

Full Length Research Paper

Dynamics and sustainability of urban and peri-urban vegetable farming in Yaoundé City, Cameroon

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In the context of rapid urbanisation of Cameroon, it is estimated that 70% of the total population will be dwelling in urban centres by 2060. Meanwhile, vegetable production has become an important economic activity for the urban and peri-urban poor because of its shorter production cycle. Thus, this study aims at describing the dynamics of the changes and sustainability within vegetable production systems in urban and peri-urban areas. A survey was conducted among 185 vegetable farmers and 184 non-vegetable farmers in urban and peri-urban areas of Yaoundé using a structured questionnaire. Descriptive results show that vegetable production is concentrated in densely populated areas with underpinning socio-economic characteristics. On average, vegetable producers are married (70.0%), educated (94.0%) and mostly young adults (24.0%). Most (70.0%) of the respondents have vegetable farming as their main source of income. The most dominant cropping system is the strip cropping system between traditional vegetables. The results of the sustainability analysis show that the profitability of vegetable production decreases with population density. While mulching, crop rotation and the application of organic manure increase with population density, land fallow is observed to decrease. The perceptions of vegetable producers and non-producers towards vegetable production are broadly similar. Finally, more than half of vegetable producers (53.0%) will not be able keep working on their plots in the next 10 years. Therefore, urban policy planners should take into account vegetable production when elaborating master and zoning plans to better preserve and integrate it as part of the urban development plan.

Key words: Urbanization, vegetable production system, sustainable agriculture, Yaoundé

INTRODUCTION

Sub-Saharan Africa (SSA) has absorbed relatively high rates of urban growth over the past 50 years. With the

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current urbanization rate of about 41.4%; it is projected that by 2030, 47% of SSA's population will be living in urban areas with the highest urbanization growth rate in the world (United Nations, 2018). Unfortunately, in many developing countries, urbanization is closely associated with urban poverty, food insecurity and malnutrition (World Bank, 2013). UNPFA (2007) projected that by 2020 about 40-45% of the poor in Africa will be concentrated in towns and cities. As a response to inadequate, unreliable and irregular access to food and lack of purchasing power; urban and peri-urban agriculture, particularly vegetable production, has therefore become an important land use option to city dwellers and a major source of livelihood in cities of SSA countries (Taiwo, 2014). It contributes to household food security, income generation, poverty alleviation, improved urban environment and strengthening the economic base of cities (Chihambakwe et al., 2018; Rezai et al., 2016; Islam and Siwar, 2012; Lynch et al., 2013; World Bank, 2013; Zasada, 2011; Smit and Nasr, 1992; Zasada, 2011).

Although vegetable production in urban and peri-urban areas is important, there exist some direct and indirect effects of urban growth that interfere with vegetable production practices such as: loss of farmland, land speculation, conversion of agricultural land to urban uses and land-use conflicts between farmers and non-farm residents (Awah Manga et al., 2018). As a result, the widespread expectation is that, in urbanized areas, vegetable production will inevitably decline (Adelaja et al., 2011).

Nevertheless, in SSA countries, urban and peri-urban vegetable production persists in various forms and adapts to the stresses of urban growth (Houimli, 2008). Enhanced by urban markets proximity, the importance of the socioeconomic and food functions of peri-urban vegetable production explains its perennity around cities and towns in SSA. (Moustier and Pagès, 1997; FAO, 2012). This perennity could be linked to the three pillars of the concept of sustainability, that is, economic, social and environmental as defined by Dauvergne (2011). Within the urban and peri-urban context however, sustainable agriculture refers largely to its capacity to retain farmland for agricultural uses (Dabat et al., 2006). In fact, land remains the main asset in the agricultural world and is getting rare especially in peri-urban areas due to pressures from rapid urbanization (Awah Manga et al., 2018).

In Cameroon, it is estimated that currently more than 24 million people live on the national territory, of which 53.8% live in urban areas, and this population is expected to grow to 55.62 million by 2060, of which 77.23% will be urban (NIS, 2015). Currently, more than one million people are directly or indirectly involved in vegetable production, processing and marketing activities (Achancho, 2013). In recent times, vegetables production represents approximately 22.9% of the total agricultural

production in Cameroon (IRAD, 2010).

In the Centre region of the country, from 2009 to 2011 for example, production levels of tomato, pepper, okra and onion were increased by 16.9, 13.9, 15.0 and 30.0% respectively on one hand; and on the other hand, the area under cultivation of these crops increased by 48, 12.3, 19.8, and 43.8% respectively (NIS, 2015). This is an indication that land under cultivation should augment with the increased importance vegetable production is getting in urbanized areas. Unfortunately, in the periphery of the Yaoundé city, 5.6% of the area surrounding rural lands is utilized for urban expansion on a yearly basis (Oliete, 2002).

Given the important role that urban and peri-urban vegetable production plays in alleviating poverty and improving nutritional status, developing appropriate and innovative technologies and policies to adequately respond to urban pressures faced by vegetable farming requires a better understanding of the existing production systems over space. The scope, forms and related practices may vary in and around the cities. Systematic classification of vegetable production systems under pressures of rapid urbanization is therefore necessary for a meaningful comparison and avoidance of misleading generalization of production systems over space. A considerable number of studies have already examined various aspects of vegetable production in Cameroon (Asongwe et al., 2014; Achancho, 2013; Berinyuy and Fontem, 2011; Sotamenou and Parrot, 2013; Kamga et al., 2013; Parrot et al., 2009; Bopda, 2008; Temple et al., 2008). Though some of these studies looked at the spatial distribution of vegetable production systems (Gockowski et al., 2003; Temgoua et al., 2012; Kamga et al., 2014), only few have considered the analysis of spatial sustainability aspects. To the best of our knowledge, this study is the first attempt to describe the spatial dynamics and sustainability aspects of vegetable farming under urban pressures in urban and peri-urban areas of Yaoundé. This paper therefore aims at describing the dynamics and sustainability aspects of vegetable farming systems under urban pressures to better ensure its perennity by preserving and developing its current and future existence respectively. In this context, while dynamics refer to spatial changes of vegetable production systems over space; sustainability refers to the capacity of vegetable farms to sustain themselves for an extended period of time in urban and peri-urban areas. In these areas indeed, the sustainability of agricultural production should reflect economic, social, ecological and land tenure aspects. According to the framework of Awah Manga et al. (2018) peri-urban vegetable farms that are economically viable, socially well-inserted, environment friendly and land tenure secured are designated as sustainable farms. This conceptualization is more adequate to assess how urbanisation process affects the sustainability of agriculture in settings that undergo rapid changes in land

uses such as urban and specifically peri-urban areas.

MATERIALS AND METHODS

Study site

The study covers Yaoundé and its surrounding areas, the Yaoundé Metropolitan Area (YMA) in the Centre Region of Cameroon. The area was selected mainly due to its location within the Humidtropics, a defunct CGIAR Research program, and intervention zones which emphasized on sustainable intensification of agricultural production. YMA belongs to the Guinean sub-equatorial climate characterized by four seasons: two rainy seasons and two dry seasons with average annual precipitation ranging from 1,500 to 2,000 mm per year. The long dry season that occurs within the period November to February, minor rainy season between March and June, a short dry season from June to August and the major rainy season from mid-August to mid-November. YMA is known for its humid climate with an average annual temperature that ranges between 17 and 30°C over the four growing seasons. The region is characterised by two types of soils: hydromorphic and ferrallitic soils (Martin and Segalen, 1966).

Sampling and data collection

The selection of respondents was guided by purposive and random sampling techniques using multi-stage sampling methods. Firstly, the YMA was divided into three rings according to the CUY (2008) in reference to the Von Thünen's monocentric model. In referring to the Von Thünen's model of distance based-gradient analysis (Von Thünen, 1826), this paper assumes that the distance to the city center is important in understanding the patterns of spatial changes and sustainability of vegetable production systems within the YMA. The inner ring goes from the city centre up to 15 km (urban area), the second ring from 15 to 25 km and the last ring from 25 to 50 km (peri-urban areas). Secondly, within these three concentric rings, two to four main vegetable production areas were selected according to their intensity of vegetable production, the orientation of production toward markets and the fact that the production site is operational at least for ten years. And lastly, within each selected production area, respondents were randomly selected and their number purposively retained according to the importance of vegetable production in that specific area. The survey was conducted from August to September 2016 by face-to-face interviews using structured questionnaires with the support of the World Vegetable Center (WorldVeg). Two types of questionnaires were designed to elicit data: one questionnaire for vegetable producers and another one for non-vegetable producers.

The questionnaire for producers enabled data collection on characteristics of the household, characteristics of land operations in the main farms, institutional arrangements and producers' perceptions about effects of urbanisation on their activity. The questionnaire for non-producers focused only on data regarding characteristics of household and their perceptions about vegetable production in their neighbourhood. A total number of 369 respondents was obtained among which 185 were vegetable producers and 184 were non-vegetable producers.

Data entry and analysis

Data were encoded in MS-Excel software and cross-checked to clean errors. A codebook was developed to explain each variable. Using the same software, data analyses was undertaken, focusing only on descriptive statistics (computation of averages and

frequencies). Frequencies and averages of similar responses were grouped and compared between the concentric zones by cross-tabulation. During the analyses, the cases with missing values were excluded from the computations.

RESULTS AND DISCUSSION

Spatial distribution of main vegetable production areas within the YMA

The main intensive vegetable production areas are spatially dispersed from the city centre up to 50 km radius. Production areas are north-south oriented. They are more concentrated in densely populated areas. That is, intensive vegetable production areas are found mostly within 0 - 15 km and 25 - 50 km that are the zones with higher population density within the YMA (Table 1). The concentric zone within 15 - 25 km is an intermediary zone which commonly includes small villages where almost all farmers cultivate vegetables mostly for their own consumption and at times for the markets. These categories of producers were not included in this study. The analyses focused on vegetable producers that are typically market oriented. According to this, data were collected on few respondents in that concentric area as can be observed in Table 1.

Description of vegetable production systems within the YMA

Socio-demographic characteristics of vegetable producers

The socio demographic characteristics of the sampled respondents are presented in Table 2. Most (57%) of vegetable producers are male. They are dominant in zone 2 (92%) and in zone 3 (66%); whereas in zone 1, close to the urban centre, female are mostly represented (56%). The results are consistent with those of Okolle et al. (2016) and Nyirenda et al. (2011) who noted that on average 63 and 70% of vegetable farmers were men respectively in south Cameroon and in Northern Malawi and Eastern Zambia respectively. Kamga et al. (2014) also showed that vegetable farmers were mostly men; 58% in rural areas and 74% in peri-urban areas, and women (78%) in urban areas of Bamenda, Cameroon. According to Ambrose-Oji (2009), men are very committed to vegetable production for sale in the market. They perceive vegetable production mainly as an income generating activity.

The vegetable producers appear to be relatively young adults (mostly in zones 1 and 2). On the whole, majority of vegetable producers (67%) belong to the age group 40-49 years. According to the concentric zones, the age group mostly represented is 30-39 years (33%), 20-29 (40%) and 40-49 (31%) respectively in zones 1, 2 and 3.

Table 1. Description of selected vegetable production areas and the number of respondents.

Distance to city center (km)	Zone	Population density	Growth rate of the population	Intensity of vegetable production	Number of vegetable producers	Number of urban residents interviewed
0-15	Zone 1	High	Low	High	79	80
15-25	Zone 2	Low	High	Low	47	44
25-50	Zone 3	Moderate	Moderate	Moderate	59	60

Table 2. Socio-economic characteristics of vegetable producers in the study area and by concentric zone.

Variable	Respondents by concentric zone (%)			
	0 -15 km	15 - 25 km	25 - 50 km	Total
Gender				
Male	44	92	66	57
Female	56	8	34	43
Age class				
< 20	1	0	3	2
20-29	16	40	10	17
30-39	33	16	12	24
40-49	22	20	31	24
50-59	23	20	25	23
>60	6	4	19	10
Education level				
None	7	12	2	6
Primary school	39	36	29	35
Secondary school	47	44	58	50
High education	8	8	12	9
Marital status				
Single	23	32	15	22
Married	68	68	75	70
Widow/widower	7	0	8	6
Divorced	2	0	2	2
Vegetable production experience				
< 10	53	40	53	51
10-19	28	16	29	26
20-29	13	28	15	16
30-39	0	12	2	2
Main source of income				
Principal activity	76	76	54	69
Secondary activity	24	24	46	31

Since vegetable production is labor-intensive with regards to field operations ranging from land preparation, maintenance, harvesting and packaging; only the youth are more willing to bear such arduous tasks (Tarla et al., 2015). On the contrary, Temgoua et al. (2012) assert that

vegetable production is mostly carried out by young farmers because they are jobless or have not yet found better livelihood opportunities elsewhere. The educational level of vegetable producers is relatively high (94%). While, only 6% of the respondents acknowledge having

no formal education; higher proportions of vegetable producers reported to have primary (35%) and secondary education (50%) respectively. Irrespective of the concentric zone, the majority of respondents have secondary educational level (47% in zone 1, 44% in zone 2 and 58% in zone 3). Similar results have been found by Abang et al. (2013), Kamga et al. (2014) and Okolle et al. (2016). It is conceivable that educated vegetable farmers have substantial background to understand the skills and technical know-how required for vegetable production and the benefits of adopting improved farming methods and technology. Considering the marital status, majority (70%) of producers are married and a much lesser percentage (22%) are single. The same trend was found by Kamga et al. (2014).

Regarding vegetable farming experience, more than half of vegetable producers (51%) admitted having less than 10 years in vegetable production. This proportion is broadly similar through different zones, with 40% in zone 2 and a slightly higher percentage (53%) in zones 1 and 3. As noted by Afari-Sefa et al. (2015), in the Ashanti and Western regions of Ghana, the number of farmers with more than ten years of experience in vegetable production also decreased rapidly in our study area. This points out that the number of new farmers engaging in vegetable farming is increasing in recent times. In the study area, vegetable production appears to be an important source of livelihood for farmers. More than half of respondents (69%) reported vegetable farming to be their main economic activity. 76% of producers acknowledge vegetable production as the main source of income within zones 1 and 2, while 54% in zone 3.

Dynamics of vegetable production systems

Typology of vegetable production system: The typology of vegetable production systems is presented in Appendix Figures 1, 2, and 3. Appendix Figure 1 shows that more than half of vegetable producers (57%) reported to own land. Number of land owners is higher in zone 2, where 96% of farmers are land owners. Zones 3 and 1 accounted for 54 and 48% of land owners, respectively. These findings place more emphasis on the fact that land ownership decreases with population density in the study area. Kamga et al. (2014) pointed out the same evidence along the rural-urban continuum of Bamenda, Cameroon by showing that more than 92% of the vegetable producers in less densely populated areas were owners of their land against 74% in densely populated ones.

If land ownership looks relatively high, the ways vegetable producers obtain access to land for farm activities are different. Appendix Figure 2 shows the mode of land acquisition as follows: inheritance (25%) and lending (51%) in zone 1, inheritance (92%) and lending (8%) in zone 2 as well as inheritance (34%) and

lending (49%) in zone 3. These results may suggest that inheritance of farmland is high when population density is still low; while, farmland lending increases with population density. With increased urbanization, farmers, especially non-natives, have access to land mainly through land purchases or at least by renting. Indeed, most urban vegetable farming sites are situated on lands belonging to private developers who have not yet commenced building of their houses (Asongwe et al., 2014).

Appendix Figure 3 presents vegetable farm sizes within the YMA. In zone 1, 44% of the respondents own small scale farms with a land size less than 500 m². Only 11% own large-scale farms with farm sizes greater than 1 500 m². Meanwhile in zones 2 and 3 respectively, 40 and 34% of the respondents possess on the average a farm size greater than 1 500 m². This finding is similar with previous results of Parrot et al. (2009), Temgoua et al. (2012) and Kamga et al. (2013) on peri-urban vegetable production in Yaoundé, Dschang and Bamenda respectively. From all these studies, population density negatively affects vegetable farm sizes.

Vegetable production systems: The dominant cropping systems are strip cropping systems between traditional vegetables and strip cropping systems involving a mix of traditional and exotic vegetables (Appendix Figure 4). About 38% of producers practice strip cropping system involving traditional vegetables in zone 1, followed by 26% engaged in strip cropping system involving a mix of traditional and exotic vegetables. In zone 2, 40% of the respondents reported practicing strip cropping system involving a mix of traditional and exotic vegetables, while a much lesser percentage (36%) reported to practice mono cropping system of exotic vegetable, notably tomato (*Lycopersicon esculentum*). In zone 3, 69% of vegetable producers reported practicing strip cropping system involving traditional and exotic vegetables. Finally, whatever the zone, mixed cropping system involving vegetable and other crops are similarly represented. 13, 12 and 14% of farmers are reportedly using this system in zones 1, 2 and 3 respectively. These results are not consistent with those of Kamga et al. (2014) in their study in Bamenda, Cameroon. They showed that more than 94% of vegetable producers practiced mono cropping systems in peri-urban and rural areas; while, 84% practiced the mix cropping vegetable production in urban areas. In reference to Teh Nguh et al. (2017), the comparison of these results suggests that vegetable producers in YMA globally opt more for diversification to ensure a sustainability of their production systems, while vegetable producers in Bamenda, especially in peri-urban and rural areas, prefer specialization to seek high competitiveness of their production systems. This is to say, strip and mix cropping systems of vegetables are seem to be preferred in densely populated areas and mono cropping system in less densely populated ones.

African nightshade (*Solanum* spp.), amaranth (*Amaranthus* spp.) and jute mallow (*Corchorus olitorius* L.) were cultivated respectively by 73, 70 and 38% of farmers as the most important grown vegetables in the YMA (Appendix Figure 5). In zone 1, the same vegetables appear once again as the most produced. In the same order, 78% of producers cultivate nightshade (*Solanum* spp.), 76% cultivate amaranth (*Amaranthus* spp.) and 52% cultivate jute mallow (*C. olitorius* L.). In zone 2, tomato (*Lycopersicon esculentum*) was reported to be the vegetable mostly cultivated. Seventy percent of vegetable producers reported cultivate tomato in this area. In zone 3, beside nightshade and amaranth; basil (*Basilicum ocimum*), hot pepper (*Capsicum chinenses*), tropical basil (*Ocimum gratissimum*), and okra (*Hibiscus esculentus*) were found as the third, the fourth and the fifth most cultivated vegetables by 39, 34 and 32% of the respondents respectively. These results indicate that vegetable producers in densely populated areas prefer to produce traditional leafy vegetables than exotic vegetables. These results are quite similar with those of other studies in different locations of Cameroon such as Dschang and Bamenda (Temgoua et al., 2012; Kamga et al., 2014; Asongwe et al., 2014). Nightshade (*Solanum* spp) for example, develops quickly and its harvest can extend for more than six months as well as it is consumed largely by farmers and the urban population.

Characterization of vegetable production systems:

Hired labour was reported by more than half of respondents (55%) to be the type of labour mostly used. However, the typology of labour used is largely dissimilar over space. In zone 1, 51% of farmers reported hire external labour in their farms. In zone 2, only 16% of respondents acknowledge to acquire external labour in their farms. In zone 3, 85% of farmers acknowledge having recourse to hired labour for their vegetable production (Appendix Figure 6). Okolle et al. (2016) describe a similar situation of enough availability of hired labour in the West region relatively to the South-West and South regions of Cameroon. Intensive vegetable production systems appear to require more hired labour than extensive ones in a such way that farm activities that are labour -intensive such as land preparation, weeding, watering, transplanting and harvesting are mostly undertaken by hired labour as opposed to use of family labour.

Fertilizers are one of the most commonly used input in the study area. The mineral fertilizer mostly used is NPK. Regarding the usage by zone, 42% of farmers reported to use chemical fertilizers in zone 1, while 64 and 73% of farmers reported to use fertilizers in zones 2 and 3 respectively (Appendix Figure 7). Comparable conclusions were found by Kamga et al. (2014). They showed that the chemical fertilizers are used by over 96% of vegetable producers in rural and peri-urban areas as against 34% in urban areas of Bamenda city, Cameroon. These findings

seem to show that mineral fertilization decreases with the proximity to the city center. This may indicate that vegetable producers close to the urban centers could be more aware about the negative effects of mineral fertilizers' misuses.

Like fertilizers, chemical pesticides are also commonly used in the study area. Overall, 94% of farmers reportedly use chemical pesticides (Appendix Figure 8). The most used chemical pesticides are insecticides and fungicides followed by herbicides. Whatever the zone, more than 90% of farmers acknowledge using chemicals with a top of 100% in zone 2. This result is in accordance of the literature acknowledging that vegetable farming attracts high application of chemicals (Nguyen et al., 2018; Hoi et al., 2016; Kamga et al., 2013). Sowley and Aforo (2014), in their study of pesticides use in vegetable production in Tamale, Ghana, reported that the majority of producers, that is 91%, used pesticides in their farms. Because vegetables are commonly susceptible to a wide range of pests and diseases, vegetable production thus requires intensive efforts in agro-chemical input application, particularly, fungicides and herbicides.

On the whole, 61% of farmers reportedly use farmer own-saved (traditional) seeds, while the same percentage of farmers (61%) admits to using improved seeds (Appendix Figure 9). In zone 1, 61% of farmers reported use traditional seeds against 58% of farmers that use improved seeds. In zone 2, 32% of producers use farmer own-saved seeds, while a much higher percentage (88%) of farmers uses improved seeds. This results is obtained certainly because an exotic vegetable, tomato (*L. esculentum*) is the vegetable mostly grown in this zone. In zone 3, 53% of interviewees reportedly use improved seeds; whereas, a slightly higher percentage of respondents (71%) recognized using traditional seeds. Similar to the situation found in zone 1, farmer own-saved seeds are mostly used in zone 3 certainly because traditional leafy vegetables are the most cultivated vegetables in this zone. These findings are not far away from those of Pousseu (2009) in her study in Yaoundé who found that 76.7% of African leafy vegetable's producers use farmer own-saved seeds which are mostly landraces since they produce their seeds themselves.

Farmers' perception on urbanization affecting vegetable production:

For the vegetable farmers in the YMA (Appendix Figure 10), urbanization is perceived mostly as a market opportunity (46%) than a threat for the vegetable production (34%). However, a non-negligible proportion among vegetable producers consider urbanization simultaneously as a market opportunity and as a threat (19%). When the different zones are considered, the perception about urbanization changes to some extent. The farther away you get from the city center, the smaller the proportion of respondents that perceive urbanization as a market opportunity. This result seems paradoxical given most of the existing literature

Table 3. Average net income per concentric zone and within the whole study area.

Concentric zones (km)	Zone	Net income per cropping cycle in XAF	Profitability per cropping cycle
0-15	Zone 1	241 156	
15-25	Zone 2	719 994	417 918
25-50	Zone 3	588 432	

argues that vegetable producers seek to move closer to urban centers as they perceive proximity to urban markets as a market opportunity (Gockowski et al., 2003; Ambrose-Oji, 2009; Awah Manga et al., 2018). However, this result is understandable if one takes into account the fact that in remote and less densely populated areas, farmers do not want to face the consequences of what the urbanization process could foster in their vicinity by way of negative effects (land use conflicts with non-farmers, land speculation, conversion of land to urban uses, household waste disposal, among others); which, on the other hand, have already been accepted and integrated in agricultural production systems in areas closed to urban centers.

Sustainability of vegetable production systems within the YMA

Economic sustainability: The proportion of vegetable producers regarding their level of net income per cropping cycle is presented in Appendix Figure 11. Forty-one percent of farmers gain less than XAF¹ 150 000, 32% generates income between XAF 150,000 and XAF 600,000, and the remaining proportion (27%) overstep the line of XAF 600,000. Among vegetable growers who generate less than XAF 150,000, the highest proportion (56%) is found in zone 1, comparatively in zone 2 (17%) and zone 3 (25%). Among those who generate more than XAF 600,000, the higher proportions (50 and 40%) are found in zones 2 and 3 respectively, comparatively to just 14% in zone 1. Comparing these incomes with the minimum salary guarantee in Cameroon, which is 36,270 XAF per month, vegetable production in YMA appears to be a worthy income generative activity.

Moreover, on average a vegetable producer gained up to XAF 417 918 per cycle (Table 3). Previous studies reported similar results. Temgoua et al. (2012) found that incomes generated by vegetable producers range between XAF 30,000 and XAF 1,000,000 per cropping cycle in Dschang. Asongwe et al. (2014) found that farmers generate an average gross income equals to XAF 750,000 in Bamenda. According to production areas retained, the highest average net income per cropping

cycle is obtained in zone 2 (XAF 719,994). The second-high average net income is in zone 3 (XAF 588,432). And, the least average net income (XAF 241,156) is in zone 1 despite the proximity to large urban markets. This situation can certainly be explained by small scale of their plots. Relatively to the other zones, the zone 1 is the area with the highest density of the population. The observed result portrays that increased population density leads to a decline in the profitability of peri-urban vegetable production through the small size of farm plots.

Environmental sustainability: Within the YMA, four sustainable soil management practices are widely used (Appendix Figure 12). These are organic manure, crops rotation, bush fallow and mulching. These are known to conserve/improve the fertility of soils in a long run and improve yields (Kurgat et al., 2018). Considering the whole sample, 85% of vegetable producers used organic manure (mostly poultry manure), 75% practiced crops rotation, while (66 and 61%) practiced bush fallow and mulching respectively. Bush fallow is less practiced due to land scarcity. Okolle et al. (2016) described an almost similar situation within agro-ecological zones in the humid tropics of Cameroon. In the Southwest region, fallow was common; while, vegetables rotation with cereals was occasional. In the West region, fallow was not common and usage of organic fertilizers was widely spread. In the Southern region, leguminous cover crops are planted to replace crop rotation. In rural and peri-urban regions of Kenya in another extent, Kurgat et al. (2018) supported that the application of organic manure is also widely disseminated with 66% of vegetable producers using organic fertilization in their farms.

Regarding the adoption of these soil management practices over space, the usage of organic manure, mulching and crop rotation are relatively more frequent in densely populated areas. 86 and 92% of producers in zones 1 and 3 respectively; against 64% of producers only in zone 2 used organic manure. Mulching is adopted by 57 and 73% of farmers in zones 1 and 3 respectively as against only 48% of farmers in zone 2. Crop rotation is highly practiced in zones 1 and 3 with 71 and 88% of farmers respectively, and at less extent in zone 2 with 60% of farmers. The fallow practice is contrarily more frequent in less densely populated area. 96% of farmers within zone 1 practice fallow, against 75 and 54% of farmers within zones 2 and 1 respectively.

Social sustainability: The social aspect of sustainability

¹ 1 USA dollar is roughly equal to XAF 561. Also, it is worthy to note that XAF 150 000 is far higher than XAF 36 270 which is the minimum salary guarantee in Cameroon

concerns the comparisons of views on issues that could potentially be a source of conflicts between farmers and the general public (Howley et al., 2014). As far as the economic welfare effects of vegetable production in the livelihoods of producers and the whole community is concerned, both vegetable farmers and the general public expressed broadly similar levels of views (Appendix Figure 13). 96 and 84% of vegetable producers and non-vegetable producers respectively, have a positive view of economic welfare effects of the vegetable production. Moreover, 26% of respondents in both socio-economic groupings recognized the utterly positive economic welfare effects. In another extent, 16% of respondents among non-vegetable producers against only 4% of respondents among producers indicate that vegetable farming has negative or at least neutral economic welfare effects. These findings are found quite similar in all the three concentric zones. This is an indication that vegetable production is widely recognised both by vegetable growers and general public as a worthy income generating activity. Unfortunately, this result is not in line with the finding of Ba and Moustier (2010) in Dakar, Senegal who reported that both vegetable producers and the general public recognize economic functions of vegetable farming in a more limited way. In fact, only 25% of vegetable producers against 11% of general public admit positive welfare effects of vegetable production in Dakar.

Concerning farmland preservation for vegetable production in urbanizing areas, both vegetable and non-vegetable producers reported views that are quite akin (Appendix Figure 14). 65% of non-vegetable producers and 74% of vegetable farmers totally agreed with farmland preservation. This result is in line with our expectations that non-farm residents will be less supportive with farmland preservation than vegetable farmers. In zones 2 and 3 surprisingly, the general public is even more supportive to the farmland preservation than vegetable producers themselves. The explanation could be that while on one hand, non-farm residents are considering more and more peri-urban areas as a support for landscape amenities and recreational activities; on the other hand, in remote and less densely populated areas, vegetable producers expect more rapid urbanization growth to expand their market opportunities.

We have noted slight differences in vegetable producers and non-producers' perception with regards to the necessity to increase regulation in vegetable production to better protect environment and consumers (Appendix Figure 15). On one hand, while 7% of farmers (totally and/or simply) disagree with the increase of regulation; just 4% of the general public expressed the same point of view. On another hand, it is observed that 50% of vegetable producers against 48% of non-vegetable producers merely agree, while 27% of vegetable producers compared to 33% of non-vegetable producers totally agree with the increase of regulation in

vegetable farming. Examining these two findings within the different concentric areas, the trends are similar. This suggests that both vegetable producers and non-producers seem to be generally aware that vegetable production in peri-urban areas must be healthy.

All these three findings are an expression of a relatively low level of conflicts between vegetable producers and non-producers concerning the current and future existence of vegetable production in peri-urban areas of Yaoundé.

Land ownership sustainability: The capacity to retain land for the purpose of agricultural activities amid treat of rapid urbanization is a key factor for the continuity of vegetable production in peri-urban areas. Fifty-three percent of vegetable producers admits their ability to retain their plots up to the next 10 years. Only 19% among them, asserts the capacity to still cultivate the same plot in the next 20 years (Appendix Figure 16). Ba and Moustier (2010) found more promising results in the municipality of Dakar, Senegal. According to these authors, 100% and 94% of vegetable producers estimated to still be able to continue growing vegetables in Dakar within 5 years and 10 years respectively. The relatively low percentage of vegetable producers with optimistic views concerning their ability to continue with farming is certainly due to the fact that agriculture is still forbidden in lowland areas of Yaoundé. A prefectural decree in Yaoundé prohibits the practice of sheathing crops within urban areas. The reason given is that these crops favour the development of mosquitoes. As a consequence, the council authorities can, at any time, withdraw these crops from the city's farm plots without explanations.

Considering the planning horizon from concentric zones perspectives, more than half of the vegetable producers are not sure to be able to keep their land after 10 years in zone 1 (58%) and zone 3 (56%). In zone 2, however, only 24% of vegetable producers admit to be at risk to lose their lands before 10 years (Appendix Figure 16). As a result, the planning horizon seems to be more negatively affected by the perception of urban growth than the actual level of population density. Vegetable producers who anticipate a rapid acceleration of urban process in their area (zone 2) consider that they will not be able to retain their plots in the long run more than producers who are already farming in densely populated areas but with moderate growth rate of population (zones 1 and 3).

For further insights, the planning horizon was computed for each concentric zone (Table 4). The average number of years that are expected for the farmers to quit their plots is 12 years. From the concentric zones perspective, the average number of years for zones 1, 2 and 3 is 10, 16 and 10 respectively. These findings clearly indicate the negative effects that the population density could have on agricultural activities.

Table 4. Average planning horizon per concentric zone and within the whole study area.

Concentric zones (km)	Zone	Number of years	Planning horizon
0-15	Zone 1	10	
15-25	Zone 2	16	12
25-50	Zone 3	10	

Conclusion

This study aims at describing the dynamics and the sustainability of vegetable farming systems in peri-urban areas of the city of Yaoundé, Cameroon. Despite high urban pressures, vegetable production is an economic activity that has propensity to grow in and around the city of Yaoundé.

The main vegetable production areas are spatially dispersed and are more concentrated in densely populated areas with underpinning socio-economic characteristics. On average, vegetable producers are married, educated and young adults. The farther away you move from the city center, the less you find women producers. On the whole, vegetables are the main source of income, especially for vegetable producers located close to the city-center. The most dominant cropping systems is strip cropping systems; however, the practice of mono cropping system on exotic vegetables is also important in areas with low population density. Irrespective of the cropping systems and concentric zones, traditional leafy vegetables are the vegetable mostly produced within the YMA.

Analysis of the sustainability of vegetable production systems under urban pressures presents some differences along the space. Firstly, the profitability of vegetable production decreases with population density. Secondly, while the application of organic manure, mulching and crop rotation increased with population density; due to inadequate land, bush fallow is less adopted. Thirdly, vegetable producer's and the general public's views and perspectives towards vegetable production in urbanized areas appear to be broadly similar. Lastly, it appeared that more than half of vegetable producers acknowledged being unable to retain their plots in activity for more than 10 years.

A policy measure that came from the results is that urban policy planners should ensure the integration of peri-urban vegetable production as part of their urban development plan. The taking into account of vegetable production in the development of master plans, urban land use plans and zoning plans, as well as the formalization of property rights and land ownership reforms would be useful to increase the security of farmland ownership and ensure the maintenance of productive agricultural areas in and around the city. Such measures would help to strengthen the economic viability, ecological sustainability and social acceptability of peri-urban vegetable production. In fact, it would also

be easier for extension services, NGO's, Research centres to assist vegetable producers for having access to information and technical support on best agricultural and environmental management practices.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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APPENDICES

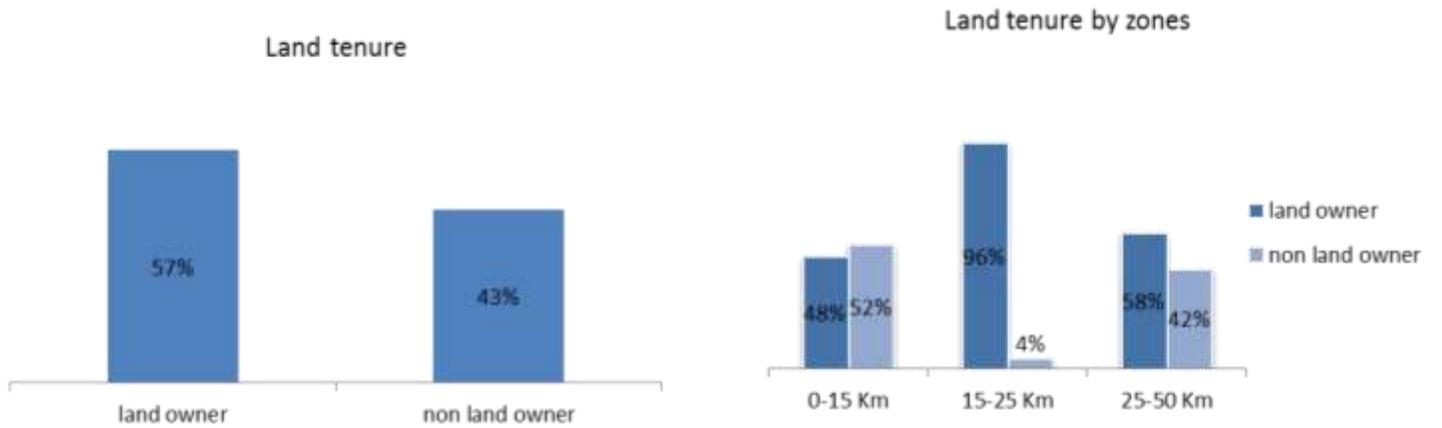


Figure 1. Land ownership in the study area and by zone.

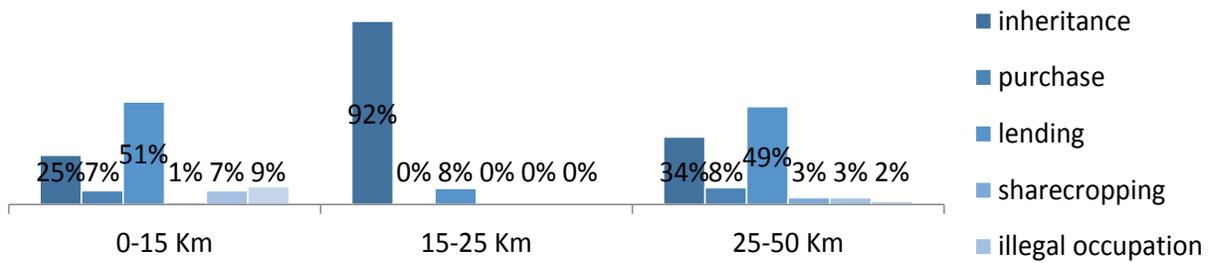


Figure 2. Mode of acquisition of farmland by concentric zone.

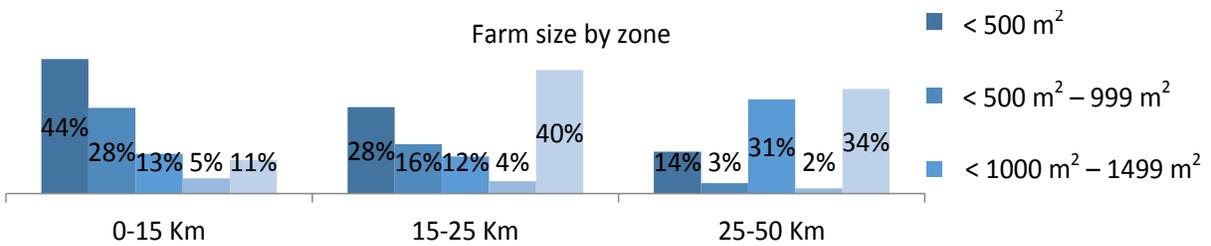


Figure 3. Farm size by concentric zone.

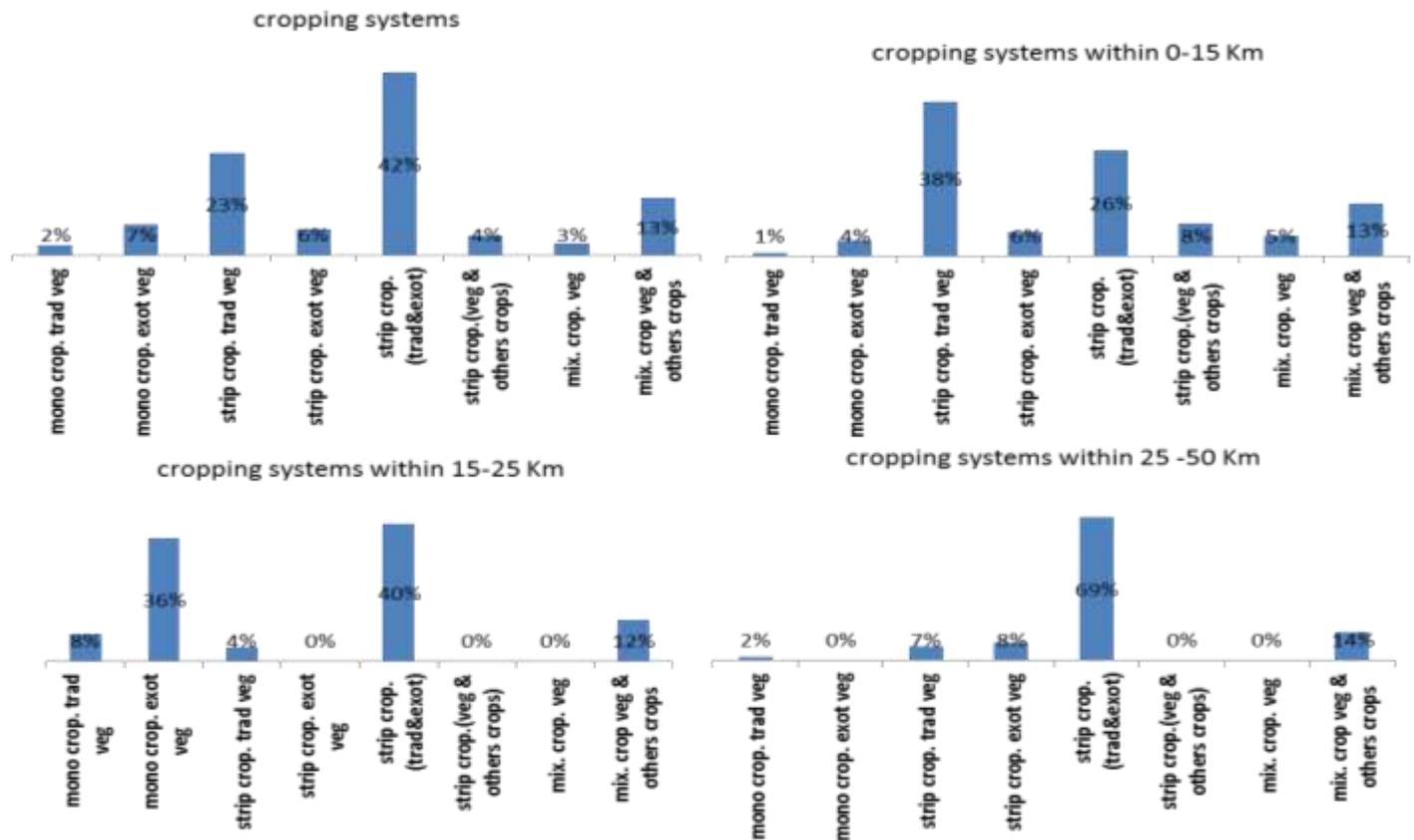


Figure 4. Cropping systems in the study area and by zone.

Mono crop. trad veg = Mono cropping system involving traditional vegetables.

Mono crop. exot veg = Mono cropping system involving exotic vegetables.

Strip crop. trad veg = Strip cropping system involving traditional vegetables.

Strip crop. exot veg = Strip cropping system involving exotic vegetables.

Strip crop. (trad & exot) = Strip cropping system involving traditional and exotic vegetables.

Strip crop.(veg & others crops) = Strip cropping system involving vegetables and others crops.

Mixed crop. veg = Mixed cropping system involving vegetables.

Mixed crop veg and others crops = Mixed cropping system involving vegetables and others crops.

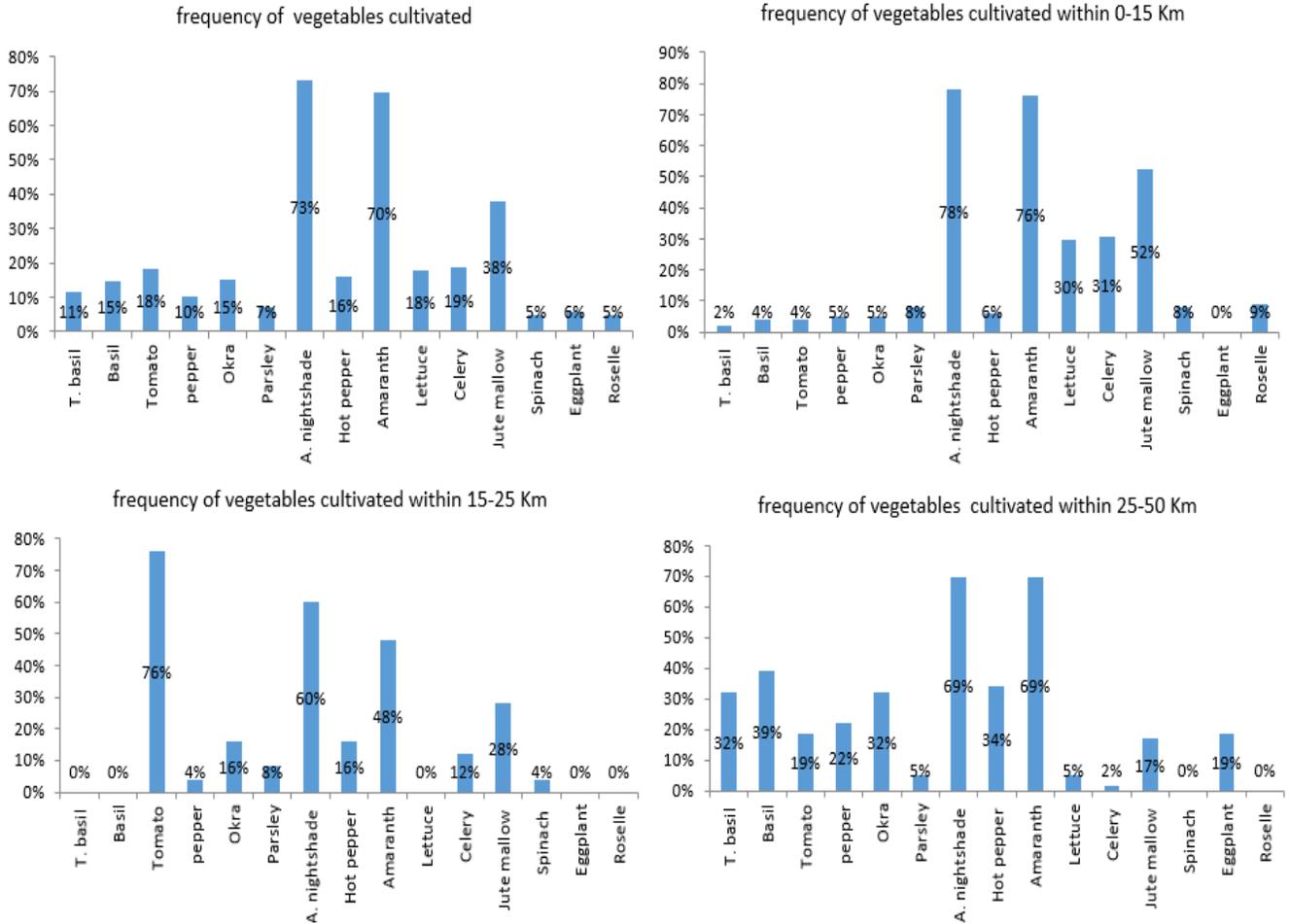


Figure 5. Percentage of vegetables mostly produced in the study area and by zone.

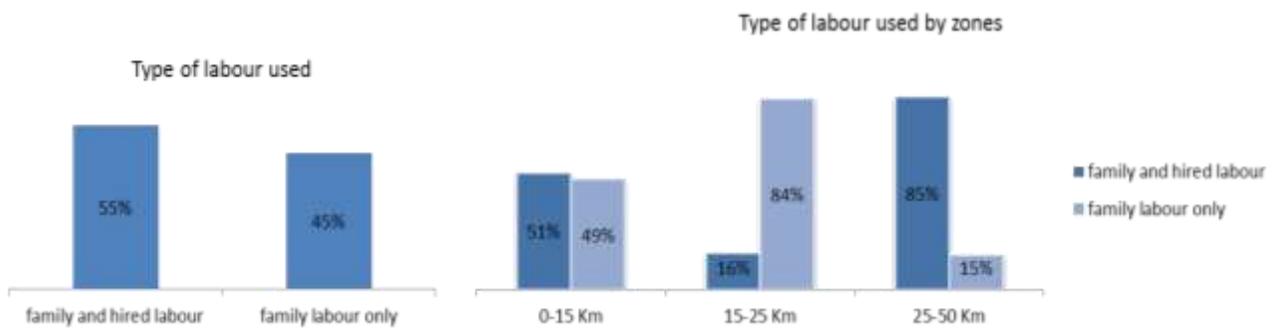


Figure 6. Type of labour used in the study area and by zone.

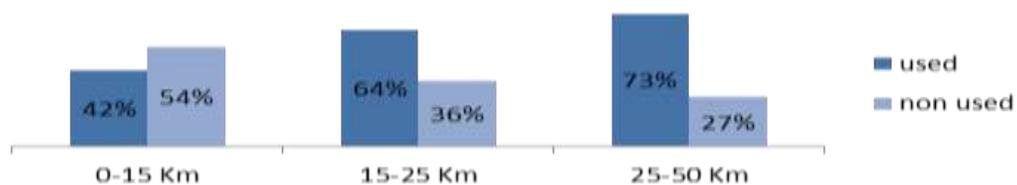


Figure 7. Percentage of vegetable farmers using mineral fertilizers by zone.

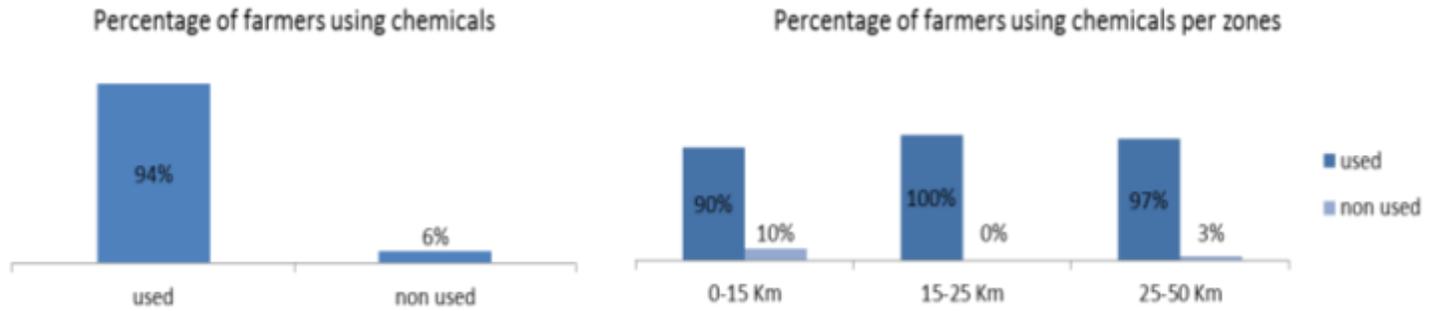


Figure 8. Percentage of vegetable farmers using chemicals in the study area and by zone.

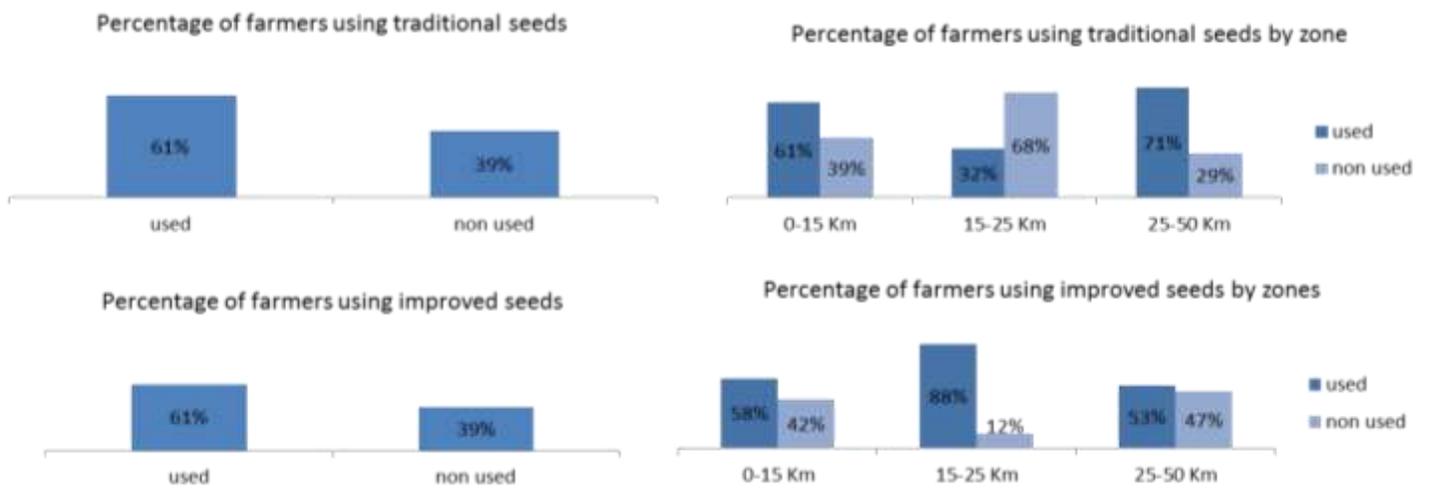


Figure 9. Percentage of vegetable farmers by type of seeds used in the study area and by zone.

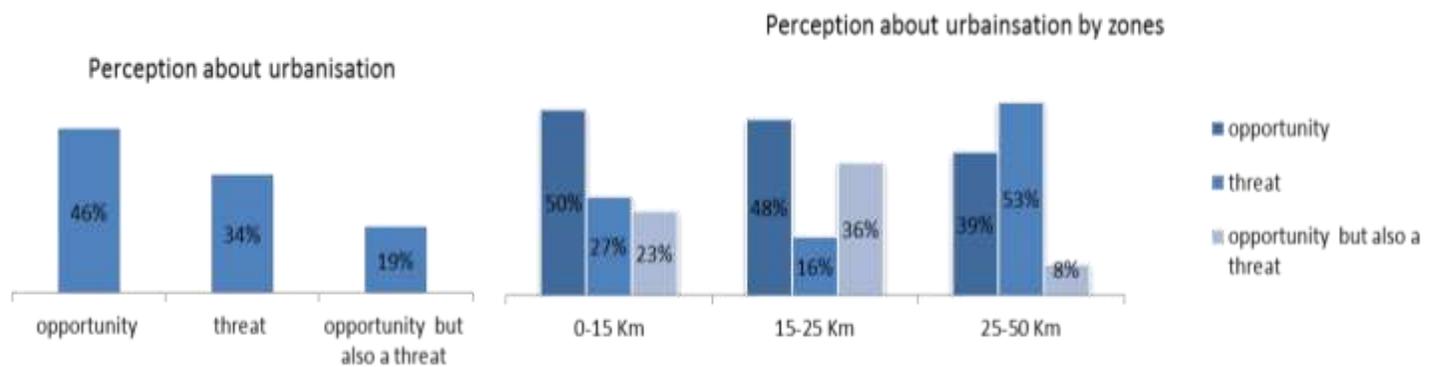


Figure 10. Perception of urbanisation in the study area and by zone.

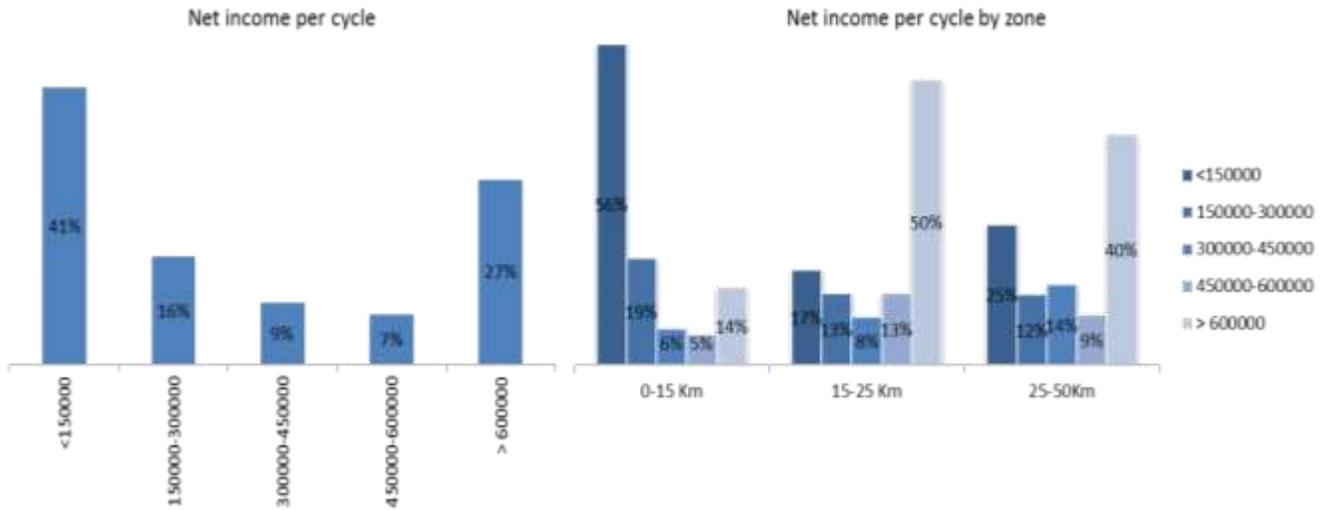


Figure 11. Percentage of vegetable farmers by class of net income per cycle in the study area and by zone.

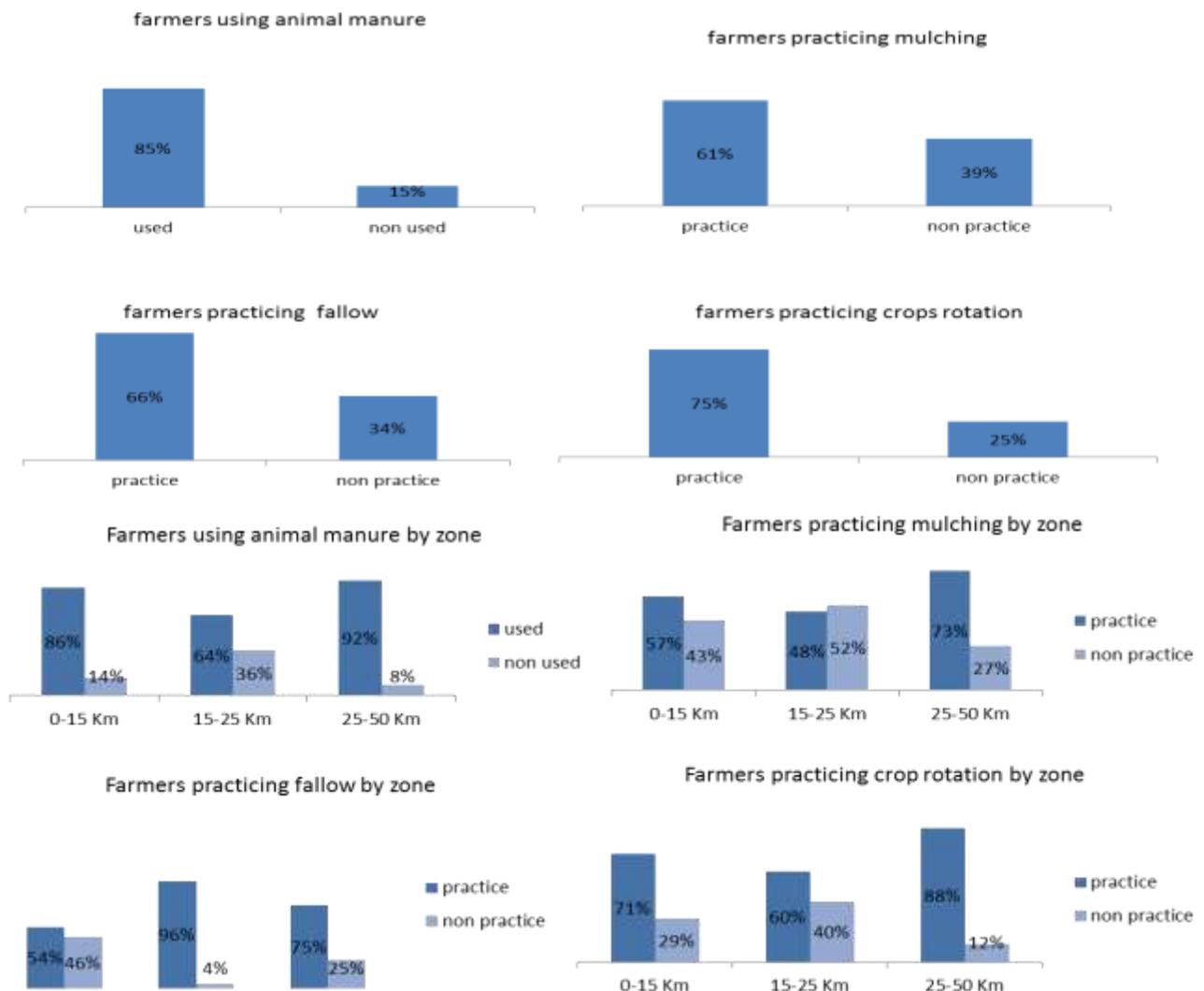


Figure 12. Percentage of vegetable farmers using natural soil management practices in the study area and by zone.

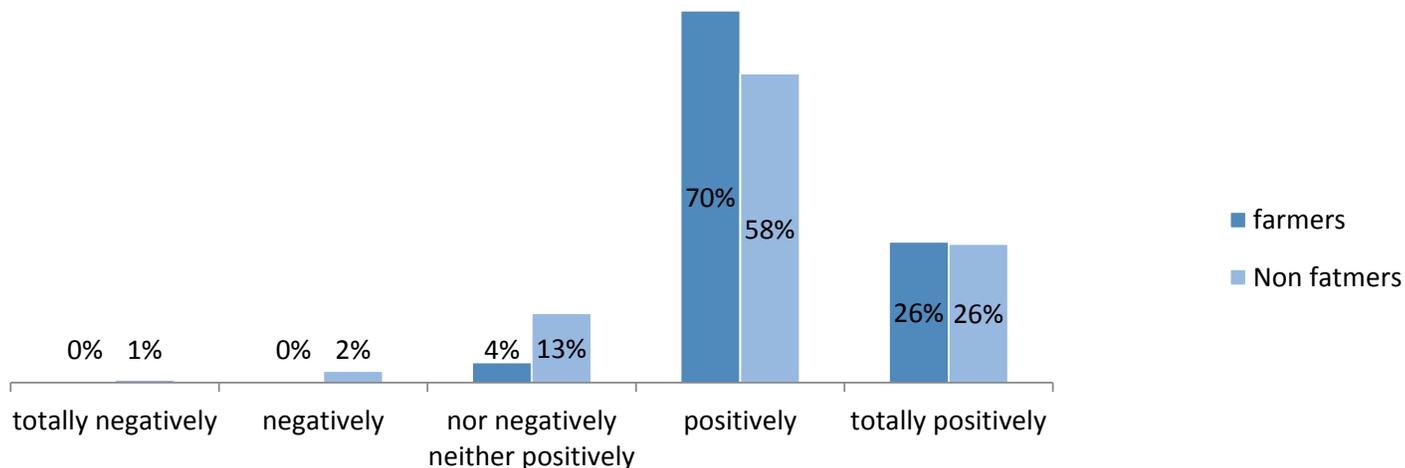


Figure 13. Percentage of views on vegetable production among farmers and non farmers within the YMA.

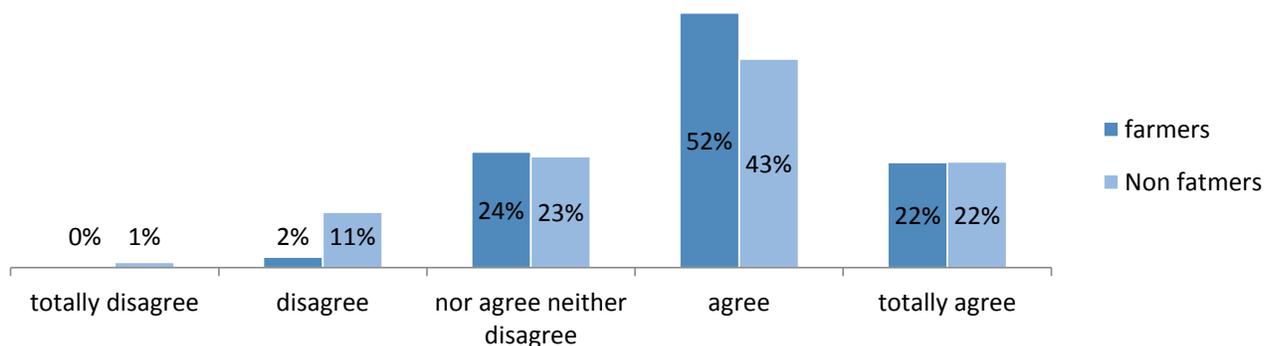


Figure 14. Percentage of views on farmland preservation among farmers and non farmers within the YMA.

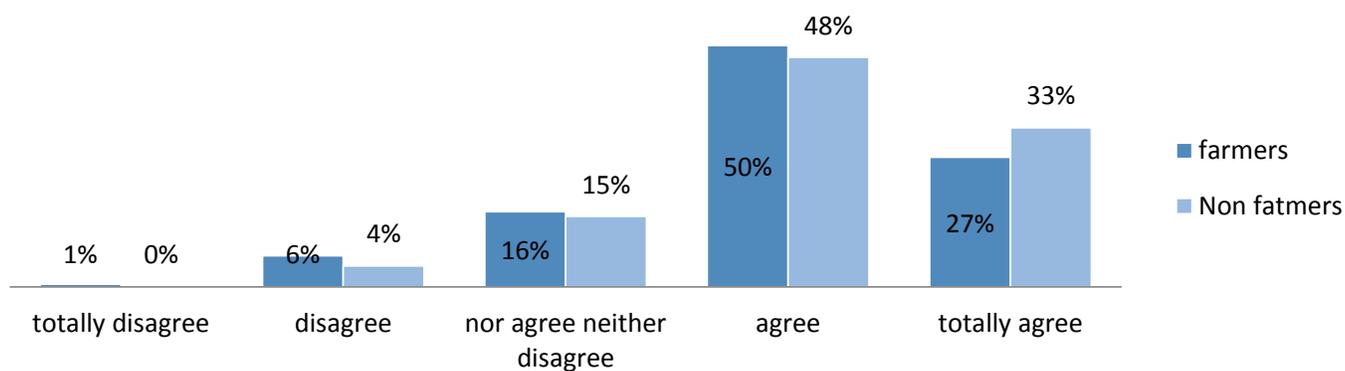


Figure 15. Percentage of views on the increase of regulation on vegetable production among farmers and non farmers within the YMA.

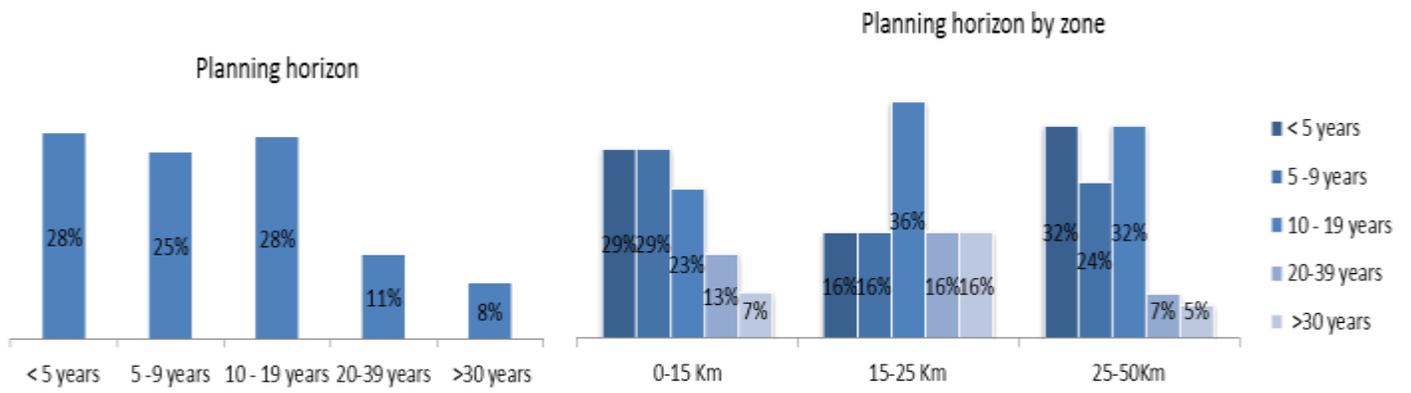


Figure 16. Percentage of vegetable farmers by class of planning horizon in the study area and by zone