Research Article

Soil Constraints to Urban Agriculture in Valley Beds of Yaoundé (Cameroon)

Ibrahima Saidou[1]* and Deborah Pritchard[2]

[1]Dryland Agricultural Systems Group, Curtin University, Bentley, Perth, Western Australia

[2]Department of Environment and Agriculture, Curtin University, Perth, Western Australia

*Corresponding author: Ibrahima Saidou, Ministry of Agriculture and Rural Development, Yaoundé, Cameroon, Tel: +237 665342407, Email: ibrahima.saidou@student.curtin.edu.au

Abstract

Food security is an increasing issue within Sub-Saharan African (SSA), particularly in urban regions with increasing population and less access to agricultural produce. A farmer socio-economic survey (n=40) and soil survey was conducted in two valley bed suburbs of Yaoundé, Cameroon in 2014 to identify soil constraints and farming practices that may limit food production. The objective of the study was to identify potential soil constraints that may limit crop growth in these valley beds. More specifically, the study aimed to identify soil physical and chemical properties affecting crop yield in two sites Nkolodom and Nkolbisson. Farmer survey on fertility management and soil sampling in these areas were conducted to characterize the sites. The depth to water-table at both sites was 60-70 cm, being dependent on the topography. The soil texture at both sites was clay loam (0-20 cm depth), though the colour of the soils ranged from red brown to yellowish brown to dark reddish brown. The soils had medium to high levels of organic carbon (C), high total nitrogen (N) and a low C/N ratio. The pH at Nkolodom was mostly neutral, though slightly acidic at Nkolbisson. The cation exchange capacity (CEC) was high at Nkolodom (21.30 cmol (+)/kg) and medium (15.85 cmol (+)/kg) at Nkolbisson, although characterised by low levels of exchangeable Ca^{2+}, Mg^{2+} and K^+. Available phosphorus (P) (Bray 2) at Nkolbisson was 400 mg/kg and 1,715 mg/kg at Nkolodom. Soil salinity levels at Nkolodom measured brackish to moderate (810 mS/m) where as low at Nkolbisson (135 mS/m). Chicken manure was the fertiliser applied by farmers spread at rates of 200 kg/ha/pa. Overall, the results show that the levels of the nutrients N and P from soil tests were considered adequate for plant growth. Salinity may pose a constraint to crop growth at Nkolodom and warrants further investigation. Soil fertility is affected by the distance from each farmers house with the most fertile soils (60%) being close to the farmer's house and poorer soils (5%) being furthest from the house where less house waste is applied.

Keywords

Food production; Soil fertility; Urban agriculture; Valley beds

Abbreviations

CEC: Cation Exchange Capacity

SSA: Sub-Saharan Africa

Introduction

Within Sub-Saharan Africa (SSA), such as Cameroon, urbanization is becoming more rapid with urban agglomerations accounting for about 52% of the population living in towns, which are characterized by a high density of about 30 inhabitants per km^2 and low incomes [1]. The imminent challenge is to feed the growing population to avoid potential famine [2]. Within SSA, the maize-legume rotation is the traditional cropping system used including a range of garden market products such as capsicum (*Capsicum annuum*), tomato (*Solanum lycopersicum sp*), basil (*Ocinum basilicum*), celery (*Apium graveolens*), lettuce and Jute mallow. Food is usually produced in rural areas and brought to the city; however, a lack of adequate local transport mechanisms for food distribution has not yet been achieved [3,4]. Consequently, urban agriculture has the potential to improve food supplies and income in urban regions to address the food shortage [5]. In 2007, urban agriculture was practiced by 13.6% of households in Yaoundé, the capital of Cameroon [6]. Overall, African agriculture is highly diverse [7,8]. Large differences between regions, soil, farming systems and crops are matched to each of the main agro-ecological zones [9,10]. Studies have

shown that a large proportion of soils in SSA are derived from old land surfaces with low levels of remaining nutrients [11]. Research to date has predominantly focused on the types of crops cultivated [12-14]; however, there is a scarcity of information related tothe suitability of these soils for agriculture, particularly in terms of their soil properties and constraints to crop production. The history of the land and the soil parent materials affect soil fertility which influences the types of farming systems [15,11]. According to the International Soil Classification System, the majority of soils in Cameroon are Ferralitic: yellow, ochre or red in color depending on the mother rock and the landscape [16] and arise from migmatitic gneiss soil parent material [17,18]. Soils of this type are categorized as clay and acidic with a pH in the range from 4 to 5.5 in CaCl2 [19]. The replenishment of nutrients for food production is an important component of good farm management and will ensure that potential yields are achieved that will help to provide adequate food supply in urban regions. Where the fallow system or shifting cultivation is practiced by smallholder farmers, the length of time since cultivation from the last fallow period influences soil fertility [20]. This study aimed to identify constraints to soil fertility and crop production in two valley bed regions in Yaoundé by investigating soil physio-chemical properties and current soil fertilizer management used by smallholder farmers that may limit potential yield and improve food supply to urban regions.

Materials and Methods

The study was conducted at Yaoundé, Cameroon (located between 3°45' and 4°00' N latitude and 11°00' and 16°12' E longitude) in the tropical forest zone. The climate is characterised by a bimodal rainfall comprising two rainy seasons (March-June and September-November) and two dry seasons. The annual rainfall ranges from 1,000 to 1,500 mm with anaverage temperature from 17°C to 30°C [21,22]. Information for the study was collected from two sites within Yaoundé during December 2014, at Nkolodom and Nkolbisson where urban agriculture is practiced.

A total of 20 respondents were interviewed at Nkolodom and Nkolbisson, respectively, comprising a total of 40 households. The participants selected had valley bed farms that ranged between 0.5 and 1 ha in size and common in these regions. Generic questions covered personal details (age, level of education, position in the household) soil fertility management, crop production and other socio-economic activities. Primary data collected included: farmer demographics such as gender of the household head, marital status, farming experience, types of crops produced, type and amount of fertilizer applied, farmers' income, yield data and soil constraints. In addition to the questionnaire, group discussions and direct observations in the field were conducted to complete the information obtained during interviews.

A total of ten soil samples were collected at random from each of two sites using a 75 mm diameter auger at 0-20 cm depth. Soil texture, consistency, pH and EC were assessed in the field for each sample. All samples at each site were then bulked into a composite sample and three sub-samples analysed at the IRAD Yaoundé soil laboratory for pH, organic matter (OM), available phosphorus (P), exchangeable bases and exchangeable cations using the methods described by [23], total nitrogen (N) using Kjeldahl method, organic carbon (OC) using chromic acid digestion analysis and saturated electrical conductivity (ECe) estimated using the [24] method.

Data collected was entered into Excel spreadsheets for analysis using Statistical Package for Social Sciences (SPSS version 17) to generate simple statistical information. The data obtained was subjected to descriptive statistical analysis at 95 % confident limit and Pearson correlation coefficient. One-way ANOVA was used to compare soil pH between sites. Previous studies used statistical analysis to describe soil constraints for urban horticulture in Yaoundé for compost adoption in sub-Saharan Africa [5,25]. I this study, we used SPSS for characterization of soil quality of valley beds for better soil fertility management by farmers.

Results and Discussions

Demographic characteristics and household activities

Of the 40 households interviewed, the demographics were similar for both Nkolodom and Nkolbisson and indicated that the majority (87.5%) of smallholder farm households were headed by males, with a minority of farms headed by females (12.5%) (Table1). The smallholder farmers inherited land from their parents. There were relatively few single farmers; 85% percent of the households were married and 15% were either single or widowed. In these villages, females were involved in many activities within the farming production system being responsible for sowing, weeding, fertilizer application and harvesting. Farming represented the main activity for 92.5% of households in the study areas, with business the main activity for only 7.5% of the households. The greater part of the household income was derived from farming (87.5%), with products from peri-urban agriculture sold to markets in the cities to generate income for families. On the other hand, almost 13% of farmers considered trading as their main source of income.

Crops grown in the study areas

The average farm size across the study site ranged from 0.5 ha to 1.0 ha, with an average of 0.8 ha. The main crops grown at the two study sites included a mixed system of maize (*Zea mays*) and a range of vegetable crops including Amaranth (*Amaranthus sp.*), lettuce (*Lectuca sp.*), Jute mallow (*Corchorus olitorius*) and Okra (*Malvacea family*) (Table 2). Very few legumes were reported. Maize production was measured in this study and will be discussed in further detail later in this paper.

Soil fertility, fertilizer source, type and application

From the farmer's perspective, three classes of soil in their system are used to assess the level of soil fertility based on visual indi-

Characteristics	Percentage		
Sex	Nkolondom	Nkolbisson	Average
Male	85	90	87.5
Female	15	10	12.5
Marital status			
Married	85	85	85
Single	10	5	7.5
Widow/widower	5	10	7.5
Occupation			
Farming	95	90	92.5
Business	5	10	7.5
Source of income			
Farming	90	85	87.5
Trading	10	15	12.5

Table 1: Household demographics of respondents (n=40)

Land use	Nkolodom (%)	Nkolbisson (%)	Average (%)
Maize	95.5	90	92.5
Lettuce	100	100	100
Amaranth	100	90	95
Okra (gumbo)	100	100	100
Jute mallow	100	100	100

Table 2: Land use by crops grown by farmers at two sites in Yaoundé

Variable	Nkolodom (%)	Nkolbisson (%)	Overall (%)
Land			
Poor	5	5	5
Average	30	40	35
Very fertile	65	55	60
Source of manure chicken			
Own source	2.5	2	2.2
Market	97.5	98	97.8

Table 3: Rating of soil fertility and source of chicken manure applied

The majority of the farmers indicated that the benefits derived from using chicken manure included yield increases and the lower cost compared to inorganic fertilizers. The farmers surveyed indicated that input costs are the major constraint limiting inorganic fertilizer use. Several studies have shown that within regions of SSA, prices of inorganic fertilizer are not affordable by smallholder farmers [29,30]. Thus, these farmers focus on chicken manure to replenish soil fertility rather than purchase inorganic fertilizers. In 2017, a bag (50 kg) of chicken manure cost $2, while a bag (50 kg) of inorganic NPK fertilizer (20-10-10) cost $30. Therefore, a 50 kg bag of NPK (20% N) would supply 10 kg N costing $3 kg/N, whereas a 50 kg bag of dried chicken manure (3.9% N) would supply 1.95 kg N costing $1.03/kg. Hence, the poultry manure is the cheaper source of N to purchase, although a larger volume is required. The typical application rate of 200 kg chicken manure applied by farmers in the survey would supply a total of 7.8 kg N/ha/pa, which is low considering the amount of N removed by harvested crop produce. Recommended fertilizer rates in SSA regions are much higher according to several researchers [31-33], for example, NPK at 150 kg/ha and urea (46% N) at 50 kg/ha to provide a total N loading of 53 kg/ha/pa. However, these loading rates and prices do not consider other nutrients supplied by chicken manure. There are few studies that have determined the nutrient value of the chicken manure being used in order to determine overall nutrient budgets for the crops grown. In comparison with other animal manures, studies have reported that chicken manure has higher amounts of N, P and K per unit volume [26,34]. Disadvantages with the use of manure can include reduction in nutrients, such as P, following long stockpiling periods [35]. The legumes grown in rotation with maize provide an important source of N [36], though were largely absent at the two sites surveyed in this study. Given the close proximity to the river systems, the overuse of inorganic fertilizers could result in nutrient loss into water bodies, which needs to be avoided and hence a better rotation with legumes should be promoted as a more environmentally friendly option.

Soil physical properties

The two study areas covered large swampy valleys adjacent to

cators such as leaf colour, plant appearance and crop yield. Sixty five percent of the respondents at Nkolodom indicated that their soil was fertile and 55% at Nkolbisson (Table 3). Forty percent of farmers from Nkolbisson and 30% of farmers at Nkolodom indicated that their soil was average with 5% of households at both sites claiming their land to be poor. The most fertile soil was located closest to the households where the kitchen waste is applied. The soil with average fertility is located at some distance from the household and receives moderate amounts of house waste and the poorer soil is situated furthest from the household, and receives minimal waste, although still cropped continuously.

Famers at both sites fertilized their crops with a similar amount of chicken manure (200 kg/ha/pa) applied by hand and cultivated in following rain. The majority (98%) of farmers bought chicken manure from market as a fertilizer whilst only 2% applied chicken manure sourced directly from their farm (Table 3). Chicken manure was selected as the predominant fertilizer based on its availability and affordability compared with inorganic fertilizer. Chicken manure is considered practical with low moisture content, ease of drying and requires less labour [26]. Poultry farming enterprises may not generally be large enough to be the primary source of manure for farming systems throughout SSA regions [27,28].

river systems. The texture for both sites was a clay loam, although the colour was different (Table 4). At Nkolbisson the topsoil (0-20 cm) was red (5YR 5/6), brown red (10YR 3/4) to yellowish brown (10YR 5/6). At Nkolodom the topsoil was dark reddish brown (2.5YR 2.5/3). The depth to water-table in these valley beds was between 60 cm and 70 cm depending on the relief, the topography position and the depth of the A horizon. In a study by [37] the Yaoundé gneiss is comprised of sandy clays in the narrow and large valleys and organic clays in the lower parts of the large valleys. From a morphological point of view, these clays are very heterogeneous with several clay loam or sandy textures as cited by diverse studies [18,38]. The large swampy valleys are at risk of waterlogging, which could inhibit plant growth by reducing the availability of oxygen and nutrients to the roots. There is also the potential leaching of nutrients into waterways through run-off from rainfall and leaching if not taken up by plant roots.

Soil property	NKOLODOM	NKOLBISSON
Colour (Munsell)	2.5YR 2.5/3	10YR 5/6
Texture	Clay loam	Clay loam
Depth towater table (cm)	60	70

Table 4: Soil physical description at the two study sites

Soil pH and electrical conductivity

The mean soil pH_{ca} of topsoil (0-20 cm) was slightly acidic at Nkolbisson at 5.2 (SD=0.174) though was more neutral at Nkolodom at 6.0 (SD=0.172) (Table 5). One-way ANOVA indicated a significant difference between the sites in terms of soil pH (P<0.05). The low pH_{ca} at Nkolbisson could potentially start to inhibit plant growth through aluminium (Al) toxicity, nodulation failure in legumes and reduce the availability of Ca, Mg, N and P in soil [39]. Soil acidity at Nkolbisson should be monitored and a solution would be for farmers to apply lime to increase soil pH and/or better manage fertiliser N inputs. In general, lime is available in the market but is not easily affordable by farmers.

The electrical conductivity (EC) value in the 0-20 cm soil depth varied between the two sites, with Nkolodom samples measuring 90 mS/m and Nkolbisson measuring 15 mS/m (Table 5). Salinity values based on a saturated extract (ECe) were calculated to be 810mS/m at Nkolodom (medium salinity) and 135mS/m at Nkolbisson (low salinity) (Table 6). The ECe gives a more definitive measurement of the salt content than EC and was estimated using the [24] technique:

ECe (mS/m) = EC (mS/m) X 9 (nominated factor determined by soil texture).

The difference in salinity levels between the two sites may be due to their position in the landscape. Nkolbisson has good soil drainage and low salinity whereas at Nkolodom the drainage

tends to be reduced by a flat landscape accumulating free salts. Salinity inhibits plant growth by reducing the osmotic pressure gradient between the plant and the soil solution, restricting the ability of the plant to absorb water and consequently, reduces the amount of plant available water stored in the soil [40,25]. Moreover, soil salinity has unfavorable effect on soil fertility and nutrient uptake in plants [41,42], reducing crop growth and production significantly [43]. Nevertheless, the threshold value differs from crop to crop [44]. Although the salinity level was rated as medium at Nkolodom, the yield of maize did not appear to be reduced, which may be a reflection of the ability of maize to be slightly tolerant to salinity, although more sensitive crops, such as peas would suffer. It is recommended that further soil sampling and sub-soil sampling be conducted at Nkolodom over different times of the growing season to ensure that salinity is not a cause for concern at this site. The selection of more salt tolerant varieties may be necessary.

Soil property	NKOLODOM	NKOLBISSON
pH 1:5 (water)[1]	6.59	5.32
pH 1:5 (CaCl2)[2]	6.0	5.2
EC 1:5(mS/m)	90	15
ECe 1:5 (mS/m)	810	135

[1] pH from Laboratory (n=3);

[2] pH from field (n=10)

Table 5: Soil pH and Electrical conductivity (EC) at the two study sites

The table 6 below shows the salinity rating used by [40] for electrical conductivity (1:5) mS/m and ECe (1:5) mS/m.

Rating	EC (1:5) mS/m	ECe (1:5) mS/m	Effect
Low	<50	<400	Minimal effect on plant growth
Medium	50-200	400-1600	Plant growth is inhibited
High	>200	>1600	Plant growth is severely restricted

Source: [40]

Table 6: Salinity Rating used for EC (1:5) mS/m and ECe (1:5) mS/m

Soil organic matter, organic carbon, total N and available P

The levels of organic matter (OM) were high at Nkolodom (4.05%) and medium at Nkolbisson (2.25%) (Table 7). These values were reflected by the levels of organic carbon (OC) at each site (2.35% and 1.30%, respectively), which according to [45] would indicate that soil at Nkolodom would have good nutrient

storage and stable structure. Once OC levels fall below 1%, soils are characterised by poor nutrient storage and unstable structure. The high levels of OM may somewhat offset any effect of salinity on plant growth at the Nkolodom site.

Soil property	NKOLODOM	NKOLBISSON
OM (%)	4.05	2.25
OC (%)	2.35	1.30
OC rating	High (>2%)	Medium (1-2%)

Source: IRAD soil laboratory Report, Yaoundé;

Organic C ratings based on Scheffer and Schachtschabel (1966)

Table 7: Soil property of the two study sites

The concentrations of total N and P at each site are given in Table 8. The Bray 2 extraction method is an estimate of the level of available P for plant uptake. The concentration of available P was high at Nkolodom (1715 mg/kg) and moderate (400 mg/kg) at Nkolbisson, as per [46] Bray P ratings. Nkolodom has more available P in soils than Nkolbisson, though both are considered sufficient at each site. The high concentrations of total N at each site would not indicate N deficiency. The ratio of carbon to nitrogen (C/N) provides an indication of the source and state of decomposition of soil OM. Low values (<10) of C/N indicate that OM is being lost at both sites [24]. This could be caused by continuous cropping without replenishment and the removal of plant material on soil. The C/N level of both sites was low being 8.3:1 and 7.6:1 at Nkolodom and Nkolbisson, respectively.

Soil property	NKOLODOM	NKOLBISSON
Total N (%)	0.29	0.17
C/N ratio	8.3	7.6
P Bray2 (mg/kg)	1715	400

Source: IRAD soil laboratory, Yaoundé

Table 8: Total N and P values for the two sites tested

Exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+)

According to [45], clay loam soils, as in this study, have good nutrient storage. The CEC measures the total cations that can be held in the exchange complex of the soil and is influenced by the clay content. A CEC of less than 5 cmol (+)/kg is considered low with a poor capacity to store nutrient cations [46]. Soils from both sites were measured to have good capacity to store cations. The CEC rating was high at Nkolodom and medium at Nkolbisson, being 21.30 cmol (+)/kg and 15.85 cmol (+)/kg, respectively (Table 9). Low levels of cations, such as Ca^{2+}, Mg^{2+} and K^+ can reduce plant growth [39,45]. [46] indicated that $Ca^{2+}<5$ cmol/kg, $Mg^{2+}<1$ cmol/kg and $K^+<0.5$ cmol/kg are considered low with deleterious effects on plant growth. Nkolbisson was characterised by relatively low levels of exchangeable cations: Ca^{2+}, Mg^{2+} and K^+ indicating that other cations, such as Aluminum (Al^{3+})

may form the majority of cations at this site. The CEC is also dependant on the pH of the soil because when soil acidity increases, more H^+ ions are attached to the colloid and other cations such as Al^{3+} are displaced. It can be seen that Nkolbisson was characterised by low levels of exchangeable Mg^{2+} and K^+ and these nutrients need to be investigated further to ensure they are not limiting plant growth.

Soil cation(cmol(+)/kg)	Nkolodom	Nkolbisson
Ca2+	7.79	4.19
Mg2+	1.59	0.83
K+	0.75	0.12
Na+	0.11	0.12
Total CEC	21.30	15.85

Source: IRAD soil laboratory, Yaoundé

Table 9: Exchangeable cations for the two sites tested

Output and productivity of maize

Based on maize production at each site, the average yield in 2013 across each farmers paddock (low to high yielding areas) was estimated to be 2.5 t/ha at Nkolodom and 2.1 t/ha at Nkolbisson. The yield declined steadily further from the house. These yields were lower compared to maize yields at the Yaoundé Institute of Research and Agricultural Development field station, (~ 3.5 t/ha) and indicate that farm yields for small-scale farmers in peri-urban areas are below the potential yield of the region [18]. The amount of N applied in chicken manure applied by farmers in the study (7.8 kg N/ha/pa) is well below that removed in crop harvest given that one ton of maize grain removes approximately 16 kg N/t. Although N may not be the limiting factor at both sites, similar mass balances can be calculated for all nutrients applied.

Badu-Apraku B and Dhliwayo T [48,49] reported that within SSA, the yield of maize was estimated at 4.4 t/ha for early maturing varieties and 5.3 t/ha for late maturing varieties. In general, there is a potential to improve crop production by introducing new management practices. It has been reported that in SSA continuous maize production without integrated soil nutrient management reduces soil fertility over time and decreases the yield [50-52]. However, it is unknown by this study if the inability to achieve potential yield is due to soil constraints or other management issues such as pests and diseases. Although the study focused on soil constraints, there are several other factors that farmers need to manage to improve yield, such as good crop management, appropriate land preparation and fertilizer, optimal plant density, improved varieties, weed, pest and disease control. Moreover, suitable intercropping in the Yaoundé valley beds need to be practiced. Soil fertility management practices to maintain soil fertility including the use of fertilizer at the right rate will close the yield gap in this region and increase production. One alternative is to make better use of composting the excess maize stubble to replenish these valley bed soils [50-54].

Conclusion and Recommendations

The two peri-urban valley bed regions of Yaoundé investigated in this study showed many similarities in terms of demographics, soil texture and depth to water-table and cropping practice that followed a traditional maize-legume rotational practice, shifting cultivation and fallow; yet differed in several properties that may affect crop growth. Crop yields are approximately 50% below the potential yield of the region, being generally lower at Nkolbisson than at Nkolodom. The levels of N and P soil appear adequate for crop growth at both sites; however, soil acidity, aluminum toxicity and low exchangeable Ca^{2+}, K^+ and Mg^{2+} could be potential constraints to crop growth at Nkolbisson. At Nkolodom, soil salinity could be a constraint to crop growth. Further research should be done to confirm the extent of soil salinity, including measuring the concentrations in subsoil and river systems. The main source of fertilizer applied by farmers at each site was chicken manure (200 kg/ha), which may contribute a small amount to the maintenance of N, P and other nutrients for plant growth and build OM, though unlikely to replace all nutrients removed by the crop. There is a need to calculate the effect of chicken manure on overall nutrient budgets over time in these study areas to improve soil parameters affecting crop yield. This could be achieved by conducting strip experiments using a range of macro and micro-nutrients and/or plant tissue testing in order to identify deficiencies and hence recommend better fertilizer practices. Given the proximity of both sites to the river, it is imperative that fertilizer is not applied in excess and washed into the river system. Peri-urban valley bed regions have the potential to increase the source of food close to regional areas, though constraints to production need to be addressed.

Acknowledgments

References

1. Drechsel P, Gyiele L, Kunze D, Cofie O (2001) Population density, soil nutrient depletion, and economic growth in sub- Saharan Africa. Ecol Econ 38: 251-258.

2. Tilman D, Balzer C, Hill J and Beffort B l (2011) Global food demand and the sustainable intensification of agriculture. Proc Natl Acad Sci 108: 20260-20240.

3. Yengoh GT, Hickler Y, Tchuinte A (2011) Agro-climatic resources and challenges to food production in Cameroon. Geocarto Int 26: 251-273.

4. Yengoh GT (2012) Determinants of yield differences in small-scale food crop farming systems in Cameroon. Agr Food Secur 1: 33.

5. Sotamenou J, Parrot L (2013) Sustainable urban agriculture and the adoption of composts in Cameroon. Int J Agr Sustainability 11: 282-295.

6. Diao X, Hazell P, Thurlow J (2010) The Role of Agriculture in African Development. World Dev 38: 1375-1383.

7. Mafongoya P, Rusinamhodzi L, Siziba S, Thierfelder C, Mvumi MB, et al. (2016). Maize productivity and profitability in Conservation Agriculture systems across agro-ecological regions in Zimbabwe: A review of knowledge and practice. Agri Ecosystems Environ 220: 211-225.

8. Mcata B, Obi A (2015) Home gardening as a strategy for food security and poverty alleviation in Rural South Africa (1343). Proceedings of the international food and agribusiness management association. ST. Paul, Minesota, USA, June 14-15.

9. Rufino MC, Dury J, Tittonell P, Van Wijk MT, Herrero M, et al. (2011) Competing use of organic resources, village-level interactions between farm types and climate variability in a communal area of NE Zimbabwe. Agric Syst 104: 175-190.

10. Tshwene C, Idowu O (2016). Water use productivity and food security among smallholder homestead food gardening and irrigation crop farmers in North West province, South Africa. J Agr Environ Int Dev 110: 73.86.

11. Zingore S, Murwira HK, Delve RJ, Giller KE (2007) Soil type, management history and current resource allocation: Three dimensions regulating variability in crop productivity on African smallholder farms. Field Crop Res 101: 296-305.

12. Orsini F, Kahane R, Nono-Womdim R, Gianquinto G (2013) Urban agriculture in the developing world: a review. Official Journal of the Institut National de la Recherche Agronomique(INRA) 33: 695-720.

13. Büttner U, Hauser S (2003) Farmers' nutrient management practices in indigenous cropping systems in southern Cameroon. Agri, Ecosystems Environ 100: 103-110.

14. Tankou CM, de Snoo GR, de Iongh H, Persoon G (2013) Soil quality assessment of cropping systems in the western highlands of Cameroon. Int J Agri Res 8: 1-16.

15. Cobo JG, Dercon G, Cadisch G (2010) Nutrient balances in African land use systems across different spatial scales: A review of approaches, challenges and progress. Agri, Ecosystems Environ 136: 1-15.

16. IUSS Working Group (2015) World Reference Base (WRB) for Soil Resources 2014, update 2015 International soil classification system for naming soils and creating legends for soil maps. World soil resources reports No. 106. FAO, Rome.

17. Onguéné Mala (1993) Différentiation pédologique dans la région de Yaoundé (Cameroun): Transformation d'un sol rouge ferralitique ensol a horizon jaune et relation avec l'évolution du modelé. Thèse Doctorat Université Paris VI, Pp 253.

18. Ngon Ngon R, Youngeu Fouateu DL, Bitom P, Bilong (2009) A geological study of clayey laterite and clayey hydromorphic material of the region of Yaounde (Cameroon): a prerequisite for local material promotion. J African Earth Sci 55: 69-78.

19. Takoutsing B, Weber JC, Tchoundjeu Zand Shepherd K (2015) Soil chemical properties dynamics as affected by land use change in the humid forest zone of Cameroon. Agroforestry Sys 1-14.

20. Tittonell P, Muriuki A, Shepherd K D, Mugendi D, Kaizzi K C, Okeyo J, Verchot L, Coe R, and Vanlauwe B, (2010). The diversity of rural livelihoods and their influence on soil fertility in agricultural systems of East Africa – A typology of smallholder farms. Agri Syst 103: 83-97.

21. Ambassa-kiki R, Tchienkoua M, Agoume V (1995) Soil and site characterization report. IRA, Yaounde, Cameroon. Mimeo. P.13.

22. Tchatat M (1996) Les jardins de case agroforestiers des basses

terres humides du Cameroun: Etude de cas des zones forestières des provinces du Centre et du Sud. Thèse de doctorat, 159 Université de Paris 6, UMR 9964, CNRS-UPS, 31405 Toulouse cedex France. Pp 145.

23. Viers J, Drupe B, Braun JJ, Deberdt S, Angeletti B, et al. (2000) Major and trace element abundances and strontium isotopes in the Nyong bassin river (Cameroon): Constraints on chemical weathering processes and elements transport mechanisms in humid tropical environments. Chemical Geology. Pp 221-241.

24. Rayment GE, Lyons DJ (2011). Soil chemical methods: Australasia Edited by D. J. Lyons. Collingwood, Vic: CSIRO Publishing.

25. Gitari WM Tshikovhi FP, Akinyemi SA (2017) Physicochemical Appraisal of Effluents Receiving Stream: A Case Study of Mvudi River, South Africa. J Environ Sci Allied Res 2017: 25-31.

26. Hass A, Gonzalez J, Lima I, Godwin H, Halvorson J, et al. (2012) Chicken Manure Biochar as Liming and Nutrient Source for Acid Appalachian Soil. J Environ Quality 41: 1096-106.

27. Materechera SA, Morutse HM (2009) Response of maize to phosphorus from fertilizer and chicken manure in a semi-arid environment of South Africa. Report 45: 261-273.

28. Delve RJ, Cadisch G, Tanner JC, Thorpe W, Thorne PJ, et al. (2001) Implications of livestock feeding management on soil fertility in the smallholder farming systems of sub-Saharan Africa. Agri, Ecosystems Environ 84: 227-243.

29. Palm C A, Gachengo C N,Delve R J, CadischJ, and Giller K E, (2001). Organic inputs for soil fertility management in tropical agroecosystems: application of an organic resource database. Agri Ecosystems Environ 83: 27-42.

30. Giller KE, Witter E, Corbeels M, Tittonell P (2009) Conservation agriculture and smallholder farming in Africa: The heretics' view. Field Crops Res 114: 23-34.

31. Olwande J, Sikei G, Mathenge M (2009) Agricultural technology adoption: A panel analysis of smallholder farmers' fertilizer use in Kenya. Center of Evaluation for Global Action.

32. Chikowo R, Zingore S, Sieglinde S, Adrian J (2014) Farm typologies, soil fertility variability and nutrient management in smallholder farming in Sub-Saharan Africa (formerly Fertilizer Research). 100: 1-18.

33. VanlauweB, Kihara J, Chivenge P, Pypers P, CoeR, et al. (2011). Agronomic use efficiency of N fertilizer in maize-based systems in sub-Saharan Africa within the context of integrated soil fertility management. Plant Soil 339: 35-50.

34. Araji A, Abdo ZO, Joyce P (2001) Efficient use of animal manure on cropland – economic analysis. Bioresource Technology 79: 179-191.

35. Peirce C, Smernik R, McBeath T (2013) Phosphorus availability in chicken manure is lower with increased stockpiling period, despite a larger orthophosphate content. Plant Soil 373: 359-372.

36. Fischer K, Hajdu F (2015) Does raising maize yields lead to poverty reduction? A case study of the Massive Food Production Programme in South Africa. Land Use Policy. 46: 304-313.

37. Nzenti JP, Barbey P, Macaudiere J, Soba D (1988) Origin and evolution of the late precambrian high grade Yaounde gneiss (Cameroon). Precambrian Res 38: 91-109.

38. R Fokoma, S Adamou, MC Teugwa, AD Begoude Boyogueno, WL

Nana, et al. (2012) Glomalin related soil protein, carbon, nitrogen and soil aggregate stability as affected by land use variation in the humid forest zone of south Cameroon. Soil Tillage Res 120: 69.

39. Gransee A, Führs H (2013) Magnesium mobility in soils as a challenge for soil and plant analysis, magnesium fertilization and root uptake under adverse growth conditions. An Int J Plant-Soil Relation 368:5-21.

40. McArthur WM (1991) Reference soils of south-western Australia. WM McArthur editors, DAW Johnston and LJ Snell sponsors, Australian Bicentennial Authority. Perth, Dept. of Agriculture, Western Australia on behalf of the Australian Society of Soil Science.

41. Power JF, Prasad R (1997) Soil fertility management for sustainable agriculture. Florida: Lewish publisher, Boca Raton, New York. 356

42. Wiegand C, Anderson G, Lingle S, Escobar D (1996) Soil salinity effects on crop growth and yeild - illustration of an analysis and mapping methodology for sugarcane. Special issue: Vegetation stress II. J Plant Physiol 148: 418-424.

43. Van Hoorn J W, Katerji N, Hamdy A, Mastrorilli M (2001) Effect of salinity on yield and nitrogen uptake of four grain legumes and on biological nitrogen contribution from the soil. Agri Water Manage 51: 87-98.

44. Ram Dular Yadav (2005) Modelling salinity effects in relation to soil fertility and crop yield: A case study of Nakhon Nong Suang District, Thailland. Thesis 150.

45. Scheffer F, Schachtschabel P (1966) Lehrbuch der Bodenkunde (Principle of pedology). Enke Verlag.

46. Rayment GE, Higginson FR (1992) Australian laboratory handbook of soil and water chemical methods Edited by FR Higginson, Australian soil and land survey handbook; v. 3. Melbourne: Inkata Press.

47. Huber D, Jones J (2013) The role of magnesium in plant disease. An Int J Plant-Soil Relation 368:73-85.

48. Badu-Apraku B, Oyekunle M, Akinwale RO, Lum AF (2011) Combining ability of early-maturing white maize inbreds under stress and nonstress environments. Agronomy J 103: 544-557.

49. Dhliwayo T, Pixley K, Menkir A, Warburton M (2009) Combining ability, genetic distances and heterosis among elite CIMMYT and IITA tropical maize inbred lines. Crop Science 49: 1201-1210.

50. Sanginga N, Woomer PL (2009) Integrated soil fertility management in Africa: principles, practices, and developmental process: CIAT.

51. Corbeels M, Jan de Graaff, Ndah TH, Penot E, Baudron F, et al. (2014) Understanding the impact and adoption of conservation agriculture in Africa: A multi-scale analysis. Agri Ecosystems Environ 187: 155-170.

52. Odunze AC, Kureh I (2009) Land use limitations and management option for a savanna zone Alfisol. J Agri Environ Int Dev 103: 321-335.

53. Orioli L, Da Canal S, Bibdi M (2015) A socio-ecological survey in Jalantai area, Alxa League, Inner Mongolia China. J Agri Environ Int Dev 109: 325-353.

54. Phillips IR, Greenway M (1998) Changes in Water-soluble and exchangeable ions, cation exchange capacity, and phosphorus(max) in soils under alternating waterlogged and drying conditions. Communications Soil Sci Plant Analys 29: 51-65.

NORCAL
OPEN ACCESS PUBLICATIONS

submit your manuscripts at
www. norcaloa.com