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Environmental impacts from overuse of chemical fertilizers and pesticides amongst market gardening in Bamenda, Cameroon

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Abstract

It is predicted that by the year 2050, majority of Africans will living in urban area. In Cameroon, urbanization rate radically evolved from 37.8 % in 1987 to 52.0 % in 2010 and projections for 2030 show that 2 out of 3 Cameroonians will live in urban areas. Such a situation will outstrip job creation and the capacity of Africans governments to control and provide essential infrastructure. It will also an increase of unemployment as well as underemployment, poverty, food insecurity and health risks among those living in and around cities. Urban and peri-urban agriculture appear to be a better response to these challenges, as observed in the case of Bamenda, where local productions around the town (rural urban continuum) remain essential to feeding citizens. However, environmental impacts studies have not been carried out to examine qualitative and quantitative positive impacts of these activities centered on crop production, mainly production of leafy traditional vegetables around the cities.

The actual context of sustainable development requires a better understanding between the vegetable gardening and the environment, which was the main focus of research. An environmental impact assessment based on gardeners' inputs was conducted along the rural-urban continuum of Bamenda in the Northwest Region Cameroon. A survey questionnaire was administered among 150 growers divided equally in rural and peri-urban areas. The survey strongly insisted on the determination of active composition, families and chemical classes using the Phytosanitary Index ACTA, as well as the list of Cameroon registered pesticides. Data on environmental impacts were processed and analyzed through the Leopold and Fecteau matrices. Two variables were used for this: original impacts factorial (crop management) and production systems. The main results show that the majority of gardeners were young (34.67 %) of 30 to 40 years age group. Most of the gardeners in urban areas (88%) grow vegetables in home gardens of smaller size (less than 0.05 ha) while in peri-urban area, 76 % of respondents have farms measuring between 0.1 to 0.25ha located near their homes. In rural areas, the majority of growers (48 %), operating away from their habitat, owned farms larger or equal to 0.25 ha. Among the chemical used in production systems on the continuum were Carbonates and Thiocarbonates (35 %) followed by organophosphate (21 %), unidentified Pyrethroids synthetic components (17 %) and Organochlorines (4 %). The threshold of environmental impacts criticality is established and appears greater or equal to the average value of 16 in the rating scale. The results of this survey confirmed that there was an uncontrolled use of chemical fertilizers on vegetables throughout the rural-urban continuum of Bamenda. The study identified lack of training and gardeners' sensitization as well as the non-compliance to the legal texts relating to the safe use of chemical fertilizers and chemicals, as the aggravating factors and causes of environmental damage around rural-urban Bamenda.

Keywords: *Agricultural fertilizers and chemicals, Bamenda, Environmental impact, Gardening, Rural-urban continuum, Vegetable production*

Résumé

Il est prévu que d'ici 2050, la majorité des Africains vivront en milieu urbain. Au Cameroun, le taux d'urbanisation a radicalement évolué, passant de 37,8% en 1987 à 52,0% en 2010 et les projections pour 2030

montrent que 2 Camerounais sur 3 vivront dans des zones urbaines. Une telle situation sera supérieure à la création d'emplois et à la capacité des gouvernements africains à contrôler et à fournir l'infrastructure essentielle. On assistera également à une augmentation du chômage ainsi que du sous-emploi, l'accentuation de la pauvreté, l'insécurité alimentaire et des risques de santé chez les personnes vivant dans les centres urbains et périurbains. L'agriculture urbaine et périurbaine semble être une meilleure réponse à ces défis, comme on l'observe dans le cas de Bamenda, où les productions locales autour de la ville (continuum urbain-rural) restent indispensables à l'alimentation des citoyens. Cependant, des études d'impacts environnementaux n'ont pas été menées pour examiner les impacts qualitatifs et quantitatifs positifs de ces activités centrées sur la production agricole, principalement la production de légumes traditionnels autour des villes.

Le contexte actuel du développement durable exige une meilleure compréhension des relations entre les cultures maraîchères et de l'environnement, ce qui était l'objectif principal de la recherche. Une évaluation de l'impact environnemental de ces cultures au milieu des producteurs a été réalisée le long du continuum rural-urbain de Bamenda dans la région du Nord-Ouest Cameroun. Un questionnaire a été administré auprès de 150 producteurs répartis également dans les zones rurales et périurbaines. L'enquête a fortement insisté sur la détermination de la masse active, les familles et les classes chimiques en utilisant le phytosanitaires Index ACTA, ainsi que la liste des pesticides homologués au Cameroun. Les données sur les impacts environnementaux ont été traitées et analysées par la matrice de Léopold et la grille de Fecteau. Deux variables ont été utilisées pour cela: impacts originaux factoriels (gestion des cultures) et les systèmes de production. Les principaux résultats montrent que la majorité des producteurs étaient jeunes avec 34,67% situés dans la tranche de 30 à 40 ans. La plupart des agriculteurs dans les zones urbaines (88%) cultivent des légumes dans les jardins familiaux de plus petite taille (moins de 0,05 ha), tandis que dans la zone périurbaine, 76% des répondants ont des parcelles mesurant entre 0,1 à 0.25ha et situées à proximité de leur domicile. Dans les zones rurales, la majorité des producteurs (48%), travaillent loin de leur habitation dans des champs de superficie supérieure ou égale à 0,25 ha. Parmi les produits chimiques utilisés dans les systèmes de production dans ce continuum on relève des carbonates et thiocarbonates (35%), suivis par les pesticides organophosphorés (21%), les pyréthroïdes synthétiques à composants non identifiés (17%) et les organochlorés (4%). Le seuil des impacts environnementaux de criticité établie est supérieur ou égal à la valeur moyenne de 16 dans l'échelle de cotation. Les résultats de cette enquête ont confirmé qu'il y avait une utilisation incontrôlée des engrais chimiques sur les légumes tout au long du continuum rural-urbain de Bamenda. L'étude a identifié le manque de formation et de sensibilisation des maraichers ainsi que la non-conformité aux textes juridiques relatifs à la sécurité dans l'utilisation des engrais et des produits chimiques, comme des facteurs aggravants et les causes de dégradation de l'environnement autour de Bamenda rurale-urbaine.

Mots-clés: *engrais agricoles et des produits chimiques, Bamenda, impact environnemental, maraîchage, continuum rural-urbain, production de légumes.*

1. Introduction

Urban and peri-urban agriculture have significantly changed over the last two decades and are better integrated to the environment as well as urban ecosystems and governance. In order to secure the future of this activity, which help many urban families and contributes to the modernization of African cities, it is better to assess its environmental impacts. Since 1980, such activities were done only in some African cities (Prain and Lee Smith, 2010) like Douala and Yaoundé. But since 1994, economic crisis with structural adjustment plan imposed to African countries, these systems have been extended to medium urban centers of Cameroon (Bafoussam, Bamenda, Maroua and Ngaoundéré).

Achieving high vegetables performance and quality in accordance with consumers demand requires several inputs: seeds, fertilizers, pesticides, growth

regulators and water. Gardening helps to strengthen food security and diversification of income sources among Cameroon farmers (Sougnabe *et al.,* 2010). In fact, the vegetable production is encouraged by an increasing demand for fresh and leafy traditional vegetables from the town people. To meet this demand, market gardeners manage the decline in soil fertility through the use of large quantities of fertilizers and without prior knowledge of the physico-chemical properties of soil exploitation (IRAD, 2003). In this view, to avoid environmental problems Abecassis (2010) stress that fertilization does not result in losses of elements responsible for pollution, particularly nitrate leaching to groundwater. Against the vegetables' enemies, gardeners make abusive use of pesticides (Kanda et al., 2006). More, these chemical fertilizers presented many advantages for agricultural purposes, public health, fighting against vectors of various parasitic diseases (Wade, 2003). Nevertheless, insect resistance to pesticides is increasingly complained about by market gardeners. Many laboratory studies have confirmed this statement by the treatment failures in the field (Brévault *et al.,* 2008). According to Sougnabe *et al.* (2010) the ineffectiveness of treatment affects the use of new active ingredients, and the overuse of chemicals. However, vegetable growers still face two major sources of environmental impact. The factorial impact (crop management including: the use of pesticides, nitrogen fertilizers, water and growth regulators) and the systemic impacts (production systems for vegetable crops practiced by farmers).

The rural-urban continuum of Bamenda (figure1), chosen for the study, is one of the main areas of production and supply of fresh vegetables in Cameroon, in which vegetable farming could experience environmental problems related to the technical route and / or the production system. This paper, based on the survey conducted in Bamenda among gardeners, characterizes the gardening and chemical fertilizers potential sources of impact, assesses the level of perceived risk associated with its use, identifies the environmental aspects of gardening and proposes mitigation measures and improvement ways.

2. Material and Methods

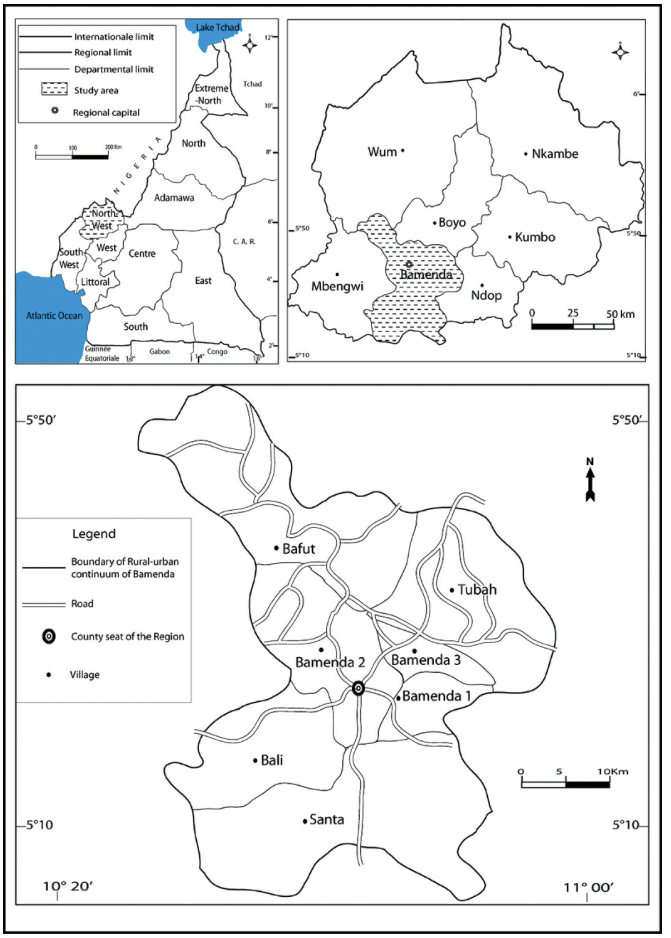
2.1. Characteristics of Bamenda' urbanization

The administration of urban space in Cameroon is complex and based on the French model as it is the case in many francophone sub-Saharan African countries. Due to the recent decentralization process drive by the Law N° 2004/019 of 22 July 2004; which application has begun in 2008, Bamenda is administratively defined as an Urban Community of three sub-divisions (Bamenda I, Bamenda II and Bamenda III as shown in figure1). Each sub-division has a separate municipal council. The reason why we have chosen to work in the Bamenda rural urban continuum (taking into account rural, peri-urban and urban areas) is that in Cameroon, each big city grows by assimilating its periphery.

Bamenda town was established in 1899. It is located in the Grassfield or Grassland ecological region. Its population evolved since the town emerged as the largest urban area in the Western Highlands of Cameroon and the town's population increased more than four-fold within 1976 and 1987 censuses (Acho-Chi, 1998). Bamenda and its region (North West) is one of the most densely populated areas of Cameroon. Bamenda itself is the fourth biggest city in the country (BUCREP, 2010).

According to Barbier (1983), the population density of the whole Grassfield Region (figure 2) was between 5-20 inhabitants/square meter. The urbanization rate in Cameroon increased from 37.8 % in 1987 to 52.0% in 2010. The urbanization rate of Bamenda is 42 %, and population grew from 48 111 inhabitants in 1976 to 488 883 inhabitants in 2010 (BUCREP, 2010), with 150-200 inhts/km² (more than 10 % yearly and a mean of 14700 inhabitants/years). Meanwhile, the city administrative grew from 488.25 to 2444 km² between 1950 to 2010.

Such a situation raised many problems such as administrative and spatial integration of the city, the contribution of urban agriculture (UA) and peri-urban agriculture (PUA) to population incomes, food security, health risks, conflicts and integration to other activities such as poultry or pastoral activities.



The rural-urban continuum of Bamenda is located in the agro ecological zone of Cameroon western highlands which benefits from a tropical mountainous climate characterized by two fairly regular seasons: humid and rainy seasons (7months) and a dry season (5 months). Bamenda and its regions receive average rainfall between 1700 and 3500mm/year in an unimodal rainfall pattern with mean temperatures ranging from 17 to 24°C annually (Acho-Chi, 1998; Nzembayie, 2007 and Tchindjang, 2012).

Concerning crop productions, Bamenda and its surrounding appear to be a great zone of high yielding crops and other industrial products. One can identify tomato, pepper, Irish potatoes, maize, rice, mangoes, guava, sweet potato, banana, cassava etc. (MINADER, AGRI-STAT N° 7,-1999; N°8-2000; N°12-2006; N°15-2009 & N°16- 2010). Bamenda region produce coffee and tea at Ndu. Tido (2006) has identified eight major vegetables including: leek (*Allium porrum L.*), tomato (*Lycopersicon esculentum Mill.*), Lettuce (*Lactuca sativa L.*), amaranth (*Amaranthus cruentus L.*), black nightshade (*Solanum scabrum.*) Carrot (*Daucus carota L.*), pepper (*Capsicum chinensis L.*), cabbage (*Brassica oleracea L.*) and traditional vegetables. This makes the rural-urban continuum of Bamenda a large vegetable production area.

So, the rural-urban continuum of Bamenda (Figure 1), chosen for the study, is one of the main areas of production and supply of fresh vegetables in Cameroon, in which vegetable farming could experience environmental problems related to the technical route and/or the production system. A survey was carried out in Bamenda among gardeners during August and September 2010. The results characterize the gardening and chemical fertilizers potential sources of impact, assess the level of perceived risk associated with its use, identify the environmental aspects of gardening and propose mitigation measures as well as improvement ways.

2.2. Survey method

Before going on field for the survey, we establish an interaction matrix between the operations of the technical elements and those of the natural environment within the rural-urban continuum in order to identify environmental impact. Secondly we downloaded a satellite map of Bamenda from internet (Google Earth) in order to set up the continuum limits before the field survey (Figure 2). Prior to the survey, a comprehensive list of districts and agriculture productions sites (stratum 1) was set up. In this list, we drew a sample of secondary unit constituted only of vegetable producers (stratum 2). Then 150 vegetable producers were sampled composed of 50 producers in each continuum area (rural, urban and peri-urban). Sampling was carried out using a rational choice based on inclusion criterion

(to be vegetable producer) and exclusion criterion (at least 15 years old) following Bosio *et al*. (1999) method. The survey was conducted from August to September 2010 by interviews using a questionnaire that aimed at characterizing the chemical inputs of gardening and its potential sources of impact, also assessing the level of risk perception associated with the use of inputs, identifies environmental aspects of gardening practices.

2.3. Data analysis

Information from individual interviews was computed in EXCEL software and later on, transferred to SPSS (Statistical Package for Social Sciences, 12th edition) for analysis. Parameters were defined following the questions sequences in the questionnaire. Frequencies of similar answers were grouped and compared between areas along the continuum by cross-tabulation. Table and graphics could therefore be drawn using Excel. Active ingredients, families and chemical classes were determined using Phytosanitary Index ACTA (Couteux and Lejeune, 2004) and the list of pesticides registered in February 16, 2010, in Cameroon (MINADER, 2010). Environmental data were processed, analyzed and characterized by Leopold (Leopold et al.1971) and Fecteau matrices adapted from Sadar (1995). The final impact assessment took place in stage three. Step one was made using a rating scale (quotation matrix) based on three variables: the sensitivity of the environment, the severity and the frequency for the impacts related to factorial technical crop management aspect (such as the use of pesticides, nitrogen fertilization, irrigation, use of growth regulators, improved seeds or improved protective equipment). Secondly, the identification of environmental impact assessment of systemic origin related to vegetable production systems practiced by farmers along the Bamenda rural-urban continuum was made. Third step consist of crossing the two original variables (Technical factor X Systemic factor) in order to obtain the significance of the final impact. The threshold of critical impact is established by equal to the dimension value greater than or equal to the average of the grid which is 16. Any impact beyond this threshold was considered as significant. Nevertheless, when an accident, a use of an indeterminate class of pesticides or pesticides not approved by the Cameroon State or Persistent Organics Pollutants pesticides, poisoning, an illness or a death were reported by respondents, the environmental impact was automatically assessed as significant, regardless of the total score obtained from this vegetable.

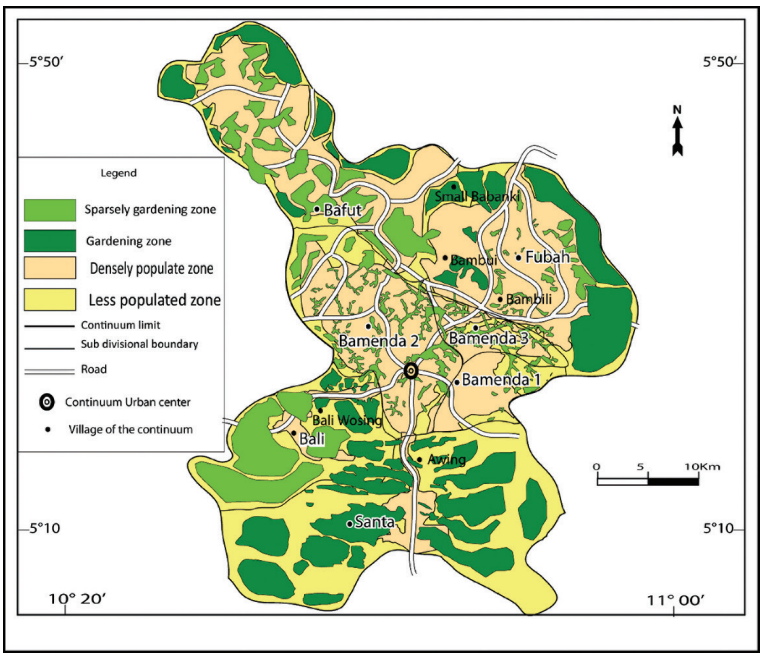


Figure 2: Bamenda rural urban continuum superimposed in Google satellite map (Source, Kamga, 2010)

3. Results

3.1. Demographic characteristics

There was almost equal representation of men (51 %) and women (49 %) as gardeners round Bamenda (Table 1), in comparison to the urban population ration of 51.4 % women.

The average size of the gardeners' family is 5.9 ± 0.5 persons, whatever the area of the continuum. Households in urban areas are equipped with appliances and audiovisual. Over 80 % of growers have communication equipment such as radio, TV and telephone.

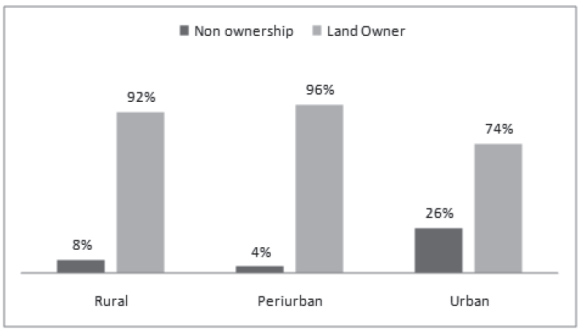


Figure 3a: Distribution of land owners

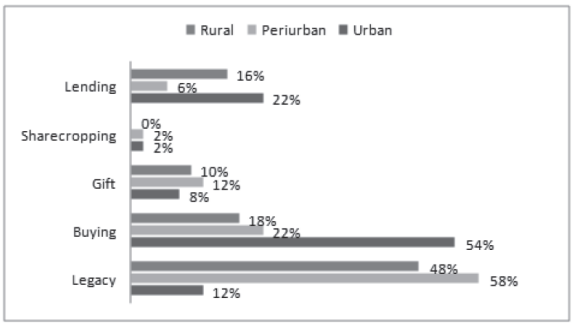


Figure 3b: Gardeners and land tenure

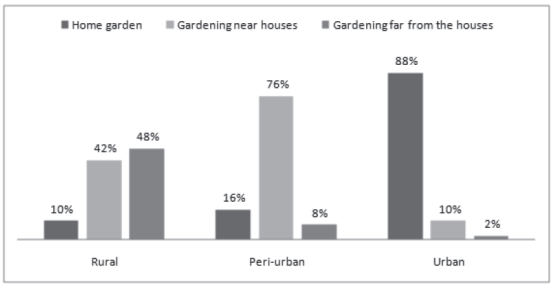


Figure 3c: Gardeners' production system

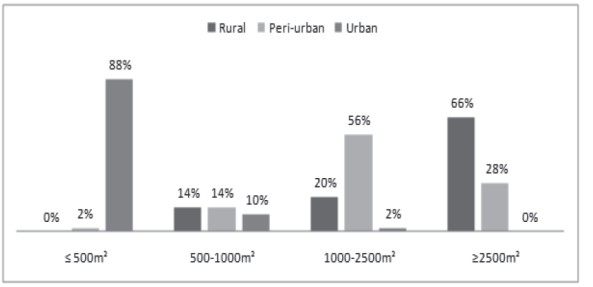


Figure 3d: Gardeners farm size

3.2. Characterization of gardening practices

3.2.1. Typology of vegetables production systems

The majority of gardeners (88 %) in urban areas grow vegetables in home gardens smaller than 0.05 ha (fig.3a-d). While in peri-urban area 76 % of respondents possess farms area between 0.1 to 0.25 ha located near their homes. In rural areas, the majority of dwellers (48%) operated away from their homes with gardens larger or equal to 0.25 ha. Peri-urban and rural parcel sizes are larger because the land belongs mainly to families depending on the mode of inheritance for more than 48 % of growers, while in urban areas access to land is attributed more to purchase (54 % of respondents).

It is worth mentioning that in the case of Yaoundé, home gardens appear to be like something linked to traditional legacy related to the history of this Region. But due to the urbanization process, these farms are smaller (142-400sqm) than what we observed within the Bamenda continuum, one can observe that traditional behavior bring peasants to do everything on farms, far from the house in the rural zone. In the peri-urban zone, most of the pieces of land are owned by legacy (58 %, figure 3b). Such a situation forced gardeners to produce vegetable near their houses (fig-

Table 1: Demographic of respondent gardeners

Variables	Characteristics	Proportions (%)
Gender	Men	51.3
	Women	48.7
Age class	<20	2.0
	21-30	20.0
	31-40	34.7
	41-50	26.0
	51-60	14.3
	>60	3.0
Level of education	None	3.0
	Primary school	48.7
	Secondary school	37.3
	Higher education	11.0

ure 3c, figure 3d), because they could have a total control of the activities.

3.3. Vegetable products

3.3.1. Exotic vegetables

The tomato (*Lycopersicon esculentum Mill*.) is the most exotic vegetable produced in peri-urban areas by 80% of respondents against 46% and 26% of producers respectively in rural and urban areas. Cabbage *(Brassica oleracea L.)* is produced in rural areas by 70% of respondents against 22% of peri-urban gardeners and urban. Pepper *(Capsicum chinensis L.)* is produced by over 5% dwellers, regardless of the zone along the continuum.

3.3.2. Traditional vegetables

Most of traditional or leafy vegetables grown black nightshade *(Solanum scabrum Mill.)* by 96% of respondents in urban areas, 68% in peri-urban and 66% in rural areas, Amaranth *(Amaranthus cruentus L.)* of water leaf *(Talinum triangulare* (Jacq.) Willd.*)* and okra *(Abelmoschus esculentus (L.) Moench)* are produced by over 54% of urban gardeners.

3.4. Inventory of the fertilizers in the technical crop management

3.4.1. Chemical fertilizers in vegetable production

Four types of commonly used fertilizers in horticulture along the Bamenda rural-urban continuum were identified. Firstly, the mineral fertilizer (NKP) is used by over 96 % of growers in rural and peri-urban areas against 34 % in urban areas. Two modes of application were observed including the manual spreading and spraying with a sprayer or a watering can.

3.4.2. Herbicides

In areas of high production, gardeners (82 %) in peri-urban and 56 % in rural areas, combine manual and chemical control of weeds. Manual control is also practiced, 94 % in urban gardens (because of the small size of land) and 44 % in rural areas due to lack of funds. The herbicides recorded are presented in Table 2.

Glyphosate and Paraquat are present throughout the Bamenda rural-urban continuum, with levels exceeding 44% in rural and sub-urban areas. These herbicides are grouped into four major chemical groups and the active matter varies from rural (3%), peri-urban (4%) to urban areas (2 %).

3.5. Phytosanitary practices among gardeners

Field survey results show that 62 % (peri-urban) and 52% (urban) of gardeners' crop production are affected by disease in their cultivation system in the rainy season. All over the rural-urban continuum, over 30 % of gardeners recognized that their culture system suffers from high pressure of phytophagous insects in the dry season. Caterpillars affected vegetables farms according to over 60% of respondents. Over 70% of growers noted the presence of ants in their plots. Moreover, in rural areas over 50% of producers noted a predominance of aphids, grasshoppers, moths and nematodes. In peri-urban areas over 52% of respondents reported the presence of white flies and moths in their farms.

3.5.1. Typology of the phytosanitary product

Over 95 % of gardeners in rural and peri-urban areas against only 16 % in urban areas, use pesticides to protect their crop. A total of 24 classes of pesticides have been identified along the continuum with 14 distinct active ingredients (Table 3).

Among the range of pesticides identified along the rural-urban continuum of Bamenda, 40 % are represented by emulsifiable concentrate more easily absorbed by the skin from aqueous solutions of soluble granules (8 %). Wettable powders (36 %) more easily absorbed through the skin came second position. Granules (12 %) as well as 4 % concentrate spray able ranks third. Adjuvant may be added to a spray solution. Some adjuvant can increase the amount of phytosanitary product use that can be spread, glue or absorbed by the skin.

These types of pesticides used by vegetable producers are distributed into four chemical families. The Carbamates and Thiocarbamate families are dominant (34.48 %), followed by Organophosphate (20.69 %), Synthetic Pyrethroids (17.24 %) and lastly Organochlorines, Neonicotinoids & Triazole (3.45 %). The undetermined categories (due to mixtures whose compositions are often ignored by gardeners) represent 17.24 % of the pesticides found along the Bamenda rural-urban continuum.

3.5.2. Sources of pesticides

Ninety-six percent (96 %) of rural and peri-urban gardeners buy their pesticides in the local market, against 14 % in urban areas. Indeed, the rural and peri-urban areas make high input use of pesticide because of the size of the farm. In urban area (84% of home gardens) with small size farms, gardeners are engaged in the activity with low intake of pesticides.

Table 2 : Active ingredients of herbicides used to protect vegetables

Chemical families	*Active ingredients*	*Continuum*		
		Rural (%)	*Peri urban (%)*	*Urban (%)*
Benzamides & Oryzalin	*Glyphosate WG*	*42*	*88*	*4*
non selective Pyridines	*Paraquat EC*	*44*	*50*	*6*
Halogenophenylures	*Diuron DF*	*5*	*10*	*0*
Substituted urea	*Limuron WP*	*0*	*8*	*0*

Table 3: Active ingredients of phytosanitary products used in the vegetable treatment

Chemical families	**Nature**	**Active elements (AE) and concentrations**	**Formulations**	**Number of actives elements**
Organophosphate	Insecticide	Pyrimiphos-methyl 20, 500g/l	emulsifiable	1
	Insecticide	Dimethoate 200g/l, 400g/l	concentrated	1
	Insecticide	Cypermethrine 20g/l + Diméthoate 200-240g/l	emulsifiable Concentrated	1
	Insecticides-Nematicide	Ethoprophos 15%	Granular	1
	Insecticide	Chlorpyrifos 480g/l	emulsifiable Concentrated	1
Carbamate and Thiocarbonate	Fungicide	Mancazebe 750-800g/l, 80%	Wettable Powder	1
	Fungicide	Manebe 80 %	Wettable Powder	1
	Fungicide	Metalaxyl 8 %+ mancozebe 64 %	Wettable Powder	1
	Insecticide-Nematicide	Carbofuran 100-350g/kg	Granular	1
Synthetic Pyrethroids	Insecticide	Deltamethrine 12,5g/l, 25g/l, 60g/l, 25g/Kg	emulsifiable Concentrated	1
	Insecticide	Cypermethrine 100, 200, 50, 12g/l	emulsifiable Concentrated	1
Organochlorines Neonicotinoids Triazoles	Fungicide	Chlorothalonil550g/l + carbendazine 100g/l	emulsifiable Concentrated	1
Organochlorines Neonicotinoids Triazoles	Insecticide	Imidaclopride 20g/l+ Lamdacyhalothrine 20g/l	emulsifiable Concentrated	1
Organochlorines Neonicotinoids Triazoles	Fungicide	Mefonoxam (Metalaxyl-M) 6 %+Cuivre metal 60 %	Wettable Powder	1
Total (AE)				14

3.5.3. Method of pesticides uses

About 96% of growers in rural and peri-urban use hand equipment against 8% of the producers of the urban area. Possession of sprayers decreases in the rural area to urban area. Four percent (4%) of urban gardeners use buckets to clean the treated crop in their garden. Two percent (2 %) of respondents in urban and peri-urban use it as a tool for watering.

3.5.4. Treatment period

The treatment period varies from one gardener to another and also from one area of the continuum to another. Indeed, this study showed that over 40% of growers in rural and peri- urban administer a cure in case of attack against 12 % in urban areas. For preventive treatment, we noted that 34 % (peri-urban) and 8% (rural) of growers treat their crops every 15 days as against 2% in urban areas. Over 20% of growers in rural and peri-urban also use preventive sprays every week, against 2 % in urban areas, without taking into account the persistence of the products used.

3.5.5. Source of information on chemical fertilizers used

Consultation and exchange of opinion with other groups of gardeners is the main source of information for 40 % and 34 % of respondents respectively in peri-urban and rural areas. In these same areas of the continuum 70 % and 42 % of gardeners get information on pesticides from retailers of agricultural fertilizers not always well trained on issues of the management and the use of chemical fertilizers.

3.6. Level of risk perception linked to the use of chemical inputs

3.6.1. Management of chemical fertilizers by gardeners

All gardeners met along the continuum, store their chemical fertilizers in their dwelling house which also serve for the storage of pesticides for more than 22 % of dwellers in rural areas and 12 % in urban areas. Similarly, 40 % and 30 % of respondents in rural and peri-urban store their pesticides under cover in the field, while 36 % and 42 % of gardeners have a community warehouse in rural and peri - urban areas respectively.

3.6.2. Gardeners' protection measures during pesticide application in vegetable

Protection measures during the plant treatment are often taken lightly by market gardeners. Indeed, 36 % of growers in rural areas have no means of protection against 8% in urban areas. In rural and peri-urban zones, 12 % and 20 % of producers have the scarf as protection tool against 4% in urban areas.

Table 4: Distribution of growers according to the symptoms listed

Symptoms	Continuum		
	Rural %	Peri-urban %	Urban %
Mucocutaneous system			
Skin heat	12	14	2
Eyes redness	2	8	0
Eyes itchy	12	28	0
Burning of the skin	12	14	0
Nails itchy	8	4	0
Fingers tingling	6	4	2
Respiratory system			
Nasal congestion	4	4	0
Cold	48	32	2
Chest heat	12	6	0
Cough	18	8	2
Alimentary canal			
Nausea	8	12	2
Vomiting	12	36	0
Salivation	0	2	0
Central nervous system			
Headache	8	8	0
Vertigo	18	60	2

Table 5: Preventive measures identified after use of products

Prophylaxis measures	Continuum		
Drink milk	90	84	84
Drink a charcoal solution	2	4	0
Remove clothes	4	20	6
Wash the back with water	0	6	0
Wash hands with water	6	0	0
Wash hands with soap and water	70	58	16
Eat with a spoon	4	2	0
Eating groundnuts	0	2	0
Take a bath	16	62	10
Drink palm oil	0	8	0
Consuming honey	0	6	0
Take a beer	0	2	0

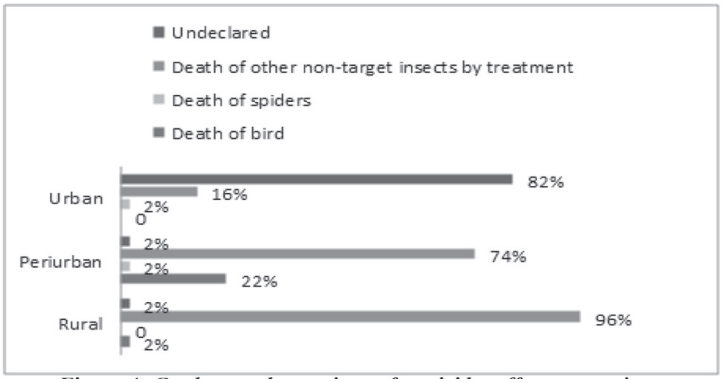


Figure 4: Gardeners observations of pesticides effects on environments

3.6.3. Health measures after vegetable treatment

On hygiene measures after vegetable treatment, there are four categories of gardeners. The first one concerns market gardeners who systematically always wash their clothes after plant treatment, we recorded more than 40 % in rural and peri-urban zones against 4% in urban areas. Those who often wash their clothes are 16 % and 24 % in rural and peri-urban respectively against 8 % in urban areas. Also, over 20 % of growers in rural and peri-urban rarely cleaned their clothes against 4 % in urban areas. The last category concerns producers who never wash their clothes (8 % in the peri - urban and 12 % in rural areas).

3.6.4. Perception of risks linked to the pesticide use

Almost all gardeners believe that chemical inputs are dangerous for health. Peri-urban vegetable producers (92%) and rural (88%) have experienced problems and disease related to the use of pesticides against 3% in urban areas. These situations drive us to assess environmental impacts of gardening along the continuum.

3.7. Environmental impacts and mitigation measures

Before assessing environmental impacts, one have to check the juridical and institutional context of pesticides management in Cameroon in order to better understand the problems related to those substances.

3.7.1. Human environmental impact

Within this paragraph and according to the field survey, we try to assess the symptoms (Table 4) that are mostly felt by gardeners. A great number of respondents complain about colds (48 % in rural and 36 % in suburban areas). Similarly 36 % in peri-urban areas have suffered from vomiting and 60 % from dizziness related to the applications of pesticides on their vegetables.

Table 6 : Synthesis of all the negative and positive impacts of gardening on the environment.

Type of impact	Sources of the impact	Mitigation or enhancement measures
Water Contamination Quotations score : -27	- Use of fertilizers - Use of pesticides (persistence) - cleaning of phytosanitary equipment in the river	- Install or build water tanks for phytosanitary equipment cleaning - Effective presence of phytosanitary agents on field - Reduce the treatment in the rainy season - Encourage the use of compost and organic fertilizers
Soil Pollution quotation score : -27	- Burial of pesticides' cans - Misuse of pesticides (persistence) - Non compliance of fertilization and dosage	- ensure compliance with dosage and frequencies of treatment - Effective presence of phytosanitary agents on field - Reduce the treatment in the rainy season (training) - Mapping the soil able to gardening
Air Pollution quotation score : -16	- Spraying of pesticides - Application of fertilizers and some pesticides - Fumigation	- Reduce the salaries during the period of strong winds (Training)
Poisoning of vegetable gardeners and consumers. quotation score : -54	- Improper handling of pesticides - Consumption of vegetables (residues of pesticides & chemical fertilizers) and water contaminated by pesticides (persistence) - Recycling of pesticides containers for domestic use	- capacity building and training of gardeners to best agricultural practices - control and analysis of the content of pesticide residues in vegetables - control and analysis of the water of the nearby rivers and springs
Impact on aquatic milieu quotation score : -27	- Contamination of rivers by pesticides and chemical fertilizers (persistence)	- Adopting erosion control practices in order to limit soil erosion
Diseases linked to the use of pesticides quotation score : -27	- Improper handling of pesticides - Lack and ignorance of protective measures - the non use of tools of protection against pesticides	- Impose the wearing of protective equipment for handling and pesticides applications - conceive intoxication and pesticides poisoning sensitation and public displays in health centers
Destruction of avi-fauna quotation score : -54	- pesticides residues on the top soil	- Reduce the use of solid pesticides and promote the use of scarecrows to keep birds
Self employment Promotion and poverty alleviation reducing unemployment quotation score : +81	- Creation of production plots of vegetables for sale	- Supporting gardeners in terms of production techniques - Provide financial support (micro credit) to vegetables growers
Food security Impact quotation score : +36	- Production of fruits & vegetables in quantity and quality along the rural-urban continuum	- Encourage gardeners also in the production of traditional vegetables (diversification of production and promotion of local biodiversity)
Income's impact quotation score : +81	- Vegetables' sale	- Improve the vegetables production methods or intensive production - Producing against season vegetables

3.7.2. Prophylaxis measures after pesticides uses

Over 84% of growers along the continuum consume milk to avoid possible poisoning related to pesticide use (Table 5). In rural and peri-urban, there are 70 % and 58 % of gardeners who wash their hands with soap and water after pesticide use. As other preventive methods recorded in peri - urban area, 8 % of gardeners drink red oil (from palm oil, because it is consider as to be efficient for poison or toxic elements), 6 % take honey and 2 % drink beer.

After feeling the first poisoning symptoms, many gardeners (60 %, 46 % and 8 % in rural, peri-urban and urban) consumed unsweetened milk. Other tricks used by respondents to overcome or circumvent the symptoms, are the consumption of red oil, honey or powdered charcoal.

3.7.3. Environmental aspect on birdlife and insect fauna

Negative impacts of chemical inputs have been identified by 96 % of gardeners in rural, 74 % in peri-urban and 16 % in urban areas along the Bamenda rural-urban continuum. They reported having seen the death of other non-target insects by treatment. 22 % and 2 % of respondents' respectively peri-urban and rural zones meet often see dead birds in their plot (figure 4), especially when the product is used in granulated form. Respondents indicate that the micro diversity of wildlife (insects, birds) useful is the direct and immediate victim of the misuse of chemical fertilizers in their environment. Organic pesticides are toxic pollutants (Organochlorines) that have properties of bio-accumulation whose effects are visible only in the long term.

3.7.4. Environmental management of empty chemical containers

Empty containers of chemical inputs have several disposals: abandoned in the fields, sent to the landfill, buried in the soil, sold to retailers, recycled for personal use. 58 % and 34 % of respondents in peri-urban and rural zones burn empty chemical containers. The burial is practiced by 46 % of respondents in rural areas against 18% in peri-urban areas. In rural area, 16 % of gardeners recycle empty chemical containers for drinking water or to keep the palm oil. 14 % of producers in peri-urban abandoned empty chemical containers on the field, contributed to environmental physical pollution.

3.7.5. Analysis of the potential environmental impacts

From data collected during field observations, we developed an interaction matrix of the gardening activities and environmental elements of the study area. Such a matrix is useful to understand the impact of any gardening operation on the biophysical environment. Specifically through the organic inputs such as seeds of different vegetables introduced, chemical fertilizers, water use and growth regulators. For these factorial impacts, the critical threshold is reached for values greater or equal to 8 on the rating scale. The advantage of interaction matrix is to help in identifying negative and positive impacts with more accuracy.

Impacts on soils: the use of chemical fertilizers contaminated soils as well as water. Whatever the prevailing production systems are, fertilizers inputs are intended to complete the soil minerals necessary to the plant growth needs. But irrational fertilization practiced by gardeners generates losses of chemicals substances responsible for pollution, particularly the nitrate leaching to groundwater. Any use of mineral fertilizers also plays heavily on fossil fuel consumption and greenhouse effects ($C0_2$) even in case of denitrification (N_20).

Impacts on biodiversity: the growing demand for fresh and leafy vegetables led to the clearing of large areas for gardening. The introduction of new vegetable varieties leads to genetic crosses between some specific intra-traditional vegetables that are now endangered. These genetic crosses will lead to new but less efficient vegetables species. Pesticide use in gardening raises the question of biodiversity conservation, creating an imbalance between insect pests and beneficial organisms.

Impacts on water: gardening is an activity that requires a permanent water source, so many rivers banks of the continuum are permanently solicited, and so, the groundwater and nearby rivers are contaminated by pesticides used in vegetable production. Leaching of fertilizers and pesticides enriched river water in minerals, heavy metals and various chemicals, leading to excessive growth of

phytoplankton and the flowering of certain aquatic weeds causing early eutrophication of waterways.

Impacts on air: residues burning during soil preparation, application of pesticides, foliar fertilizers and burning of empty pesticides package contaminate or pollute the air and strengthens the content of greenhouse gas (GHG) emissions in the ambient atmosphere. On the micro soil, aquatic and avian fauna, gardeners have found the death of several animals.

Impacts on human milieu: agricultural landscape has also changed because of the vegetables production systems implemented. Tree stands and ligneous flora are altered due to the clearing of land and the replacement of some species (raffia and eucalyptus) in favor of vegetable crops.

Critical toxic problems vis-à-vis the human life has been identified. Gardeners' health is threatened. In fact the study found more symptoms of diseases related to the handling of pesticides. The misuse or inappropriate use of pesticides also threatens the health of consumers and vegetables can be contaminated by those pesticides.

Positive impacts

Despite these negative impacts, gardening along the Bamenda rural-urban continuum has many positive effects (Table 6) if one takes in account poverty and low standard of living observed in the continuum. Some of these impacts are summarized below.

Employment and incomes: gardening is an opportunity for self-employment easy and enables peasants to avoid idleness of youth. Marketing of vegetables is a source of additional income and security features. Fresh vegetable products can meet the needs of the living populations in terms of income and sometimes quality.

Yields and food security: the use of chemical and biological fertilizers contributes to higher yields and enhances food security along the Bamenda rural-urban continuum.

Crop livestock integration: gardeners use poultry manure to fertilize their farms. It is the same thing with the use of cattle dung.

Table 6 is the synthesis of all the negative and positive impacts of gardening on the environment shows major negative impacts. Whatever the impact identified mitigation measures are suggested for the negative impacts and enhancement measures for positive impacts. We tried to put the score obtained by each impact from the quotation matrix.

4. Discussion

The use of chemical inputs has shown its advantages including increasing yields production by eliminating or reducing pests of vegetable crops. According to Marquis (2005) a positive impact of gardening on Nkolondom near Yaoundé isthat it is more profitable than other crops to the farmer because of cash income and health improvement linked to vegetable consumption. However, misuse of chemical inputs aggravates the negative impacts of this activity on the environment (FAO, 1998). WHO (World Health Organization) estimates to more than one million the annually victims of poisoning among which twenty thousand have died (Levine, 1986). We observed along the Bamenda rural-urban continuum some unskilled phytosanitary practices similar to those observed in Togo (Kanda *et al*., 2006) and Botswana (Obopile *et al*., 2008) that can cause serious negative effects to man and the environment.

The intensive use of chemical fertilizers in peri-urban and rural areas corroborates the observations of (Gockowski *et al*., 2001) for which vegetable production systems in urban areas of Yaoundé are intensive in terms of agricultural inputs. The same observations have been made by Nguegang (2003, 2008). In the continuum urban areas dominated by small gardens, the use of chemical inputs is low which corresponds well with the observation of Drescher (1998) in Zambian urban home gardens, butis in contrary to what Mvogo (2004), has observed at Nkolondom. He stressed on the fact that the cultivation of small areas has led gardeners to excessively use fertilizers and pesticides. But the main explanation could be found in the fact that Bamenda continuum still dominated by rural behavior, lack of information on pesticides and the biggest size of rural and peri urban gardens. About the chemical inputs used in gardening, upstream in the technical route, we identified four chemical fertilizers and herbicides made up of eight four active ingredients.

Table 7: Best agricultural practices identified along the continuum.

Best agricultural techniques practices	Continuum		
	Rural %	Periurban %	Urban %
Low cost fertilization	80	82	50
Rotative gardening	5	10	34
Benefiting from traditional vegetables	10	12	18
Promotion of integrated fighting methods	5	10	16
Vegetable markets with low fertilizers use	52	4	22
Promotion of organic fertilizers	80	82	64
Prevention of insect resistance to pesticides	22	22	34
Fighting against soil erosion	96	16	22
Control of seed stocks and it origin	10	40	30
Initiating to vegetable certification	7	12	6
Agroforestery and gardening	80	4	4
Improved fallow land practices	82	10	14

Source: Kamga, 2011

With regard to pesticides, 24 categories were identified with 14 different active ingredients dominated by Carbamates and Thiocarbamates. In Niayes (Senegal), Cisse *et al*., (2003), recorded in the peri-urban area a dominance of organophosphates. For the unclassified formulations, this study identified 17.24 % that is lower than the 26 % found by Cissé *et al*., (2003) in the Niayes area. The use of pesticide also requires equipments of protection to ensure the users safety. Whatever the area of rural-urban continuum, the lack of body protective equipment increases the risk of toxicity. Also, the lack of physical protection exposes farmers to various diseases that may be caused by the use of pesticides. Pathologies identified (neurological, respiratory, and digestive) remain the same along the continuum and are identical to those found by Wade (2003) in Senegal.

Increasing the efficiency of inputs is a powerful lever to increase the sustainability of vegetable production systems. However, the juxtaposition of many techniques used by gardeners has significant adverse impacts on the environment. The reduced use of pesticides and nitrogen fertilizers are mitigation measures that must be accompanied by resources (breeding lines, increasing varieties, biotechnology) that may contain genes of interest to meet the current problems in the production of vegetables (Balfourier *et al*., 2007). Bouchard *et al*. (2008), while working on cereals have shown that the association of hardy and high yielding varieties in intensive driving show that if we reduced by 30 % in value inputs, while yields decrease and the indicator of treatment frequency is reduced by 35 %. Meynard *et al*. (2010), working on the economic relevance of the reduction of chemical inputs in the production systems, noted the sensible use of high yielding varieties still allowing the farmer to have high gross margins.

Many surveys within African cities show that Women are mostly involved in market gardening than men. It is the case in Yaoundé where Vaxelaire (2010) recorded 63 % of female against 37 % of male. Apart from Accra and Addis Ababa, Prain and Lee Smith (2010) obtained the same results in some African cities like Kenya and Kampala. In urban area, because of the price of a piece of land and the difficulty to access it, many gardeners buying or lending their piece of land smaller than 500sqm preferred house gardens. The second and third techniques help gardeners to have a better control on their nurseries.

Strengthening economic activities and exchange: apart from gardening, vegetables production leads to trade not only within Bamenda and its surrounding, but towards the two biggest cities of Douala & Yaoundé in terms of vegetable sold and also fertilizers provided. Reports from Bopda (2008) and Vaxelaire (2010) say that 10% of manure produced in Yaoundé is sold in Bamenda.

Market gardening is the activity of young adults (20% were aged between 21 and 30 years and 35 % were aged between 31 and 40 years) and middle-aged adults between 41-50 years (26 %). Almost half 49% have at least the level of primary and 37 had secondary level of education. Vaxelaire (2010) find nearly the same results at Yaoundé (44 % and 24 %) and conclude that it is a familial activity. Apart from this, we recommend the sensitation and capacity building of gardeners to the best agricultural practices we tried to assess on field (table 7).

Although these impacts (water contamination, soils' pollution, air pollution, poisoning of vegetable gardeners and consumers, impact on aquatic milieu, diseases linked to the use of pesticides, destruction of avifauna, self employment promotion and poverty alleviation reducing unemployment, food security impact And income's impact) have not been identified in Yaoundé case study, although this study has not deeply investigated on the economic aspects (income). But one can notice that 75-98 % of vegetable produced are consumed within the Bamenda continuum.

5. Conclusion

The lack of best agricultural practices and misuse of inputs by gardeners expose the environment to severe damages and populations at risk of serious poisoning along the Bamenda rural-urban continuum. Today it is certainly true that vegetable production plays an important role in the food security of populations and the livelihoods of households. However, the activity of vegetable production can become a danger to the environment and human health when the use of chemical inputs increases and becomes uncontrolled. Ninety-six percent (96 %) of rural and peri-urban gardeners buy their pesticides in the local market, against 14 % in urban areas. It is therefore important to strengthen the existing regulations regarding environmental impact studies and detailed summary on vegetable farms and in particular, importation, distribution, storage and use of chemical fertilizers. Under these conditions, the proper use of inputs requires growers to ensure a healthy diet for an urban population of the rural-urban continuum of steadily growing in Bamenda. This involves:

- Conducting environmental impact assessment summary or detailed matching of the management plan and environmental monitoring;
- Encouraging growers to adopt good agricultural practices and to buy fertilizers from licensed traders and licensed products and use of improved vegetable varieties which requires minimum or no spraying;
- Strengthening urban agricultural extension services
- The evaluation of residues of individual pesticides in major vegetables consumed by people along the rural-urban continuum of Bamenda.

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