

## Original Research Article

# GIS-Based Analysis of Indigenous and Technical Knowledge of Soil Suitability Evaluation of Cocoa, Citrus and Oil Palm

### ABSTRACT

A study was carried out to assess local knowledge about soil suitability in four villages in the Ejisu-Juabeng District in the Ashanti region of Ghana. This study described two approaches in soil mapping using geopedologic approach forwarded by Zinck (1988) and the farmer approach using their spatial knowledge and experience. Both maps were assessed for their suitability for cocoa, oil palm and citrus. First, farmers created their soil map and then assessed the soil suitability for a selected number of tree crops which are important for them economically. Secondly, on the other side which is the side of the expert, the approach for soil suitability classification was performed using the Automated Land Evaluation System (ALES) which uses the Food and Agriculture Organization (FAO) framework for land evaluation that defines suitability by employing matching (comparison) between land quality/land characteristics and land use requirement. The expert and farmer suitability maps were then compared using spatial analysis within the Geographic Information Systems (GIS) environment to determine levels of spatial correlation and the level of agreement among the maps. Farmers' suitability maps for cocoa accounted for 81% of the study area, citrus and oil palm accounted 71% and 26% respectively. In the expert suitability map 66% of the study was suitable for cocoa, citrus and oil palm accounted for 41% and 39% respectively. The overall accuracy from the map comparison was 67% for cocoa, 43% for citrus and 14% for oil palm. The results of spatial correlation between expert and local soil suitability map units reflect differences and similarities in the ways both systems classify soils. Critical is the evaluation of topsoil characteristics, as the understanding and monitoring of topsoil dynamics are fundamental for land use decision-making by farmers. Merging technical and local thinking is indispensable to formulate sustainable land management schemes for agricultural production.

*Keywords: Local knowledge, soil suitability, geopedologic, Ejisu Juabeng, Ashanti Ghana*

### 1. INTRODUCTION

Land evaluation and land use planning provide the framework for predicting the suitability and management of the land resource on the basis of their attributes for a specific land utilization type. Information acquisition provides the basis for the implementation of land-use decisions based on the analysis of land use and land, giving estimated required inputs and the projected outputs in socio-economic settings.

[1] ~~Stated-stated~~ that sustainable land management requires the adoption of land use to the potentials and constraints of the local environment within a socio-economic settings. [2] and [3] among other authors consider land evaluation as an

**Comment [JK1]:** give examples

**Comment [JK2]:** how can information be acquired? Are there different types? If so, which ones?

interface between land resource survey and land use planning. The information obtained from this interaction is used for the formulation of a framework upon which plans and decisions are based upon.

Expert knowledge of land resource survey and the knowledge of those who are associated with the land and natural resources can provide the necessary information as an input for comprehensive sustainable and management of our land resources.

There is a growing interest and recognition of the importance of local technical knowledge in the planning, using and the sustainable management of the land resources. [4] emphasized the need to develop management technologies for sustainable land use with local farmers. [4] argues that most technologies that were developed for farmers do not perform well and stress the need to develop technologies according to the local settings.

The attention paid to local soil knowledge in recent years is the result of a greater recognition that the knowledge of people who have been interacting with their soils for a long time can offer many insights about the sustainable management of tropical soils [5].

According to [1] and [6] by experience, farmers have developed land use systems that are well adapted to the potentials and constraints of their land. The authors stated that farmers have developed informal systems of land quality appraisal based on observation and experimentation which might often be accurate and better adapted than the technical recommendations forwarded by extensionists.

In recent times, there is a growing recognition of the importance of indigenous knowledge in the planning and decision making that relates to the sustainable management of natural resources. This trend is directly related to the growing realization that development efforts that ignore local technologies, local systems of knowledge, and the local environment generally fail to achieve their desired objectives. Indigenous population possesses a store of knowledge and technology that have been accumulated from their direct interaction with the environment.

The Soil Research Institute of the Council for Scientific and Industrial Research in Ghana is mandated for generating information and technology for effective planning, utilization and management of our land and soil resources for sustainable agriculture, industry and the environment. As much as there have been progress in their task, more need to be done when it comes to developing technologies with the farmers at the local level. Results from some of these research findings using contemporary scientific methods are more expensive to be adopted by local farmers. This is substantiated by the statement from [1] that resource professionals use methods for land quality evaluation that often perform poorly when it comes to predicting land productivity at parcel level. This makes conventional research findings difficult to adapt to local conditions. Studying local knowledge of land resources and soils allows for a comprehensive and holistic approach because it is intricately linked to the practical needs of use and management of local ecosystems [7]. For this reason, a comparative analysis of indigenous and technical knowledge of assessing land-soil suitability within the framework of the socio-economic settings to support planning and decision making processes at the local field level.

The objective of the study was to assess the extent to which indigenous and technical knowledge based soil and land resource evaluation approaches complement and contrast each other. While the specific objectives were

1. To assess the suitability of the biophysical attributes of the soils and land resources for crop growth using expert knowledge
2. To elicit and structure local knowledge on selected land use types and the biophysical requirement for land evaluation
3. To compare farmers delineated soil suitability map with the expert soil suitability map

## 2. DESCRIPTION OF THE STUDY AREA

The study area is located in the Ejisu-Juabeng District. Politically the administrative district is positioned in the Centre of the Ashanti region sharing boundaries with Kumasi and Kwabre districts in the east, Afigya Sekyere and Asante Akim North districts in the west and Bosomtwe Kwanwoma and Akim south Districts in south. It lies between latitudes 6°15' N and 6°45' N and longitude 1°15' W and 1°23' W with its capital Ejisu, located 20m away from Kumasi. The district covers an area of 637.4 square kilometers.

Geomorphologically, the district forms part of a dissected peneplain and as a whole, therefore, the topography of the district is generally gently undulating, ranging between 240 – 300 meters above sea level. The study area is situated around the Forest Dissected Physiographic region of Ghana. The soils of the area are developed from metamorphosed sediment principally of phyllites, granites, and Tarkwaian and Voltaian sandstone rock. Characteristically the upper slope soils are well drained and red in colour. Down slope, as internal drainage conditions deteriorate, soil colour change to brown and yellowish-brown. In the ill-drained valley bottom the soils are grey in colour more or less mottled with yellow or orange. The area is well drained with a number of different rivers and streams running through it, some of which are perennial, whereas others are seasonal.

**Comment [JK3]:** Information on what exactly?

**Comment [JK4]:** Name other studies on local soil knowledge

**Comment [JK5]:** Please include a reference for that statement

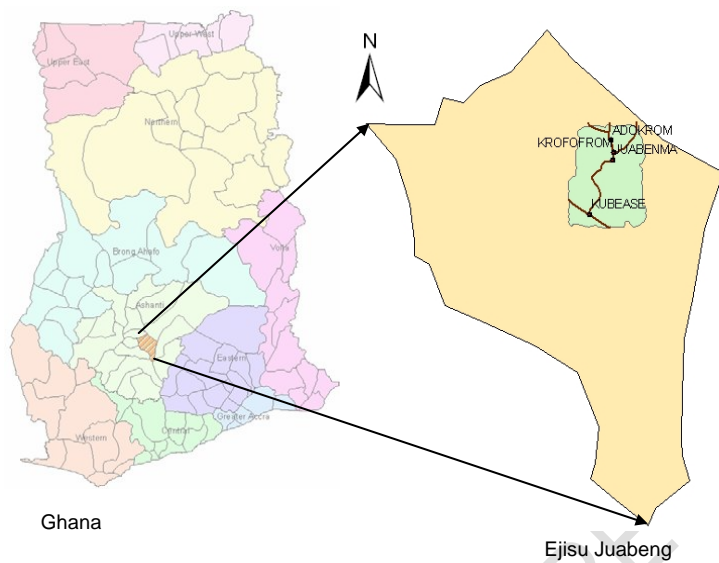
**Comment [JK6]:** Why? Please explain

**Comment [JK7]:** Please define indigenous and technical knowledge or give examples, preferably earlier in the introduction.

**Comment [JK8]:** I do not think you discuss this at the end of your paper.

**Comment [JK9]:** Which biophysical attributes are you referring to?

**Comment [JK10]:** Optional: add information on average rainfall or temperature



**Fig 1.** Regional map of Ghana showing the location of Ejisu-Juabeng District

**2.1 Land use practice.**

Most farmers in the study area own the Land-land and the average farm holdings are 4.9 hectares. The commonly cultivated crops are cocoyam, plantain, banana, cassava, maize, cocoa, oil palm and citrus. Farmers cultivate mixed food crops which dominate in the first few years of perennial crops such as cocoa, oil palm and citrus. -Figure 2 shows how oil palm and cocoa have being intercropped with food crops.



**Fig. 2:** Oil palm intercropped with food crop b) Cocoa intercropped with food crop

**Comment [JK11]:** See comments in the Review Form

**Comment [JK12]:** As I understood from your paragraph above, both oil palm and cocoa are food crops as well. The figure caption is therefore were unspecific (in short: food crop intercropped with food crop). Can you name the other food crops?

The system of farming involves the inter-cropping of food crops with cocoa or oil palm or citrus at the early stage of plantation. Gradually the arable crops are phased out as the canopy of the tree close up completely. This system of farming according to farmers is ecologically and economically sound since it provides adequate protection for the young seedlings, maintain moisture content and also control erosion and emergence of weed.

**Comment [JK13]:** Is there a specific name for this farming system?

**Comment [JK14]:** Is this statement only based on farmers interviews (maybe add reference: personal communication with xxx) or can you add another reference?

### 2.2 Research Approach

This chapter describes the data used and the methods which were followed during this research work. Both secondary data (climatic data, Soil map 1:250,000, Topographic maps, satellite images) and primary data (interviews, farm walk, workshop and soil analysis) were used. The primary data were obtained from the field through interviews, farm walk workshops, profile description and soil analysis. The research approach was in two parts, each corresponds to an output of the studies. The first part deals with farmers' soils and their land suitability maps. The second also accounts for soil map and the land suitability maps base on scientific technical knowledge within the framework of FAO land evaluation [8][9] and the Automated Land Evaluation Systems [10].

**Comment [JK15]:** Where was the climate data used? Is the climate changing throughout the study area?

**Comment [JK16]:** Explain, why was secondary and primary data (and the different data types) used?

**Comment [JK17]:** What was the soil analysed for?

### 2.3 Farmers Approach

Farmers were interviewed in their farms regarding the way they manage their land, land tenure system, cultivation practices, capital intensity, and labour intensity as the key attribute of their land utilization types. The questionnaire that was administered guided the interview in attaining the necessary information on the key attributes. Farmers were interviewed in their farms, at every point where the interview was conducted soil samples (bulk sample) were taken and the x and y coordinates were recorded from a Geographic Position System (GPS) together with the farmers answers to the questionnaire. The interviews also indicated farmers' perception of assessing their soils suitability for cocoa, citrus and oil palm cultivation. Soil names were based on multiple criteria including texture, colour, consistence and stoniness. With the purpose of creating maps that represent farmers' perception of soil within their land units and their potentials for crop cultivation, a workshop was organized for some selected farmers. The farmers verified and validated the information on the various soils within the land units that was obtained from individual farmers during the interview. During the workshop farmers synchronized and characterized the soil units and also ranked crops on the various types of soils according to their yield performance. They also pointed out the limitations of the various soils to the land use types.

**Comment [JK18]:** Which land units were defined?

**Comment [JK19]:** Is the yield performance only based on the soil type or also on the farming system/number of workers etc?



Fig. 3 Workshop with group of farmers

## 3. RESULTS AND DISCUSSION

After the consensus building among the farmers, the various group of farmers representing the different villages sketched the different land unit of their villages with the aid of topographic map with a scale of 1:250000 and with a Landsat TM image (R4G3B2) as a reference point for farmers. After this exercise, farmers were able to identify the various topographic features such as rivers, upper slope, lower and the inland valley and also identified the type of soils in the land unit. The farmers then proceeded in sketching their soil unit boundaries and identified their suitable uses as they have indicated in table 1 and 2. The result of this assignment produced farmers' soil map and their land suitability map.

**Comment [JK20]:** This is part of the methods

**Comment [JK21]:** I do not think this statement is referring to table 2 and table 2 needs another explanatory sentence. Also where do the yield assessments come from? Are they based on actual figures or just estimates?

**Comment [JK22]:** Why are also food crops (which food crops? Are not all of them food crops?) and rice mentioned, if the study focusses on cocoa, oil palm and citrus?

Table 1. Ranking of crop to different types of soils by farmers

Local soil names	cocoa	oil	citrus	food crops	rice	total
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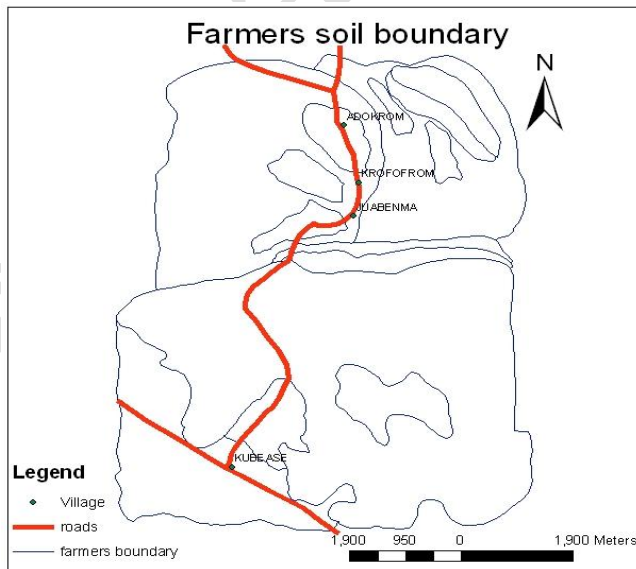
Dotikooko	2	0	1	3	0	6
Dotituntum	2	1	3	4	0	9
Afowea	4	1	0	3	2	10
WuraAnwea	0	1	0	3	2	6
Wura clay	0	2	0	0	1	3
<b>TOTAL</b>	<b>8</b>	<b>5</b>	<b>4</b>	<b>13</b>	<b>5</b>	<b>35</b>

**Comment [JK23]:** What does this row refer to? Is it important? If so, mention in referring paragraph or table caption.

**Comment [JK24]:** Explain what this column is referring to? The total number of fields of these soil type used for the referring crop?

**Table 2: Yield Assessment on the different types of soil by farmers**

Local soil names	cocoa	oil palm	citrus	food crops	rice
Dotikooko	1625kg/ha	0	5000kg/ha	3750kg/ha	0
Dotituntum	1950kg/ha	4-5 tons/ha	3125kg/ha	3750kg/ha	0
Afowea	1300kg/ha	3-4 tons/ha	0	3750kg/ha	1500kg/ha
WuraAnwea	0	4-5 tons/ha	0	1250kg/ha	1500kg/ha
Wura clay	0	3-4 tons/ha	0	0	2100kg/ha



**Fig. 4. Farmers delineated soil boundary**

**Comment [JK25]:** Please see comments in the Review Form.

The farmers' soil maps were scanned and exported to Arc Map software and was then digitized and the various attributes within the various delineated land units were assigned accordingly.

**Comment [JK26]:** This is part of the methods

### 3.1 Expert Approach

The expert suitability maps for cocoa, citrus and oil palm in the study area were created within the FAO framework for land evaluation. The socio-economic survey in the study area which was obtained from key informant during the interviews with the key attribute such as capital intensity, labour intensity, farm size and management practices attach gave the impetus to extract or formulate the land-use requirements and land qualities. A data base with land qualities, land characteristics, soil map units and a decision for suitability was created and was an input into the Automated Land Evaluation System (ALES) version 4.5 developed by [11]. In ALES the suitability assessment is based on matrices and decision tree that allow for the comparison between land characteristics.

**Comment [JK27]:** Which soil types/characteristics or climate conditions are needed for the specific crops?

The expert soil suitability evaluation started with the processing of a base map of the study area. A satellite image (Aster2007) and a Digital Elevation Model (DEM) were exported into Integrated Land and Water Information System (ILWIS) software to generate a three dimension image. The overlay of the raster map over the DEM made it possible to visualize the various geo-morphological features in three dimensions for screen digitizing. With the visualization of 3D, the various Relief types and Land forms were delineated from the landscape using the geopedologic approach by [12]. This procedure involves the interpretation of Aerial photo or satellite image using a stepwise approach according to hierarchical levels of systems. The soil content of the various units within the geoform map was checked in the field. The check was in a form of soil samples analysis and soil profile description. From this, the expert soil map was generated.

**Comment [JK28]:** What is the geoform map?

The result of the suitability maps from ALES and the suitability maps of the farmers were converted into raster format using the same georeferenced base. The maps were overlaid using the GIS cross function in ILWIS software. This operation allows the comparison of pixels at the same position in both maps. The resulting combination gives an output cross table which include the combination of the input suitability classes, the number of pixels that occur in each combination and the surface area of each combination.

**Comment [JK29]:** Where is the resulting map?

A confusion matrix was established from the cross maps and their related cross tables. The matrix was used to determine the correlation percentage of similar technical and indigenous soil suitability classes. The matrix also assessed the spatial accuracy for suitability maps from their combined attribute table.

**Comment [JK30]:** These paragraphs explain the methodology but no results or discussion?

**Table 3: Similarity Matrix for cocoa. Expert vs. Farmer suitability**

**Comment [JK31]:** Please see comment in Review Form

		Expert suitability base on ALES Model					
		Class	1	2	3	Total	User Accuracy
Farmer suitability	1	54.7	3.3	23.7	81.7	0.669119167	
	2	0.6	10.4	4.1	15.1	0.692377756	
	3	0.5	0.7	2.0	3.2	0.617907751	
	Total	55.8	14.5	29.8	100.0		
	Producer Accuracy	0.980823	0.721896	0.06637			

Overall Accuracy	Kappa	d	q	N

67%	0.4	67.1	4871.7	100
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**Comment [JK32]:** Comment on accuracy, kappa, etc? Are the results reliable? Is the accuracy good or not sufficient?

#### 4. CONCLUSION

Comparatively, farmer soil assessment is directly based on the evaluation of the land characteristics that influence land use based on the surface soil characteristics while the expert assessment emphasizes on the sub soil characterization. However, these two knowledge systems reveal some similarity from the spatial correlation.

Farmer created their soil unit maps for the study area. They assigned suitability classes to the soil units. The suitable areas for cocoa and citrus accounted 81% and 70% respectively while oil palm accounted for 26%. When compared with the expert suitability map obtained from FAO framework, there was a very low correspondence in oil palm mainly due to farmers' classification of some soil unit as not suitable whereas the expert classified them as moderately suitable under the ALES model.

**Comment [JK33]:** Where do these values come from? What does this mean? Do not mention new results, especially if they have not been mentioned in the results section before?

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