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Drivers of the Chemical Quality of Market Gardening Soils in the Urban and Peri-Urban Environment of Bobo-Dioulasso (Burkina Faso): Impact of Fertilizers Sources and Sites Location

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Abstract

Urban and peri-urban agriculture plays a key role by providing many goods and services. In particular, it provides diversified food and employment for vulnerable groups (youth and women). However, it often involves negative externalities due to non-conventional soils fertility management practices. This study aimed to investigate the chemical quality of soils over six (06) sites of the market gardening area of Bobo-Dioulasso (Burkina Faso) as affected by fertilizers uses and sites location. Thirty (30) representative market gardening farms, located in urban, semi-urban and rural areas, were randomly selected from a baseline survey database. Within each farm, composite soil samples made up of 3 individual cores were taken over the 0 - 15 cm soil depth for determining soils carbon, total nitrogen, available phosphorus contents and pH-water. These data were normalized and summarized to compute a synthetic Soil Fertility Index (SFI). The data processing was focused on a Principal Component Analysis and an Ascendant Hierarchical Classification in order to make a typology of the vegetable farms. Fertilizers management effects on soils quality were compared through Variance Analysis (ANOVA) following a GLM procedure in Rstudio software. As main results, soils chemical parameters, except for available K, were affected by the location of the sites. Soils in urban farms are less acidic (on average pH = 6.9), while semi-urban and rural sites (Samadeni, Nakaguana) have more acidic soils. However, the latter site had the highest values of C and N. Moreover, the long-term application of organic matter sources results in improving of the chemical quality of the market garden soil. The SFI is positively correlated with the rate of applied organic fertilizers, and the cultivation duration. On the other hand, soil quality tends to decrease with the expansion of the area, due to a dilution effect of the organic fertilizer doses. All these results suggest that there is a real scope to reinforce the position of the market garden as an opportunity for recycling organic wastes and sequestration of carbon by promoting relevant fertilization packages that strongly rely on organic matters sources (Compost, Biochar, etc.).

Keywords

Gardening, Soil Fertility Index, Chemical Fertility, Bobo-Dioulasso

1. Introduction

By 2050, sub-Saharan Africa (SSA) will be home for about 2.5 billion inhabitants (17% - 21% of world population) [1]. This population growth is due to a rapid increase rate of urban population. Indeed, according to projections, SSA will experience an account for two-fold increase of his urban of the expected population growth by 2050 [2]. Currently, 62% of the urban population in SSA lives in slums [3]. This urban population structure is correlated to economic and food vulnerability, as cities are highly dependent on urban and peri-urban agriculture and are more exposed (than rural areas) to rising prices of essential commodities [4].

In this context, urban and peri-urban agriculture plays a key role, due to its socio-economic and environmental functions [5]. Moreover, it provides sufficient food and diversified nutritional diet. It also contributes to the development of the living environment through bio-waste disposal, thus contributing to the sanitation and human health. It is also a pilar for the economic integration of youth and women, who derive most of their livelihood from urban informal activities. This is the case, for example, with market gardening, which provides 94% of the income and 30% of households' food [6]. At the macro-economic level, incomes from vegetable crops (onion, cabbage, tomato, eggplant, okra) selling reached 421 million euros in 2018 in Burkina Faso [7].

As a main component of urban and peri-urban agriculture, market gardening is perfectly integrated into the environment of African cities [8]. However, the sustainability of market gardening is threatened by rapid urbanization [5]. As a result, market gardening areas are increasingly restricted, with intensification and inadequate resources management being the most common practice. Indeed, several studies analyzing market gardening practices in West Africa (Bobo-Dioulasso in Burkina Faso, Kano in Nigeria, Niamey in Niger and Sikasso in Mali), have revealed excessive applications of fertilizers ([9] [10] [11] [12] [13]) and phytosanitary products [14]. These excessive quantities, coupled with insufficient quality of organic waste [15], lead to risks for both human and environmental health ([13] [16]). The above justifies the current global dynamics in fostering agro-ecological transitions based, among other things, on the use of sustainable and more economical practices, which also enhance the resilience of farming systems. In this perspective, it is essential to have a better understanding of the current state of soils quality under market gardening practices. This can serve not only as a reference to assess future changes but also to motivate stakeholders to adopt more sustainable practices. Thus, the current study was aimed at assessing soils chemical quality in the market gardening areas as affected by fertilizers management in the urban, semi-urban and rural areas of Bobo-Dioulasso. This study is innovative in its holistic approach to understand soil quality by taking into account not only market gardening practices but also the socio-economic environment of producers. Thus, the results should help to better understand the determinants of soil quality and to promote more adapted farming practices according to the specific environments.

2. Methodology

Location and Description of the Study Sites

The study was carried out in the province of Houet, whose capital city is Bobo-Dioulasso (**Figure 1**). Bobo-Dioulasso (11˚03' and 11˚07' north latitude and between 04˚19' and 04˚36' west longitude) is the second largest and the cultural

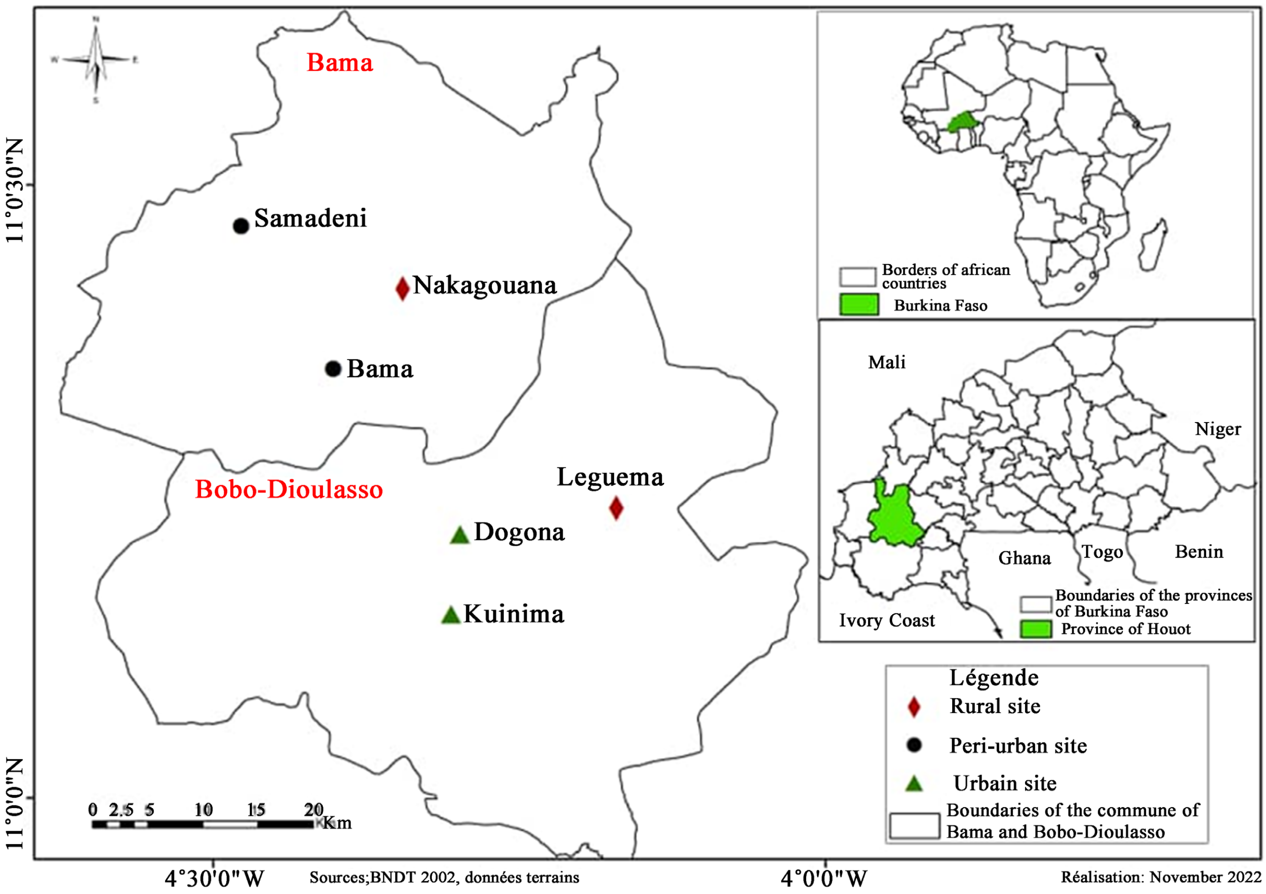


Figure 1. Geographical location of the study area (adapted map pending).

and economic capital of Burkina Faso. The poverty index rate was 24.7% in 2018 [17]. According to the latest population census [18], the city had 904,920 inhabitants in 2019 (16.9% of the national population), 51.33% of whom were women. Despite this women proportion, the population involve in market gardeners is predominantly male (98% and 2% female). Their average age is 43 years (20 to 80 years). They are generally married (93.8%) and practice market gardening as their main activity (73%). Women are more involved in the selling of vegetables products. The average experience of market gardeners is 21 years. Among the market gardeners, 29.2% are non-literate and 31.2% are literate. The remaining has primary (31.3%) or secondary (8.3%) education rate [19].

The geographical location of the study area provides it a South Sudanese climate with two contrasting seasons: a dry season (from November to April) and a rainy season (from May to October). The dry season consists of a cold period (November to January) and a hot period (February to April). Average temperatures range between 25˚C and 30˚C and it is the favourable period for cultivation. A unimodal rainy season occurs from May to October during which the humid monsoon winds blow. Although rainfall is relatively abundant with a annual average ranging from 800 to 1200 mm, the strong intra-annual variations in rainfall events negatively affect crops yields. Soils are mainly tropical ferruginous with on sandy-clay (Lixisols) to clay-sandy textures (Luvisols), associated with hydromorphic soils with pseudogley in lowlands, with silty-clay materials. In addition, ferralitic soils, weakly to moderately desaturated and often associated with Lixisols, occupy the upper part of slopes. Vegetables production soils are more often deep, well drained, chemically poor, with low buffering capacity and sensitive to acidification due to the long-standing exclusive use of mineral fertilizers.

The Comoé and Mouhoun Rivers and their tributaries irrigate the province. The Houet River, from which the province derives its name flows through the town and several market gardening sites are located along. The other important rivers in terms of water supply for agricultural production are the Kou, which flows West side of Bobo-Dioulasso.

3. Selection of Sites and Vegetable Farms

A total of six (06) sites and thirty (30) vegetable gardens were chosen for the study (**Table 1**). They were selected from a database of 96 vegetable farms in 20 urban, semi-urban and rural areas (from the PARADE project implemented in 2014 to 2019) of Houet province. The selected sites are representative of the contrasting environments that determine market opportunities for agricultural inputs and products in this region.

Farms sampling was done in such a way to retain those that had not yet received fertilizers application during the current season. In addition, the selected plots are dispersed to take into account the spatial heterogeneity of the site. This

Table 1. Characteristics of the selected market-gardening exploitations.

Environment	Market garden site	Distance from the town of Bobo-Dioualasso	Number of plots sampled	Water source
Urban	Kuinima = KUI	0	5	Well
	Dogona = DOG	0	7	Marigot Houet
Semi urban	Samandeni = SAM	40	5	Dam
	Bama = BAM	30	4	Kou River
Rural	Legumea = LEG	15	4	Kou River
	Nakaguana = NAK	40	5	Kou River

scattering also allows to cover as much as possible the social diversity of the market gardeners, because the neighboring plots belong most often to people coming from the same extended family.

3.1. Soil Sampling and Analysis

The selected fields were georeferenced. In 2016, three soil samples were taken from the 0 - 15 cm soil depth and across the diagonal of each plot. These 3 samples were mixed together and a composite sample was then taken, crushed and sieved to retain the fine fraction (<2 mm) for laboratory analysis.

Total soil carbon was measured following the Walkley-Black method. The value obtained was multiplied by 1.724 to obtain the organic matter content of the soil. Total nitrogen was determined following the Kjedhal method. The available phosphorus (Bray I) was determined by photocolorimetry. The available potassium was extracted with a mixed solution of hydrochloric (0.1 N) and oxalic (0.4 N) acids and measured with a flame photometer. The pH_{eau} was measured by direct reading with an electrode pH meter in a solution of soil (1 g) and water (2.5 ml). All these analysis methods are detailed in [20].

3.2. Data Analysis and Processing

A first approach of analysis based on principal components (PCA) and hierarchical ascending classification (HAC) allowed making a typology of farms based on market gardening practices. For this purpose, six quantitative variables were used: the area of the farm, the annual dose of organic fertilizer, the annual dose of mineral fertilizer, the annual dose of synthetic pesticides, the length of time the plot has been cultivated and the synthetic index of chemical fertility of the soil (IFS). This index is the sum of the normalized values (0 to 1) of the analytical indicators following the procedure proposed by [21]. In order to assess the effect of cropping practices on soil chemical quality, the variance test (ANOVA) was performed following the GLM procedure. If necessary, this is completed by comparing the means. These tests were performed using Rstudio software version 3.5.3 (R Development Core Team, 2019).

4. The Results

4.1. Some Structural and Functional Characteristics of Production Systems

The intra-urban farms (Kuinima and Dogona) on the one hand, and the extra-urban farms (Bama, Samadeni, Leguema, Nakaguana) on the other hand, are opposed in terms of surface area, farming duration and inputs rate (**Table 2**). Indeed, the urban plots located upstream and downstream of the Houet marigot are the smallest but also the oldest cultivated plots. On the other hand, they receive significantly more fertilizer (mineral and organic) and pesticides than those in extra-urban farms. According to the baseline survey results (not shown), almost all farmers (99%) apply mineral fertilizer. The use of organic fertilizer and synthetic pesticides (92% and 97% of gardeners respectively) is also widespread, in contrast to organic pesticides (7%). In sum, vegetable growing systems are more intensive in urban areas than in other areas.

Crops are much diversified on all the surveyed sites, with fifteen market garden crops varieties (**Figure 2**). They are produced mainly during the dry season (**Figure 1**). During this period, tomato and cabbage are cropping in more than 50% of the farms, and to a lesser extent lettuce and pepper (≈30% and more),

Table 2. Some characteristics of the vegetable farms according to the sites.

Features		Urban site		Semi-urban site		Rural site	
		Kuinima	**Dogona**	**Bama**	**Samadeni**	**Leguema**	**Nakaguana**
Average area (±Sd) exploited (ha)		0..11 ± 0.11	0.47 ± 0.57	0.75 ± 0.54	0.65± 0.49	0.60 ± 0.36	0.85 ± 0.42
Average age (±Sd) of cultivated plots (years)		32.6 ± 11.9	26.8 ± 16.9	20.5 ± 10.8	5.4 ± 2.9	14.0 ± 17.4	18 ± 8.1
Mineral manure (t/ha/year)		8.47 ± 8.17	3.67 ± 5.83	0.98 ± 0.58	1.10 ± 0.80	1.26 ± 1.40	8.6 ± 11.44
Organic manure (t/ha/year)		126.7 ± 165	69.15 ± 69.07	5.32 ± 3.25	14.88 ± 19.17	4.12 ± 5.66	2.3 ± 2.6
Pesticide dosage (l/ha/year)		47.9 ± 70.46	69.72 ± 111.77	8.25 ± 6.95	7.72 ± 7.60	6.31 ± 1.66	10.36 ± 7.73
% gardeners producing the crops	Lettuce	80	100	-			
	Pepper	80	100	50	60		20
	Cabbage	60	60	75	40	75	100
	Green Bean	60		25	60	25	40
	Tomato	20	100	25	60	75	60
	Onion	20			20		
	Parsley	20					
	Eggplant			25			
	Potato			25			
	Okra				20		
Producers practising crop rotation (%)		100	80	75	100	100	20

Sd: standard deviation.

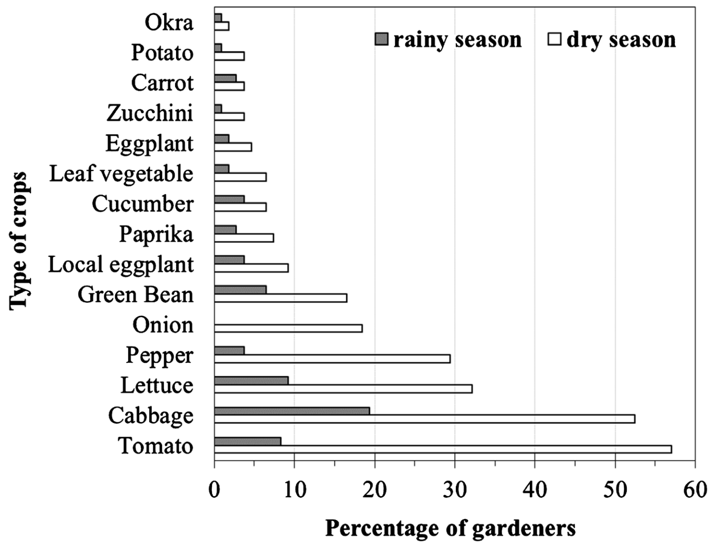


Figure 2. Speculations produced by market gardeners by season.

followed by bulbous onion and green bean, which are present in more than 10% of the farms. Among these most important crops in the dry season, only cabbage exceeds the 10% threshold of farms. On the other hand, onions are totally absent during this period.

Overall, the level of crop diversification decreases from one urban site to another (Table 2). This implies that vegetable farmers practice more vegetable crops rotation in urban areas than in other sites. This is because urban sites are more dedicated to vegetable crops. While, within non-urban sites, cereals crops are grown as vegetables sometimes alternated with vegetable crops during rainy season. This contributes to a reduction in the frequency of cropping in the rainy season compared to the dry season, as illustrated in Figure 2. Moreover, regardless of sites location, it could be noticed that the common crops produced are cabbage, tomatoes and peppers. Leafy vegetables (lettuce and parsley) are produced exclusively in towns because of the proximity of consumers and their highly perishable nature.

4.2. Chemical Quality Indicators for Soil on Market Gardening Sites

Soils chemical components varied significantly across the study sites, except for available K (Table 3).

Most farms in the urban sites are less acidic than those in semi-urban and rural sites. Plots located at Samadeni (semi-urban area) and Nakaguana (rural area) exhibited relative more acidic soils than the others. However, the latter site has the highest total C and N contents. Moreover, the two urban sites are globally richer, including for P_Bray I. In accordance, the synthetic soil fertility index (SFI) shows that the soil quality is relatively better in urban areas than the other locations. Plots at Samadeni (semi-urban site) showed lowest chemical quality.

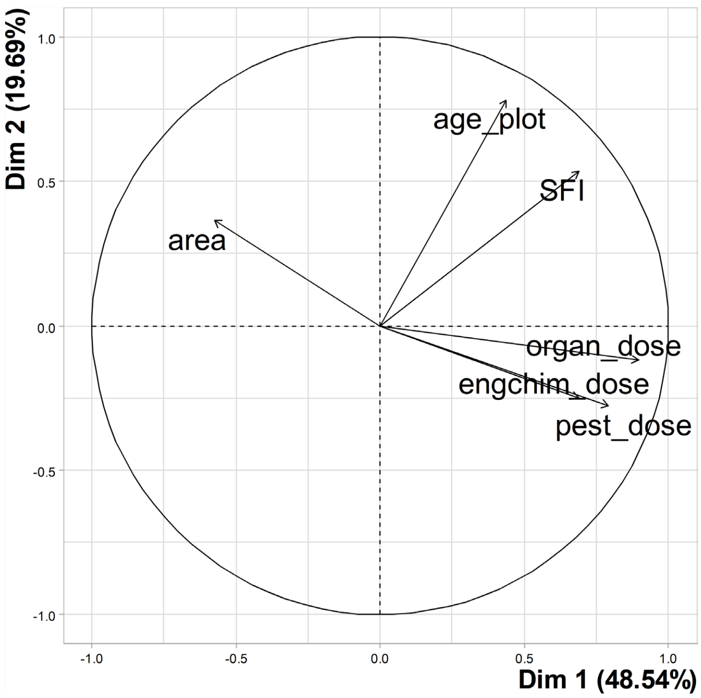
4.3. Typology of Vegetable Farms in the Houet Province

The vegetable gardens from the three environments (urban, semi-urban and rural) are discriminated through the first two principal components, which account for 69.17% of the information contained in the sample (Figure 3). The first axis characterizes the relationship between the doses of mineral fertilizer

Table 3. Chemical characteristics of the soils of the different market garden sites.

Website	pH water (-)	C total (%)	Ntotal (%)	P_Bray I (mg/kg)	K_disp (mg/kg)	SFI (-)
KUI (n = 5)	$6.98^{b} \pm 0.49$	$1.79^{ab} \pm 0.64$	$0.12^{ab} \pm 0.05$	$116.47^{ab} \pm 54.35$	157.95 ± 42.37	$3.10^{a} \pm 0.69$
DOG (n = 7)	$6.98^{b} \pm 0.44$	$1.48^{ab} \pm 0.60$	$0.10^{ab} \pm 0.03$	$127.89^{a} \pm 56.25$	94.37 ± 21.64	$2.44^{ab} \pm 0.74$
BAM (n = 4)	$5.89^{ab} \pm 0.68$	$1.24^{ab} \pm 0.16$	$0.09^{ab} \pm 0.01$	$26.89^{bc} \pm 26.48$	128.33 ± 71.81	$1.65^{bc} \pm 0.55$
SAM (n = 4)	$4.84^{a} \pm 0.34$	$1.34^{ab} \pm 0.11$	$0.09^{ab} \pm 0.01$	$11.02^{c} \pm 9.63$	107.80 ± 55.76	$1.20^{c} \pm 0.38$
LEG (n = 4)	$6.20^{ab} \pm 0.50$	$0.77^{a} \pm 0.17$	$0.06^{a} \pm 0.01$	$85.92^{abc} \pm 14.56$	112.04 ± 57.51	$1.50^{bc} \pm 0.57$
NAK (n = 5)	$4.76^{a} \pm 0.25$	$2.24^{b} \pm 0.19$	$0.14^{b} \pm 0.01$	$18.23^{c} \pm 8.79$	95.75 ± 55.25	$1.97^{bc} \pm 0.36$
p_value	<0.001	0.005	0.014	<0.001	0.398	<0.001
Meaning	HRT	HS	S	HRT	NS	HRT

Values with the same letters in the same column are not significantly different at the 5% level. KUI = Kuinima; DOG = Dogona; BAM = Bama; SAM = Samandeni; LEG = Leguema; NAK = Nakaguana. C total = total carbon; N total = total nitrogen; P_Bray I = available phosphorus; K disp = available potassium; IFS = synthetic soil fertility index.



Area: area of the farm; age_plot: number of years the plot has been cultivated; SFI: soil fertility index; organ_dose: dose of organic fertilizer; pest_dose: dose of synthetic pesticides; engchim_dose: dose of mineral fertilizer.

Figure 3. Graphical representation of the variables on axes 1 and 2 from the principal component analysis (PCA).

(engchim-dose), organic fertilizer (organ_dose), synthetic pesticides (pest_dose) and the soil fertility index (SFI) on the one hand, and farms size on the other hand. Inputs rate is positively associated with to SFI and negatively with farms size. Thus, it separates high level of intensification to low level of intensification farms. Axis 1 can, therefore be referred as the intensification level axis.

The second axis can be named as farming duration axis. Indeed, the number of years plots have been used (age_plot) is positively correlated with this axis, as are the SFI and the area, but to a lesser extent. It mainly opposes old farms to those that are relatively more recent.

The AHC discriminates the vegetable farms into three classes (Table 4) with proportions ranging from 6.67% (class III) to 66.67% (class I). It can be seen that the gradient of intensification and the fertility index increases from class I to class III.

Class I: With 2/3 of the farms, this category includes the youngest (≈13.5 years) and the least intensive farms. The large majority (85%) is extra-urban and is located on dry and irrigated plains. They have the largest surface areas (0.72 ± 0.47 ha) but use relatively low mineral fertilizer (3.06 t/ha/yr), organic amendments (11.08 t/ha/yr) and synthetic pesticides (8.93 L/ha/yr). Irrigation is mainly based on the gravity system taking water from marigots and dams.

Class II: This category includes 26.67% of the farms. Unlike class I, class II farms are mostly (88%) intra-urban located on dry plains and irrigated by gravity system and sprinkler. The plots are the oldest cultivated in the region (≈35 years on average), and are significantly smaller in size (0.28 ± 0.24 ha) than those of the previous class. Fertilizer and pesticide inputs are also higher than in the farms that belong to the Class I.

Class III: This class is marginal with 6.67% of farms. Farms are also located in urban areas. They are in dry plains irrigated with sprinklers using water from swamps and wells. The plots are the smallest (0.02 ± 0.01 ha) and submitted to long cropping periods (≈27 years on average). They receive the highest rates of fertilizers and pesticides. In sum, CLASS I (2/3 of the gardeners) is less intensive and concerns extra-urban farms as opposed to CLASS II and III whose farms are

Table 4. Characteristics of the three classes of vegetable farms resulting from the hierarchical ascending classification (mean values ± standard deviation).

Indicators	Unit	Class I (n = 20)	Class II (n = 8)	Class III (n = 2)
Surface area exploited	Ha	0.72 ± 0.47	0.28 ± 0.33	0.02 ± 0.01
Age of plot	year	13.50 ± 11.46	35.25 ± 0.26	27 ± 12.73
Mineral fertiliser rate	T/ha/year	3.06 ± 6.42	3.71 ± 5.08	17.04 ± 2.30
Dose of synthetic pesticides	L/ha/year	8.93 ± 6.77	26.78 ± 29.12	241.67 ± 106.07
Dose of organic fertilizer	T/ha/year	11.08 ± 15.86	52.90 ± 58.24	301.25 ± 139.65
Soil fertility index	--	1.57 ± 0.4	2.74 ± 0.49	3.66 ± 0.31

intra-urban and more intensive in term of fertilizers uses.

4.4. Relationship between IFS and Some Farm Characteristics

The correlation matrix (Table 5) and linear regressions (Figure 4) indicate that

Table 5. Correlation between IFS and farm characteristics. Rank correlation coefficients (Spearman) are above the diagonal.

	age_plot	engchim_dose	SFI	organ_dose	pest_dose	area
age_plot		0.15	0.63	0.23	0.32	−0.21
engchim_dose	ns		0.08	0.21	0.28	−0.40
SFI	***	ns		0.52	0.33	−0.37
organ_dose	ns	ns	**		0.44	−0.45
pest_dose	ns	ns	ns	*		−0.42
area	ns	*	*	*	*	

Correlation coefficients that are significant ($p < 0.05$) are in bold. Below the diagonal, the degree of statistical significance is indicated as follows: ns: nonsignificant, *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$. age_plot: length of time the plot has been cultivated; engchim_dose: dose of mineral fertilizer, SFI: synthetic index of soil fertility, organ_dose: dose of mineral fertilizer, pest_dose: dose of synthetic pesticides, area: individual area of the farmer.

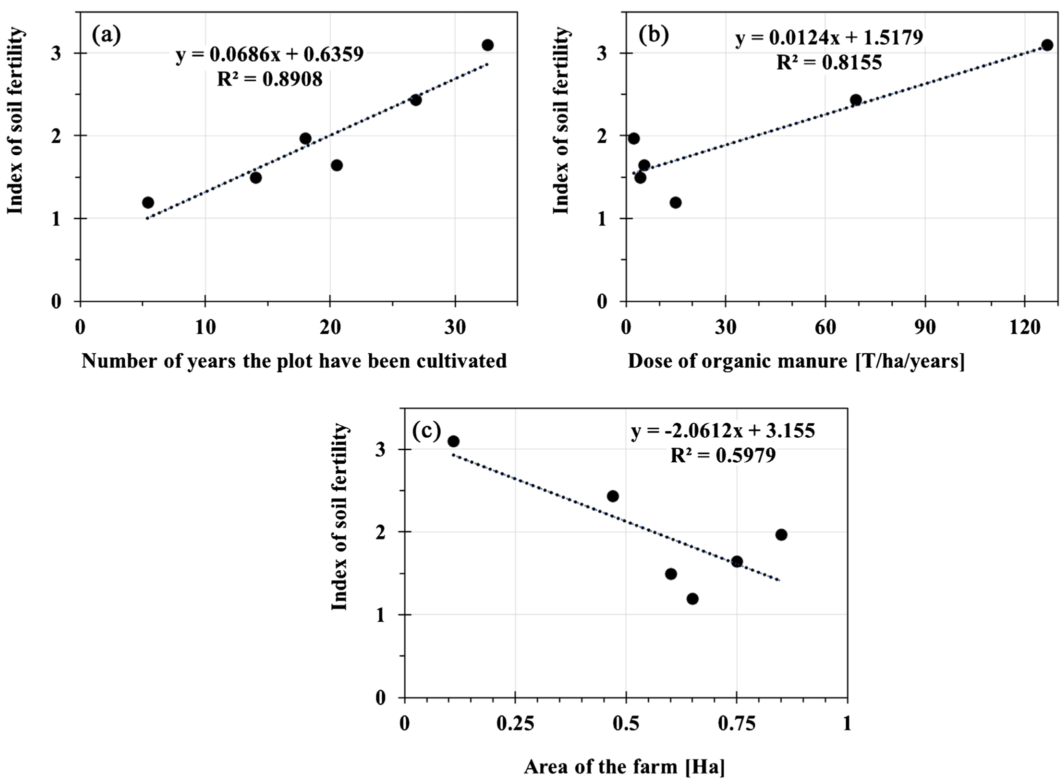


Figure 4. Linear regression (regression line, regression equation, determination coefficient) between the soil fertility index and the number of years the plot has been cultivated (a), the organic manure dose (b) and the area of the farms (c).

the SFI is positively and significantly correlated to the rate of organic fertilizers, and the age of the plots. Otherwise, organic inputs in the long term are beneficial for the improvement of the chemical quality of the market garden soil. In contrast, soil quality tends to decrease with increasing farms size due to the dilution effect of the organic fertilizer doses.

5. Discussion

The socio-economic environments contribute to a differentiated structuring of market garden production practices. Indeed, under the effect of demographic pressure in the city, we observe a general dynamic of conversion of agricultural plots into housing. Thus, for example, the diachronic analysis of the urban perimeter of Kuinima by [22] showed that this site lost about 10% of its cultivated area to spontaneous dwellings between 2002 (63 ha) and 2012 (57 ha), forcing actors to annex new lands that were considered to be not very conducive to crops. In addition, the successive fragmentation of plots from one generation of farmers to the next explains why the areas cultivated in urban areas are significantly smaller compared to those in semi-urban and rural areas, as several authors in Burkina Faso and West Africa have also noted ([6] [13] [23] [24]). This limited availability of land resources in urban areas reduces the profit margins of vegetable crops compared to those in rural areas [25].

Because of this reduction in individual farms area, the intensive practices adopted by producers are mainly a financial compensation strategy. These include crop diversification and rotation that involve short-cycle crops such as lettuce, and those that offer multiple harvests possibilities [25]. Thus, we found that lettuce is exclusively produced in urban areas, while pepper is widely preferred in the city (80% to 100% of producers) than elsewhere (20% to 60% of producers). Moreover, pepper crops receive the maximum amount of nitrogen inputs (on average 515 kg/ha/year), followed by cabbage (391 kg/ha) and tomato (311 kg/ha) [13]. These two crops, in addition with onions, are the top three market garden crops nationwide [7].

The need to enhance the productivity of vegetable crops in response to growing demand justifies the increasing level of intensification from rural to intra-urban farms. This trend is concordant with the findings of our recent studies carried out at the scale of the Houet province [13]. Thus, the high rates doses of synthetic pesticides, as also observed by [14], confirm the need for better management practices in order to secure production while reducing negative externalities. In addition, fertilization is not efficient since the use of high amounts of organic fertilizers did not imply a concomitant reduction in the synthetic mineral fertilizers inputs. Several previous studies reported the excessive use of mineral fertilizers on market gardening sites in Bobo-Dioulasso ([10] [11]). For instance, studies show that average nitrogen inputs for a single cropping cycle in rural and urban areas ranged from 671 to 1828 kg/ha, whereas the average needs do not exceed 140 kg/ha for vegetables [17] [26].

These highly variable amount of fertilizer used can be explained by the fact that there are no specific fertilization recommendations for vegetable crops in the region. Moreover, due to their low level of education, most market gardeners are unaware of the fertilizing value of fertilizers sources used. In fact, the systematic use of large amounts of mineral fertilizers is seen as a strategy to induce rapid plant growth and guarantee maximum yields. In addition, the input credit given to farmers by the vegetable products sellers is an incentive for intensive input use in urban areas. Therefore, the environmental sustainability of vegetable systems becomes a major challenge that most vegetable producers are not aware of despite the financial implications. Our study showed that the soil fertility index (SFI) does not seem to be affected by increased doses of mineral fertilizers, although they may be associated with environmental risks such as water pollution ([25] [27] [28]). However, many research results shown that bio-fertilizers, due to their richness in organic matter and exchangeable bases [29], are very beneficial in improving the soil fertility index as suggested by our results. This suggests that there is a real opportunity to valorize these alternative sources of organic matter (bio-waste or Biochar) [29] and subsequently sequester carbon in order to contribute to GHG reduction. However, the challenge of the sanitary side effect of bio-waste must be mastered upstream, through advisory support, to preserve the quality of food and the health of farmers (handling) and consumers.

6. Conclusion

In a context of rapid urbanization and reduction of market gardening areas, gardeners are forced to intensify their production by using sometimes very high inputs doses (mineral and organic fertilizers, pesticides) in order to maintain their incomes level. Indeed, our results revealed an increasing gradient in the level of intensification of market garden cropping from rural to urban areas. However, they show that the soil fertility index (SFI) is not sensitive to mineral fertilizers inputs rate, in the one hand, but is positively correlated to organic fertilizers inputs rate and the cultivation duration. In contrast, it is negatively influenced by the expansion of the cultivated areas. More important, results show that fertilizers management led to a significant improvement of urban vegetable soils fertility compared to those in rural areas. Although these excessive inputs rates of fertilizers obey a concern to maintain productivity at an economically viable level, there is a scope for better management by reducing some of the sources used. Indeed, since our results show that the SFI does not seem to be affected by the amount of mineral fertilizer applied, effort must be devoted to supporting gardeners (mostly not educated) to better manage fertilizer. An effort in advisory support must be done to help the (mostly uneducated) gardeners to use mineral fertilizers as little as possible. Since SFI is positively correlated to organic fertilizers inputs rate, this implies that mineral fertilizers could be substituted by alternative sources of organic fertilizer, such as compost from sorted organic waste or biochar. Such alternatives should also allow for more efficient farming given the continuing trend of increasing prices of mineral fertilizers and market garden products. Further research efforts should be devoted to the development of site-specific rational fertilization packages that sustainably improve the SFI in Urban, Semi-Urban and Rural vegetables production in the region.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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