International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(Research Article)

Study of the pedological quality of an overexploited soil and the operating constraints: Case of market gardening sites from Kimuenza to Kinshasa

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International Journal of Science and Research Archive, 2023, 09(01), 533–540

Publication history: Received on 14April 2023; revised 17 June 2023; accepted on 19 June 2023

Article DOI: https://doi.org/10.30574/ijsra.2023.9.1.0406

Abstract

The study aims at assessing the quality of the market garden soil of Kimuenza and the constraints faced with its productivity. The analysis was carried out on the one hand, by Hach UV-visible spectroscopy based on the beer-Lambert law, for the physicochemical parameters, by X-ray fluorescence for the saturation elements and on the other hand, by ICP- MS for metallic trace elements. The detection limit and the reproducibility of these methods have been confirmed.

The obtained indicated that the soil is poor in nutrients necessary for plants, low water retention and a sandy texture and has a high rate of Cd varying between 9.6 to 12.1 mg/Kg in all sites.

Keywords: Soil-Physicochemistry; Pedology; Overexploited; Overfed; Constraint

1. Introduction

Soil fertility traditionally refers to an ability to produce plant biomass. The main indicators for routine monitoring of the fertility of cultivated soil are studied.

Market gardening in Kinshasa faces major challenges including the problem of space and overpopulation with the extension of the city, to which must be added the increase in the supply and demand of market gardening products.

This situation leads to a subdivision in non-urbanized areas leading to a lack of adequate housing, lack of secure food, lack of drinking water, market gardening space and green space.

Cultivation practices are far from guaranteeing the sanitary quality of the vegetables produced. Mineral and organic super fertilization and overexploitation of soils make it difficult to assess soil reserves, volume of organic matter [1].

The peri-urban market garden soils pose the deficiency of several minerals likely to nourish the vegetables. The major mineral forms absorbed by vegetables are: phosphate ions (HPO_4^{2-}, $H_2PO_4^-$), calcium Ca^{2+}, magnesium Mg^{2+}, potassium K^+, nitrate NO_3^- and sulphate SO_4^{2-}). P, K, Mg and Ca have in common a biogeochemical cycle starting with

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the alteration of the source rock. Constituents of organic matter, P, Mg and Ca are present there in a variable fraction, in organic and mineral form, and made available fairly quickly by the release of cellular contents and progressive mineralization of the organic fraction. K, is always in ionic form in the plant or in the soil [2].

Due to the overexploitation of this soil with excessive use of fertilizers and pesticides, the soil loses its productivity qualities. So the soil can no longer produce without it being amended. Vegetable crops grown from this soil require careful consideration as its quality becomes questionable.

The purpose of soil fertilization is to provide plants with the major nutrients. Lack or excess of these elements is often responsible for low yields.

The major soil elements sought in this soil are: Mg, Ca, P, N, Al, Si, Mn, Fe, K, Ti and S which account for 94.4% and the trace elements are: Nb, Rb, Zr, Cu, Zn, Ni, Na, Cà, Cr, Ba, La, Th, As, Cd, Pb which can prevent the evolution of plants and at the same time contaminate them [**3-4].**

The Province of Kinshasa is almost completely covered with sandy soils inherited from the overlying sands of the *Kalahari system* [5-6]. These soils belong to the large group of *ferrallitic*soils. They are characterized by an advanced stage of spoilage, show an acid reaction and have a low reserve (balance) of nutrients which make them marginal for agriculture. [7]. The low chemical fertility and the very limited water retention capacity constitute severe limitations of their agronomic potential. Deep nutrient leaching is favored in these soils. When they are cleared and left bare, the decrease in biological activity is even faster [8].

The objective pursued in this study is to characterize the overexploited and overfertilized market garden soil of Kimuenza in order to determine its quality and face the constraint due to its productivity.

2. Area, materials and methods

2.1. Environmental study

Soil samples from the surface horizons were used for the present investigation. On each site, a profile was carried out and a composite sample was prepared from small core samples of soil taken in a dispersed manner over an area of approximately one hectare for Site de Pont Ma vallée (Lat. S 04 º 28 ˈ 32 ,4'' and Log. E), Kiala site (Lat. S 04 º 28 ˈ 40.1'' and Long. E 015 º 16'28.8''), Regideso catchment site (Lat. S 04 º 28 ˈ 53.8'' and Long. E 015 º 16'20.9''), Tshilombo Site (Lat. S 04 º 29'36.7'' and Long. E 015 º 15'23.4'') and the Mafunfu site (Lat. S 04 º 29'53.7'' and Long. E 015 º 15'19.5'').

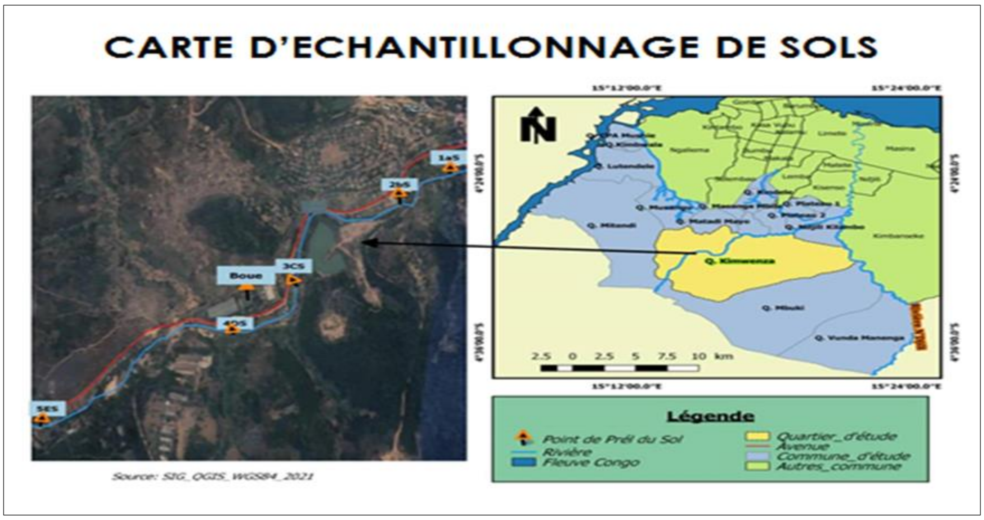


Figure 1 Kimuenza market garden soil sampling map

All the sites are peri-urban market gardening sites in Kimuenza, in the urban-rural commune of Mont Ngafula, district of Lukunga, city of Kinshasa. They are located between the Lukaya River and the road that leads to the Mafumfu group and this road with low traffic of motorized vehicles and a few motorcycles or vehicles that rarely pass there for the transport of agents from CARRIKIM, Regideso, Chute de Lukaya, lolaya Bonobo, Minocongo and the market gardening population as well as the sellers of vegetables from different corners of the city of Kinshasa.

All these market gardening sites are located along the watershed of the Lukaya River have common characteristics including: the use of droppings, urea and NPK to amend the soil, pesticides.

The geospatial coordinates made it possible to establish the sampling maps of the market gardening sites above

Using the den, 5 samples of market garden soil were taken from each site at a depth of 0-25 cm. Another composite sample of all market gardening sites was made.

2.2. Analysis methods

2.2.1. Physico-chemical characterization of soils and manure

The soil pH was measured using a “combined pH electrode” pH meter. The pH (H_2O) is measured in the proportion 1/2.5, a soil-water suspension, using the CONSORT 532 brand pH meter.

The organic matter is calculated on the basis of the organic carbon values obtained according to the method of Walkley and Black. (%MO=%CO x 1.724). The organic carbon of sludge is determined by ISO 14 235 standard. It is an oxidation of the organic carbon of the soil, sludge and manure by potassium bicarbonate ($K_2Cr_2O_7$) in excess, in an acid medium. (H_2SO_4) hot.

$^{-1}$ potassium bicarbonate solution and 7.5 mL of concentrated H_2SO_4. After centrifugation (10 min at 3000 – Scientific Bioblock and sigma type 2-15) and filtration at 0.45 µm. the filtrate obtained is assayed at 580 nm using a **HACH visible UV spectrophotometer.** The assay is done using a calibration curve established from glucose, chosen as a reference to the organic component.

The water content was determined in each soil sample which was taken using a split corer, by the oven set at 105°C. the difference in weight before and after parboiling made it possible to determine the water content.

The weight before and after steaming at 105°C made it possible to determine the dryness, the humidity, the dry matter, the consistency of the soil samples. Dryness determines the consistency of each sludge.

The texture of the soils was carried out by adding hot hydrogen peroxide to it to destroy the organic matter, separate the sand from the silts and clay. Adding sodium hexametaphosphate flocculates the clay and separates it from the silts.

Cation exchange capacityrepresents the maximum potential of a soil to fix cations. It is the overall sum of the places available on the negative charges of colloids of the sludge, droppings for the fixing of the cations (H^+, K^+, Na^+, Ca^{+2} Mn^{2+}, Fe^{3+}, and Al^{3+}). Sheis determined by the cobalt chloride hexamine $[Co(NH_3)_6Cl_3]$ method according to standard NF X 31-130 (Afnor, 2004). The principle is based on the fact that the cobalthexamine $Co(NH_3)_6^{+3}$ ions adsorb on the surface of a sludge and thus displace the cations retained by the support. CEC measurement required 5 g of sludge, suspended in 25 mL of a 0.016 mol L^{-1} $Co(NH_3)_6Cl_3$ solution. Shaken for 3 hours in a centrifuge for 14 minutes at 3000 – BioblockScientif and sigma 2-15 type, then filtered at 0.45 µm, the excess $Co(NH_3)_6^{+3}$ ions are determined by colorimetry at 470 nm, using a **HACH visible UV spectrophotometer.** ThereCEC is expressed in meq/100g of soil. A calibration curve established from the 5 standard solutions (0.01; 0.02; 0.03; 0.04; and 0.05).

The determination of phosphorus by the method of Bray, this happens by the complexation by ammonium fluoride which binds to phosphorus. The latter is assayed by spectrophotometer with molybdenum blue.

2.2.2. Dosage of total nitrogen by Kjeldahl method

The exchangeable cation content was determined according to standard NF X31-161 (Afnor, 2004).

5 g of soil are subjected to a suspension of 1 mol/L ammonium acetate adjusted to pH=7 using acetic acid at mol/L or 1 mol/L ammonia. The mixture is stirred for 1 hour (1 KA Labor technik KS 501-digital model orbital magnetic stirrer - 150 revolutions/min), centrifuged for 14 minutes at 3000 –Bioblock scientific and sigma type 2-15, then filtered at 0.45 µm. the dosage is carried out by a HACH visible UV spectrophotometer based on the Beer–Lambert law, the wavelength of each element of which is associated with its capsule (buffer).

The saturation and major elements were produced by CREN-K X-Ray Fluorescence. A soil sample was heated to 105°C, cooled and ground and sieved with a 2mm sieve. 4 g of the sample and associated with 1 g of CEREOX then formed the pellets using a pelletizer. The pellets obtained are analyzed with an X-ray fluorescence spectrometer and carried out on each face of the pellet to obtain the chemical composition of each pellet and the different proportions and the results are expressed in %. And The soil samples were taken by solution treatment at the "United Scientific" Laboratory in Lubumbashi. The samples were weighed and dried in an oven at a temperature of 60° C. until a constant weight was obtained. After drying, the samples were weighed, ground and sieved separately at 2 mm. Half a gram (0.5g) of each sample is dissolved by mixing 6 mL of hydrogen peroxide (H_2O_2) and 6 mL of nitric acid (HNO_3) in a DigiPREP at a temperature of 95°C for a duration of 3 hours. The determination of metallic trace elements was carried out by mass spectrometry with induced coupling plasma (ICP-MS) of the ACRO brand. The results are expressed in mg/Kg.

All the results obtained were subjected to statistical methods to identify either the differences or a comparison.

3. Results and discussion

The results recorded in graph 2 of the physicochemical parameters reveal that the saturation rate is very low in all the soils studied (<25%). All nutrients are Ca, Mg and K are the most important basic cations in agriculture or market gardening. The ideal values of base saturation for these three cations are 70 to 85% for Ca, 10 to 15% for Mg and 4 to 7% for K [9]. The cation exchange capacity varies between 3.79 to 5.41 mg/100g of soil. Ion mobility is not intense where ions must move to feed plants.

There is an imbalance between the cations due to the degree of the soil's own alteration and overexploitation.

The particle size analysis of the soils studied showed on the one hand a sandy-clayey texture for the Kiala, Mavalée, Regideso catchment sites following fertilization with poultry droppings which had just been sprayed, which affects the pH and the texture of the soil. . And sandy for the Tshilombo and Mafunfu sites, of which fine sands are the main constituents and can be classified under the heading areferrasols (dystrica) [10]. This soil exhibits physical properties where water retention is low and porosity is high with optimal drainage conditions. Since organic carbon is higher in the soil,CO>2.4%,THEsoils of the Regideso and Kiala catchment sites [2.19-2.85%]AlevelpupilinMO, so high fertility. The Tshilombo and Mafunfu sites [1.1-1.5%] have a moderately low level of MO because they vary in % CO from 0.8-1.5% and the Mavalée site is low because the CO <0.8%.

The soil pH varies between 6.8 to 7.8 in all sites except the Tshilombo site where the pH is 6.37 and in Mafunfu where the pH is 5.71. This pH is slightly acidic. That of the Mavallée and Kiala sites is basic due to the influence of fertilization products and Tshilombo and CattageRegideso 6.8. The pH obtained in different soil samples is far superior to those found for the sandy soil of the same site (4.9), there was an improvement due to the use of droppings [11].

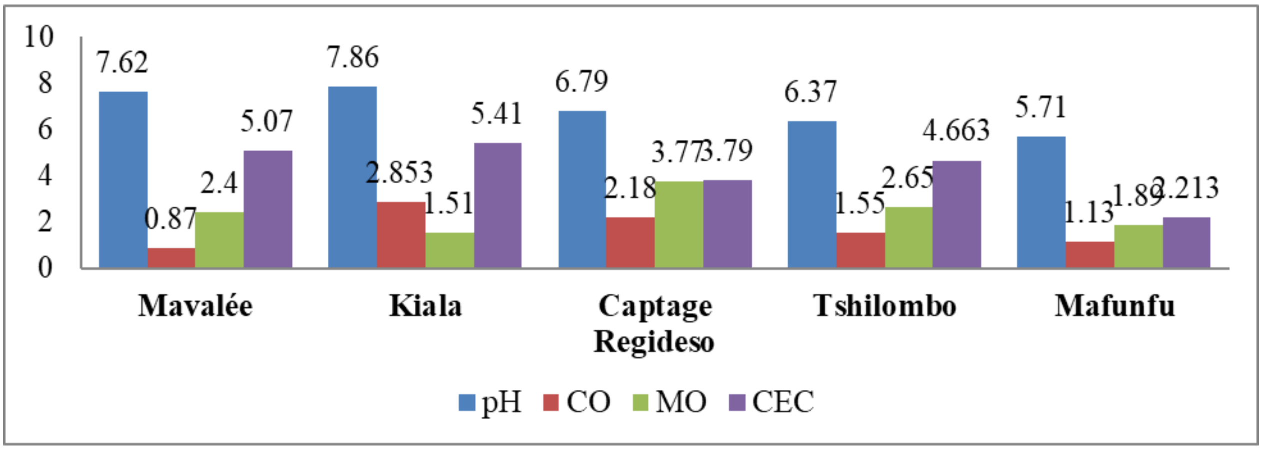


Figure 1 Physicochemical parameters of market garden soils in Kimuenza

The total contents of major elements shown in graphic 2 show that:

Potassium has a higher rate than in the soil of the Tshilombo site (0.998%) and low the Mavallée site (0.448). All sites have low potassium levels but above 0.16% the norm. The market garden soil is depleted in potassium due to overexploitation and the intense demand for crops. Overexploitation of soils makes it difficult to assess soil reserves, volume of organic matter [1].

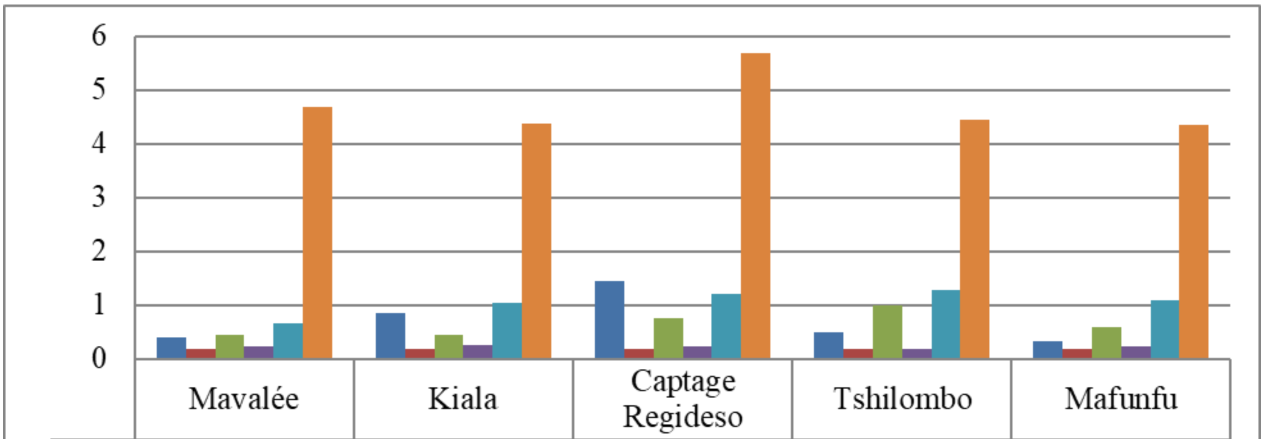
Calcium in the peri-urban market garden soils of Kimwenza varies between 0.323% at Mafunfu and 1.435% at the Regideso catchment site. The Ca concentration of the Regideso and Kiala catchment sites is very high due to the proximity of the Kiala quarry which crushes the stones and evacuates the calcium carbonate in the form of dust. They are higher in calcium than in potassium.

Magnesium in the peri-urban market garden soils of Kimwenza varies between 0.167% (CaptageRegideso) and 0.183% (Kiala). Soil is low in magnesium.

Market garden soils still have a higher rate of iron than that of calcium and potassium. Its concentrations vary between 0.657% (mavalée site) and 1.2815% (Tshilombo site). The world population (60-80%) would be deficient in iron, of which 30% would be anemic, hence increasing the rate of iron in edible plants would be necessary, hence the use of iron as fertilizer would provide iron [12].

Aluminum in the peri-urban market garden soils of Kimwenza is less abundant and varies between 4.346% (Mafunfu) to 5.689% Regideso catchment. The discharge of settling sludge from the Lukaya plant influences the quantity of aluminum in the soil of this site. The pH being > 5.5, the aluminum is in the form of $Al(OH)_3$ and the exchangeable Al^{3+} does not exist. On the Mafunfu site, where the pH is around 5.5, the Al^{3+} content will tend to increase [13-14].

Na is very low at all sites. It varies from 0.19% (Tshilombo) and 0.254% (Kiala).



	Mavalée	Kiala	Captage Regideso	Tshilombo	Mafunfu
Ca	0.3957	0.855	1.435	0.483	0.323
Mg	0.177	0.1834	0.1677	0.1796	0.169
K	0.448	0.452	0.7487	0.988	0.596
Na	0.229	0.254	0.216	0.19	0.226
Fe	0.657	1.029	1.213	1.281	1.085
Al	4.68	4.367	5.689	4.456	4.346

Figure 2 The total contents of major elements

The other elements constituting the chemical fertilizers such as N and P, are listed in Table 1.

Nitrogen in the peri-urban market gardening soils of Kimwenza is very low compared to crop demand and varies in all sites between 0.01% (Mavalée) to 0.1% (Tshilombo).

Phosphorus in the peri-urban market garden soils of Kimwenza varies between 0.206% (Tshilombo) to 0.23% (Kiala). So it is low for soil with a market gardening tendency.

The sulfur in the peri-urban market gardening soils of Kimwenza is very low and varies from 0.105% (Mavallée) to 0.13% (CaptageRegideso). This high sulfur value in this site comes from the discharge of water purification sludge from the Lukaya plant.

The most abundant silicon in the earth's crust and in the peri-urban market gardening soils of Kimwenza varies between 56.8 to 60.8%.

Table 1 The other elements constituting the chemical fertilizers

	Si	**S**	**P**	**N**
Mavalee	57.69±2.53	0.105±0.009	0.22+0.0005	0.01±.00
Kiala	56.843±1.758	0.124±0.007	0.230±0.0456	0.09±0.019
Regideso capture	60.846±2.056	0.13±0.1064	0.211±0.019	0.08±0.0194
Tshilombo	56.896±3.186	0.111±0.0188	0.206±0.0123	0.1±0.00
Mafunfu	56.936±1.414	0.121±0.056	0.216±0.042	0.07±0.013

The metallic trace elements present in the market garden soils of Kimuenza are listed in tables 2a, 2b and 2c :

The total contents of metallic trace elements present in the market garden soils of Kimuenza in different sites studied indicate that the potential availability of minor or major metallic trace elements depends on soil types and their characteristics including acidity (pH), humidity , organic matter content and oxidation-reduction potential [15]**.** Whatever the final destination, knowledge of the levels of metallic trace elements is essential in the event of recovery [16]. Market garden **soils** contain some metallic trace elements. These ETMs are far below the limit values. Only Cd varies between 9.6 to 12.1 mg/Kg, values higher than the standards for market garden soil, 2 mg/Kg (NF 441/1985) and 3 mg/Kg.

These heavy metals present are much lower than the concentrations allowed in soils where crops can be grown, except for Cd which has high concentrations.

Table 2a Metallic trace elements present in the market garden soils of Kimuenza

	Mn	**Cr**	**Ni**	**Cu**
Mavalee	222.53±4.607	31.333±2.271	22.133±2.011	30.93±1.687
Kiala	251.75±0.9471	33.166±1.816	26.4±3.698	37.8±3.114
Regideso capture	233.7±4.672	35.8±2.141	24.766±2.206	33.6±3.114
Tshilombo	235.466±8.630	30.933±1.103	23.166±1.232	29.6±1.946
Mafunfu	228.5±23.165	31.466±1.622	22.133±1.881	27.615±0.0315

Table 2b Metallic trace elements present in the market garden soils of Kimuenza

	Cr	**Pb**	**Rb**
Mavalee	11.233±3.049	3.24±0.428	16.63±0.843
Kiala	10.15±0.315	3.906±0.207	17.133±1.492
Regideso capture	12.1±1.557	3.906±0.207	16.633±1.038
Tshilombo	9.633±0.908	3.1±0.194	16.733± **2.400**
Mafunfu	10.866±1.881	3.4±0.584	15.11±0.798

NFU 441 1985	2	100	
Directive 1986-88	3	300	
EEC, 1986	3	300	

Table 2c Metallic trace elements present in the market garden soils of Kimuenza

	Cu	Zn	As
Mavalee	30.93±1.687	25.4±3.504	1.1±0.00
Kiala	37.8±3.114	26.826±3.400	1.3±0.00
Regideso capture	33.6±3.114	22.603±1.155	1.6±0.389
Tshilombo	29.6±1.946	22.4±1.946	1.01±0.00
Mafunfu	27.615±0.0315	21.966±1622	1.02±0.00
NFU 441 1985	100	300	
Directive 1986-88	140	300	
EEC, 1986	50-140	300	

4. Conclusion

The objective of this study aimed characterizing the overexploited and overfertilized soil of Kimuenza. The obtained results showed that the soil of Kimuenza is poor in major elements due to the composition of its texture and its water retention is low. Ideal base saturation values for essential cations are not reached.

The soil has undergone changes due to the influence of the uncontrolled use of fertilizers and overexploitation, thus accumulating metallic trace elements such as Cd and preventing its use.

As the soil has no nutrient reserves for plants, we recommend using a fertilizer capable of increasing water retention to stabilize the major elements, such as water purification sludge.

Compliance with ethical standards

Acknowledgments

We would like to thank the Chemical Laboratories of Center Nucléire de Kinshasa and United Scienfic de Lubumbashi for supporting us in carrying out this study. our thanks also go to the laboratory technicians of the Pedology Laboratory of the Faculty of Agronomy of the University of Kinshasa for the preparation of the samples.

Disclosure of conflict of interest

There is no conflict of interest either between the authors or with third parties in this study.

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