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Urban effects on the adoption of soil conservation practices in urban and peri-urban vegetable production of Yaoundé, Cameroon

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A R T I C L E I N F O

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A B S T R A C T

Rapid urbanisation has put farming systems under stress. Yet, conservation agriculture promotes environmentally friendly and productive agriculture. This paper therefore aims at estimating the effects of urbanisation on the adoption of soil conservation practices (SCPs) in urban and peri-urban vegetable production in Yaoundé, Cameroon. Data from a survey conducted by the World Vegetable Center among 185 vegetable producers and Google Maps were analysed using a Multivariate Probit model with robust standard errors to investigate the adoption of four interdependent SCPs. Descriptive results showed that the most SCP adopted was organic manure (85 %), the least adopted was mulching (61 %), and that the adoption intensity was relatively high as the mean number of SCPs adopted was 2.87 out of 4. In addition, the regression results showed that urbanisation reduces the adoption of SCPs; in particular, proximity to city centre reduces the adoption of crop rotation, organic manure, mulching, and fallow, while population density decreases the practice of fallow. Henceforth, to ease the perverse effects of urbanisation on the adoption of SCPs, decision-makers and local authorities should ensure the preservation of productive agricultural zones by elaborating urban master and zoning plans that take into account agricultural purposes, and by formalising property rights on agricultural lands in urbanising areas.

Introduction

According to the latest estimates, the urban population in Sub-Saharan Africa (SSA), which currently stands at 441 million people, is expected to reach 1260 million by 2050 [1]. At the same time, while cities are sprawling, densities of population are undoubtedly declining. A one percent decline in densities per year between 2000 and 2050 would quadruple the urban land area in developing countries [2]. Along with rapid urbanisation and city sprawl, there is an intensification of resource scarcity and environmental degradation in urbanising areas [3]. Urbanisation leads to the conversion of natural landscapes to urban sceneries and strengthens, specifically in the peri-urban transition settings, the competition for land among industrial, commercial, residential, and agricultural uses [4]. Considered to be one of the main drivers of the consumption and degradation of fertile soils essential for agriculture and food

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production, rapid urbanisation is posing direct and indirect adverse effects on food security and soil resources [3].

As a result, agriculture, especially urban and peri-urban agriculture, urgently needs to increase food production to meet the growing urban food demand and dietary changes in cities of SSA countries [5,6]. Urban and peri-urban vegetable production has been shown to significantly contribute to income generation, household food security, and poverty alleviation [7–9]. However, rapid urbanisation has led to increased population densities and scarcity of new agricultural lands, which reduce the fallow period and soil fertility and increase soil erosion in urban and peri-urban farming [5,10]. Intensive production on farms that decrease in size or at least remain steady also poses a threat to urban and peri-urban vegetable production. Due to the small size of their farms, most urban and peri-urban farmers are compelled to unsustainably intensify crop production on the same piece of land. They find themselves in a vicious cycle of land degradation, low agricultural productivity, low returns allowing for investments, pursued overuse of resources, and expanding demand for land to preserve livelihoods in the long run [11–14].

Under this rapid urbanisation process, an improved soil management approach that aims to produce more food while maintaining or improving soil quality is needed to compensate for productivity losses due to land degradation [15,16]. In this sense, for example, the adoption of Soil Conservation Practices (SCPs) has been largely promoted in SSA, even though more in rural areas than in urban and peri-urban areas [17]. The adoption of SCPs, which include crop rotation, mulching, intercropping, no-tillage, planted windbreaks, and numerous other SCPs, is a key concern of the agenda of agricultural development policy [12,18]. These SCPs have been shown to increase crop yield and incomes, improve soil quality and resilience, and reduce soil erosion and land degradation [19–21]. Particularly, in urban and peri-urban areas in SSA, the use of SCPs has enhanced the productivity of soil and other related natural resources aimed at enhancing plant nutrition [22–24].

In numerous previous studies [5,12,19,25–34], household farmers' drivers of SCP adoption have been largely investigated. Predictors influencing the adoption of SCPs were grouped into personal features, demographic, socio-economic, institutional and psychological factors, economic and risk factors, environmental and biophysical factors, infrastructural factors, and social capital factors. However, this literature has placed more emphasis on cereal and staple crops in rural areas, neglecting high-value crops such as vegetables in urban and/or peri-urban areas, despite their recognised importance in ensuring food and nutrition security in urban settings in SSA. Only two studies have focused on the adoption of sustainable intensification practices in vegetable production to the best of our knowledge. Abdulai et al., [25] examined the adoption of safer irrigation technologies among vegetable farmers in Kumasi, while Kurgat et al., [5] focused on the adoption of interrelated sustainable intensification practices in rural and peri-urban vegetable production in Kenya. Moreover, although a typical farmer is subject to a rational choice of bundles of SCPs among several practices depending on his or her attributes [34], this literature has rarely considered the interrelated nature of SCPs, since they may be driven by multiple factors linked by trade-offs and/or synergistic effects between the different practices. Kurgat et al., [5] observed that there is little empirical evidence regarding the scale of adoption of interrelated sustainable intensification practices in smallholder vegetable production systems. Last but not least, this literature has rarely considered urbanisation factors as a group of determinants in SCP' adoption studies, even though urbanisation is progressively bringing urban markets closer to urban and peri-urban vegetable production areas and increasing population density in these locations.

Apart from Kurgat et al., [5], who examined the adoption of interrelated sustainable intensification practices in vegetable production in rural and peri-urban areas of Kenya; studies that specifically capture the effects of urbanisation on the adoption of interrelated sustainable intensification practices such as SCPs in urban and peri-urban areas are, to the best of our knowledge, non-existent. As the current urbanisation process in cities and towns in SSA is rapid [1], this paper is positioned as a major contribution to analyse the effects of urbanisation on the adoption of interrelated SCPs in urban and peri-urban vegetable production in Yaoundé, Cameroon. The paper makes three contributions: (1) It enriches the literature with empirical evidence on the adoption of interrelated SCPs in vegetable production in urban and peri-urban settings in SSA. (2) Empirically, it uses the more appropriate multivariate analysis to analyse the adoption of interrelated SCPs, as opposed to the use of binary logistic analysis. (3) Finally, by highlighting the role of urbanisation in the adoption of interrelated SCPs, it shows that proximity to the city center and population density significantly influence the sustainable intensification of agriculture in urban and peri-urban settings. In this study, four main SCPs were scrutinised. These SCPs consisted of crop rotation, organic manure, mulching, and fallow. They are the most widely used among the vegetable farmers in the study area according to Awah Manga et al., [35].

The remainder of the paper is structured as follows: Section 2 depicts the theoretical framework upon which the paper is hinged. Section 3 describes the methodology including materials and methods used. Section 4 presents the descriptive and the regression results, while section 5 discusses our findings. A summary and conclusion follow in Section 6.

Urbanisation and adoption of SCPs in urban and peri-urban agriculture: the theoretical nexus

As part of the analysis of spatial externalities, Andrews and Chetrick [36] suggested that agglomeration economies can explain the effects of urbanisation on agriculture in the vicinity of urban centres. According to Parr [37], agglomeration effects can be spatially extended in at least three dimensions, namely the intra-urban space, the inter-urban space, and the metropolitan region. The intra-urban space is the most natural spatial dimension to consider, as agglomeration effects are not geographically confined at a single point. A farm, for example, enjoys productivity advantages throughout the agglomeration due to the presence of public infrastructure. The second dimension is the inter-urban space, where exposure to agglomeration effects no longer even depends on immediate proximity to the city, especially in the case of non-manufacturing activities such as services and agriculture [38]. The final dimension is the metropolitan space, where agglomeration effects are now available within and even beyond the boundaries of a metropolis [39]. As a result, it is no longer necessary to be located within or even close to cities in order to experience urban agglomeration effects in agriculture, but simply to have access to them [38]. Therefore, as urban agglomeration effects dissipate over space from urban centres to peri-urban and urban areas, (Richardson 1995), Andrews and Chetrick [36] have indicated that, as in urban areas, urban agglomeration effects are also intensified by population density and attenuated by the distance to the city centre.

Urbanisation is progressively bringing urban markets closer to peri-urban agricultural areas and increasing population density in these locations. As a result, the abundant literature analysing both the influence of population density and the accessibility of urban markets on sustainable agricultural land management [14,40–42] provides an understanding of the impact of urbanisation on the adoption of SCPs in urban and peri-urban agriculture. Improved market access, which increases returns to land and labour, is generally considered to be the driving force behind the adoption of new agricultural practices [43]. Even in the absence of high population density, improved access to urban markets influences agricultural intensification and agro-ecological conditions in production areas [41]. However, population pressure is also known to drive farmers to adopt soil rejuvenation and/or SCPs to maintain their activities and living standards in the context of resource scarcity and agro-ecosystem degradation [44–46].

More recently, in the Boserup-Ruthenberg framework presented by Binswanger and Savastano [40], population density and market access are considered simultaneously as the main drivers of agricultural intensification. They are the main drivers of the evolution of farming systems, respectively defining the constraints and opportunities of farming households located in production areas close to urban centres. Access to urban markets and population growth can simultaneously lead to a virtuous circle of agricultural intensification. They lead to a reduction in fallow, increased use of organic manure and fertilisers to compensate for declining soil fertility, and investment in soil conservation to maintain or increase agricultural production and farm incomes [47,48]. Thus, according to Binswanger and Savastano [40], population density provides the need for intensification, while improved access to urban markets creates the opportunity. However, the increase in agricultural production comes at the cost of an increase in labour and other inputs per unit of land. Positive results will only be achieved if agricultural innovations stimulate productivity growth. Thus, if population growth reduces the availability of land and the practice of fallow, and if new market opportunities emerge, farmers will sustainably intensify their production system.

According to Essombe et al., (2018), urbanisation can be captured by both proximity to the city centre and population density. Proximity to the city centre is measured by the road distance between the centre of the city and the centre of the vegetable production area where the vegetable producer's farm is located. The centre of city is considered as the central point from which urban effects propagate. Population density is measured by the number of persons per square kilometre in agricultural areas, corresponding for example to the enumeration areas where the vegetable producer's farm is located.

Materials and methods

Study area

The study covers the Yaoundé metropolitan area. The Yaoundé metropolitan area is the area located from the city centre of Yaoundé up to 50 Km around. The area was selected mainly due to its location within the *Humidtropics*[d] intervention zones in Cameroon, a research program promoting sustainable intensification of agricultural production. In addition, Yaoundé is among the top two large cities in Cameroon and is the political and administrative capital of the country. With an annual population growth rate of 5.3 %, the size of its population now exceeds 3 656 000 inhabitants [1]. Moreover, Yaoundé's urban area expands fourfold every 20 years [49], with 5.6 % of the surrounding rural land used for urban expansion each year [50]. The Yaoundé metropolitan area belongs to the Guinean sub-equatorial climate with average annual rainfall ranging from 1 500 mm to 2 000 mm per year. The study area is known for its humid climate with an average annual temperature that ranges between 17 °C and 30 °C throughout the year. The study area is characterised by two types of soils, namely hydromorphic soils and ferrallitic soils [51].

Data collection

Primary and secondary data were collected for the study. Primary data were collected by the World Vegetable Centre (WorldVeg) from August to September 2016. The mission of WorldVeg is dedicated to research and development to realise the potential of vegetables for healthier lives and more sustainable livelihoods. In the absence of a reliable baseline survey of vegetable production areas, a multi-stage sampling method was employed using purposive and random sampling techniques.

According to Von Thünen's model of distance based-gradient analysis [52], the distance to the city centre was assumed to be essential to appreciate the vegetable producers' decision making in relation to the adoption of SCPs in this study. Hence in the first stage, following the urban master plan of Yaoundé city, the Yaoundé metropolitan area was divided into three concentric rings. Based on their exposure to urbanisation, the three rings are in such a way that the first ring goes from the city centre up to 15 Km, the second from 15 Km to 25 Km and the third from 25 Km up to 50 Km [4,53].[e] The inner concentric ring represents the urban area, which is characterised by higher population density and intensive vegetable production areas. The second and the third concentric rings represent the peri-urban areas (Table 1). Considering the characterization of the intensity of activity in vegetable production areas within the study area carried out by Pousseu [54], the next stages were taken. In the second stage, three (03) main production areas

[d] Humidtropics project was a CGIAR research program led by the International Institute of Tropical Agriculture (IITA) with the WorldVeg as one of the core partners.

[e] For example, peri-urban areas are estimated to be between 10 and 40 km from urban centres in the study of (Chagomoka et al. [85]) in Burkina Faso.

were selected from each concentric ring. In this stage, production areas with the highest production intensities in each concentric ring and whose production is market-oriented were selected. Finally, in the last stage, respondents were randomly selected at the production area level and their number was purposively retained according to the average number of vegetable producers in each production zone. Of the 190 respondents selected within the study area, only 185 questionnaires were considered complete and valid for further analysis. The number of vegetable producers selected per concentric ring is presented in Table 1. With a structured questionnaire, information on socio-demographic features, economic status, institutional and environmental characteristics, and the production system, including the soil management practices such as crop rotation, organic manure, mulching and fallow were collected.

As far as secondary data are concerned, they were used to capture the extent of urbanisation. On one hand, secondary data refer to the total number of persons and the size of residential areas (enumeration area), which are helpful to measure the population density in each production area. On the other hand, secondary data also refers to the distances by road between the Yaoundé city centre and the centres of different vegetable production areas selected in the study.[f] While the information used to compute population density was obtained from the Central Bureau of Census and Population Studies in Cameroon [55], distances in kilometres were computed from Google Maps.

Model structure

Vegetable farmers do not adopt SCPs singularly but in combination due to the complementarity and substitutability between the different sustainable soil management practices in vegetable production systems. Thus, in this study, a Multivariate Probit Model (MVP) was used to analyse the effects of urbanisation on the adoption of interrelated SCPs. A MVP model take into account the effects of covariates on the probabilities of adopting SCPs and facilitates the understanding of the interconnectedness between the different SCPs through the estimation of their respective correlations [56]. Previous studies have used univariate Logit and Probit models. Unfortunately, however, they failed to consider the SCPs' multiplicity nature and the potential correlations of the error terms between the adoption equations [57], leading to possible biased estimates [58].Therefore, following Kurgat et al., [5], in addition to the urbanisation variables, a range of other predictors were considered to influence farmers' decision to adopt the four SCPs, namely crop rotation, organic manure, mulching and fallow. These four sustainable soil management practices are the most widely used among vegetable farmers in urban and peri-urban areas of Yaoundé [35]. Let assume SCP_i a random variable taking the values 1, 2, 3 and 4 for a positive integer representing all the four SCPs and X a set of predictors. SCP_{ik} indicates whether or not a vegetable farmer has selected a particular SCP. Hence, the MVP in this study used four binary dependent variables SCP_{i1}, SCP_{i2}, SCP_{i3} and SCP_{i4} such that:

$$SCP^*_{ik} = x'_{ik}\beta_k + \varepsilon_{ik} \ \forall \ k = 1, 2, \ 3 \ and \ 4 \tag{1}$$

$$SCP_{ik} = \begin{cases} 1 \ if \ SCP^*_{ik} > 0 \\ 0 \ otherwise \end{cases} \tag{2}$$

where, β_k is a vector of parameters to be estimated for each SCP (k) and SCP^*_{ik} is the latent variable. In Eq. (1), the assumption was that the latent variable y^*_{ik} captures the unobserved preferences associated with k^{th} choice of SCPs. It is also assumed to be a linear combination of urbanisation, socio-demographic, economic, institutional and environmental characteristics (x'_{ik}) that are observed to be affecting the simultaneous adoption of SCPs, and the unobserved characteristics that are captured by the random error terms (ε_{ik}). Considering the nature of the latent variable the estimations in this study were based on observable binary variables SCP_{ik}. Furthermore, the unobserved random errors are assumed to jointly follow a multivariate normal distribution (MVN) with a zero conditional mean and a covariance matrix (Ω) such that:

$$\varepsilon_{ik} \sim MVN \ (0, \ \Omega) \tag{3}$$

$$\Omega = \begin{pmatrix} 1 & \rho_{12} & \rho_{13} & \rho_{14} \\ \rho_{12} & 1 & \rho_{23} & \rho_{24} \\ \rho_{13} & \rho_{32} & 1 & \rho_{34} \\ \rho_{14} & \rho_{42} & \rho_{34} & 1 \end{pmatrix} \tag{4}$$

The off-diagonal elements represent the correlation of unobserved random terms describing the interdependencies between the four SCPs. A positive correlation points out complementarity between the SCPs, while a negative correlation indicates substitutability between them. All models presented have been estimated using STATA 14.2 software.

[f] The distances calculated from Google Maps were obtained by selecting two locations as one would to do get directions. The central location was the centre of Yaoundé city considered as the centre market. The other locations were the central point of each farm. However, the distances from the centre to farms in the same production areas did not really differ in average as vegetable production is concentrated in small sites in urban and peri-urban areas of Yaoundé.

Table 1
Sampling size and description of concentric rings.

Distance to city centre	Population density	Number of respondents
0–15 km	High	79
15–25 km	Low	47
25–50 km	Moderate	59
TOTAL		185

Variables description

The variables used in this study are consistent with Alemu [59], Assefa and Hans-Rudolf [60], Bidogeza et al., [61], Bidogeza et al., [44], Binswanger and Savastano [40], Clay et al., [62], Demeke [63], Feder et al., [28], Knowler and Bradshaw [17], Ligonja (2015), Neill and Lee [64], Soule et al., (2000), Okoye [65], Teshome et al., [66] and Young and Shortle [67]. Four binary endogenous interdependent variables relatively to the four SCPs (Organic manure, Mulching, fallow and crop rotation) most widely used by farmers in vegetable production within the study area [35]. The SCPs are adopted in the study area to reduce soil erosion, to conserve soil and to maintain the soil long term productivity. Although the adoption of agricultural technologies is in reality an agricultural systems problem that necessitates concerted and cross-disciplinary efforts [68]; however, in this study, the definition of conservation agriculture adoption still refers to physical presence of SCPs on some part of land of the farmer since at least the two last seasons.

Apart from urbanisation variables that are proximity to city centre and density of population, thirteen other independent variables were identified grounded on the field survey results. The independent variables are a mixture of discrete and continuous variables. At the earlier stage, we ran a pairwise correlation matrice to evaluate the relationship between our potential covariate two by two. This guided us to the inclusion of some explanatory variables at the expense of others. We also computed the Variance Inflation Factor (VIF) to detect multicollinearity among our covariates. Table 2 summarises the variables used in the study and their characteristics.

Results

Magnitude of adoption and interdependences among SCPs

It is clear from our study that the extent of adoption of SCPs varies considerably between practices (Table 3). The most and least common SCPs used by urban and peri-urban vegetable farmers were organic manure[g] (85 % of farmers) and mulching (61 % of farmers). Fallow was also rarely practised and crop rotation was only moderately used. Of the farmers surveyed, 66 % reported practising fallow and 75 % crop rotation. In terms of the adoption of these SCPs across the study area, the use of fallow tends to be more common in less densely populated areas. Indeed, 96 % of farmers in the second concentric ring practice fallow, compared to 54.5 % and 74.5 % of farmers in the first and third concentric rings respectively. However, the use of organic manure, mulching and crop rotation tended to be higher in the more densely populated areas.[h]

Table 4 shows the adoption intensity, referring to the number of SCPs adopted simultaneously by a vegetable farmer, ranging from zero to four. The mean number of SCPs adopted was 2.87 (greater than 2) with a standard deviation of 0.2733. Also, the adopters of four SCPs were the highest. They were 66 accounting for 35 % of the total vegetable farmers. The adopters of one SCP were the least. They were only 24 vegetable farmers representing 12.97 % of the total. Only 2 vegetable farmers out of 185 did not adopt any SCP.

Table 5 indicates that the null hypothesis of no interdependence between the SCPs was rejected at a significance level of 5 % based on the likelihood ratio test (chi2(6) = 21.4193, $P < 0.05$). The result revealed evidence of interdependencies between SCPs. This result supported that the MVP model is preferable to the single equation probit model in this adoption study. Table 5 shows that 3 out of 6 pairwise correlation coefficients are significantly correlated, indicating that some SCPs complement each other as their signs were positive. Specifically, crop rotation and organic manure use were positively correlated, as were crop rotation and fallow, and organic manure and fallow.

Urbanisation effects on SCPs adoption in peri-urban vegetable production areas of Yaoundé

The results in Table 6 show that urbanisation, captured by proximity to the city centre and population density, has negative effects on the adoption of SCPs in urban and peri-urban vegetable production in Yaoundé. On one the hand, the results indicated that proximity to the city centre negatively affects the adoption of crop rotation, organic manure, mulching, and fallow. On the other hand, the same results revealed that population density negatively affects the adoption of fallow and has no significant effect on the adoption of crop rotation, organic manure, and mulching. In urban and peri-urban vegetable production areas, as population density increases, vegetable farmers are less prone to adopt fallow.

Other factors that are socio-demographic, economic, institutional, physical, and perception in nature also help to understand the adoption of SCPs by urban and peri-urban vegetable farmers. Among the socio-demographic variables, the age of the farmer negatively

[g] In the urban and peri-urban areas of Yaoundé, the type of organic manure mostly used is poultry manure.
[h] According to Table 1, the most densely populated areas are the first and the third rings; while the least densely populated area is the second ring.

Table 2
Definitions and units of measurement of variables included in the model.

Variables	Type	Measure	Expected sign*
Dependent variables			
Organic manure	Discrete	1 if the farmer adopts the practice; 0 otherwise	
Mulching	Discrete	1 if the farmer adopts the practice; 0 otherwise	
Fallow	Discrete	1 if the farmer adopts the practice; 0 otherwise	
Crop rotation	Discrete	1 if the farmer adopts the practice; 0 otherwise	
Explanatory variables			
Age	Continuous	Age in years	+/-
Household size	Continuous	Number of persons	+
Gender	Discrete	0= Female, 1= Male	+/-
Education	Discrete	0= No education level, 1= Primary school, 2= Secondary school, 3= High school	+/-
Agricultural experience		Number of years	+
Land ownership	Discrete	0= No, 1= Yes	
Plot size	Discrete	0= <500 m^2, 1= Between 500 and 999m^2, 2= Between 1000 and 1499m^2, 3= >1500m^2	–
Off-farm activities	Discrete	0= No, 1= Yes	+/-
Group membership	Discrete	0= No, 1= Yes	+
Agricultural credit access	Discrete	0= No, 1= Yes	+/-
Distance home to plot	Discrete	0= <1 Km, 1= Between 1 Km and 2 Km, 2= Between 2 Km and 3 Km, 3= >3 Km	–
Plot accessibility	Discrete	0= Poor accessibility, 1= Average accessibility, 2= Good accessibility	+/-
Perception of soil degradation	Discrete	0= No, 1= Yes	+
Density of population	Continuous	Density per Km^2	+
Distance to the city centre	Continuous	Distance in Km	+

* +/-, +, - signs indicate positive or negative, positive and negative influence on adoption of SCPs respectively.

Table 3
Percentage of adoption level of SCPs in urban and peri-urban vegetable production areas of Yaoundé.

Soil conservation practices	Percentage of adoption			
	Total percentage	Percentage within 0 Km-15 Km	Percentage within 15 Km-25 Km	Percentage within 25 Km-50 Km
Crop rotation	75	71.2	60	88.1
Organic manure	85	86.1	64	91.5
Mulching	61	57.4	48	72.8
Fallow	66	54.4	96	74.5

influences the adoption of crop rotation, but has no significant effect on the adoption of organic manure, mulching, and fallow. The farmer's household size increases the adoption of organic manure, but has no effect on the adoption of other SCPs. The level of education is positively related to the adoption of organic manure and mulching; while it does not affect the adoption of crop rotation and fallow.

With regard to economic variables, ownership of the plot has mixed effects on the adoption of SCPs. It decreases the adoption of

Table 4
Number of soil conservation practices adopted in urban and peri-urban vegetable production areas of Yaoundé.

Number of SCPs adopted	Total percentage of adopters	Percentage of adopters within 0 Km-15 Km	Percentage of adopters within 15 Km-25 Km	Percentage of adopters within 25 Km-50 Km
0	1.1	2	0	0
1	12.9	13.8	12	11.8
2	18.9	20.8	28	11.8
3	31.4	39.6	40	13.6
4	35.7	23.8	20	62.8

Table 5
Correlation coefficients of the adoption of SCPs from MVP Model.

	ρ Crop rotation	ρ Organic manure	ρ Mulching
ρ Organic manure	0.3**		
ρ Mulching	0.1	0.1	
ρ Fallow	0.6***	0.3*	0.04

Likelihood ratio test of: ρ Organic manure = ρ Crop rotation = ρ Mulching = ρ Crop rotation = ρ Fallow = ρ Crop rotation = ρ Mulching = ρ Organic manure = ρ Fallow = ρ Organic manure = ρ Fallow = ρ Mulching = 0; chi2(6) = 21.4193 Prob > chi2 = 0.0015.
***, ** and * indicate significance at $p < 0.001$, 0.05 and 0.1 respectively.

Table 6
MVP modelling of the influence of urbanisation on the adoption of SCPs in urban and peri-urban vegetable farms of Yaoundé.

VARIABLES	Crop rotation	Organic manure	Mulching	Fallow
Socio-demographic variables				
age	**−0.0200* (0.0111)**	0.00969 (0.0125)	0.00854 (0.0108)	−0.0102 (0.0115)
Gender				
male	0.205(0.267)	−0.145 (0.301)	−0.347 (0.253)	0.250 (0.280)
Household size	0.0291 (0.0272)	**0.0844** (0.0331)**	0.0144 (0.0282)	−0.00722 (0.0279)
Education level				
Primary school	0.152 (0.454)	**1.853*** (0.484)**	0.250 (0.470)	−0.0290 (0.414)
Secondary school	−0.0265 (0.458)	**1.554*** (0.420)**	**0.897* (0.464)**	0.0910 (0.433)
High school	0.360 (0.598)	**2.079*** (0.668)**	**1.179** (0.563)**	0.156 (0.565)
Agricultural experience	0.0184 (0.0133)	−0.00641 (0.0141)	0.0205 (0.0133)	−0.0137 (0.0134)
Economic variables				
Land ownership	0.0149 (0.295)	**−0.993*** (0.315)**	−0.261(0.259)	**0.941*** (0.278)**
Off-farm economic activity	−0.0921 (0.241)	0.200 (0.255)	−0.184 (0.233)	−0.0750 (0.233)
Plot size				
Between 500 m^2 and 1500 m^2	0.411 (0.284)	0.378 (0.318)	0.0350 (0.260)	0.00786 (0.274)
>1500m^2	0.00831 (0.330)	−0.100 (0.363)	**−0.551* (0.323)**	0.173 (0.345)
Access to credit	**−0.983*** (0.344)**	**−0.585* (0.329)**	−0.308 (0.304)	**−0.876*** (0.284)**
Institutional variables				
Group membership	**−0.575** (0.278)**	−0.0565 (0.327)	−0.413 (0.287)	−0.305 (0.285)
Physical and perception variables				
Distance plot - residence				
Between 1Km and 2 Km	−0.154 (0.327)	−0.224 (0.402)	−0.0705 (0.311)	**0.607* (0.316)**
Between 2Km et 3Km	−0.404 (0.321)	**−1.156*** (0.374)**	−0.351 (0.297)	0.377 (0.329)
>3km	−0.517 (0.346)	**−1.289*** (0.374)**	0.216 (0.326)	**0.868*** (0.318)**
Plot accessibility				
Average accessibility	−0.0810 (0.284)	**−0.736** (0.333)**	**−1.240*** (0.283)**	**−0.981*** (0.295)**
Good accessibility	0.308 (0.317)	−0.502 (0.321)	−0.132 (0.273)	0.288 (0.307)
Perception of soil degradation	**0.679** (0.268)**	0.275 (0.281)	−0.100 (0.221)	**0.371* (0.225)**
Urbanisation variables				
Distance to city centre	**0.045*** (0.0103)**	**0.023** (0.0100)**	**0.0205** (0.0089)**	**0.0152* (0.008)**
lnpopdensity	0.131 (0.0999)	- 0.149 (0.105)	−0.0790 (0.0898)	**−0.229** (0.100)**
Constant	−0.825 (0.982)	0.296 (1.004)	0.129 (0.901)	**1.608* (0.960)**
Number of obs	185			
Wald chi2(84)	425.41			
Log pseudolikelihood	−309.1681			
Prob > chi2	0.0000			

***, ** and * indicate significance at $p < 0.001$, 0.05 and 0.1 respectively.

organic manure and increases the practice of fallow. The size of the plot reduces the willingness of vegetable farmers to adopt mulching but has no effect on the adoption of other SCPs. Access to credit negatively affects the adoption of crop rotation, organic manure, and fallow but does not affect the adoption of mulching.

Institutional variables also help to understand the adoption of SCPs in the study area. That is, being a member of one group of farmers appeared to reduce the adoption of crop rotation, but has no effect on the adoption of organic manure, fallow, and mulching.

Finally, physical and perception variables equally affect the adoption of SCPs in urban and peri-urban vegetable production in Yaoundé. Plot distance from the residence has mixed effects on the adoption of SCPs. It reduces the willingness of vegetable farmers to use organic manure and increases the adoption of fallow. Average accessibility compared to poor accessibility of production areas negatively affects the adoption of organic manure, mulching, and fallow. Perceived soil degradation increases the adoption of crop rotation and fallow, but has no effect on the adoption of organic manure and mulching.

Discussions

The results of this study showed that urbanisation does affect the adoption of interrelated SCPs in urban and peri-urban vegetable production in Yaoundé. The results on the extent of SCPs' adoption indicated that organic manure was the most widely adopted SCPs, with a slightly higher proportion than the 66 % adoption rate reported by peri-urban and rural vegetable farmers in Kenya [5], while mulching was the least widespread adopted practice due to its laborious implementation [19]. Fallow was equally seldom used. Okolle et al., [69] described a similar situation in agroecological zones in the humid tropics of Cameroon, including Yaoundé city, by explaining that land scarcity does not allow for long fallow periods. In terms of adoption intensity, the results showed that the majority of vegetable farmers adopted more than one SCP at the same time and that there were complementarities between the adopted SCPs. This finding indicates a certain interest in sustainable land management in the study area, certainly due to the exposure to urbanisation, which has forced urban and peri-urban farmers to manage their land sustainably. Complementarities between SCPs mean that the adoption of a given SCP may also affect the adoption of other SCPs. This finding is somewhat similar to previous studies indicating that farmers adopt simultaneously more than one SCP to better sustainably manage their land [5,19]. Within the study area, urban and peri-urban vegetable farmers tend to prioritise the use of organic manure, which they associate with crop rotation alone or with crop rotation and fallow, depending on the availability of their resources.

Besides, the results magnified that urbanization, through proximity to city centre and population density has negative effects on the adoption of SCPs in vegetable production of Yaoundé. On one hand, proximity to the centre reduced the adoption of fallow in a consistent way with the literature and the adoption of crop rotation, organic manure, and mulching in a non-consistent manner [70, 71]; Soule et al., 2000). These contradictions, however, find several explanations in Shiferaw et al., (2009). These authors supported the idea that the rate of SCPs adoption varies depending on whether access to urban markets affects the types and/or the prices of the products. In terms of type of products, thanks to their relatively short cropping cycles and ability to enable quick and permanent incomes, cropping systems of traditional leafy vegetables[i] are preferred close to urban centre more than cropping systems of exotic vegetables or mixed cropping systems between traditional leafy and exotic vegetables [35]. As a result, the practice of crop rotation is low close to the urban centre as vegetable farmers specialise in only a few types of (traditional leafy) vegetables. On the contrary, this practice increases as ones moves away from the city centre, as production becomes more diversified with cropping systems that increasingly include a mix of traditional leafy and exotic vegetables. Similarly, the practice of mulching is also low close to the urban centre. Due to land constraints, farmers feel losing time and income by adopting mulching when comparing the time required by the mulching process to assimilate residues as organic amendments in the soil with the length of traditional leafy vegetable cropping cycles. During a field survey, in fact, one vegetable farmer located close to urban centre reported in this logic that « *j'ai l'impression de perdre du temps et de l'argent en attendant que la terre se repose par le paillage, au lieu de planter immédiatement de nouveaux légumes feuilles que je vais renforcer avec les engrais chimiques et organiques pour que d'ici un mois ou un mois et demi je commence la récolte et à vendre…* ».[j] Thus, as land constraints decrease when one moves away from the centre, the practice of mulching tends to increase.

Looking at the price of vegetables grown instead, some studies suggest a positive relationship between the price of agricultural products and the adoption of SCPs ([72]; Shiferaw et al., 2009). Specifically in urban markets of Yaoundé, the average prices of exotic vegetables exceed the average prices of traditional leafy vegetables. For example, if a kilogram of pepper and tomato, that are exotic vegetables, cost respectively $ 0.53 and 0.40 on average in 2016 [49], the average price of one kilogram of leafy vegetables was instead between $ 0.25 to 0.33 during the same year [73]. Hence, as traditional leafy vegetables mostly cultivated close to the urban centre are relatively cheaper than exotic vegetables mostly grown further away from the city centre, the adoption rates of crop rotation, organic manure, and mulching are decreasing with proximity to the centre due to the price difference of vegetables produced across the space.

On the other hand, population density was found to reduce the adoption of fallow but with no effects on the adoption of crop rotation, organic manure, and mulching. Similar findings have been made throughout the literature as it is widely recognised that increasing population density leads to the scarcity of agricultural land, increased cropping frequency, and reduced fallow period [41]. Nevertheless, the non-significant influence of population density on crop rotation, organic manure, and mulching could be explained by Pender et al., [14]. They reported that previous studies had shown that the population density effects on SCP adoption are only effective in areas where urban infrastructures and services are not well developed. Thus, due to a certain level of urban development in urban and peri-urban areas of Yaoundé, it looks as if demographic pressure has little or no effects on the adoption of SCPs in vegetable production. It has to be seen with Binswanger and Savastano [40] that, within the study area, the opportunity to adopt SCPs due to increased access to urban markets is greater than the need to adopt soil management practices due to population pressure. A complementary explanation for the insignificance of population density on the adoption of SCPs could be the fact that vegetable producers in and around Yaoundé are accustomed to changing site location when land constraints become high. Soua Mboo et al., [74] and Temple et al., [75] have shown within the study area that vegetable producers change their production location on average 5 times in only 9 years. Production locations close to the city centre are disappearing while others are emerging further away from the centre [76].

Finally, the results suggested that the adoption of SCPs by urban and peri-urban vegetable farmers also largely depends on other type of factors. Firstly, the socio-demographic variables seemed to affect the adoption of SCPs. The adoption of crop rotation is negatively influenced by the age of the farmer. The crop rotation falls into the category of SCPs with positive long-term effects. Thus, with age, producers anticipate exiting from agriculture in a few years, especially in urban and peri-urban areas. This result is similar to studies of Barry et al., [77] and Ersado et al., [70]. The farmer's household size augments the adoption of organic manure. Large family labour could be useful for transportation, storage, and application of organic manure on vegetable plots. However, some studies argued that large households have a high preference for the present as they spend most of their income on food and other basic needs, thus reducing therefore their ability to invest in the adoption of SCPs [78–80]. A high level of education enables farmers to have a better understanding of the advantages associated with SCPs such as organic manure and mulching, to obtain and apply information concerning the implementation of these practices, and to improve their ability to optimise the allocation of their resources for these purposes [28,63].

Secondly, economic variables were determinants of SCP adoption. Ownership of the plot reduces the adoption of organic manure

[i] Traditional vegetables referred here are those also known as Traditional African Leafy Vegetables in the literature. They are composed of Nightshade (*Solanum ssp*), Amaranth (*Amaranthus spp.*) and Jute mallow (*Corchorus olitorius L.*). Their urban demand is high and their cropping cycles are relatively short approximatively 1 month. The exotic vegetables as far as are concerned are composed of Lettuce (*Lactuca sativa*), Celery (*Apium graveolens* L.,), Tomato (Lycopersicum esculentum), Hot peper (capsicum chinenses), Pepper (capsicum frutesescens), Bell peper (capsicum annuum), Basilic tropical (ocimum gratissimum), and Eggplant (*Solanum melongena L.*). The length of cropping cyles of fruit vegetables among these exotic vegetables quoted varies from 3 to 4 months.

[j] *"I feel like I'm wasting time and money by waiting for the soil to rest by mulching, instead of immediately planting new leafy vegetables that I'm going to reinforce with chemical and organic fertilisers so that in a month or a month and a half I can start harvesting and selling..."*.

and increases the practice of fallow. The adoption of organic manure generates costs like costs of purchase, storage, and application but short term benefits in terms of productivity. Thus, non-owners may prefer productivity benefits while land owners are reluctant to bear the costs. All other things being equal, the owners may ultimately prefer SCPs that do not generate financial costs, such as fallow. The adoption and maintenance of SCPs like mulching in large farms require high expenses (Norris and Batie, 1987) or a greater amount of labour used. Thus, the adoption of mulching decreases among vegetable farmers with plots of >1500 m^2 compared to those with plots of less than 500 m^2. Similar results are reported by Clay et al., [62] and Shortle and Miranowski (1986). Access to credit reduces the adoption of crop rotation, organic manure, and fallow. Since the credit received is generally not formal within the study area, there is little chance for adoption of crop rotation as vegetable producers receive cash in advance from wholesalers who order the type of vegetables to be produced; adoption of organic manure which has long term benefits while farmers prefer to maximise in the short term by opting for chemical fertilizers; and, adoption of fallow as farmers sign forward contracts with wholesalers [73]. These findings are opposite with the idea that additional financial resources for farming could increase the adoption of conservation agriculture [81].

Thirdly, the institutional variables seemed to reduce the adoption of crop rotation. More precisely, being a member of a farmers' organization reduced the propensity to adopt crop rotation in urban and peri-urban vegetable production in Yaoundé. A possible explanation for this finding is that farmers' organizations in the study area do not promote SCPs, as Shrestha and Ligonja [82] have shown that farmers' organisations provide information that could motivate farmers to adopt SCPs.

And fourthly, physical and perception variables also explained the adoption of SCPs. Plot distance from the residence reduces the willingness of vegetable farmers to use organic manure and increases the adoption of fallow. Long distances discourage farmers because it means more work to transport bags of manure [59,63]. Conversely, the increase in the adoption of fallow could be explained by the fact that vegetable farmers may be forced to leave land rest on distant plots due to the regular and large amount of labour required in vegetable production. Similar results were found by Alemu [59] and [63]. Since the accessibility of agricultural land increases the likelihood of land conversion to urban uses and that the benefits of adopting SCPs are only realised in the long term, the accessibility of production areas reduces the adoption of organic manure, mulching, and fallow in this study. This finding supports the idea of Soule et al., [83] that the more accessible a production area is, the less likely the farmer who owns plot in that area is to adopt SCPs. The adoption of crop rotation and fallow augments with perceived soil degradation. A possible explanation could be that vegetable farmers use crop rotation because different types of vegetables have diverse soil nutrient requirements; they also use fallow mainly for the set of cultivation practices necessary to prepare the land for the natural replenishment of soil nutrients [84]. This result is similar to that of Assefa and Hans-Rudolf [60] who found that farmers' perception of soil degradation problems in the Arbaminch and Chencha regions was a major condition that led them to use fallow and crop rotation, among others.

Conclusions

This study is one of the first to analyse the effects of urbanisation on the adoption of interrelated SCPs among urban and peri-urban vegetable producers in Yaoundé, Cameroon. The effects of urbanisation on urban and peri-urban vegetable production have been described using the concept of agglomeration economies defined as spatial externalities due to the proximity to the concentration of populations and economic activities. Descriptive results pointed out that the most adopted SCP is organic manure, while the least adopted is mulching. The adoption intensity of multiple SCPs is high as more than half of the practices are on average adopted simultaneously. Similarly, the results also indicated complementarities between SCPs, meaning that any policy that drives change in the adoption of a given SCP would also affect the adoption of other SCPs. Hence, any public policy established for sustainable land management should promote the adoption of SCPs in bundles instead of a single SCP to adequately attain the desired productivity and environmental protection targets in urban and peri-urban vegetable production.

The regression results revealed that urbanisation reduces the adoption of SCPs. In particular, proximity to city centre negatively affects the adoption of crop rotation, organic manure, mulching, and fallow; while population density decreases the adoption of fallow. Therefore, public policies should reinforce the connection of vegetable producers to effective and efficient markets to ease the perverse effects of urban market access. They should also reinforce land tenure security in urban and peri-urban vegetable production to mitigate perverse effects of population pressure. For example, decision-makers and local authorities should ensure the preservation of productive agricultural zones by formalising property rights and ownership reforms on agricultural lands. Such decisions would effectively contribute to reducing the uncertainty urban and peri-urban vegetable farmers face about keeping their land into agriculture in an urbanising environment; and, as a result, lead to a more productive and environmentally friendly vegetable production.

Aside urbanisation factors, the other major factors influencing the adoption of the interdepend SCPs are the age of the producer, the household size of the producer, the education level of the farmer, land ownership, plot size, farmer group membership, access to credit, the plot distance from residence, the plot accessibility and the perception of soil degradation by the farmer himself. These factors influence the adoption decision of SCP in several ways implying the promotion of sustainable land management through well steered policies and programmes. Specifically, policy efforts that seek to improve formal agricultural credit access to urban and peri-urban farmers as well as farmer's organisations operations could be other good channels for promoting the adoption of SCPs in urban and peri-urban vegetable production. Therefore, future studies in cities and towns in SSA should deepen the analysis of the influence of urbanisation through the lens of agglomeration economy theory and a mix of socio-demographic, economic, and institutional factors on the adoption of SCPs in vegetable production. These future studies may be needed to generate evidence on the relative importance of the spatial context and the complexity of SCPs in vegetable production to provide insights for sustainable land management in vegetable production in urban and peri-urban areas.

CRediT authorship contribution statement

Lucien Armel Awah Manga: Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing, Formal analysis, Resources. **Jean-Claude Bidogeza:** Supervision, Writing – review & editing, Resources. **Victor Afari-Sefa:** Supervision, Writing – review & editing, Resources.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

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