Soil Properties on Farmers' Fields Amended with Untreated Solid Urban Wastes in Ouagadougou Peri-urban Area, Burkina Faso

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Summary

In Burkina Faso untreated Solid Urban Wastes (SUW) are commonly used as agricultural fertilizers. This study aims to highlight the impacts of this current practice on soil agronomic properties and crop production. Sampling was carried out in Ouagadougou sub-urban agricultural fields. Agronomic tests, physical and chemical analyses were carried out following lab common procedures. The fertility of the soils was assessed through a greenhouse experiment with maize as test crop. The results showed that amendment significantly increased the pH, total C, N, P and available P contents as p-values were <0.01 for these parameters. The averages maize height and aboveground biomass yield in amended plots were 124% and 164% higher than in the non-amended plots respectively. Also, trace metal elements (Cu, Zn, Pb, Ni and Cr) concentrations were higher in the amended fields than in the control ones, suggesting that urban waste also carries contaminants that constitute risks for public health. This research showed that the use of SUW as fertilizer has agronomic advantages as it increases the essential nutrient content of the soil and regulates its pH. However an adequate pretreatment is necessary to avoid risks related to contaminants such as trace metal elements.

Résumé

Propriétés des sols des champs agricoles amendés avec des déchets urbains non traités en zone péri-urbaine de Ouagadougou, Burkina Faso

Au Burkina Faso, les déchets urbains non traités sont beaucoup utilisés comme fertilisants agricoles. Cette étude avait pour objectif de déterminer les impacts de cette pratique courante sur les propriétés agronomiques du sol et sur la production végétale. L'échantillonnage a été effectué dans des champs agricoles en périphérie de Ouagadougou. Un test agronomique et des analyses physiques et chimiques ont été réalisés suivant les procédures courantes de laboratoire. La fertilité des sols étudiés a été évaluée à travers une culture de maïs dans des petits pots sous conditions de serre. Les résultats ont montré que les amendements entrainaient une augmentation significative du pH, des C, N et P totaux ainsi que du P disponible. La taille moyenne des plants et le rendement en termes de biomasse aérienne des plantes issues des sols amendés étaient respectivement 124% et 164% plus élevés que ceux issus du sol témoin non amendé. En outre, les concentrations des éléments traces métalliques (Cu, Zn, Pb, Ni et Cr) étaient plus élevées dans les sols amendés que dans les sols non amendés suggérant que les amendements n'apportent pas seulement des nutriments pour la croissance des plantes, mais aussi des contaminants pouvant présenter un risque pour la santé humaine. Cette étude a montré que l'utilisation des déchets urbains solides comme amendement a des avantages agronomiques car elle augmente les teneurs en nutriments essentiels du sol et elle régule son pH, mais il est nécessaire qu'un prétraitement adéquat soit fait pour éviter les risques liés aux contaminants tels que les éléments de métaux traces.

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Introduction

Located in the heart of West Africa, Burkina Faso is a landlocked country with a surface of 274,000 km². Its population was estimated at more than 14.01 million residents in 2006 with an annual growth rate of 3.1% and 3.18 million of urbans residents (35). Agriculture accounts for 32% of the gross domestic product and is practiced by 80% of the active population.
Burkina Faso, like many sub-Saharan countries, is facing drastic climatic conditions, high population pressure and especially low soil fertility (15, 16, 26, 37). Indeed, 11%, 2%, 34% and 49% of the lands in Burkina Faso are considered at very high, high, moderate and low levels of degradation, respectively (42). In other words, lands are naturally poor in organic matter (<0,6%) (42). In addition, the effects of climate change and the overuse of land have contributed to the depletion of the soil in N and P (3), two major nutrients limiting agricultural production [32]. Ouagadougou is also facing significant production of urban solid wastes (SUW).
According to the office of sustainable development of Ouagadougou, solid waste production in the city is estimated to be 300,000 tons per year from which, 60% are collected (24). Spreading of SUW is an attractive recycling strategy because of the presence of recyclable organic material (65-90%) (1, 40) which is beneficial for plant growth and agricultural soils fertilization (14). Furthermore, it is an affordable source of nutrients to agriculture and a mitigation of waste disposal problems (10).
Because of their fertilizing value, SUW are commonly used by farmers in peri-urban agriculture to support agricultural production (12), which contributes to cover the food needs and fight against poverty.
However, these wastes, composed globally of domestic breeding products and wastes from hospitals and industries, are used without prior sorting or pretreatment (composting).
Therefore, the potential presence of trace metal elements (TME) and other unknown components can have detrimental effects on the environment (soil degradation) and human health (4, 23, 43).
In order to optimize the use of SUW as amendment in agricultural lands, it is necessary to evaluate their impact on the soil properties.
The aim of this study was to highlight the impacts of the use of untreated SUW on soil agronomic properties and crop production and to strengthen the public awareness of the potentially associated risks. The specific objectives were:

- to determine the chemical characteristics, including TME, of soil after treatment with SUW, and
- to assess the impact of SUW on maize yields in a greenhouse experiment.

Maize was selected as a test crop because it's a widespread staple crop in sub-Saharan Africa (SSA). It occupies more than 33 million ha each year (11). From some 200 million ha cultivated in SSA, maize farms cover almost 17%. This crop is also the highest component of the national diet in 22 countries worldwide from which, 16 are located in Africa (31).

Material and methods

Study sites and soils sampling

This study was conducted on 2 agricultural sites located in the surrounding zone of Ouagadougou: Toudwéogo in the north and Nagrin in the south (Figure 1).
The landscape is slightly undulating, with a slope of less than 2%, and the soils are derived from granites and migmatites (17). All soils have been classified as petroplinthic Leptosol (11).
In the area, the annual rainfall is between 600 and 900 mm, and falls from May to October (19). According to the meteorological station of IRD in Ouagadougou, the annual rainfall was 736.4 and 883.7 mm in 2013 and 2014, respectively. The area of Ouagadougou has a tropical climate with monthly average temperature between 20 and 30 °C.
Several annual crops (sorghum, peanut, cowpeas, maize, sorrel, okra, etc.) are usually cultivated.
For more than 20 years, these soils have been amended with raw urban waste (without sorting nor pretreatment).
For both study sites, the SUW used usually contain livestock wastes (manure of cattle, goats, pigs and poultry, and slaughterhouse waste), organic household wastes (vegetables), as well as papers, glass, plastic, scrap iron, cans, and some contain hospital and pharmaceutical wastes. Wastes disposal has been free or cheap to farmers for amendments so that the amounts applied ranged from 20 to 30 tons per ha and per year.
Sampling was carried out in March 2013 in the Toudwéogo site and in March 2014 in the Nagrin site on plots amended with SUW and on unamended plots (control field). At each site, sampling was carried out on the surface layer (0-5 cm) in both amended and unamended fields in order to assess the benefits from the amendment on soil agronomic properties and crop production. The amended plots (*Am*) and unamended (*Na*) had a surface of 1.5 ha and 0.5 ha, respectively, for the site of Toudwéogo; for the site of Nagrin it was 2 ha and 0.75 ha for the amended plot and unamended plot, respectively.
The sampling was carried out using a plastic shovel previously cleaned with alcohol and demineralized water and put in clean plastic bags for the agronomic tests.

In amended plots, 5 transects of 20 m were considered. In each transect, sampling was carried out both in the rhizosphere (*am_rhizo*) and in the interlining space (*am_int*) i.e outside of the direct influence of plants roots. The idea, while sampling in the rhizosphere and in the interlining space, is to see whether the physical and chemical characteristics of the soil around the roots (where the microbial activity is generally more intense) are different from that of the interlining (because plant root could absorb C, N, P and/or TME). From a given transect, 5 composite samples (of approximately 5 kg each) were collected from the rhizosphere area by mixing 2 consecutive samples collected every 2 m; in addition, 5 composite samples were collected from the interlining space by mixing 2 consecutive samples collected every 2 m (Figure 2). Then, 10 samples were obtained from each transect, allowing a collection of 50 samples (5x10) from the amended plot in each site.

In unamended plots, 2 transects of 20 m were considered and the sampling was carried out only at the interlining space. Five composite samples per transect were collected by mixing 2 consecutive samples collected every 2 m, allowing a collection of 10 samples (2x5) from the unamended plot in each site.

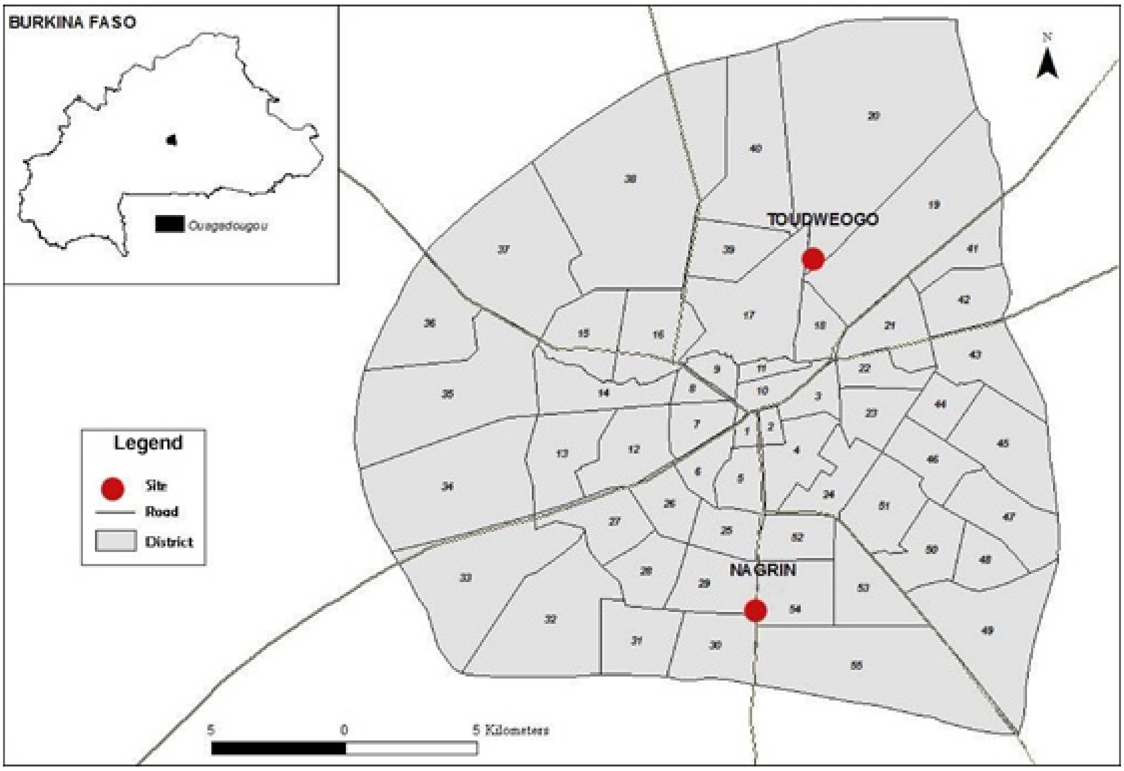

Figure 1: Map of Ouagadougou city illustrating the sampling sites.

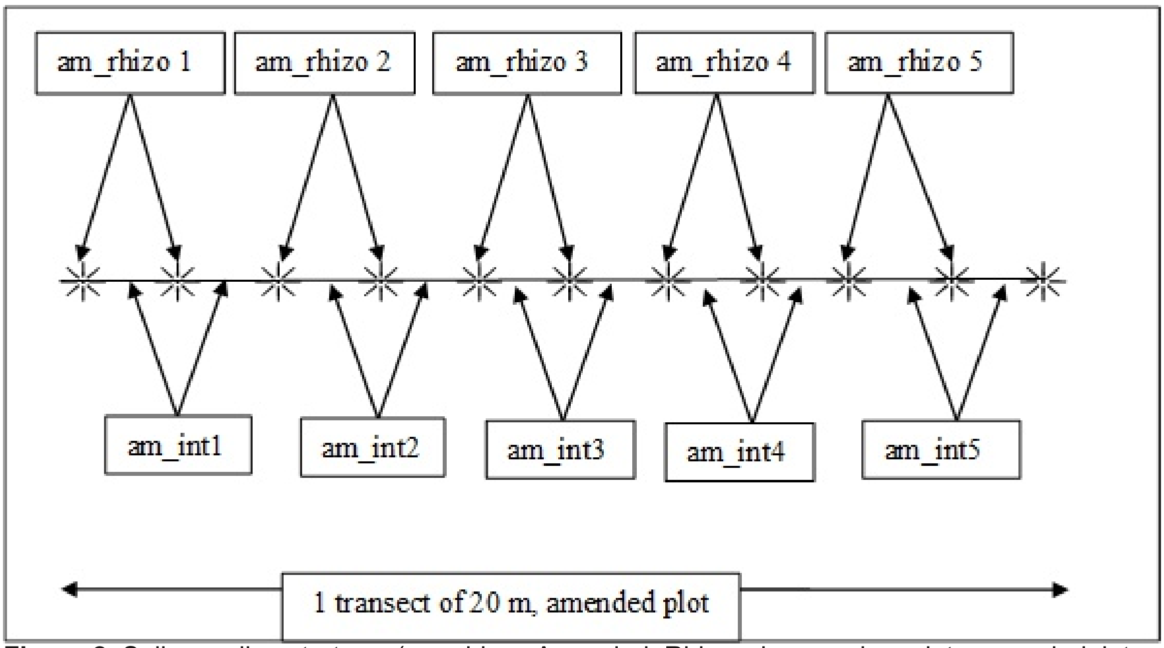

Figure 2: Soil sampling strategy, (am_rhizo : Amended_Rhizosphere and am_int : amended_interline).

These samples were used as control. Finally, the substrate (SUW), i.e. raw solid urban waste used by famers to fertilize their fields was sampled for analyses in order to compare the results with the data of amended and unamended soils.

Physical and chemical parameters analyses

Soil samples were air-dried and then gently broken up using a pestle and mortar, and sieved at 2 mm. Two aliquots (100 g) were ground to 0.2 and 0.5 mm for further analyses: pH, total carbon (TC), total nitrogen (TN), total phosphorus (TP) and available phosphorus (Pav). pH-values in water (pH-H_2O) and in potassium chloride (pH-KCl) of soil samples have been determined according to NF EN 13037 (30). The C and N concentrations in the soil samples were determined on 0.2 mm ground aliquots by dry combustion using an elemental analyzer (CHN Fisons/Carlo Erba NA 2000, Milan, Italy). As all of the soil samples were carbonate-free, total C was considered equal to organic C. Total phosphorus was determined (using an auto analyzer) by mineralization with sulfo-salicylic acid. Samples were subjected to a mineralization with sulphuric acid (H_2SO_4) and salicylic acid ($C_7H_6O_3$) mixture in a presence of hydrogen peroxide (H_2O_2). Selenium (Se) was used as catalyst. At the end of mineralization, total phosphorus was measured by spectrometry at 880 nm by the molybdenum blue method (BUNASOLS of Burkina Faso). The available P (Pav) concentration was determined using the modified Olsen Dabin procedure for samples collected (extraction using sodium bicarbonate at pH 8.5) with colorimetric assay. Lastly, another aliquot of 100 g was also ground and sieved (0.2 mm diameter) for quantification of five trace metal elements (TME), such as copper (Cu), zinc (Zn), lead (Pb), nickel (Ni) and chromium (Cr).

The total levels of TME (such as Pb, Cu, Zn, Ni and Cr) were analyzed in a suspension of the 0.2 mm fraction of a ground soil. It was made by acid attack of the solid phases, according to standard NF X 31-147, July 1996, after calcination at 450 °C during 3 hours, using a mixture of a concentrated hydrofluoric acid and per-chloric acid (9).

Greenhouse test

The fertility of soils under study was assessed using an experiment with maize (*Zea mays*) as a test plant in small pots under greenhouse conditions, with soil samples collected at Toudwéogo. This activity was done from May to June 2013. Each pot contained 1 kg of soil where 5 seeds have been sown. Maize seeds were sorted before being sown. All the samples collected at Toudwéogo were tested (am-rhizo, am-inter and Na). Thus, 60 pots were obtained in total from which 25 pots contained soil from the amended plot - rhizosphere (am_rhizo), 25 from the amended plot - interlining (am_int), and 10 pots from the unamended plot (control).

Each pot was daily watered with 150 ml in the morning and evening during 56 days. One week after germination, a thinning was carried out, by selecting the best seedlings. The weekly growth of the plants was measured up to 8 weeks after sowing.

Biomass quantification

After 8 weeks, the entire plants (root and aerial parts) were harvested and placed in an oven at 70 °C until constant weight. After 72 hours approximately, the total dry biomass of each pot was weighed to determine biomass yield; the aerial biomass (BA) and the root biomass (BR) were handled separately and expressed in grams. Maize biomass yield was used to assess soil fertility.

Statistical analysis

The results were analyzed using the Microsoft Office Excel 2010 and XLSTAT Pro version 7.5.2. Analysis of variance ANOVA according to Fisher test and the linear correlations test were carried with the threshold 5%.

Résultats et discussion

Soil pH

The results showed that the average pH-H_2O values were above neutrality in the amended (Am_rhizo, Am_int) soils (7.6±0.14) while it was below neutrality in the control (Na) soils (6.5±0.13) at the Toudweogo site (Figure 3). At Nagrin, pH-H_2O was above neutrality in both the amended and the control soils (7.5±0.34 and 7.3±0.07, respectively).

In the organic fertilizer (SUW) pH-H_2O was 7.4 in Toudweogo site and 7.3 in Nagrin site. From these observations, it appears that the pH has increased by more than one unit in the amended soils of Toudwéogo compared to the unamended ones of the same site. This slight increase could be attributed to SUW spreading. This modification of pH was not perceptible in the soils of Nagrin because the unamended soils had already a neutral pH. However, the amendment may have contributed to maintain the pH around neutrality in the amended soils (Nagrin site).

These results can be explained by the fact that composts generally have a relatively high pH (8) and have large amounts of buffer substances, such as carbohydrates, lipids, protein, humic acid, etc. (20, 46).

The pH is a critical parameter for the plant mineral nutrition because it directly influences the availability of soil biogenic salts, their possible toxicity and soil microbiological activity. Indeed, when pH is near neutral (pH=7), the availability of essential plant nutrients (nitrogen, phosphorus, potassium, calcium, magnesium and trace elements) in the soil is maximum (27).

The “ideal” soil pH is close to neutral, and neutral soils are considered to fall within a range from a slightly acidic pH of 6.5 to slightly alkaline pH of 7.5 (27). In addition this range of pH is generally very compatible to plant root growth.

pH-KCl is generally lower than the pH-H_2O except for soils containing metallic ions (33). In Toudweogo site, this hypothesis was verified in all the samples. However, the difference between pH-H_2O and pH-KCl was much more significant in the control soils compared to the amended soils. Indeed, this difference was 0.6 in the unamended soils (Na) against 0.2 in the amended ones (Am_rhizo, Am_inter) (Figure 3) as if it had an evolution of the pH-KCl value of the amended soils towards the pH-H_2O value of the same soils. This result suggests a possible presence of metallic ions such as Fe, Cd, Cu, Cr, As, Pb and Ni in amended soils as it has been established in a previous study (33). This might confirm the hypothesis that the amendments provide chemical contaminants to the soil even if their concentrations are not enough yet to return the pH-KCl > pH-H_2O (Figure 3).

In Nagrin site, pH-H_2O is lower than the pH-KCl for both the amended and the control soils. This result suggests that these soils should be contaminated with TME. As shown further by TME assessment, amended and unamended soils are both contaminated with Cu, Zn, Pb, Ni and Cr at Nagrin and Toudweogo sites.

The hypothesis that the amendments provide chemical contaminants in soil should be maintained even if among the concentration of TME quantified in this study (Cu, Zn, Pb, Ni and Cr), there are no significant differences between the soils of Nagrin and Toudweogo sites. The differences in the pH trends in Nagrin and Toudweogo could be explained by the possible presence in Nagrin, of other TME such as Cd and Hg (45), not quantified in this work that could have increased the pH-KCl. Furthermore, the analysis of TC, TN, TP and Pav revealed higher concentrations in the soils of Nagrin compared to those of Toudwéogo (Table 1).

This strong TC concentration in Nagrin site suggests a spreading of enormous quantities of SUW and could confirm the fact that the soils of this site contained high concentration of other chemical elements (such as Cd and Hg) than those quantified in this study (Cu, Zn, Pb, Ni and Cr).

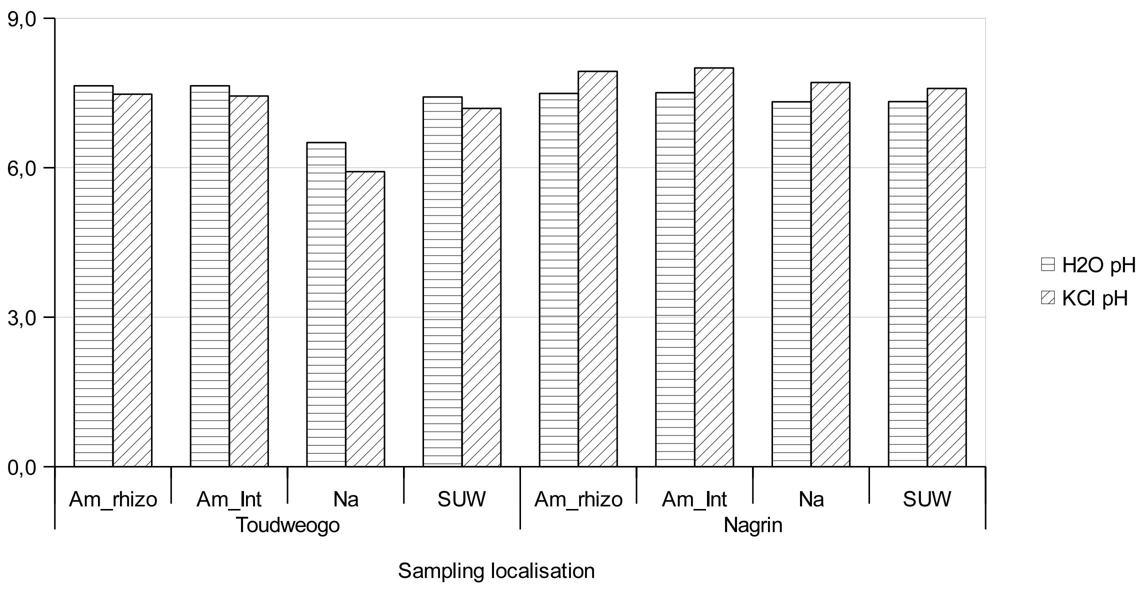

Figure 3: Average values of pH in Toudwéogo and Nagrin soils samples. Am_rhizo (average of 25 values)= amended plot, sampling at the rhizosphere; Am_int (average of 25 values)= amended plot, sampling at the Inter-line; Na (average of 10 values)= unamended soil. SUW: raw solid urban waste. The bars on histograms represent the standard deviation.

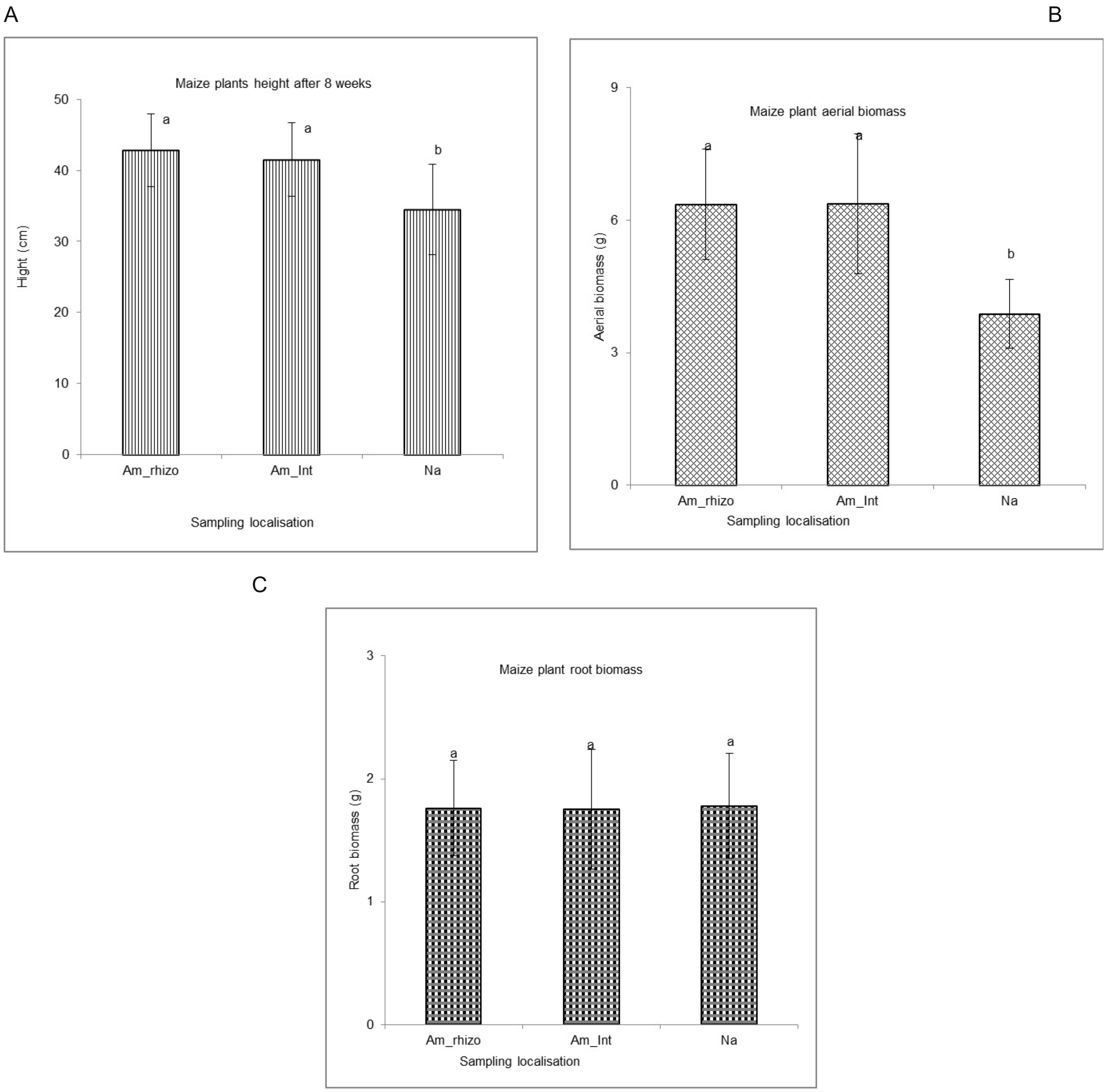

Figure 4: Average height of maize plants (A), aerial (B) and root (C) biomass. The values are expressed as a gram (g) or centimeter (cm). Am_rhizo= Plot amended, sampling at the rhizosphere; am_Int= Plot amended, sampling at spacing that i.e, outside of the influence of roots; Na= non-amended soil (control). The bars on histograms represent the standard deviation. The parameters (Height, Aerial or Roots biomass) of the same site (Nagrin or Toudwéogo) affected by the same letter (a or b) are not significantly different.

Tableau 1

Average chemical parameters of amended, unamended soil and the substratum in “Toudwéogo” and “Nagrin”.

Sampling localisation		TC (%)	TN (%)	TP (ppm)	P av. (ppm)
	Am_rhizo	1.48 ± 0.78a	0.12 ± 0.06a	952.2 ± 576a	190.4 ± 115a
Toudwéogo	Am_int	1.23 ± 0.06a	0.10 ± 0.06a	638.5 ± 316ab	127.7 ± 63b
	Na	0.22 ± 0.03ab	0.02 ± 0.003ab	162.6 ± 55b	32.5 ± 11b
	F Pr.	*< 0.0001*	*< 0.0001*	*< 0.0001*	*< 0.0001*
	Am_rhizo	3.38 ± 1.03b	0.21 ± 0.07b	1487.6 ± 1080a	275.7 ± 142a
Nagrin	Am_int	3.67 ± 0.83b	0.23 ± 0.08b	1220.2 ± 405a	230.4 ± 80a
	Na	1.39 ± 0.30c	0.09 ± 0.02**c**	475.3 ± 147a	110.7 ± 33b
	F Pr.	*< 0.0001*	*< 0.0001*	*0.007*	*0.001*

Legend

TC= total carbon; TN: total nitrogen; TP: total phosphorus; Pav.: available phosphorus. Am_rhizo= amended Plot, sampling at the rhizosphere; Am_int= amended Plot, sampling at spacing i.e, outside of the influence of roots; Na= unamended soil (control); SUW: solid urban waste. The values of the same column, the same site (“Nagrin” or “Toudwéogo”) and affected by the same letter are not significantly different according to Ficher ANOVA. F Pr.= Level of significance with the threshold 5%.

Total carbon, Total nitrogen, Total phosphorus and available phosphorus

Total carbon (TC), total nitrogen (TN), total phosphorus (TP) and available phosphorus (Pav) were higher in the amended plots compared to the unamended plot (Table 1) in both Toudwéogo and Nagrin sites. When comparing TC, TN, TP and Pav values in the am_rhizo and Am_int collected in both sites, it appears that except for phosphorus (TP and Pav) values in Toudweogo, there are no significant differences. Other important observations are the lower values of TC, TN, TP and Pav obtained with the SUW of Toudwéogo. Indeed, in the SUW from Toudweogo the values of TC, TN, TP and Pav were respectively 0.44%, 0.04%, 669.7 ppm and 133.9 ppm against 5.68%, 0.44%, 1,691 ppm and 352 ppm respectively for TC, TN, TP and Pav in the SUW from Nagrin. That could be related to the nature of the substrates which were of different origins: livestock wastes (manure of cattle, goats, pigs, poultry and slaughterhouse waste), organic household wastes (vegetables), as well as papers, glass, plastic, scrap iron, cans, etc. That could also explain why the contents in TC, TN, TP and Pav in the soil of Nagrin were higher compared to those in Toudwéogo soil. These differences in contents between the two sites could also find explanations in the quantities as well as the frequencies of waste application which are not controlled. This underlines the need that waste users be trained for better results.

Average C/N ratio was approximately 12 for all the amended and unamended soils of Toudwéogo. This indicates a good composting of the organic matter. For the Nagrin site, average C/N ratios were 16.5 and 14.7 for the amended and unamended soils, respectively. This means a reduced biological activity leading to a bad composting of organic matter in the amended soils of Nagrin site. Indeed, the C/N ratio is an amendment quality indicator. The higher the C/N ratio (>12), the lower the biological activity and mineralization. An organic material with a high C/N (>15-20, incomplete composting) can induce a risk of "nitrogen deficiency" for the plants, because of soil micro-organisms will use the available nitrogen for the mineralization process (18). However the C/N ratio is regarded as a partial indicator of amendment quality and needs to be supplemented by other information such as the proportions of the components of the compost and the level of composting.

These results show that the use of solid urban waste increases the contents in nutrients (C, N and P) for the plants as previously reported by many other authors (13, 28). It is also known that organic matter contributes to maintaining soil moisture by increasing the soil water retention capacity (10, 13, 20).

Former work highlighted a significant correlation between the quantity of compost, the content in organic carbon and the cation exchange capacity (CEC) in the soil (13). Also an increase in the cations Ca, K and Na in relation to the rise of the pH and the CEC has been observed (21). We also observed that the content of available phosphorus increased in the amended plot related to SUW contribution (Table 1).

Orthophosphate (the main form of available phosphorus) is the second most limiting macronutrient (after nitrogen) for plant growth (38).
Therefore, it is likely that the application of compost provided conditions to immobilize orthophosphate, keeping phosphorus in available form for plant growth (6). For all the quantified parameters (TC, TN, TP and Pav), their content in the soils of Nagrin are higher than those of Toudwéogo. This could be linked to the quality of the amendments used on these two sites because of the distinct composition of urban waste.

Impact of amendment on maize plant growth

The results of the experiment test with maize (Figure 4- A, B, C) have confirmed the beneficial effects of using urban waste as organic fertilizers in reference to the results of TC, TN, TP and Pav analyses and to previous studies (20).
We noted a very small height of the plants in the control soil (Na) compared to the amended plot; the difference was highly significant (p=0.0001) suggesting a deficiency in nutritive elements in the unamended soils (Figure 4-A).
The average height and the average aerial biomass yield of maize plants in amended plot were respectively 124% and 164% higher compared to unamended soils (Figures 4- A, B).
The difference in aerial biomass was also very significant (p<0.0001). However, there were no significant difference in the average root biomass yields between the amended and the unamended plots (Figure 4-C).
The Pearson correlation test revealed a significant correlation between the height and TC (p=0.02), aerial biomass and TC (p=0.003) and aerial biomass and TP (p=0,001). This shows that SUW had a positive effect on maize growth in the amended pot.
The regional average maize yields for traditional agriculture may reach 1.7 $t.ha^{-1}$ in West Africa, 1.5 $t.ha^{-1}$ in East Africa and 1.1 $t.ha^{-1}$ in Southern Africa (41). Although certain countries (such as Ethiopia, with >3 $t.ha^{-1}$) have appreciably reinforced their productivity, the average maize yield in SSA (estimated at <1.8 $t.ha^{-1}$) remains far below the expected average yield of ~5 $t.ha^{-1}$ in the field with improved varieties, with optimal inputs and under improved conditions of management, following the International Center of Improvement of Maize and Corn (Mexico) / International Institute of Tropical Agriculture (Nigeria).
Several projects have been implemented in SSA in order to improve land productivity. But most of these projects were focused on the selection of natural or improved varieties (e.g., Drought Tolerant Maize for Africa, Water Efficient Maize for Africa, Nutritionally-enriched Maize for Ethiopia…) (2, 25) or improved crop management practices, in particular rotation between cereals and legumes (22).
These strategies are very well and the researchers must be thanked and encouraged. However we could use organic amendments such as urban waste which improves the water retention capacity of the soil instead of using drought-resistant maize varieties. In Burkina Faso, cereal production has been evaluated at 4,898,544 tons for the campaign of 2012/2013 (8).
The maize records a production of 1,556,316 tons which represent approximately 32% of the total cereal production. This production is in rise of 44.50% compared to the cereal production in 2011/2012, and also in rise of 67.30% compared to the five last year's average (8).
These increases could be further improved with a suitable exploitation of urban waste in agriculture. Indeed, a very important report in Burkina Faso is growing maize around houses, particularly in the countryside, with satisfactory yields.
The only possible explanation is the "natural composting" of the domestic rejections around the concessions which returned this part of the soil suitable for maize cultivation. No chemical fertilizer alone can give soil as many benefits as organic manure.
Thus, looking agricultural soil poverty (15, 36, 37), facing the enormous quantities of urban waste produced in the big towns of sub-Saharan Africa (300 000 tons/year for Ouagadougou, Burkina Faso) and the difficulties which the municipalities of these cities meet for their elimination, SUW valorization in agriculture proves necessary even imperative.

Trace metal elements

The results showed that all soil samples collected at both sites (Toudwéogo in 2013 and Nagrin in 2014), are contaminated with TME (Figure 5). However, their concentrations varied widely, with the highest values in the amended soils.
The highest lead (Pb) concentration (436.43 $mg. kg^{-1}$ dry soil) was found in amended soils of Toudwéogo site. Zin had the highest concentration with average values ranging from 134.28 to 388.62 $mg.kg^{-1}$ (dry weight equivalent of soil) in the samples collected from Nagrin. The lowest TME concentrations were found in unamended soils. The SUW of Toudwéogo in 2013 had the highest Zn concentration (1,118.56 mg. kg^{-1} dry SUW). Apart from Zn and Pb, the highest concentrations of TME were found in SUW (Figure 5). Therefore, raw urban wastes could be a source of TME in agricultural soils.
The presence of TME in SUW could be explained by the illegal dumping of the electric batteries containing Zn powder. Lead could come from the combustion engine exhaust, electric batteries, mercury amalgams, ores treatment wastes etc. To summarize, various sources of TME are very widespread in developing countries where the control methods are limited.

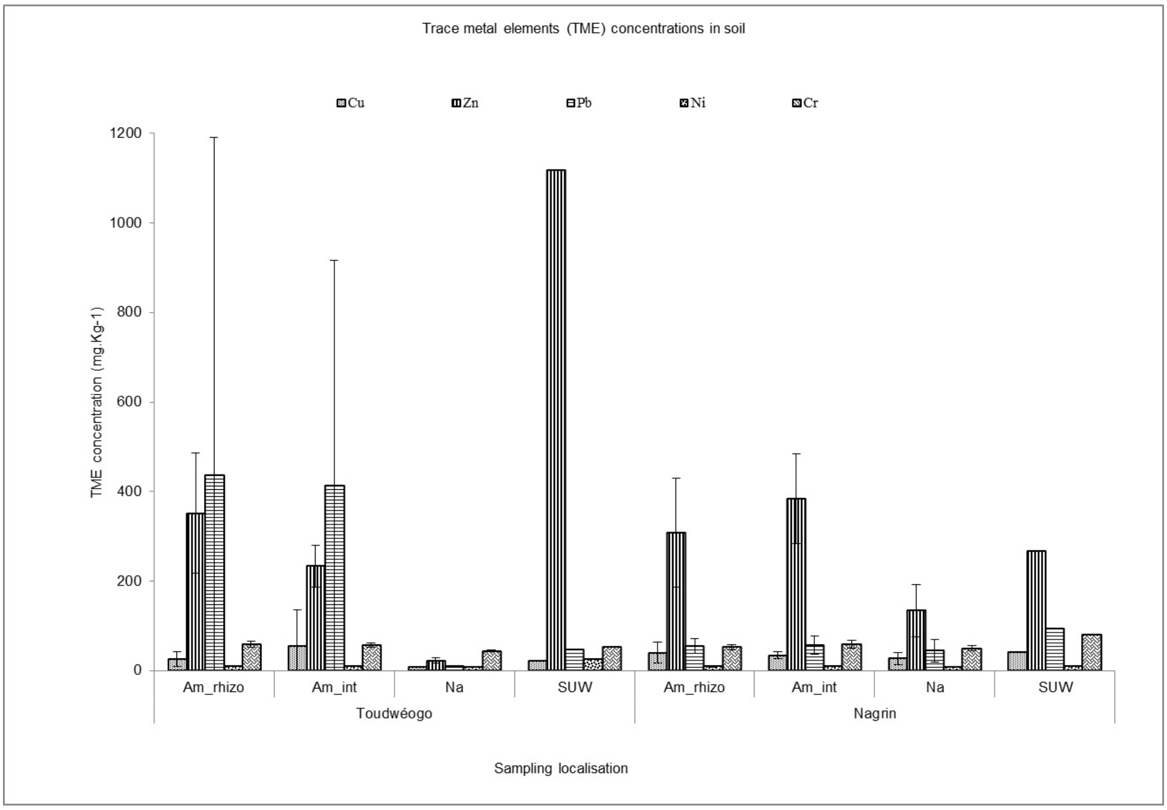

Figure 5: Histogram of trace metal element (Cu, Zn, Pb, Ni and Cr) in the soil samples of Nagrin and Toudwéogo sites; Am_rhizo= Samples collected at the rhizosphere from plot amended with urban waste; Am_int= Plot amended, sampling at interspaced area, outside of the influence of the roots; Na= non-amended soil collected at interspaced area; SUW (substrate): raw solid urban waste used for soil amendment. The bars on histograms represent standard deviation.

It has been highlighted that TME, such as Cd, Zn, Pb and Hg, were enriched in the amended field and enhance the dangers which could join SUW spreading if adequate measures are not taken (45). Indeed, TME could be a serious ecological threat if they are introduced into the food chain by bioaccumulation (39). Many other studies have shown that TME could be incorporated by crop plants (5) and cause potential safety problems on agricultural products intended for human and animal consumption (7). Furthermore, TME are known to impact soil bacterial diversity and their characteristics. For example, Hg is a biologically potent TME which has been shown to affect bacterial diversity in soil, partly owing to the selection for Hg-resistant bacteria (29, 34). The Hg effects are associated with the bioavailable fraction of the metal, which is controlled by factors such as pH, amount of dissolved organic carbon, and clay content (44).

Just like mercury selects Hg-resistant bacteria, it has been shown that bacterial exposure of *Pseudomonas aeruginosa* to low Zn doses co-selects for strains resistant not only to several TME (zinc, cadmium and cobalt) but also to imipenem, an antibiotic of the carbapenem class (8).

Conclusion

The use of urban solid wastes as fertilizers in agriculture has agronomic advantages.

This study reveals that the agricultural valorization of urban solid waste is essential and even imperative. But, there are few, if any in developing countries, formal structures for this cross-sectoral dialogue between the farmers, municipalities, researchers and backers. Among the possibilities for enhancing these links is the inclusion of recycling of organic wastes as a core element in new wastes management plans. This may require some formal participation of official agencies (e.g. Ministry of Agriculture) and farmers' associations in the municipal committees reviewing the new core plans for waste management.

Policy should consider urban waste not as a dangerous nuisance but as a source of nutrients for agriculture and would provide place for "separating dangerous wastes system". In Burkina Faso, as association between agricultural and breeding is promoting, as organizational links like than the SDGD (Schéma Directeur de Gestion des Déchets/Directing Diagram for Waste Management) need to be strengthened between the wastes management and (peri-) urban agricultural sectors.

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