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Effects of agricultural practices on properties and metal content in urban garden soils in a tropical metropolitan area

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Abstract: The appearance of agriculture in urban areas improved the healthiness of the diet of people by enabling their consumption of fresh vegetables and fruits. This study assessed the level of fertility, and the impact of the cropping system and of the exploitation time on the physicochemical properties and the pseudo-total and EDTA-extractable metals contents of the vegetable soils of urban garden of in Libreville (Gabon). The results indicated a low fertility of the cultivated soils. The metal contents in the open field cultured soils were generally different from the soils cultured under shelters. Except Al that could be toxic for cultivated vegetables, the soil properties and metal element concentrations decreased significantly with time in the open field soil, while they did not vary in open shade cultured soils. The pseudo-total cadmium concentration was below the detection limit in all soils. Multivariate analysis showed that Al, Fe and Pb were of lithogenic origin, while Cu, Zn and Mn were of anthropogenic origin.

Keywords: soil fertility; metal mobility; multivariate statistical analysis; Libreville.

INTRODUCTION

Rapid urbanization in developing countries is accompanied by a growing demand for food, which raises the problem of securing urban food and nutritional supplies.[1] This demand relies in part on agriculture inside or close to cities.[2] Thus, it is often observed that market-gardening farming systems, including leafy vegetables, have recently increased within or near expanding cities.[3] Urban farmers concerned with maintaining soil productivity must consider the impacts of agricultural practices upon the features of the production sites.

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Conventional open field farming has played a significant role in improving food and fiber productivity to meet human consumption demands, but has led to soil erosion, soil nutrient depletion and excessive fertilizer use.[4] The problems arising from conventional agricultural open field management have led to the development and promotion of other farming practices with regard to the improvement of soil fertility and quality.[5]

Farming in protected environments, such a greenhouses or under shelters, is a frequently utilized technique by horticultural producers. It allows plant protection against the action of external agents, such as high and low temperature, intense precipitation and strong winds.[6] Greenhouses or shelters promote rationalization of the production factors, result in less pesticide use and minimize the incidence of pathogens and insects.[7] They also promote increased production of fresh and dry matter, and foliar areas and leaf numbers.[6] The main advantage of protected farming is that the yield and quality of vegetables are higher.[8]

Temporal changes in physicochemical properties and heavy metal levels of cultivated soils according to the exploitation time or to agricultural practices, *i.e.*, in open fields or under shelters, have been already reported.[9–11] However, few studies dealt with the effects of both cultural practices and exploitation time. The present study was aimed at assessing the effects of agricultural practices and farming time on the properties and metal concentrations in soils of urban gardens located at different sites in the City of Libreville (Gabon).

EXPERIMENTAL

This study was realized in 2008 and 2009 in urban garden areas of Libreville (Fig. 1). The city is situated in West Gabon (9°25′ E and 0°27′ N). The climate is hot and humid with two rain seasons and two dry seasons. It is characterized by an average rate of annual rainfall that varies from 1,600 to 1,800 mm. Hygrometry is usually above 80 % and reaches 100 % during the rain seasons. Monthly-averaged temperatures oscillate between 25 and 28 °C, with daily minima (18 °C) in July and maxima (35 °C) in April.

The population of the urban area of Libreville is estimated at about 648,000 inhabitants, which represents nearly half the total population of the country. Farmers grow vegetables on plots of 100 to 10,000 m^2 within the city and its surroundings. They use both techniques open field (OF) and under a protection structure (under shelters) (PS), as other market gardening crops producers in the World.[6]

Nine sites were selected for this study (Fig. 1). The major distinctions between the plots were the exploitation periods (between 2 and 38 years) and the cultural practices (OF or PS). The study plots were separated in four groups: urban gardens cultivated in open fields for less than ten years (OF1), in open fields but for more than ten years (OF2), urban gardens cultivated under shelters for less than ten years (PS1) and under shelters for more than ten years (PS2). Two sites presented two plots belonging to different groups; hence, this study concerned eleven urban garden plots (Fig. 1).

Surface soils (0–10 cm) were collected using the technique of systematic random sampling with 3 replicates.[12] The soil samples were air dried, then crushed in a mortar, passed through a 2 mm sieve and stored in polyethylene bags. The fraction > 2 mm was discarded.[13]

A part of the fraction < 2 mm was crushed with a tungsten carbide blade grinder and subsequently sieved through a 0.2 mm titanium mesh.

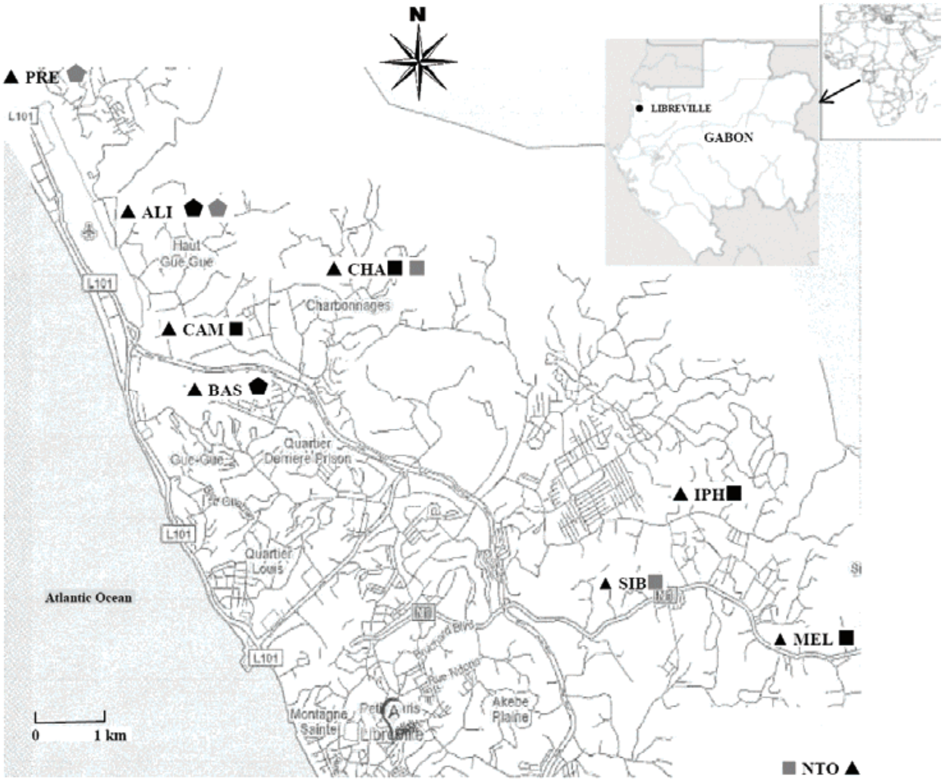

Fig. 1. Location of studied urban gardens in Libreville with sampling sites: (▲) gardens under shelters (PS) = ⬟: exploited for less than10 years (PS1) and exploited for more than 10 years (PS2); gardens in open fields (OF) = ■: exploited for less than 10 years (OF1) and exploited for more than 10 years (OF2).

The physicochemical properties of the soil were assessed according to the ISO standard.[14] They included: particle size (three fractions), pH, conductivity (*EC*), cation exchange capacity (*CEC*), total Kjeldahl nitrogen (*TKN*) and total organic carbon (*TOC*). Considering that the average content of carbon in soil organic matter was 58 %, the conversion factor 1.724 was used to calculate the percentage of organic matter (*OM*) from the content of organic carbon.[15]

Soil samples were mineralized in microwave mineralizer using *aqua regia* (1/3 HNO_3+2/3 HCl, ultra grade purity) according to the AFNOR NF X31-151 standard.[14] The mineralization products were filtered through a 0.45 μm mesh and the concentrations of the metals in the filtrates were determined by ICP-AES (Jobin Yvon Horiba, Spectra 2000). Quality assurance–quality controls and accuracy were checked using standard soil reference materials (CRM-SS1, EPA-3050A) with accuracies within 100±10 %. In order to determine the mobile or "potentially available" fraction of metals in the studied soils, the 0.05 M EDTA extraction procedure at pH 7, proposed by Quevauviller, was used.[16]

The mean, standard error and mean comparison test were performed. A correlation matrix was used to identify the relationship between heavy metal contents and soil properties. Multivariate analysis methods, such as Principal Component Analysis (PCA), cluster analysis and two-way analysis of variance (ANOVA) were used to extract information from the physicochemical and metallic analysis of the soils. PCA and cluster analysis were interpreted in accordance with the hypothetical source of heavy metals (lithogenic, anthropogenic or mixed). The statistical analyses were performed using XLSTAT 2010 software, version 6.04.

RESULTS AND DISCUSSION

The mean values of analyzed parameters are presented in Table I. A comparison of the fertility parameters (pH, *TNK*, *CEC* and *OM*) was performed between the present data and those proposed by Landon as mean ranges of tropical soil fertility.[17] The soils were acidic with pH values in the range proposed

TABLE I. Physicochemical properties and concentrations of pseudo-total metal (subscript: tot) and EDTA-extracted metal (subscript: mob), expressed in mg kg^{-1} of dry weight, of cultivated soils; and variance analysis results (ANOVA); N: number of samples; ns: non-significant; *: $p < 0.05$; **: $p < 0.01$; the means in same line followed by same letter do not differ at the stated significance level of 0.05

Parameter	Groups of cultivated gardens				Two-way ANOVA (Tukey HSD) *F* (variance and probability)		
	PS1 (N = 6)	PS2 (N = 6)	OF1 (N = 12)	OF2 (N = 9)	Agricultural system	Time of exploitation	System *x* Time
EC / µS cm^{-1}	312^{a}	235^{ab}	247^{ab}	100^{b}	4.366*	5.011*	0.233 ns
pH$_{water}$	6.17^{a}	6.00^{a}	6.49^{a}	4.98^{b}	14.212**	1.216 ns	9.526**
pH$_{KCl}$	5.71^{a}	5.49^{a}	5.65^{a}	4.44^{b}	6.594*	3.172 ns	3.926 ns
ΔpH	0.5^{a}	0.5^{a}	0.8^{a}	1.2^{a}	1.412 ns	3.928 ns	2.853 ns
TKN / mg g^{-1}	1.27^{b}	1.17^{b}	2.06^{a}	1.23^{b}	12.851**	13.473**	10.092**
MO / g g^{-1}	18.9^{b}	22.3^{b}	33.9^{a}	23.3^{b}	1.772 ns	11.218**	8.781**
Sands, g kg^{-1}	833^{a}	848^{a}	435^{c}	633^{b}	3.600 ns	35.734**	3.065 ns
Loams, g kg^{-1}	99^{b}	86^{b}	319^{a}	226^{a}	1.944 ns	23.807**	0.852 ns
Clays, g kg^{-1}	69^{c}	66^{c}	250^{a}	141^{b}	6.273*	38.911**	6.259*
CEC / meq 100 g^{-1}	4.4^{b}	3.8^{b}	13^{a}	3.8^{b}	6.063*	5.229*	5.031*
Al$_{tot}$	9135^{c}	9144^{c}	28269^{a}	19863^{b}	2.271 ns	36.878**	2.542 ns
Cd$_{tot}$	<1.85	<1.85	<1.85	<1.85	<1.85	<1.85	<1.85
Cu$_{tot}$	24^{a}	30.3^{a}	19.5^{a}	17.3^{a}	0.108 ns	7.461**	0.759 ns
Fe$_{tot}$	14206^{b}	16002^{b}	29030^{a}	13641^{b}	13.703**	11.639**	22.873**
Mn$_{tot}$	214^{b}	324^{ab}	640^{a}	250^{b}	2.393 ns	3.679 ns	7.405**
Pb$_{tot}$	7.2^{b}	3.2^{b}	17.3^{a}	6.7^{b}	19.42**	22.266**	6.648*
Zn$_{tot}$	44.5^{a}	55.1^{a}	44.8^{a}	23.6^{b}	4.089 ns	28.643**	30.975**
Al$_{mob}$	143 ^{a}	177 ^{a}	125 ^{a}	202 ^{a}	4.378*	0.056 ns	0.426 ns
Cd$_{mob}$	< 0.30	< 0.30	< 0.30	< 0.30	< 0.30	< 0.30	< 0.30
Cu$_{mob}$	2.15^{ab}	2.57^{ab}	3.29^{a}	1.03^{b}	5.345 ns	0.542*	9.973**
Fe$_{mob}$	313^{a}	196^{ab}	120^{b}	127^{b}	1.841 ns	22.21**	5.643*
Mn$_{mob}$	26.9^{b}	33.8^{b}	99.7^{a}	30.8^{b}	8.408*	8.218*	8.003**
Pb$_{mob}$	1.32^{b}	0.65^{b}	3.2^{a}	0.47^{b}	8.112**	3.375 ns	4.597*
Zn$_{mob}$	10.8^{b}	17.7^{a}	4.4^{c}	2.6^{c}	3.976 ns	78.624**	11.865**

by Landon (5.5–7.0), except OF2 soils with average pH<5. The *TNK*, *CEC* and *OM* in all soils were below the standards of tropical soil fertility, *i.e.*, 2–4 g kg^{-1}, 15–25 meq kg^{-1} and 40–100 g kg^{-1}, respectively.[17]

Analysis of variance (ANOVA) showed that the conductivity was higher in the PS gardens and recent gardens (influence of exploitation time). The results indicated that salts were more strongly accumulated in the PS1 soils than in the others soils. The time of exploitation seemed to play an important role in the evolution of all soil properties, except pH. A significant increase of sand content and a significant decrease in *EC*, *TKN*, *MO*, silt, clay and *CEC* were found with increasing exploitation time. This could be linked to low intakes of organic fertilizers for vegetable production, indeed it should be noted that for studied urban gardens as well as in other Africa small sub-Saharan farms, only low quantities of fertilizers were applied.[18] Urban gardens are generally far away from poultry farms and neither solid wastes nor waste water for intakes are used.[19]

The values of the physicochemical properties with time were not significantly different in the PS soils, with most of them decreasing with time in open field soils. It was estimated that more than 50 % of the world's potentially arable lands are acidic and up to 60 % of the acid soils in the world occur in developing countries in South America, Central Africa and Southeast Asia, where food production is critical. Soil acidity is a natural occurrence in tropical and subtropical zones.[20] The decrease of pH in OF soils led to a decrease in soil fertility and may cause aluminum toxicity and lots of micronutrients.[21]

Low fertility is a characteristic of many tropical soils, mainly because of the significant and rapid degradation of organic matter, but also because of leaching, weathering of minerals and low-input agricultural practices.[23] A chronosequence study by Moebius-Clune *et al.*[10] showed that most soil quality indicators followed exponential decay trends under continuous low-input for maize, and that organic matter and quality indicators (P, Zn and K possibly) were preserved under kitchen garden polyculture with organic inputs.[10] These results suggested that regular organic inputs could significantly reduce degradation of soils, especially with regards to nutrient retention and soil structure. Organic matter is essential for soil life by allowing a soil to perform efficiently its primary function of supporting plant growth. Its endemic deficiency in tropical soils is a major factor contributing to their low productivity.[24] Organic matter facilitates two essential categories of soil processes: organic matter stabilization and decomposition. Loss of stable organic matter results in destabilization of aggregates over time and thus in a decrease of cation retention (as represented by *CEC*), buffering of pH, and soil structure, which in turn decreases water storage, infiltration, root proliferation and physical access to nutrients, with increased likelihood of surface crusting, runoff and erosion.[10] A non-appropriate amendment of mineral fertilizers could sometimes lead to low yields, depending on the physical and biological characteristics of the soil.[25] Organic matter and pH are the most important factors that control the availability of metals in soil. Increase content of soil organic matter could improve soil *CEC*, a parameter that could affect the concentrations of total and exchangeable metals.[26]

The low inputs of organic–matter and crop residues could be the major reasons for the low soil fertility of gardens in the area of Libreville. A survey among urban gardeners of Libreville indicated that the mineral fertilizer NPK and urea were the most used. However, to improve soil quality, the use of lime could increase the soil pH, and the employment of organic fertilizers, such as manure or compost, could increase the organic matter contents. These types of organic fertilizers are widely used by urban gardeners in other African countries because they are readily available. In Senegal, for example, nitrogen fertilizer (poultry manure, cow dung and garbage) are available locally at low cost. Hence, farmers prefer to settle near garbage dumps because of their important resources in organic matter at low cost.[22] It is therefore necessary to add organic matter to improve agricultural soil quality in the region of Libreville.

In all the analyzed soil samples, the Cd concentrations were below the detection limits of the ICP-AES analysis (1.85 mg kg^{-1}).

The Al, Cu, Fe, Mn, Pb and Zn pseudo-total concentrations in the studied soils are presented in Table I. They were below or within the ranges reported in the literature for uncontaminated soils.[27] However, the coefficients of variation (*CV*) showed considerable heterogeneities for Al, Cu, Mn and Pb (58.3, 51.1, 83.7 and 76.2 %, respectively). The heterogeneities of Fe and Zn were relatively lower (*CV* <50 %). According to Kabata-Pendias and Pendias,[27] the allowable or tolerable concentration of a metal element in soil is the limit concentration of this element over which the plants produced are considered dangerous for human or animal health. However, it is not advisable to interpret some results based only on pseudo-total concentrations. The determination of the total concentrations of metals in soils may be useful in predicting their potential risk to the environment, but it is not a good indicator of the metal mobility to plants, which depends on the physicochemical properties of soils.[28] Therefore, the mobility of a metal element is important in the evaluation of the effect of metal uptake by plants.

The levels of EDTA-extractable metals found in the soils are presented in Table I. The mean concentrations of metals were all within the ranges of concentrations of mobile metals in agricultural soils proposed by Berrow and Burridge.[29] Among all metals, the more readily available pool was particularly important for Zn (around 27 % of pseudo-total metal), indicating that Zn was potentially bioavailable and/or may leach through the soil. The mobility potential of the other studied metals was less important (12 % for Mn and < 10 % for Al, Cu and Fe, relative to the pseudo-total contents). A correlation analysis was performed between the physicochemical properties (*EC*, pH, *TKN*, *MO*, clay and

CEC) and the EDTA-extractable metals (Table II). Cu was the only metal presenting significant positive correlation coefficients with all soil parameters. The correlations between Mn and Pb and the soil parameters were also all positives, but not always significant. Significant negatives correlations were observed with Al, Fe and Zn. Thus, according to these correlation analysis results, the physicochemical properties seemed to play a crucial role in metal bioavailability.

TABLE II. Correlation coefficient (Pearson) matrices between the physicochemical soil parameters and the EDTA-extractable metal concentrations in soils from Libreville, Gabon

Metal	*EC*	pH_{water}	*TKN*	*OM*	Clay	*CEC*
Al	–0.331	–0.589	–0.236	–0.356	0.089	–0.149
Cu	0.497	0.430	0.608	0.522	0.515	0.658
Fe	0.353	0.010	–0.308	–0.370	–0.420	–0.129
Mn	0.301	0.131	0.721	0.680	0.758	0.787
Pb	0.134	0.464	0.275	0.359	0.182	0.185
Zn	0.209	0.298	–0.326	–0.285	–0.483	–0.228

In general, urban garden soils cultivated under shelters and in open field soils presented different metal pseudo-total concentrations, except for Mn. In open fields, the average Al, Fe and Pb concentrations in the soils were, respectively, 2.66, 1.41 and 2.46 times higher than those of soils under shelters were, whereas the average soil concentrations of Cu and Zn were, respectively, 1.48 and 1.41 lower. In both agricultural practices, the soils presented different metal concentrations for EDTA-extractable Fe, Mn and Zn. The Fe and Zn concentrations were higher (2.24 and 3.99 times, respectively) and the Mn concentrations were lower (2.09) in PS than in OF. No significant differences were found in the mobile Zn values between PS1 and PS2. For soils in open fields, the Al, Fe, Mn, Pb and Zn pseudo-total and mobile Cu, Mn and Pb concentrations were significantly higher on recent than on former cultivated soils. The mean ratios PS1/PS2 of these parameters were, respectively, 1.42, 2.13, 2.56, 2.58, 1.90, 3.19, 3.24 and 6.81. These differences could be attributed to leaching of the former open field soils that were more exposed to weather than the young soils. Soil degradation is a major agricultural and environmental problem, particularly in tropical soils. Soil erosion *via* water appears to be the most widespread process of soil degradation. Water erosion is a primary cause for the loss of nutrients and organic matter, and certainly also plays a role in acidification, pollution, and sometimes compaction and subsidence.[30,31]

The exploitation time of cultivated soils influenced the pseudo-total Mn, Fe, and Pb contents, which were higher in recently cultivated soils. The loss of organic matter in PS2 soils led to a *CEC* decrease. It could be hypothesized that losses of OM and fine mineral constituents were the main causes for the loss of nutrients and metals, and the remaining organic matter in soil had become more inert with time, and therefore unable to retain cations and make them available for plants.[10]

The mobile Al content in soil could allow the risks of plant poisoning to assessed by application of the relation proposed by Boyer: Al×100/(sum of exchangeable base cations + Al).[32] In Brazil, this relationship allowed a threshold value of 45–50 to be proposed above which crops are generally not viable. The exchangeable bases of the studied soils were determined by Ondo.[33] The results showed that for OF2 soils, the threshold of 45–50 was generally exceeded (up to 74), raising fears of low crop yields on these soils.

The "cropping practices" factor showed that the pseudo-total Al, Fe and Pb contents and the mobile Mn contents were significantly highest in open field soils, and the pseudo-total Cu and Zn, and mobile Cu, Fe and Zn concentrations were significantly higher in soils under shelters. The trends showed that soils in open field were more exposed to erosion than soils under shelters. This led to leaching of Cu and Zn and increases in the Al, Fe and Pb contents. A study on the effects of erosion by Oguz *et al*. showed a decrease in Cu content and an increase in Fe, Mn and Zn concentrations in the surface soil.[34]

In general, correlation analysis is useful to investigate associations between parameters.[11] The results of the Pearson coefficients in the correlation analysis for heavy metal concentrations in the studied soils are shown in Table III. Most of the metal concentrations were positively correlated with each other and correlations were significant and positive between Al and Fe ($p < 0.001$), Al and Mn ($p < 0.01$), Al and Pb ($p < 0.01$), Fe and Mn ($p < 0.001$), Fe and Pb ($p < 0.001$), and Fe and Zn ($p < 0.05$). The significantly positive correlations of Mn, Pb and Zn with Fe and Al suggested their strong associations with Fe and Mn oxides in the soils, which could be important products of parent rock weathering.[35] Cu was negatively correlated with Al ($p < 0.01$) and Pb ($p < 0.01$). The origin of Cu could be anthropogenic, as applied organic fertilizers and pesticides, which have been extensively investigated in other studies.[11,33,36]

TABLE III. Correlation coefficient (Pearson) matrices between pseudo-total metal concentrations in urban gardens soils from Libreville, Gabon; $*p < 0.05$; $**p < 0.01$; $***p < 0.001$

	Al	Cu	Fe	Mn	Pb	Zn
Al	1					
Cu	–0.439**	1				
Fe	0.730***	–0.014	1			
Mn	0.468**	0.244	0.668***	1		
Pb	0.442**	–0,436**	0.507***	0.087	1	
Zn	–0.130	0.245	0.332*	0.230	0.232	1

In this study, an agglomerative hierarchical cluster analysis (HCA) was performed to identify different geochemical groups. This clustering divided the metals into groups with significant correlations within the groups. The dendrogram (Fig. 2) showed two distinct groups of elements. Cu and Zn formed a distinct group (Group I). Al and Fe formed another one (Group II), and Mn and Pb joined this last group. Based on these groups, the origin of the metals in the studied soils in Libreville could be ascribed to two different origins.

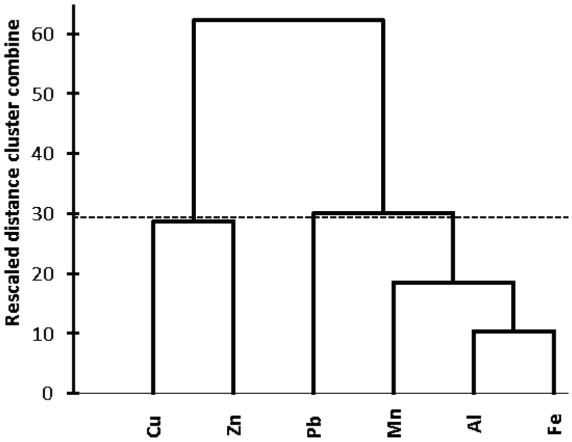

Fig. 2. Dendrogram of hierarchical cluster analysis of the metal concentrations in the studied soils.

The results of Principal Component Analysis to determine the origin of metals in the studied soils are presented in Table IV. Metals were correlated with a two-component model representing 70.8 % of the variability.

TABLE IV. Principal component analysis in 2-D loading plots for the 6 metals in the urban garden soils of Libreville, Gabon

Parameter	PC1	PC2
Eigenvalue	2.61	1.63
Variability, %	43.58	27.18
Cumulated, %	43.58	70.77
Al	0.848	–0.301
Cu	–0.279	0.867
Fe	0.925	0.231
Mn	0.661	0.526
Pb	0.672	–0.334
Zn	0.270	0.590

The first two principal components (PC1 and PC2) had eigenvalues >1 and accounted for 70.8 % of the total variance. The first principal component PC1 explained 43.6 % of the total variance, and had high positive loadings of Al and Fe (> 0.85), Mn and Pb (> 0.66). Al and Fe are included in the chemical composition of major minerals in soils. Both metals and Mn sometimes occur especially in lateritic soils as oxides, hydroxides or oxyhydroxides.[37] Reactivity and generally high surface areas of Mn and Fe oxides make them proficient sorbents of many inorganic cations, such as Pb among others. In particular, Mn (III/IV) and Fe (III) oxide/hydroxide mineral particles and coatings in soils seem to have a strong affinity for Pb.[38] These results suggested that the PC1 component could be linked to soil minerals and contents of Al, Fe, Mn and Pb. PC1 could thus be considered as a lithogenic component.

The second principal component (PC2) explained 27.2 % of the total variance, and had high positive loadings of Cu and Zn (> 0.8 and > 0.6, respectively). This component could be considered as an anthropogenic component. This factor is likely due to human activities, particularly application of fertilizer and pesticides in agriculture. Zhang indicated that metals such as Cu and Zn in urban soils may also be linked to pollution from traffic: wear of brake discs and motor vehicle exhausts.[39] In agricultural soils, the concentrations of these metals may also stem from pesticides and fertilizers.[36] The correlation between Mn and OF2 (0.526) indicated that, in addition to a lithogenic origin, Mn could also stem from an anthropogenic source.[40]

CONCLUSIONS

Poverty in Libreville, as in cities in developing countries, has contributed to the development of urban agriculture. This has increased vegetable production on urban soils, both in open fields and under shelters, which has contributed to an improvement in the quality of food in the region. Agricultural practices adopted by market gardeners involved use of small quantities of organic matter or fertilizer. These practices maintained low fertility and nutrient levels, and metal contents below the averages of tropical soils. Significant differences were found between cultivated soils under shelters and in open fields. There was no significant difference between soils under shelters with time of exploitation. In contrast, in open field soils, significant acidification, losses of nutrients and metals, and aluminum mobility were observed. Multivariate statistical analysis identified the origin of metals in agricultural soils of Libreville. Hence, a management program of soil quality should be performed to protect soils against the effects of climate, and to improve significantly soil fertility and yields of crops. The Gabonese authorities should encourage the research and formulation of agricultural policies at the national level, to develop a database on cultivated soils characteristics and to improve extension services of agricultural practices and environmentally friendly production. Such research, including Geographic Information System (GIS), could confirm the results of this study.

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ИЗВОД

УТИЦАЈ ПОЉОПРИВРЕДНЕ ПРАКСЕ НА СВОЈСТВА И САДРЖАЈ МЕТАЛА У ГРАДСКИМ БАШТАМА ТРОПСКОГ ПОДРУЧЈА

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Обрада земље у урбаним подручјима побољшала је здраву исхрану људи, због конзумирања свежег воћа и поврћа. Ова студија процењује ниво плодности, утицај система узгајања и времена експлоатације на физичкохемијска својства и псеудо-тотални и EDTA-екстрактабилни садржај метала у земљишту градских башта за узгајање поврћа у Либревилу (Габон). Добијени резултати указују на ниску плодност обрађеног земљишта. Садржај метала је био генерално различит између отвореног и заклоњеног земљишта. Осим Al, који би могао бити токсичан за узгајано поврће, концентрације метала су значајно временом опадале у отвореном земљишту, а нису варирале у заклоњеном земљишту. Псеудо-тотални садржај кадмијума био је испод границе детекције у свим земљиштима. Мултиваријантна анализа показала је да су Al, Fe и Pb били литогеног порекла, док су Cu, Zn и Mn били антропогеног.

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