SOIL QUALITY IN THE VOLTA REGION OF GHANA – RECONCILING RICE FARMERS' PERCEPTION WITH SCIENTIFIC EVIDENCE

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ABSTRACT

The Volta Region of Ghana is the third largest producer of rice in the country, producing about 83,936MT per annum which is about 17% of total national production. The government of Ghana has identified rice as a priority crop in the region for poverty reduction and ensuring food security, and thus has formulated policies to boost production. Intense rice production however demands that appropriate soil fertility management strategies are put in place to ensure the soil resources in the region do not deteriorate. The farmers' perceptions and their ability to evaluate soil quality and adopt appropriate management techniques therefore becomes relevant and needs to be investigated and compared to existing scientific soil knowledge for a participatory management of the soil resources in the region. This study explored and identified the most important soil quality indicators known and used by farmers in the classification of their soils. Farmers' relations and concepts towards the identified indicators were also assessed. Finally, the research investigated how farmers' perception about soil quality indicators matches with scientific evidence. The mixed method approach was the main study design employed in conducting this study. Participatory rural appraisal (PRA) tools such as focused group discussions, individual interviews and pair wise rankings were the main methods used to collect data from 124 rice farmers in three rice growing districts of Biakoye, Jasikan and Kadjebi in the northern Volta Region of Ghana. Soil samples from selected rice fields were also collected at plough depth of 0-20cm for laboratory analysis and for subsequent comparisons with farmer opinions. Qualitative content analysis was the main method used for data analysis of all transcribed interviews. Collected soil samples were analyzed quantitatively using standardized laboratory procedures. Research findings revealed that in all farmers were able to name 20 soil quality indicators out of which five (vegetation cover, soil color, earthworms, soil structure and texture) turned out to be the most important used by the farmers for soil quality evaluation and classification. Based on these indicators five major local soil types *(tordor, ntaariɛɛ, ojeka, apibour and montro)* were also named and classified by the farmers. Farmers have locally created terms for fertility management and strategies which matches well with scientific terms. With respect to soil chemical analysis, it was revealed that on the whole farmers' assessment merges well with the measured soil chemical parameters. The study concludes that indeed farmers have a relatively good and broader view of soil fertility and its' management focusing more on top soil features rather than sub soil characteristics as compared to scientists. The study therefore recommends a participatory development of extension contents to train farmers on innovative ways of maintaining soil fertility with a focus more on motivation and reinforcement of farmer knowledge as it is evident farmers already possess a considerable amount of soil knowledge.

Keywords: Rice farmers, Soil quality indicators, Soil fertility, Local knowledge, Scientific Knowledge

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1. Introduction

The decline in soil fertility is now a key worry for policy makers worldwide. In Sub-Saharan Africa, it is considered a matter of urgency as failing food production is associated to subsistence crises and that unless curtailed, many parts of the continent would increasingly become food insecure (ROY & NABHAN, 1999; SCOONES & TOULMIN, 1999). ROY & NABHAN, (1999) argued that the consequences of allowing the continual degradation of Africa's soil resources would be severe not only for individual countries' economy but for the welfare of millions of rural households whose livelihoods depends on agriculture (ROY & NABHAN, 1999). The World Bank and the Food and Agricultural Organization (FAO) in 1996 for instance, adopted a Soil Fertility Initiative for Sub-Saharan Africa as a way of mitigating the problem of soil fertility decline in the continent. The aim of the initiative was to solve the problem of soil productivity decline through the recognition of and building upon existing local soil knowledge and farming systems, as well as soil and nutrient management practices that will lead to a sustained agricultural productions for future generations (ROY & NABHAN, 1999). As a follow up to this initiative, and to emphasize the importance of soil in food production and the development of agriculture, the FAO again declared the year 2015 as the international year of soil to show its' commitment to preserving and improving the world's soil resources (CHEMNITZ & WEIGELT, 2015). This placed soil in the limelight of the world as one of the most important resources in agricultural and rural development.

However, debates on the best ways on maintaining the soil is still ongoing as there are no fixed solutions due to the dynamic nature of soil systems which are specific to their locations. Review of literature depicts a considerable divide in the scientific world which has led to different soil classification systems like the FAO, the USDA and the French soil classification systems. There is also the division between scientists and the real users of soil fertility management technologies who are the farmers (INGRAM ET AL., 2006). This situation has led to a number of experts referring to soil fertility management on smallholder farms as being a complex activity and therefore calls for active participation of farmers and scientists for collaborative efforts towards the designing of a sustained soil improvement strategy, that is adaptable in the specified localities, for enhanced agricultural productivity (WEBER 1956; LONG 1992, TSOUVALIS ET AL., 2000; MORGAN & MURDOCH, 2000; FAIRHEAD & SCOONES, 2005; MOWO ET AL., 2006; INGRAM ET AL., 2006).

Local soil knowledge defined by (WINKLERPRINS, 1999 P 151) as *"the knowledge people living in a particular environment for some periods of time have of soil properties and soil"* is now widely recognized to exist and to be of practical value. It is increasingly understood that for development purposes, local soil knowledge can be a better starting point for communication than scientific soil classifications such as the FAO, the USDA or the French soil classification systems (HABARUREMA & STEINER, 1997; NIEMEIJER & MAZZUCATO, 2003). In the last two decades there have been increasing recognition that indigenous knowledge can yield insight into soil quality (BARRIOS & TREJO, 2003; LIMA ET AL, 2010; HAGEL ET AL., 2013). A number of studies have demonstrated the importance of indigenous knowledge in agricultural research and extension (SCOONES & THOMPSON, 1994; MULDER, 2000; LIMA ET AL, 2011). Some have also looked at the duality of scientific and folk knowledge to try to explain the differences in perceptions held by the scientific world and that held by the local farmers (see TSOUVALIS ET AL., 2000; MORGAN & MURDOCH, 2000; FAIRHEAD & SCOONES, 2005; MOWO ET AL., 2006; INGRAM ET AL., 2006). Whilst others also accentuate the socio-cultural dimensions of knowledge and have designed their research in terms of contradictory world of thoughts, knowledge cultures and different conceptions of reality (WEBER 1956; LONG 1992, TSOUVALIS ET AL 2000; INGRAM ET AL., 2006). Conversely, only few have tried to comprehend the type of link that exists between the natures of soil knowledge posses by local farmers and that held by the scientific community. It is true that the relevance of local knowledge may include potential 'local relevance and sensitivity to complex environmental interactions' but without inputs from science local definitions can sometimes be limited and will not be able to cope with prevailing environmental changes. Therefore the participatory approach of capitalizing on both knowledge systems could allow the surpassing of site specificity challenges and empirical nature of knowledge and thus give way to 'extrapolation' of knowledge over time (COOK ET AL.., 1998; BARRIOS & TREJO, 2003). AS WINKLERPRINS, (1999) and *(*DAWOE ET AL., 2012,) stressed respectively that, it is important that local knowledge is linked to scientific soil knowledge for a sustainable land management since *"the hope* *of sustainable agriculture rests on the integration of all experiences instead of the over reliance on one tradition at the expense of the other" (*DAWOE ET AL., 2012, P 97).

However, with regards to Ghana, especially in the Northern Volta Region which falls in the semi-deciduous zone of the country, literature is missing on the perceptions the local farmers have on soil quality indicators and how these influences their management and adoption of specific local soil management strategies as against scientific practices. Understanding the knowledge and perceptions of the farmers on soil quality indicators could make communication between the farmers and scientists or stakeholders working to promote soil management in the region to be more efficient and the implementation of soil protection strategies improved. In view of this the paper explored and analyzed to what extent the perceptions of rice farmers on soil quality and fertility management differ from scientific evidence and practices with specific objectives being;

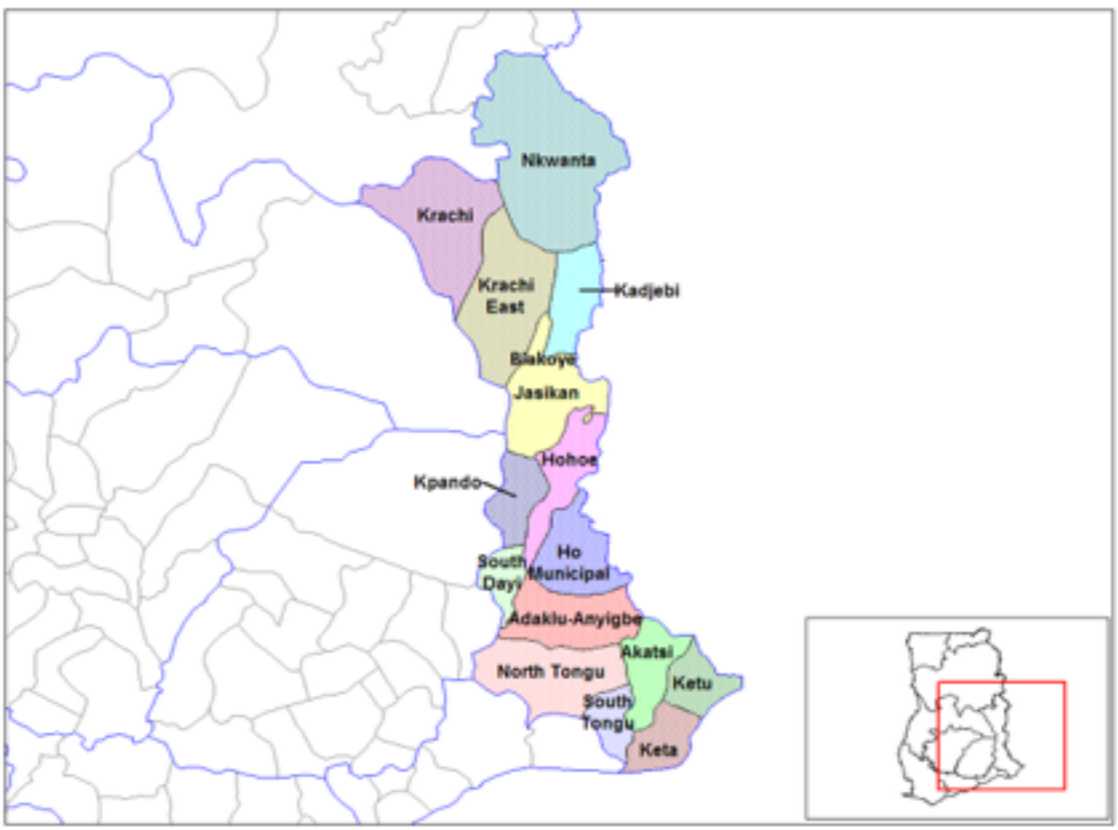
- Identification of the most important soil quality indicators known and used by farmers for fertility assessment
- How farmers use and perceive the identified indicators with regards to soil fertility evaluation and management
- Identify how farmers' perceptions match with scientific evidence.

2. Methods of Data Collection and Analysis

2.1 Site description

The research was carried out in Ghana, West Africa with smallholder rice farmers in the districts of Biakoye, Jasikan and Kadjebi located in the northern Volta Region of Ghana. Twi, Buɛm and Ewe are the major local languages spoken by the natives of these districts. Christianity, Islamic and traditional religion is the major religious practices found in these districts. The districts are heterogeneous in ethnicity but are strongly connected by these common religious practices and local languages spoken. Agriculture is the backbone for economic development in the districts with subsistence farming as the dominant agricultural practice. The total population of the districts based on 2010 population census is 184,385 with an average land holding size of less than 1ha. The districts fall within the semi-deciduous rainforest zones of the country with an average annual rainfall ranging between 1250mm – 1800mm during the dry and wet seasons respectively. Rainfall pattern in the districts is bimodal with the average annual temperatures ranging between 22^{o}C and 34^{o}C during both seasons. Topography within these areas is undulating and hilly with mountain ranges surrounding most of the areas. The soils are relatively fertile ranging from sandy loam to silty clay with forest Ochrosol which includes the alluvialoams found mostly along the major rivers to the west and southern parts of the districts (GHANA, 2014).

Figure 1: Map of Ghana showing research locations



Adapted from GOOGLE MAPS, 2016

2.2 Data collection

The mixed methods research design (CRESSWELL ET AL., 2003) was employed in carrying out this study. Purposive sampling technique was the main methods for drawing participants from 12 villages for data collection at both the community and household levels. The main approach to data collection was interviews using semi-structured interview guidelines. Focused group discussions, individual interviews, rankings and transect walks were major tools used in collecting farmer perceptive data on soil quality and fertility management. Review of major literature, expert interviews, laboratory analysis of collected soil samples served as data collected from the scientific perception of soil quality and fertility management which were used to compare farmer opinions. Interview guides were pre-tested in 2 different rice farming communities and this helped in the reformulation and modification of the interview guidelines to ensure the right data to achieve study aims were collected. 124 farmers were interviewed in groups of 10 rice farmers from 12 different rice growing towns using semi-structured interview guides and this served as data collected mainly out of focused group discussions (FGDs). After each FGD section, 2 farmers who own their field were selected for further in-depth interviews followed by collection of soil samples for laboratory analysis. Farmers were also asked during individual interviews to intuitively rate their soils as part of the general exploration of farmer soil knowledge about their fields which were later compared to scientific ratings to see how far they matched or deviated from each other. Land owners were selected for further interviews and not those renting in order to minimize errors due to possible lack of knowledge regarding the management of their fields. During interviews (FGDs and individual), farmers were taken through series of discussions with questions like *"can you tell me in general what you know about your farm / land / soil?"*, "*what makes a good / bad soil"* to *"what do you use these indicators for?"* These were entry point questions to incite discussions and to as well get from the farmers view / perspective what they know about their soils. Interviews were conducted in Twi a major local language spoken by the farmers. These were tape recorded and later transcribed for further analysis.

2.3 Analysis of data

Hsieh's qualitative content analysis (HSIEH, 2005) was used for data analysis for all interviews. Firstly, a preliminary review of all transcripts was made while congruently noting down interesting information or topics emanating into a Microsoft spreadsheet. The notes made were then re-read and different types of information found were listed down. The lists obtained were then categorized. From this categorization, major or minor themes, subtopics, relevant phrases and story lines that explained the concepts and knowledge of soil indicators and fertility management were obtained. After this a second but an in depth review of all themes, main or subtopics were compared and contrasted. Furthermore, the frequencies of occurrence of specific themes or topics in the transcripts were counted and noted down. These were rearranged in degrees of importance in order to give meanings to words used and ascertain the relevance of such themes from the farmers' perspective. Where necessary farmer quotes from the transcripts were used to support specific topics or themes to give a deeper understanding on how farmers discussed major themes or topics that emanated from the various discussions or interviews. After all the themes, factors, or topics were clearly structured, further analysis on each theme or topic was conducted by constant reading of transcripts repeatedly. With the support of relevant scientific literature, themes or topics were interpreted to give clearer meanings to farmer views that came out from the transcripts. The Kendall's text of concordance (SUGRI ET AL.., 2012) was used to confirm farmer agreement on the most important soil quality indicators that emanated from rankings.

2.3.1 Soil sampling and chemical analysis

37 soil samples from 11 selected farmer rice fields were collected using the grid method of sampling (WOLLENHAUPT & WOLKOWSKI, 1994). The collection of samples was done at a plough depth of 0-20cm using the auger on farmer rice fields at the end of every individual interview. Soils were sampled from single farmer rice fields without site fertility classification into fertile and infertile soils. Soil samples were taken in a ratio of 1:2 weighing 100g each. Soil samples were then transferred to the soil laboratory for further chemical analysis. The collected soil samples were air-dried for 2 days, homogenized, grounded and passed through a 2mm sieve for a routine chemical analysis. The following analysis was conducted to obtain the various results from the soils sampled. Soil pH was done in water using a ratio of 1:2.5; Organic carbon (OC) was done by Walkley and Black methods (WALKLEY & BLACK, 1934) and Nitrogen (N) was determined by the wet oxidation Kjeldahl method (KJELDAHL, 1883). Available phosphorus was determined by Bray1 (BRAY & KURTZ, 1945) method. The soil exchangeable cations, that is Potassium (P), Calcium (Ca) and Magnesium, (Mg), amounts were extracted and analyzed after leaching the soil with 1molar (1M) of ammonium acetate (NH_4OAC) at pH 7. Values of P, Ca and Mg were then determined by an atomic absorption

spectrophotometer and a flame Photometer. Soil texture was determined by the hydrometer method and calculated using the USDA soil texture calculator. Since farmers were made to rate their fields during individual interviews in degrees of fertility, a scientific rating was made using laboratory results from 7 soil nutrient indicators (NPK, %OC, pH and Ca:Mg). These were compared to farmer ratings to see how far they matched or deviated. Calculations of the scientific rates were done using optimum[1] nutrient requirements for tropical rice fields proposed by (LANDON, 1991; SIÉ ET AL, 2008) as the basis for the calculations.

3. Results

3.1 Most Important Farmer Indicator for Soil Fertility Evaluation

20 local soil quality indicators were named by the farmers for fertility evaluation. Following (DESBIEZ, 2004 & DAWOE ET AL., 2012) methods, these indicators were grouped into (table 1):
(a) Soil characteristic indicators (soil color, texture);
(b) Crop performance indicators (vegetation growth);
(c) Biological indicators (earthworms) and
(d) Topographical indicators (slope of land).

Farmers accounted that black soil was not an important indicator for fertility assessment as they are other soil colors like the red and grey soils which are equally fertile. Thus the role of soil color as a fertility indicator was linked to the presence of earthworms due to the presence of different colors of fertile soils.

[1] Note: compiled scientific rates are optimum requirements and not standards found in all tropical soils. For site specific fertility assessment or fertilizer recommendations it is advised a thorough soil analysis is conducted for the site in question. However these rates can serve as a guide.

Table 1: Classification of named soil quality indicators with supporting farmer statement

Soil Indicator	Supporting Farmer Statements
Soil Physical Characteristics e.g. soil color, texture, structure	*[...], "it is true the color even tells us which crop will do well on a particular land,[..], both the black and red soils are important to us*[08.4]*."*
Biological e.g. earthworms	*"Some of us when we see earthworms or earthworm droppings (Anansekofie) is an indication that the soil is fertile*[01.2]*".*
Crop performance e.g. vegetation growth	*"When Acheampong is on the field and its leaves are green, it means the land is good, also when spear grasses are there, we can conclude the land is not fertile*[1]*".*
Topography e.g. slope of land	*"My land is not in the valley like the others, so it is not flat, when it rains it mostly washes the top soil away, it used to be black but now it only left with the sand*[2]*".*

5 indicators out of the 20 named indicators were ranked as the most important indicators used by the farmers for fertility evaluation. These were vegetation cover, soil color, earthworms, soil structure and texture (table 2). These indicators are physical characteristics based on the surface layer of the soil. Vegetation growth was the most important indicator for fertility evaluation out of the 5 due to farmer usage of the occurrence specific native plant species on the soil to differentiate between a fertile and an infertile soil. Native plant species like *alfalfa* (*Medicago sativa)* or *'Acheampong' (Chromolaena odorata)* are found on fertile soils whilst species like '*Yaa kankan' (Ageratum conyzoides)* or *'sobge'* (*Heteroprogon contortus)* occur on infertile soils or soils with low fertility (table 3).

Table 2: Farmer ranking of most important soil quality indicators for fertility evaluation

Farmer indicator	FGDs	Individual interview
	Ranks	
Vegetation growth	1 (1.7)	1 (1.5)
color	2 (2.5)	2 (2.3)
Earthworm	2 (2.5)	2 (2.3)
Structure	5 (3.1)	4 (3.5)
Texture	4 (3)	5 (3.6)
	Test statistics	
Kendall's W	0.06	0.10
X^2	2.70	10.54
df	4	4
p-value	0.61^{NS}	0.03^{S}

( ) = Actual farmer rankings N=124 n = 26[2]

[2] Twenty six individual farmers took part in the ranking exercises-but only 11 farmers were interviewed in-depth

Table 3: Local and scientific names of weed indicators for soil fertility evaluation

Local name of plant/weeds	Scientific name	
	Common on good soils	Common on bad / dying soil
Acheampong	*Chromolaena odorata*	
Sogbe		*Heteroprogon contortus*
Kuffour / Mahama grass		*Acmella radicans*
Alfalfa	*Medicago sativa*	
Jenja / Ohomo	*Tithonia diversifolia*	
Techie Willington / Yaw dente	*Cetrosema pubescens*	
Yaa kankan		*Ageratum conyzoides*
Enyina	*Momordica charantia*	

3.2 Farmer Soil Types and Terminologies for fertility management

Based on the characteristics of the named indicators, farmers classify their soils into five main soil types on the basis of slope of land, soil color, texture, water holding capacity, soil workability / structure and soil suitability to crops (table 4). *Ntaariɛɛ, tordor*, *and abondo* are names for soils found on rice fields. Whilst the rest were soils found on other crop producing fields. Farmers attached high economic significance to both *tordor* and *ntaariɛɛ* since these were considered the most suitable soils for rice cultivation and the cultivation of other crops.
From the farmers account, the most important soil type with respect to rice production was *"ntaariɛɛ"*, a common term used to describe soils found in the valleys where rice is cultivated. When quizzed why the term *"ntaariɛɛ"*? Farmers could not give any precise explanations except one farmer who said; *"[...], that is how it has been called by my grandparents, I think it was because it is located on the flat lands in the valleys, mostly sticky and water logged most of the time and the only crops they grow there was rice*[5]*".* Due to variations in local dialects same soil types were named differently in different villages and districts. For example farmer description of *atɛkyɛ* from one village largely corresponds to farmer description of *ntaariɛɛ* from the other village. This observation was due to the fact that same soils could be named differently by members of the same ethnic group but from different villages due to variations in languages and oral accounts of historical changes that are specific to the towns in questions as was also found out by (WINKLERPRINS, 1999).
Apart from local soil classifications by the farmers, they also have varied local terminologies used to describe soil fertility status which served as a medium of communication on the best fertility management strategies to adopt (table 5). The local terminologies were reported in 3 local languages of Twi, Ewe and Buem. The terms *Asaase*/Anyinbga*** (land) and *noteɛ / ɛke*** (soil) were frequently used to replace each other since the meaning for both terms were the same. With regards to soil fertility, the following terms were used to describe the various degrees of soil nutrient availability. Soils that are fertile and could support plant growth were generally referred to as *sradeɛ wor asaase nu mu** (fatty land / fertile soil), or *Wunsɛ anyingba*** (a strong land/fertile soil). Whilst soils with decreased or depleted soil fertility were described as *ebrɛ aba asaase nu mu** (a stressed land / reduced soil fertility) and *aduane asa** (food is finished in the land / depleted soil fertility). *Asaasea enyini** is a term used by the farmers to describe a fallowed land that has regained its fertility status. From the farmers' perspective depending on the degree of soil nutrient depletion, any

one of the following local fertility management strategies on table 6 will be adopted as a way to solve the problem.

Table 4: Reported farmer soil types with characteristics

Farmer soil type	Study location / District	Characteristics					
		Slope	Color	Texture	Water holding capacity	Workability	Crop suitability
Tordor	1, 2, 3	Undulating	Black/ ash	Not very smooth when rubbed, sticky when wet, cracks heavily on drying, **(sandy clay)**	Holds an appreciable amount of water, can be water logged	Easily workable	Almost all crops, mostly rice
Lɛja/atɛkyɛ/ ntaariɛɛ	1,2, 3	Flat	Red/ brown/ grey/ black	more rough between fingers, feels compacted and slimy when wet, Cracks when dry **(sandy clay)**	Holds a lot of water, waterlogged	Difficult to work when wet	Rice, Okra
Abondo, Ojeka, Konwimgo/ Conwlilo	2, 3	Up-hills	Red/ brown /black	Feels gritty in the palm, holds loosely when molded, cracks less when dry **(sandy clay)**	Holds appreciable amount of water, Easily drains	Not difficult to work when wet	Rice, Okra, Cassava, Tomatoes, Groundnut, Maize, Onions
Embusaea/ Apibour*, Tumbutey**	1,3	Up-hills	White/ red/grey	Very rough **(stony)**	Drains very quickly	Difficult to work	Cocoa, cassava, yam
Montro/ Kowadjele**	1,3	Up-hills	White/ pink	Very smooth and looks like paint **(clay)**	Water logging	Difficult to work	Cocoa

Districts: 1=Kadjebi; 2= Jasikan; 3= Biakoye *=Not found on rice fields () = Farmer soil texture prediction

Table 5: Local terminologies for soil fertility practices matched with scientific terms

Local terminology	Literal meaning	Scientific term
Sraadɛɛ*/Amii**/ Aduane*	Fat/ Food	Soil nutrients
Asaase*/Anyingba**	Land/Soil	Soil
Ahɔnden*/ Wunsɛ**	Strength	Soil fertility
Asaasea eyɛ den	Hard/dried land	High density/Dried land
Asaase nu abrɛ	The land is tired	Reduced soil fertility
Ahɔnden asa / Aduane asa	Soil strength is finished	Depleted soil nutrients
Asaase tumtum/korkor/fiitaa	Black/red/white soil	Dark/red/light soil
Asaasea eye twaan	The soil is sticky /Elastic	Clay soil
Asaasea nsuo djinamu	Water logged soil	Water logged soil
Beposo*/Kodzi**	On the hill soil	Upland soil
Ntaarieem/Tarieem	In valley bottom	Lowland soil
Asaase monomono	Fresh land	Virgin land
Katree	Empty land	Desert/Bare land
Embusai*/ɛkpɛɛ**/Tumbutey**	Small stones	Gravels
Daa***	Silt	Silt
Nsunusunu*/ Vorkli**/Bafona***	Earthworm	Earthworm
Leba***/Leja***	Loam soil	Loamy soil
Enwuraa*/ ɛgbɛ**	Grasses	Weeds
Kala*/Korla**	Color	Color
Anasekoofiɛ*	Small mounds	Earthworm droppings
Asaasea enyini	Matured land	Fallowed land

Twi*: Ewe**: Buem***

3.3 Locally Adopted Soil Fertility Strategies

Farmers have adopted local fertility management strategies based on farming experience and interactions with the local environment. When asked the question: *"what do you do to maintain or improve soil fertility?"* farmers named at least one of the following common practices found in (table 6). The most popular system adopted by the farmers was the application of inorganic fertilizer which was attributed to ease of application and as a recommended practice from extension agents and

NGOs that mostly distribute new varieties of rice seeds. The least popular among the local fertility management systems was manure application which farmers said was due to scarcity since they rarely keep farm animals. Farmers also face certain challenges that prevent them from getting maximum benefits from their widely adopted local fertility management strategies. Farmer knowledge on major soil constituents were limiting and this affected farmer motivation to recognize the significance of their local soil knowledge, resulting in farmer usage of inorganic fertilizer more relative to other cost effective local methods.

Table 6: Local soil fertility management strategies and major limitations[3]

Local term for fertility management	Number of farmers who mentioned strategy	Common/Scientific term	Limitations
Yɛ gu fertilizer	115	Inorganic fertilizer application	Cost of fertilizer, scarcity
Yɛ de chaffs gu asaase no so	90	Spreading of rice straw on land	Labor, capital
Yɛ gu ɛduro hye nwura no	75	Minimum tillage/chemical weed control	Cost of chemicals, capital
Yɛtwa nwura na y'ahye no	45	Slash and burn	Bush fires
Yɛ gya asaase no tu hɔ	40	Fallow	Land scarcity, growth of population
Yɛ de mmoa bini gu asaase no so	10	Application of farm animal manure	Labor, scarcity, scent

3.4 Local factors influencing soil quality

Farmers' concepts of soil fertility improvement go beyond the nutrient status of the soil but instead the interactions of other local factors ranging from socio-economic to socio-cultural factors (table 7). At the local level farmers discuss these factors as important factors influencing the adoption of specific fertility management strategies and subsequently soil productivity. Socio-economic factors which include money and labor was the most influencing factors affecting soils productivity from the farmers' perspective. From the farmers views availability of money determines whether they can afford to buy a fertilizer or hire a power tiller for land cultivation which also influences the fertility level of the soils. However some farmers were also of the view that land scarcity due to population increase in the districts also influences their interest to either invest in soil fertility strategies to

[3] It is worth noting that all soil management practices mentioned by farmers were what they know to do as a way of conserving or improving soil fertility. It is however sad to note that none of these were consciously practiced / done by most of the farmers interviewed

improve the fertility of the land or not, since most of them are renting and may leave the land in the shortest possible time.

Table 7: Local factors influencing soil quality

Local factors	Occurrence
Socio-economic	55
Perceived soil degradation	44
Environmental	32
Topographical	17
Land tenure	12
Socio - cultural	4

3.4 Farmer Soil Quality Evaluation Matched with Soil Analysis

Ntaariɛɛ and *Tordor* were the predominant soil types used for rice cultivation on farmer fields visited in all study sites. *Ntaariɛɛ* on average was rated by the farmers as the more fertile soil for rice cultivation in comparison to *tordor.* All the soil types were rated moderately fertile from both the scientific and farmer rates respectively. The rates ranged between 1.50 – 2.25 for farmers and 2.30 for scientific rates for the identified soil types, therefore indicating slight variations between the two types of soil ratings (table 8). Table 8 shows soil chemical results from the selected rice fields in average values. Mean pH within the study sites recorded for the two soil types ranged from 6.6 – 6.9 indicating neutral pH levels which is suitable for rice cultivation. Soil texture for both soil types (*ntaariɛɛ* & *tordor)* was recorded to be sandy clay loam. Mean values for percentage organic carbon (%OC) was 3.0 showing a relatively high OC content for the soils. Averagely nitrogen (%N) contents for the two major soil types found in the three districts ranged from 0.28% - 0.30%. The average C/N ratio was between 10.43 to 10.71, whiles average values for phosphorus (total P) was between 10.62mg/kg to 13.76 mg/kg across the study sites for the named soil types. Average values recorded for soil exchangeable cations (K, Ca & Mg,) were 163mg/kg - 169mg/kg, 2.70cmol+/kg - 4.26 cmol+/kg and 2.08 cmol+/kg - 2.49 cmol+/kg for the soil types identified in the respective districts. The soil type *tordor* recorded the highest value in all the exchangeable cations compared to *ntaariɛɛ*, the soil type identified in the Kadjebi district recording the least values in K, Ca, and Mg respectively. The recorded values of NPK for the soil types indicates limiting NPK conditions in the two soil types used for rice cultivation from the farmer field sampled in the districts. Comparing the results from soil chemical analysis with farmers' opinions based on famer ratings and the scientific rates shows a high degree of similarities between what farmers say about their soils as compared to analyzed soil chemical properties.

Table 8: Average results of soil chemical analysis from named farmer soil types[4]

Farmer soil type	Soil Physico-Chemical Properties													Textural class	Farmer rate (1-3)	Scientific rates (1-3)
	pH	OC %	OM %	N %	C/N	P mg/kg	K mg/kg	Ca cmol+/kg	Mg cmol+/kg	Ca/Mg	Sand %	Silt %	Clay %			
Ntaariεε[1]	6.92	3.03	5.21	0.29	10.45	12.63	162.99	2.70	2.08	1.30	66.23	13.59	20.19	Sandy clay loam	1.50 Std(0.71)	2.30
Tordor[2]	6.59	3.00	5.16	0.28	10.71	10.62	169.50	3.63	2.49	1.46	61.38	14.15	24.54	Sandy clay loam	2.25 Std(0.5)	2.30
Ntaariεε[3]	6.61	3.13	5.38	0.30	10.43	13.76	164.15	4.26	2.23	1.91	61.60	13.07	22.98	Sandy clay loam	1.80 Std(0.45)	2.30

1= Kadjebi district; 2= Jasikan district; 3= Biakoye district N=11
Stdv = Standard deviation

Rate: 1= fertile; 2= moderately fertile; 3=low fertility

[4] Soil results presented are in average values per soil type found in a district. E.g. *Ntaariεε* was the main soil type found in all farmer rice fields in district 1. So all values for *Ntaariεε* in district 1 were averaged and that is what is presented on the table as main results. The procedure is repeated for the other soil types in district 2 and 3 respectively.

4. Discussion

4.1 Farmer soil knowledge

Farmers in the study districts predominantly evaluate soil fertility by using soil physical characteristics based on top soil properties. Principally vegetation growth, soil color, earthworms, soil structure and texture were the main soil quality indicators farmers use to determine the fertility of the soil. The most important indicator is vegetation growth which is contrary to the results from other similar studies like (LIMA ET AL., 201; DAWOE ET AL., 2012, & YESHANEH, 2015) which found out that the most important indicator for local fertility assessment was soil color. From these related studies, it was observed that farmers linked soil fertility to black soils due to the presence of high organic matter and earthworm or microbial activities. But this was not the case with the farmers from this study as they have other soil types which are not black but equally fertile and support rice production due to the presence of high organic matter and earthworms. The use of vegetation growth as a main soil quality indicator by farmers over the other identified indicators was linked to the farmers' ability to easily differentiate a good soil from a bad soil from a distance due to the nature of growth of the vegetation or occurrence of specific native plant species on the fields. This practice was due to the abundance of different plant species in the study location, which falls in the semi-deciduous forest zones of the country, and so the use of vegetation cover as a first indicator for fertility assessment becomes important and relatively easier compared to the other indicators. "*Before I even get to a land, I start observing the nature of growth of the weeds and crops from a distance [..] and if the leaves are very green, it is a clear indication that the soil is very fertile and anything I grow there will produce a lot₃'*[5] *a* farmer accounted.

Studies have shown that vegetation cover can lead to a reduced use of inorganic fertilizer because the natural biomass often serves as an organic fertilizer for most uncultivated fields after some periods of time (see MURAGE ET AL., 2000; BARRIOS & TREJO, 2003; LIMA ET AL., 2011; DAWOE ET AL., 2012). Farmers accounts in the study location however confirms this assertion as they believe that, the falling and decomposing of the leaves, branches or the entire biomass of the vegetation has enormous contribution to soil fertility improvement. More so, BARRIOS & TREJO (2003) also found out that, the most important soil quality indicators for farmers from different regions in Latin America were the use of naturally occurring native plant species which matches to farmer practices from this study. The collection and molding of soil samples in the palm as a way of assessing soil quality through the use of soil texture and structure was also a major practice of farmers in soil fertility assessments. Depending on how a soil holds together in the palm or quickly disintegrates when dropped determines the soils' fertility, and in some cases the type of crops that can be grown on the specified soil. As explained by a farmer *"for instance when you want to farm okro, you pick samples of the soil, mold it in your hand and leave it to fall on the ground, if it splits then it mean the land is not good for okro. If it however stays intact even as it falls on the ground, then you will have a very good harvest; when the soil holds as you drop it on the ground, so it means the soil is strong enough to hold water₀₉.₃*[6] . This statement demonstrates the farmers' knowledge on the roles of soil texture and structure in water and nutrient holding capacity as well as soil workability which ultimately affects crop performance.

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[5] Statement by a farmer to support why he considers the growth rate of naturally occurring plants/weeds as a very important fertility indicators over the others during an in depth interview in Kudje - Concept here is visual assessment from a distance

[6] Identified storylines of how farmers perceived their soils in relation to named indicators. Farmers perceptions are deeply rooted in their farming experiences and practices

4.1.1 Farmer perceptions on soil Indicators and fertility management

Results indicated that farmers use the identified soil quality indicators in naming of local soil types based on farming experience and have developed specific local fertility terms which informs them on the best fertility management strategy to adopt to remedy the problems of soil fertility decline. Generally farmer soil classification was influenced by slope of land which influences soil depth, soil water and nutrient holding capacity as well as the soils suitability to specific crops like rice. For instance *ntaariɛɛ* which is the major named soil type for rice cultivation is located in the valley bottom and holds a high amount of water and thus is considered the best soil for rice production from the farmers' perspective. Slope which is a very important indicator for soil fertility and its capacity to influence soil water and nutrient holding capacity as well as the production of specific crops in the tropical regions has also been reported by CORBEELS ET AL., (2000) in their study where they observed a correlation existing between the units of soil classification relative to the topography and the soil's water holding capacity.

Meanwhile, the other soils found at the bottom of the toposequence were also found to have a considerably high clayey texture, whilst the soils on the upper hills were sandier, and have a relatively low water holding capacity. This confirms the farmers' perceptions of preferring the soil types in the valley bottom which are clayey and can hold high amounts of water for rice cultivation relative to uphill soils which are sandier and drains quickly. Never the less, findings on (table 4) are in tandem with results from other related studies in Sub-Saharan Africa and other parts of the world. For instance, in Niger, farmers named and classified three major soil types of *jigawa*, *geza* and *hako* on the basis soil texture, erosion, slope of land as well as soil structure. Also in Kenya local farmers soil classification was equally based on physical characteristics like soil color, texture, structure and the toposequence (see AMBOUTA ET AL., 1998; MANGO, 2000; MURAGE ET AL., 2000; DESBIEZ ET AL., 2004).

Base on specific local terms farmers could express and determine the various degrees of nutrient status in the soil. Terms like *asaase a sradeɛ / aduane / ahɔɔden wo mu"* and *"asaase a aduane / ahɔɔden asaa" were* used to describe soils with high or low fertility respectively as was also discovered by (DAWOE ET AL, 2012). According to (DAWOE ET AL, 2012) these terms defines the operative concepts of farmers and thus explains their understandings and perceptive knowledge about soils and soil fertility. Therefore making their perceptions of soil fertility broader, going beyond soil nutrient contents alone. However the intertwining usage of these terms also informs the farmers the type of fertility management to adopt. A land that is described as *"asaase a aduane / ahɔɔden asaa"* (depleted soil fertility) from the farmers perspective will be restored quickly through the application of inorganic fertilizer whilst a land of reduced soil fertility *("asaase nu abrɛ")* is restored through the fallow period. The dynamic perceptions of farmers through the use of specific local operating concepts suggests that the decline in soil fertility is linked to a complex of interacting factors and constraints that influences a soils capacity to optimally perform a particular function that supports crop production (DAWOE ET AL, 2012).

These factors ranging from socio-economic to socio-cultural factors actually form the core concepts of how farmers discuss the topic of soils and soil properties at the local levels which also influences management strategies. In actual fact, the farmers' concepts, perception and interpretation of soil fertility is similar to soil productivity definitions by the International Soil Science Society (ISSS, 1996) which defines soil as *"the capacity of a soil in its normal environment to produce a specified plant or sequence of plants under a particular system of soil management"*. Meaning emphasis is laid not only on soil nutrients but as well other related factors like farm management decisions that influence crop performance. This is illustrated by the farmers' understandings of soils from a more 'holistic' perspective other than plant soil nutrients alone. From this perspective the farmers are seen to variously discussed soil fertility as a multi-faceted concept that includes all parameters other than soil nutrients influencing crop yield. Meanwhile other related studies like those from (BEHRENS 1989; CARNEY 1991; BROUWERS 1993; MAFALACUSSER, 1995; WINKLERPRINS, 1999; BARRIOS & TREJO, 2003, DAWOE ET AL, 2012) also emphasized the vital role the discussions of local soil knowledge plays in the context of socio-economic and socio-cultural dynamics in the overall planning of sustainable land use and soil management practices by local farmers.

4.2 Reconciling farmer soil knowledge to chemical soil results

Typically, classical scientific indicators of soil quality may include but not limited to soil attributes such as bulk density, pH, NPK, effective rooting depth, soil temperature, total Carbon and electrical conductivity. Whilst, on the other hand the more variable and physical soil indicators use by farmers for soil fertility evaluations may include; soil color, soil texture and structure, the presence / absence of local plant species and soil macro organisms (see Doran & Parkin, 1996; Barrios et al., 2012; DAWOE et al, 2012). Through the use of local indicators the farmers rated their soils to be moderately fertile and this showed a good correspondence between farmers fertility assessment as against scientific laboratory assessment of the same soils types. Through chemical analyses all the soil types described by farmers as being moderately fertile were seen to have high pH, organic matter, Ca and Mg values but lower values of NPK signifying moderately fertile soils in the selected farmer fields. This result is however similar to the results of Iringu et al., (1996), Murage et al., (2000), CORBEELS et al., (2000), Desbiez et al., (2004) and Dawoe et al., (2012) who found out in their studies in Kenya, Ethiopia and Ghana that farmers intuitive and overall assessments of soil quality indicators on productive and non-productive soils matched well with laboratory measured soil attributes. Therefore giving evidence that, there is always a considerable overlap between scientific knowledge of thoughts and farmers perceptions of soil quality and fertility evaluations. This good match between farmer and scientific assessment of the same field suggest that both farmers and scientists to a large extent share the same knowledge of agricultural and mores of experimentations but different knowledge systems due to differences in expertise, environmental and technological exposure or advancement (Bentley, 1992; Dawoe et al., 2012). Whilst farmers are more interested in solutions and ideas that are specific to their localities, scientists are more interested in the broader biophysical processes at a larger scale which might not fit into the specific situations of the farmers. Nevertheless Desbiez et al., (2004) suggests that while scientists can provide the depth of understanding of soil biophysical process, local farmers can also contribute the context- specific knowledge needed to adapt this understanding to their local biophysical and socio-economic situations. Meanwhile the facilitator role also played by extension agents can be an important factor in promoting this vital link between the two worlds of expertise (Desbiez et al., 2004; Dawoe et al., 2012).

5. Conclusion and recommendation

The reconciliation of smallholder rice farmers' soil knowledge in three districts of the northern Volta Region of Ghana to scientific soil knowledge or evidence served as the main focus of this study. The study thus concludes that the rice farmers' perceptions and practices about soil quality and fertility management in the study locations fundamentally are not different from scientifically documented knowledge and practices. Also from the diversity of farmers' knowledge right from identification of soil quality indicators through the adoption of specific local management strategies, it can be concluded that the rice farmers have a broader view of soil fertility which focuses more on top soil features as against scientific perspective.

The use of local plant species were however important soil quality indicators for fertility evaluation in all the districts visited. The use of these local plant species as soil quality indicators were linked to farmer knowledge base and this can be used to develop extension contents that can be used to train farmers on innovative ways of fertility management. This therefore can aid in the adoption of an integrated but improved fertility management technologies in the districts than the introduction of 'foreign' fertility management strategies. Socio-economic factors were seen to be a major factor influencing farmers' decisions on the adoption of specific management systems which invariably influences soil productivity and subsequently crop yield. This should be factored in management decisions when designing appropriate management technologies in the districts since farmers' understandings of soil fertility goes beyond only nutrient cycling but as well the interactions of other local factors. A participatory development of extension contents focusing more on farmer motivation to adopt local management strategies is therefore encouraged towards a sustainable management of the soil resources in the districts.

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Apendix

Statements from farmers used to support study results.

Participant‘s code	Source of statement
08.4	Farmer 4 in group 8: FGD / Biakoye district
1	Farmer 1 Individual interview / Jasikan district
2	Farmer 2 individual interview / Biakoye district
3	Farmer 3 individual interview / Jasikan district
5	Farmer 5 individual interview / Jasikan district
09.3	Farmer 3 in group 9 FGD / Biakoye district
01.2	Farmer 2 in group 1 FGD / Kadjebi district
8	Farmer 8 individual interview Jasikan district
05.3	Farmer 3 in group 5 FGD Jasikan district