International Journal of Plant & Soil Science

29(2): 1-8, 2019; Article no.IJPSS.50120
ISSN: 2320-7035

GIS-based Analysis of Indigenous and Technical Knowledge of Soil Suitability Evaluation of Cocoa, Citrus and Oil Palm in Ejisu-Juabeng District, Ashanti Region, Ghana

Edward Calys-Tagoe[1*], Adams Sadick[2], Gideon Asamoah[3] and Mandela Alema[2]

[1]Department of Soil Fertility and Plant Nutrition, CSIR - Soil Research Institute, Ghana.
[2]Department of Soil Analytical Services, CSIR - Soil Research Institute, Ghana.
[3]Department of Soil Microbiology, CSIR - Soil Research Institute, Ghana.

Authors' contributions

This work was carried out in collaboration among all authors. Author ECT designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AS and GA managed the analyses of the study. Author MA managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2019/v29i230139
Editor(s):
(1) Dr. Muhammad Shehzad, Department of Agronomy, Faculty of Agriculture, The University of Poonch, Rawalakot, Azad Jammu and Kashmir, Pakistan.
Reviewers:
(1) Balthazar Michael Msanya, Sokoine Uniiversity of Agriculture, Tanzania.
(2) Juliane Krenz, University of Basel, Switzerland.
(3) R. Shenbagavalli, iNurture Education Solutions Pvt. Ltd, India.
Complete Peer review History: http://www.sdiarticle3.com/review-history/50120

Original Research Article

Received 07 May 2019
Accepted 17 July 2019
Published 07 August 2019

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 promoted 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

**Corresponding author: E-mail: sadickadams1971@gmail.com;*

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 for 71% and 26% respectively. In the expert suitability map 66% of the study area 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 rational basis for the implementation of land-use decisions based on the analysis of land use and land, giving estimates of required inputs and the projected outputs in socio-economic settings.

Cools, Pauw and Deckers [1] stated that sustainable land management requires the adoption of land use to the potentials and constrains of the local environment within a socio-economic settings. De et al. [2], Lagacherie et al. [3] among other authors consider land evaluation as an 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.

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 and sustainable 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. Dittoh [4] emphasized the need to develop management technologies for sustainable land use with local farmers. Dittoh [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 Cools, Pauw and Deckers [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 current 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 type 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 the 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 20 m 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.

2.1 Land Use Practice

Most farmers in the study area own 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. Fig. 2 shows how oil palm and cocoa have being intercropped with 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 trees 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.

2.2 Research Approach

This section 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 based on scientific technical knowledge within the framework of FAO land evaluation [8,9] and the Automated Land Evaluation Systems [10].

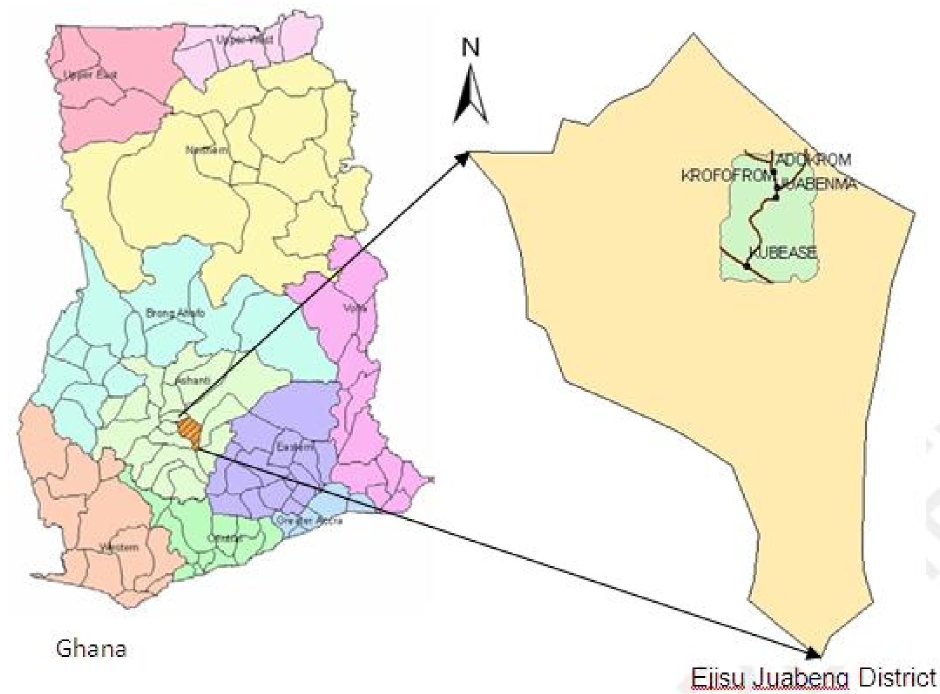

Fig. 1. Regional map of Ghana showing the location of Ejisu-Juabeng District

(a) **(b)**

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

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 attributes 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

Fig. 3. Workshop with group of farmers

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.

3. RESULTS AND DISCUSSION

After the consensus building among the farmers, the various group of farmers representing the different villages sketched the different land units 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 Tables 1 and 2. The result of this assignment produced farmers' soil map and their land suitability map.

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

Local soil names	Cocoa	Oil palm	citrus	Food crops	Rice	Total
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
Total	8	5	4	13	5	35

Table 2. Yield assessment on the different types of soil by farmers

Local soil names	Cocoa	Oil palm	Citrus	Food crops	Rice
Dotikooko	1625 kg/ha	0	5000 kg/ha	3750 kg/ha	0
Dotituntum	1950 kg/ha	4-5 tons/ha	3125 kg/ha	3750 kg/ha	0
Afowea	1300 kg/ha	3-4 tons/ha	0	3750 kg/ha	1500 kg/ha
WuraAnwea	0	4-5 tons/ha	0	1250 kg/ha	1500 kg/ha
Wura clay	0	3-4 tons/ha	0	0	2100 kg/ha

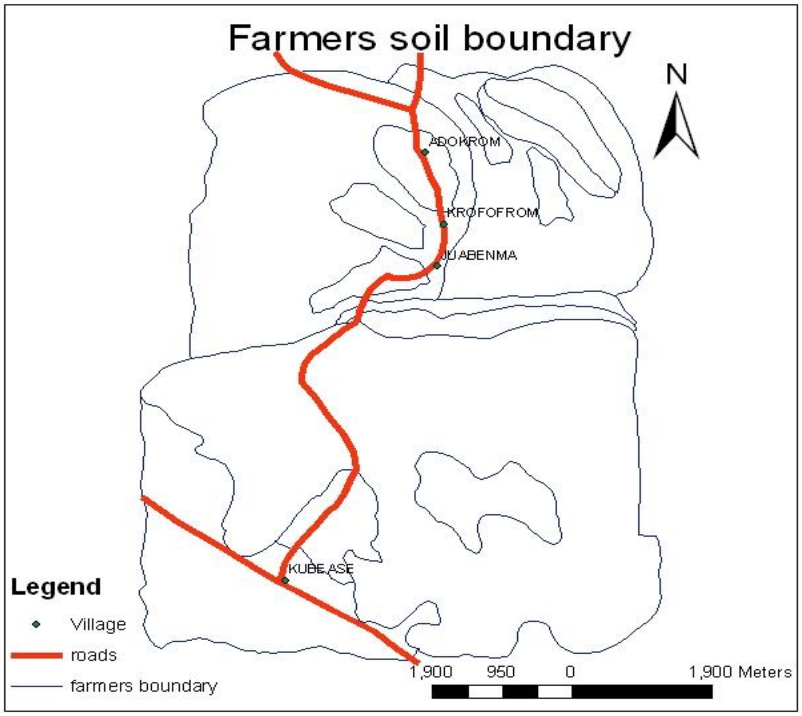

Fig. 4. Farmers delineated soil boundary

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.

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 informants during the interviews with the key attribute such as capital intensity, labour intensity, farm size and management practices 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 Rossiter [11]. In ALES the suitability assessment is based on matrices and decision tree that allow for the comparison between land characteristics.

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 Zinck [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.

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 includes the combination of the input suitability classes, the number of pixels that occur in each combination and the surface area of each combination.

Table 3. Similarity matrix for cocoa expert vs. farmer suitability

	Expert suitability base on ALES model					User accuracy
	Class	1	2	3	Total	
Farmer uitability	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

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 indigenou soil suitability classes. The matrix also assessed the spatial accuracy for suitability maps from their combined attribute in Table 3.

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.

Farmers 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 for 81% and 70% respectively while oil palm accoutred 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 units as not suitable whereas the expert classified them as moderately suitable under the ALES model.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Cools N, De Pauw E, Deckers J. Towards an integration of conventional land evaluation methods and farmers' soil suitability assessment: A case study in northwestern Syria. Agriculture, Ecosystems & Environment. 2003;95(1): 327-342.
2. De la Rosa D, Mayol F, Diaz-Pereira E, Fernandez M, de la Rosa D. A land evaluation decision support system (Micro LEIS DSS) for agricultural soil protection: With special reference to the Mediterranean region. Environmental Modelling & Software. 2004;19(10):929-942.
3. Lagacherie P, Cazemier DR, Martin-Clouaire R, Wassenaar T. A spatial approach using imprecise soil data for modelling crop yields over vast areas. Agriculture, Ecosystems & Environment. 2000;81(1):5-16.
4. Dittoh S. Effective aid for small farmers in Sub-Saharan Africa: Southern civil society perspectives. Under the Canadian food security policy group. University of Development Studies, Temale, Ghana; 2006.
5. Barrera-Bassols N, Zinck JA, Van Ranst E. Local soil classification and comparison of indigenous and technical soil maps in a Mesoamerican community using spatial analysis. Geoderma. 2006;135:140-162.
6. Alves AGC. Local knowledge and soil use: An ethnopedological approach. Interciencia. 2005;30(9):524.
7. Barrera-Bassols N, Zinck JA. Ethnopedology in a worldwide perspective: An annotated bibliography. ITC Publication. ITC, Enschede. 2000;77:636.
8. FAO. Guidelines: Land evaluation for rainfed agriculture. FAO Soil Bulletin. Rome. 1983;52.
9. FAO. A framework for land evaluation. Soil Bulletin 32, FAO, Rome. 1976;116.

10. Rossiter DG. Automated Land Evaluation System: ALES version 4.65 user's manual. SCAS teaching series; T93-2 revision 6. Cornell University, Department of Soil, Crop & Atmospheric Sciences, Ithaca. 1997;279.

11. Rossiter DG. A theoretical framework for land evaluation. Geoderma. 1996;72(3-4): 165-190.

12. Zinck JA. Physiography and soils: Soil survey courses subject matter K6, ITC, Enschede; 1989.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle3.com/review-history/50120