were used as land resource database, hence generating diagnostic factor rating for LURs for maize, upland rice and beans.

After generating the suitability classes for the respective LUTs on each of the soil types, a spatial suitability model was generated using ArcGIS (10.1) software.

Comparing indigenous knowledge land evaluation model with scientific land evaluation model

Results from the two data sets were compared using the ArcGIS (10.1) software. The suitability rankings produced by ALES were entered as attribute data for each of the indigenous knowledge and modern scientific data sets. The four suitability classes S1, S2, S3 and N were re-classified into two suitability orders S (Suitable) and N (Not suitable) in order to obtain better spatial suitability comparisons of results from the two

DOI: 10.18697/ajfand.87.17555

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

data sets. The 'contain' spatial query was applied in the comparison of the suitability results from the two data sets. To get a topological relationship, a polygon map for the scientific criteria was used as a source layer, whereas a point map for the indigenous evaluation was the target layer. Therefore, for each of the crops, it was possible to establish whether suitability results of a given mapping unit (modern scientific data set) corresponded to the results of the indigenous evaluation or not. Suitability rankings from the new attribute table of the clipped map were exported into MS Office Excel 2007 software for calculations to determine the percentage of agreement between the results of the two different evaluations. The results were displayed in three suitability maps and on a graph (Figures 3 and 4).

RESULTS AND DISCUSSION

Land suitability based on indigenous knowledge

Results from the farmers show variations in land suitability among maize, upland rice and beans' plots. The first outstanding variation in results was recorded at Abim, where the land was rated not suitable for beans, but highly suitable for maize, and marginally suitable for upland rice. Secondly, Oberabic, where rice and beans were rated not suitable, maize was rated highly suitable. Finally, Kal farmers' plots were highly suitable for rice and beans and not suitable for maize. Table 1 shows the suitability ratings for all the LUTs on the various farmers' plots.

Areas suitable for maize were in most cases not suitable for beans. Whereas maize requires a longer rainfall period during the grain-filling stage of growth, too much rainfall during flowering [11] can cause bean flowers and small pods to fall. In cases where intercropping of beans and maize was practiced, the beans would be planted after the maize has sprouted (after a period of three weeks on average). This means moisture requirements during the growing period are different for the two crops.

Generally, the southern part of the study area (Amuru sub county) was rated more suitable for maize (not for upland rice or beans) compared to the north (Pabbo sub County). The micro-climate of Amuru sub County reveals relatively more rainfall as evidenced by the dominance of wooded savanna, than Pabbo sub County which is covered by open grassland vegetation. Pabbo area is located on the rain-shadow side of the Kilak hills (2500m above sea level), which modify the local climate.

Beans require a relatively shorter rainfall period compared to maize. Upland rice also requires relatively lower rainfall than maize. In their categorization, farmers generally concurred that villages which were suitable for upland rice were equally suitable for beans as well. However, there is a practice of intercropping rice with maize, and not with beans. The reason is rice will grow taller and cut off sunlight from the beans, whereas maize will still allow sunlight to reach the rice during the growing period.

DOI: 10.18697/ajfand.87.17555

Land suitability based on the modern scientific data set

Climate resources

Climate resources (rainfall and temperature) were found to be suitable for the three crops. The area receives a single maxima type of rainfall, which is favourable for the growth of annual crops. The main growing season runs from August to November. This season receives longer and heavier rainfall (540mm) than the shorter growing season which starts in late March to the end of May (406mm). In the evaluation, all the two growing periods for all the crops were considered. The rainy seasons coincide with relatively cooler temperatures to facilitate crop growth. Temperatures start rising in November from an average of 24°C up to 26.2°C in March. From April, temperatures start dropping from 24.75°C to 23.85°C in October. February is the hottest and driest month with an average temperature of 26°C and rainfall of 24mm, respectively. The coolest and wettest month is August with averages of 23.15°C and 208.6mm, respectively. Figure 2 shows the average monthly temperatures and the rainfall curves.

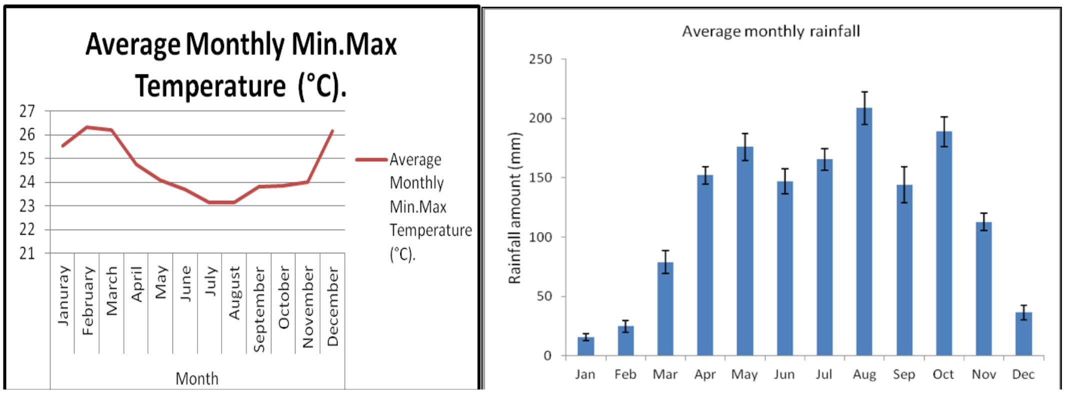

Figure 2: Average monthly temperature and rainfall curves

Suitability rating for the LMUs

The results show that maize is highly suitable on eutric Regosols *(S1)*, moderately suitable on Acric Ferralsols *(S2),* and marginally suitable on Leptosols *(S3)*. Upland rice and beans are moderately suitable on Leptosols *(S2)*, and marginally suitable on Acric Ferralsols *(S3) (Table 3)*. Upland rice and beans have similar suitability classes across all the soil types because they have similar land use requirements.

Eutric Regosols have the highest suitability compared to other soil types. There is no crop which is marginally suitable (*S3*) or not suitable (*N*) on the soils because the cultivated part is covered by alluvial soils transported from the neighbouring Guruguru hills. Acric Ferralsols have the least suitability relative to other soil types, but are moderately suitable for maize.

Comparing land suitability evaluation based on indigenous knowledge and scientific method

Comparison of spatial models generated from suitability ratings based on the indigenous knowledge and the scientific methods indicate that there was a 75% agreement for maize and upland rice, and 71% agreement for beans. This means majority of the areas which were considered suitable/not suitable based on the modern

DOI: 10.18697/ajfand.87.17555

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

scientific data set evaluation were also found to be suitable/not suitable by the indigenous evaluation. Studies comparing traditional and modern scientific land suitability evaluations have been undertaken [12, 13, 14] and all report a significant level of agreement between the two knowledge systems. However, some authors [15] identified significant variations in the two systems; indigenous knowledge evaluation provided a better understanding of the impact of microclimatic variations on crop productivity than the scientific evaluation. This is because scientific weather data collection sites may have a greater spatial extent from each other, and the analysis of the data may always involve averaging and approximation. A global gridded dataset would not apply to the study area as well because it is so small.

Although indigenous and modern scientific knowledge systems may have methodologically different approaches of investigation, the results are comparable. Indigenous people rely on accumulated experiences of observation of and interaction with their environment whereas scientific knowledge dwells on reductionism and controlled experimentation. The spatial representation of the comparison of the two evaluations for the three crops is presented in Figure 3.

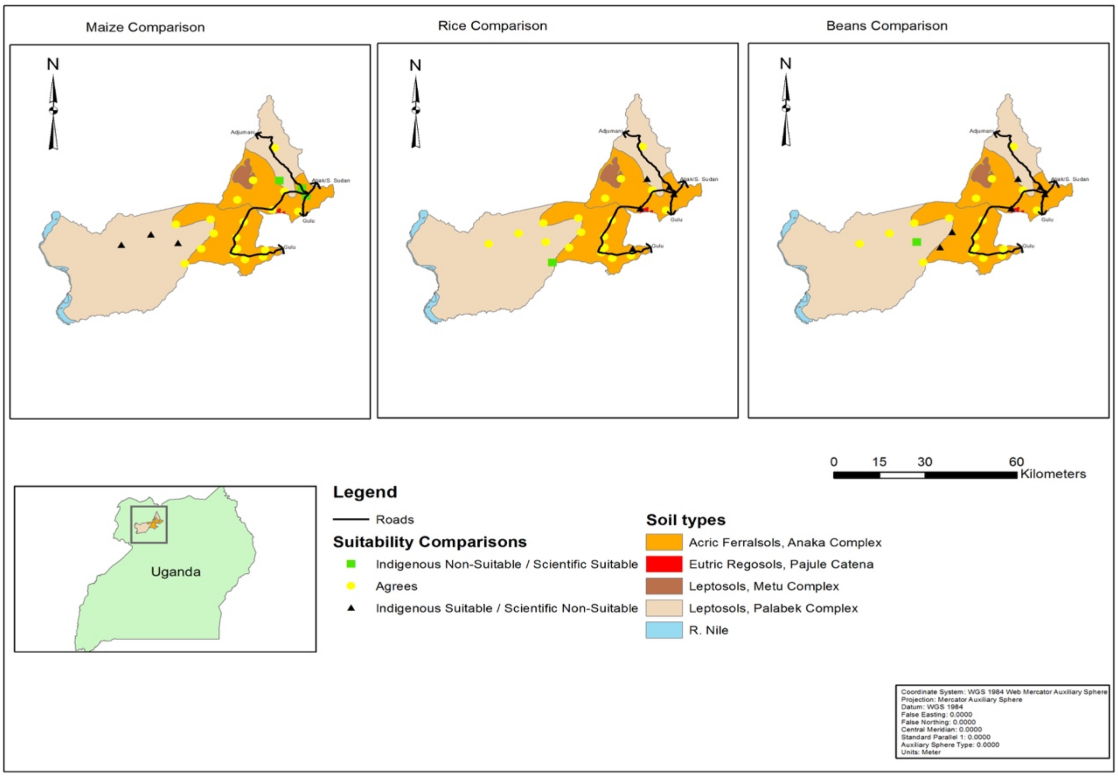

Figure 3: Spatial comparison of indigenous and modern scientific suitability evaluation for maize, rice and beans

Graphical representation of the comparison is presented in Figure 4, where convergence at the middle line shows agreement between the indigenous and the formal scientific land evaluation results.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

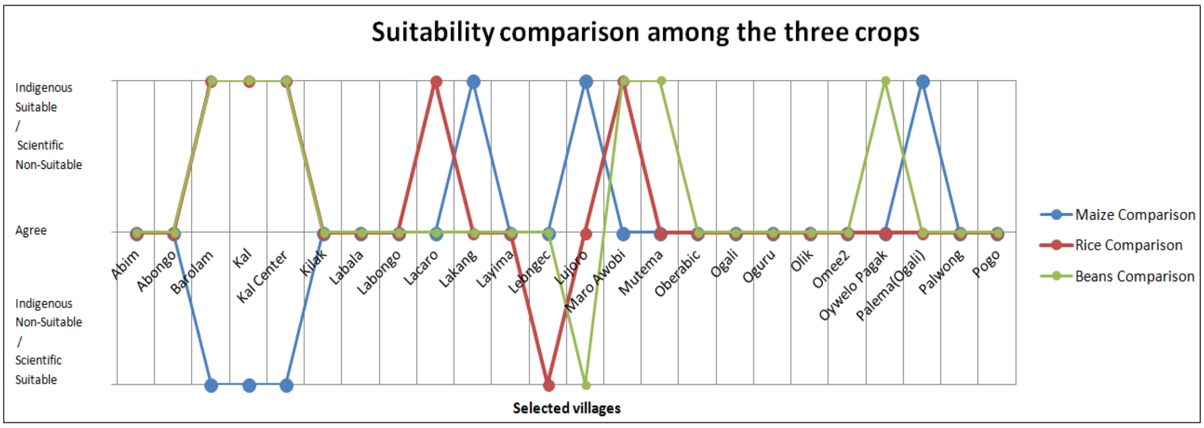

Figure 4: Graphical comparison of the two suitability ratings

Divergence upwards or downwards from the central line indicates that the two data sets were in disagreement. The upper line of the graph reveals that indigenous evaluation rated the land suitable while the modern scientific data set rated it not suitable. The lower line of the graph shows a scenario where indigenous method rated the land not suitable, contrary to the scientific method.

Results of the modern scientific evaluation show that Acric Ferralsols are marginally suitable for rice; this is because of the pH value of 5.23, which is lower than the required range for rice (5.6-7.3). During field work, it was observed that in the areas where this soil type is located, farmers do not extensively cultivate rice. For example, in areas of Labala Parish of Pabbo sub County, the intensity of rice growing is not as high as that of Pogo, Kal and Oguru areas (dominated by Leptosols, which are moderately suitable for rice (*S2*) according to the scientific evaluation). Although the farmers' decisions were not based on the technical interpretation of the soil resources, through trial and error, a characteristic of indigenous knowledge, they have found out that the area is not suitable for rice.

Rice is largely grown in Pabbo compared to Amuru sub county when some areas in all the sub Counties are dominated by leptosols, which are moderately suitable for the crop. The reason is areas suitable for rice in Amuru sub county (Lakang area) were until 2010 gazetted by the area chiefs as a communal hunting and grazing areas. Therefore, settlement is recent, and there has not been enough time for people to experiment with the land for suitability assessment using indigenous knowledge.

The results from the indigenous knowledge and the modern scientific land evaluations may not at all times reflect the actual land use being practiced. Farmers keep changing crops depending on the available labour, land and capital (to purchase the inputs). Factors like the cultural land use allocation system, power relations between men and women at household level, and land availability may affect land allocation and use as explained by Nuwategeka and Nyeko [8].

The desire to compare indigenous and scientific land evaluation knowledge systems is driven by the nature of most rural agricultural practices. Whereas scientific land use

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

maps may exist, often they are prepared at scales which ignore local micro variations in landscape and climate. As observed by Orimoloye *et.al.* [12], maps are presented in scales of 1:25,000 or smaller, implying a minimum delineation of 2.5ha. Farmers' fields in most rural areas of developing countries are no more than 0.5ha. In this case, integrating indigenous knowledge land use options would make up for the weaknesses in the scientific knowledge system.

Integrating indigenous knowledge and modern scientific land suitability evaluations may be feasible for farmers since both knowledge systems may fall short of precise results due to scale and perception problems, respectively. When analyzed on a large scale, small but important parameters that affect suitability of the land for specific crops may be ignored, for example slope inclination, micro climate of a location and intra-soil type variations. This is common for modern scientific evaluations where a single soil type is treated as an independent and separate land management unit, and climate data applying to a relatively larger area, like in the current study.

For example, in this study, Eutric regosols were the best rated soils for all the three crops when according to FAO [16], these are soils characterized by a surface layer of rocky material with course texture. There is a seeming contradiction between the characteristics of the soil type and the relatively high suitability ratings. The cultivated area around these soils is located at the foothills of Guruguru hills, where eroded top soil from the hills has made rich alluvial deposits. Because of the soil map scale being small, this alluvial soil island was categorized within the greater eutric regosols soil type during soil mapping. The largest area covered by this soil type is located in the neighbouring Lamogi sub County, which is outside the study area.

However, indigenous knowledge evaluation accounted for the micro details of the land because the survey was site-specific: involving farmers to evaluate individual crop fields where they carry out agriculture; so, it had better scale compared to the scientific method. The differences in scale, however, did not significantly affect the results since the suitability classes were re-classed from four classes to two classes, that is, 'suitable' and 'not suitable'. Nevertheless, the evaluations, despite their inherent weaknesses, are important for land use decision-making processes, especially in circumstances where there is limited or no land resource data.

Acric ferralsols had the least suitability for all the crops. These soils are a result of high rates of weathering of soil rich in sesquioxide clays, and have low cation exchange capacity [16]. The lower the cation exchange capacity, the lower the fertility of a soil. This is because organic matter provides one of the sites for cation exchange in a soil, and naturally, this means the higher the organic matter content, the higher will be the cation exchange capacity.

DOI: 10.18697/ajfand.87.17555

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

CONCLUSIONS

Comparatively, indigenous knowledge-based land evaluation systems produce almost similar results with methods based on formal scientific evaluations. Methodological differences in investigations between the two knowledge systems exist, with the indigenous system being largely unstructured and informal while the scientific one is structured and formal. For a successful comparison of the two knowledge systems, a lot of formal scientific techniques must be employed in order to structure the informal, subjective, and largely descriptive pool of indigenous knowledge data. Validation with other data sets based on objective measurement of land resources like soil survey and climate data is necessary to determine the degree of computation (the precision of prediction) of indigenous knowledge land evaluation models. Given that indigenous agricultural knowledge is to a greater degree based on observable environmental attributes like plants, soil and topography, the use of geographical information systems can aid in modelling because parameters can be localized to apply to a specific place. Therefore, technical scientific land evaluations can be enhanced by input from the indigenous knowledge datasets.

DOI: 10.18697/ajfand.87.17555

Table 1: Diagnostic factor rating for Land Use Requirements

Land Use Requirements		**Factor rating**			
Land Quality	***Diagnostic factor***	***S1***	***S2***	***S3***	***N***
Maize					
Nutrient availability	Soil colour	Dark brown	Light brown	Reddish gray/Pinkish white	-
	Indicator plants	*Panicum maximum, Neonotonia wightii, Commelina* spp	*Sorghum Halepense, Imperata cylindrica*	*Agropyron repens, Striga asiatica (spp)*	*Heteranthera zosterifolia, Trianthema portulacustrum, Euphorbia heterophylla.*
	Indicator soil organisms	*Lumbricus terrestris, Uraeotyphlus spp*	*Incisitermes minor, Larvae of Gryllus bimaculatus*	*Heterocephalus glaber*	*Gryllus bimaculatus, Solenopsis invicta.*
	Natural vegetation density	High	Medium	Low	Very low
	Vegetation species diversity	High	Medium	Low	Very low
Rooting condition	Soil compactness	Very soft ground	Soft ground	Hard ground	-
Moisture availability	Rain season	August – November	March-May	Dry season	Dry season
Drainage/flooding hazard	Topography	Mid slope	Hill top	Valley bottom	Valley bottom
Factor rating for rice					
Nutrient availability	Soil colour	Dark brown	Light brown	Reddish gray	Pinkish white
	Indicator plants	*Panicum maximum, Neonotonia wightii, Commelina* spp	*Sorghum Halepense, Imperata cylindrica*	*Agropyron repens, Rottboellia cochinchinnensis*	*Heteranthera zosterifolia, Striga asiatica (spp), Amaranthus spinosus*
	Indicator soil organisms	*Lumbricus terrestris, Uraeotyphlus spp, Incisitermes minor*	*Incisitermes minor, Larvae of Gryllus bimaculatus*	*Heterocephalus glaber*	*Gryllus bimaculatus, Solenopsis invicta.*
	Natural vegetation density	High	Medium	Low	Very low

DOI: 10.18697/ajfand.87.17555

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

	Vegetation species diversity	High	Medium	Low	Very low
Rooting condition	Soil compactness	Very soft ground	Soft ground	Hard ground	Very hard ground
Moisture availability	Rain season	August – November	March-May	Dry season	Dry season
Drainage/flooding hazard	Topography	Mid slope	Valley bottom	Hill top	-
			Beans		
Nutrient availability	Soil colour	Dark brown	Light brown	Reddish gray	Pinkish white
	Indicator plants	*Panicum maximum, Neonotonia wightii, Commelina* spp	*Sorghum Halepense, Imperata cylindrica*	*Agropyron repens, Setaria pumila*	*Striga asiatica (spp),Heterant hera zosterifolia, Euphorbia heterophylla*
	Indicator soil organisms	*Lumbricus terrestris, Uraeotyphlus spp, Incisitermes minor*	*Incisitermes minor, Larvae of Gryllus bimaculatus*	*Heterocephalus glaber*	*Gryllus bimaculatus, Solenopsis invicta.*
	Natural vegetation density	High	Medium	Low	Very low
	Vegetation species diversity	High	Medium	Low	Very low
Rooting condition	Soil compactness	Very soft ground	Soft ground	Hard ground	Very hard ground
Moisture availability	Rain season	March -May	August-November	Dry season	Dry season
Drainage/flooding hazard	Topography	Mid slope	Hill top	Valley floor	Valley bottom

DOI: 10.18697/ajfand.87.17555

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 2: Indigenous knowledge Land Characteristics for the various farmers' plots

	Land Manage ment Unit	**Code**	**Soil colour**	**Indicator plants**	**Hardness/ softness of the ground**	**Soil organisms**	**Natural vegetation density**	**Vegetation species diversity**
1	Oguru	Og	Dark brown, light brown, reddish gray	*Setaria pumila, Panicum maximum, Sorghum Halepense*	Hard	*Larvae of Gryllus bimaculatus, Lumbricus terrestris*	High	high
2	Barolam	Ba	Light brown	*Agropyron repens*	Soft	*Uraeotyphlus spp,*	High	moderate
3	Mutema	Mu	Dark brown, pinkish white	*Setaria pumila, Hyparrhenia rufa*	Hard	*Lumbricus terrestris*	Moderate	moderate
4	Ogali	Oga	Pinkish white, reddish gray	*Lantana camara*	Soft	*Oecanthus fultoni*	High	Low
5	Lakang	Lak	Reddish gray and light brown	*Panicum maximum, Hyparrhenia rufa*	Soft	*Gryllus bimaculatus, Incisitermes minor*	High	Very high
6	Lujoro	Lu	Light brown	*Hyparrhenia rufa, Striga asiatica (spp)*	Hard	None	Moderate	high
7	Pogo	Po	Light brown	*Imperata cylindrical, Hyparrhenia rufa, Lantana camara*	Hard	*Incisitermes minor*	High	Very high
8	Palwong	Pa	Reddish gray, light brown	*Striga asiatica (spp), Lantana camara*	Hard	*Solenopsis invicta, Monomorium minimum*	Moderate	Low
9	Labala	Lab	Pinkish white ,reddish brown	None	Soft	None	High	Low
10	Kal	Kal	Light brown	*Imperata cylindrical, Heteranthera zosterifolia*	Hard	*Larvae of Gryllus bimaculatus*	Moderate	Very high
11	Oberabic	Ob	Light brown, pinkish white	*Imperata cylindrical, Sorghum Halepense,*	Soft	*Heterocephal us glaber, Solenopsis invicta*	Low	Low

DOI: 10.18697/ajfand.87.17555

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

				Striga asiatica (spp)				
12	Kilak	Kil	Dark brown, light brown	*Imperata cylindrical,*	Soft	*Lumbricus terrestris*	Low	moderate
13	Lebngec	Leb	Light brown, reddish gray	*Rottboellia cochinchinnensis, Striga asiatica (spp)*	Hard	*Lumbricus terrestris, Gryllus bimaculatus*	High	moderate
14	Omee 2	Om	Light brown	*Amaranthus spinosus*	Hard	*Larvae of Gryllus bimaculatus, Uraeotyphlus spp*	moderate	high
15	Palema	Pal	Dark brown	*Neonotonia wightii, Sorghum Halepense, Hyparrhenia rufa*	Soft	*Lumbricus terrestris, Uraeotyphlus spp*	Low	moderate
16	Abongo	Abo	Light brown, reddish gray	*Lantana camara*	Hard	None	Low	Low
17	Abim	Abi	Light brown	*Neonotonia wightii, Lantana camara, Striga asiatica (spp)*	Hard	*Solenopsis invicta, Larvae of Gryllus bimaculatus*	Moderate	moderate
18	Oywelo Pagak	Op	Light brown	*Bidens Pilosa, Agropyron repens*	Soft	*Lumbricus terrestris*	High	moderate
19	Kal Centre	KaC	Light brown	*Panicum maximum, Amaranthus spinosus*	Hard	*Insulamon unicorn*	Low	moderate
20	Maro awobi	Ma	Dark brown, light brown	*Neonotonia wightii, Imperata cylindrical, Agropyron repens*	Soft	*Lumbricus terrestris, Uraeotyphlus spp*	High	Very high
21	Olik	Ol	Light brown	*Neonotonia wightii, Panicum maximum, Striga asiatica (spp)*	Soft	*Lumbricus terrestris*	Very high	high

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

22	Labongo	Lbo	Light brown	*Imperata cylindrical, Striga asiatica (spp)*	Hard	*Gryllus bimaculatus*	Moderate	Low
23	Lacaro	Lac	Dark brown, light brown	*Commelina* spp, *Bidens Pilosa, Setaria pumila, Sorghum Halepense, Lantana camara*	Soft	*Lumbricus terrestris*	High	Very high
24	Layima	Lay	Pinkish white, reddish gray	*Bidens Pilosa, Agropyron repens, Heteranthera zosterifolia, Striga asiatica (spp)*	Soft	*Gryllus bimaculatus*	Moderate	Low

Table 3: Land mapping units and qualities with severity levels used for physical suitability assessment

Land mapping unit	Code	Depth	N	P	K	pH	%Base	CEC	%OC
Leptosols (Palabek complex)	LeP	d	vi	s	vs	n	vad	vl	ina
Acric ferralsols (Anaka complex)	AF	d	vi	i	i	a	mad	low	ad
Eutric regosols (Pajule catena)	ER	d	vi	vs	s	a	ad	low	mad
Leptosols (metu complex)	LeM	d	vi	vs	s	n	vad	vl	ina

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 4: Factor rating of land use requirements for maize (*Zea mays*)

Land use requirement			Factor rating			
Land quality	**Diagnostic factor**	**Unit**	**(S1)**	**(S2)**	**(S3)**	**(n)**
Temperature regime	Mean temperature during growing season	Degrees centigrade	24-30	18-22 25-31	15-18 32-35	<15 >35
Moisture availability	Rainfall in growing season	(mm)	500-800	450-500	400-449	<400
Nutrient availability	Reaction	pH	5.0-6.5	6.5-7.0	7.0-8.0	>8.0 or <5.0
	Organic carbon	%	>2.0	1.2-2.0	0.8-1.2	<0.8
	N	%	>8.0	7.0-8.0	4.0-6.9	<4.0
	P	mEq/100g	>0.4	0.2-0.4	0.07-0.19	<0.07
	K	%	>3.5	2.0-3.5	0.5-2.0	<0.5
	Base saturation	%	>35	20-35	20-10	5
Nutrient retention capacity	Cation exchange capacity	mEq/100g clay	>24	16-24	12-16	<12
Rooting condition	Soil effective depth	cm	>75	50-75	25-50	<25
Erosion hazard (e)	Slope	Class	A	B	C	>C

DOI: 10.18697/ajfand.87.17555

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 5: Land use requirements for beans (*Phaseolus vulgaris)*

Land Use Requirement			Factor rating			
Land Quality	**Diagnostic factor**	**Unit**	**S1**	**S2**	**S3**	**n**
Temperature (t)	Mean temperature in growing period	^{0}C	20-30	31-33	33-35	>35
				17-19	15-16	<15
Moisture availability (m)	Total rainfall in growing period	mm	>600	400-600	300-400	<300
Oxygen availability (o)	Soil drainage	Class	5,6	4	3	1,2
Nutrient availability (n)	Organic carbon	%	>2.0	1.0-2.0	0.5-1.0	<0.5
	Nitrogen content (N)	%	>0.2	0.1-0.2	0.02-0.1	<0.02
	Phosphorus (P)	mg/kg	>40	20-40	5-20	<5
	Base saturation	%	>80	50-80	30-50	<30
	Potassium (K)	%	>3.0	2.0-3.0	0.2-2.0	<0.2
Nutrient retention capacity	Cation exchange capacity (CEC)	mEq/100g clay	>25	13-25	6-12	<6
Rooting conditions (r)	Effective Soil depth	Cm	>50	30-50	15-30	<15
Soil toxicities (z)	Reaction	pH	5.6-6.5	6.6-7.8	7.9-8.4	>8.4
				5.1-5.5	4.5-5.0	<4.5
Erosion hazard (e)	slope	Class	A,B	C	D	>D

DOI: 10.18697/ajfand.87.17555

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 6: Land Use Requirements for rice (*Oryza sativa*)

Land Use Requirements			**Factor rating**			
Land Quality	**Diagnostic factor**	**Unit**	**S1**	**S2**	**S3**	**n**
Temperature (t)	Mean temperature in growing period	°C	22-30	31-33	34-35	>35
				20-21	18-19	<18
Moisture availability (m)	Total rainfall in growing period	mm	650-800	450-650	350-450	<350
Oxygen availability (o)	Soil drainage	Class	1,2,3	4	5	6
Nutrient availability (n)	Organic carbon	%	2.4-4.0	1.0-2.0	0.5-1.0	<0.5 >5.0
	Nitrogen content (N)	%	>0.2	0.1-0.2	0.05-0.1	<0.05
	Phosphorous (P)	mg/kg	>40	20-40	10-20	<10
	Base saturation	%	>75	50-75	30-50	<30
	Potassium (K)	%	>3.5	2.0-3.5	0.5-2.0	<0.5
Nutrient retention capacity	Cation exchange capacity (CEC)	mEq/100g	>25	13-25	6-13	<6
Rooting conditions (r)	Soil depth	cm	>50	25-50	15-25	<15
Soil toxicities (z)	Reaction	pH	5.6-7.3	7.4-7.8	7.9-8.4	>8.4
				5.1-5.5	4.5-5.0	<4.5
Erosion hazard (e)	Slope	Class	A	B	C	>C

DOI: 10.18697/ajfand.87.17555

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4 November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 7: Suitability classes for the different farmers' plots

s/n	LMU	Suitability ranking		
		Maize	Rice	Beans
1	Oguru	S2	S3	S3
2	Barolam	S3	S2	S1
3	Mutema	S2	S3	S1
4	Ogali	S2	S2	S3
5	Lakang	S1	S1	S1
6	Lujoro	S1	S2	S3
7	Pogo	S3	S2	S2
8	Palwong	S2	S3	S3
9	Labala	S2	S3	S3
10	Kal	N	S1	S1
11	Oberabic	S1	N	N
12	Kilak	S3	S3	S3
13	Lebngec	S3	S3	S2
14	Omee 2	S2	S3	S3
15	Palema	S1	S2	S2
16	Abongo	S2	S3	S3
17	Abim	S1	S3	N
18	Oywelo Pagak	S2	S3	S1
19	Kal Centre	S3	S2	S1
20	Maro awobi	S1	S1	S1
21	Olik	S1	S3	S3
22	Labongo	S2	N	S3
23	Lacaro	S2	S3	S3
24	Layima	S2	S3	S3

Key for the codes:
S1= highly suitable, ***S2= moderately suitable,***
S3=marginally suitable, ***N= not suitable.***

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 8: Suitability classes for maize, rice and beans on the various LMUs

LMU	CROP		
	Maize	**Rice**	**Beans**
	Suitability ratings		
Leptosols (Palabek complex)	S3	S2	S2
Acric ferralsols (Anaka complex)	S2	S3	S3
Eutric regosols (Pajule catena)	S1	S2	S2
Leptosols (metu complex)	S3	S2	S2

DOI: 10.18697/ajfand.87.17555

REFERENCES

1. **FAO.** Guidelines: Land Evaluation for Rain-fed Agriculture. Soil Bulletin No. 52. Food and Agriculture Organization of the United Nations, Rome. 1983.

2. **De la Rosa D and CA van Diepen** Qualitative and Quantitative Land Evaluations. Land Use and Land Cover, Encyclopedia of Life Support Systems and Unesco, Eolss Publishers, Oxford. 2002.

3. **Dumanski J, Bindraban PS, Pettapiece WW, Bullock P, Robert JAJ and A Thomasson** Land Classifications, Sustainable Management, and Ecosystem Health. Encyclopedia of Life Support Systems and UNESCO, Oxford. 2012.

4. **FAO.** A Framework for Land Evaluation. Soils Bulletin No. 32. Food and Agriculture Organization of the United Nations. Rome. 1976.

5. **De la Rosa D, Mayor F, Diaz-Pereira E, Fernandez M, and D Jr De la Rosa** A Land Evaluation Decision Support System (Micro LEIS DSS) for Agricultural Soil Protection with Specific Reference to the Mediterranean Region, *J. Env. Modeling & Software.* 2004; **19**: 929-942.

6. **Ogeen AT, Southard SB and RJ Southard** A Revised Storie Index for Use with Digital Soils Information. University of California. 2008.

7. **World Bank Group** Indigenous knowledge and development. http://www.worldbank.org/afr/ik/basic.htm. 1997. (*Accessed on 23rd March 2015*).

8. **Nuwategeka E and M Nyeko** Indigenous Land Suitability Evaluation System of the Acholi Tribe of Northern Uganda. *J. Agri. Ext & Rur. Dev.* 2017; **9(5)**: 97-110.

9. **Seebauer M** Uganda Research Trial Study: Analysis of the Eucalyptus Trials in Amuru District, Northern Uganda. Unique Forestry Consultants, Freiburg. 2011.

10. **Saaty T L** Decision Making with the Analytic Hierarchy Process. *Int. J. Services Sciences* 2008; **1 (1)**: 83-89.

11. **Albert S** How to Grow Green/snap Beans. http://www.harvesttotable.com/2009/03/how_to_grow_green_or_snap_bean/. *Accessed on 17th September 2014.* 2009.

12. **Orimoloye J R, Akinbola G E and M Abubakar** Indigenous Knowledge on Land Evaluation and Soil Fertility Management among Rubber Farmers in Southern Nigeria. *World Rur. Observ.* 2011; **3(2)**: 70-76.

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 19 No. 4 November 2019 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

13. **Mowo J G, Janssen B H, Oenema O, German L A, Mrena J P and RS Shemdoe** Soil Fertility Evaluation and Management by Smallholder Farmer Communities in Northern Tanzania. *Agri., Ecosys. & Env.* 2006; **116**: 47-59.

14. **Sojayya P** Comparison between Conventional Land Evaluation and a Method based on Farmers' Indigenous Knowledge. Master of Science Thesis, International Institute of Geo-information Science and Earth Observation, Enschede, The Netherlands. 2005.

15. **Cools N, De Pauw E and J Deckers** Towards an Integration of Conventional Land Evaluation Methods and Farmers' Soil Suitability Assessment: A Case Study in Northwestern Syria. *Agric., Ecosys. & Envi.* 2003; **95**: 327-342.

16. **FAO.** Soil Map of the World: Revised Legend. Food and Agricultural Organization of the United Nations, Rome. 2005.

17. **Radwanski S A** Soil Memoirs for Uganda. Department of Agriculture, Entebbe. 1967.

18. **Kaaya A K, Msanya B M and J P Mrena** Soil and Land Evaluation of Part of Sokoine University of Agriculture Farm (Tanzania) for Some Crops Under Rain-Fed Conditions. *Afr. Study Monographs*. 1994; **15(2)**: 97-117.

DOI: 10.18697/ajfand.87.17555