Journal of Agriculture and Ecology Research International

12(4): 1-12, 2017; Article no.JAERI.35496
ISSN: 2394-1073

Food Security and Environmental Implications of Urban Wetlands Utilisation as Vegetable Gardens: The Case of Bamenda Municipality Cameroon

Godswill Azinwie Asongwe[1*], Bernard P. K. Yerima[2], Aaron Suh Tening[3] and Elizabeth Sailieh Mbomi[1]

[1]Department of Development Studies, Pan African Institute for Development -West Africa (PAID-WA), P.O.Box 133, Buea, Cameroon.
[2]Department of Soil Sciences, University of Dschang, P.O.Box 69, Dschang, Cameroon.
[3]Department of Agronomic and Applied Molecular Sciences, University of Buea, P.O.Box 63, Buea, Cameroon.

Authors' contributions

This work was carried out in collaboration between all authors. Author GAA proposed the topic, wrote the protocol carried out the fieldwork and wrote the initial manuscript. Authors BPKY and AST validated the topic, the protocol and went through the initial manuscript. Author ESM assisted in framing the statistical procedures. All authors validated the final manuscripts.

Article Information

DOI: 10.9734/JAERI/2017/35496
Editor(s):
(1) Aneeza Soobadar, Agricultural Chemistry Department, Mauritius Sugarcane Industry Research Institute, Mauritius.
Reviewers:
(1) Dusit Athinuwat, Thammasat University, Thailand.
(2) M. Yuvaraj, Tamil Nadu Agricultural University, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/20910

Original Research Article

Received 15th July 2017
Accepted 26th August 2017
Published 9th September 2017

ABSTRACT

Wetland agriculture brings significant benefits to food security, health and income. However, ill-considered development often leads to deleterious environmental impacts and harmful consequences to people's livelihoods. This study using multi-criteria approach addresses possible environmental and food security hazards' in vegetable gardens in urban wetlands of the Bamenda municipality, besides conflicts over access. It evaluates their ecological status, soil heavy metal loads, and their accumulation in vegetables. Twenty-one samples each of surface soils and *Solanum scarbrum* were collected from vegetable gardens in the municipality and analysed for their heavy metal (Cd, Pb, Cr, and Mn) content using the atomic absorption spectrometry. Theresults indicated that the wetlands of the municipality have been moderately modified with a

**Corresponding author: E-mail: asongwe2003@gmail.com;*

loss and change of biota such as the *Raffia fanifera*. Pollution load indices varied considerably at the different sites, and ranged from unpolluted through slight pollution to medium pollution. The mean values of bioaccumulation factor (BAF) for *Solanum scarbrum*, stood at Cd>Mn>Pb>Cr, with respective values of 1.23, 1.14, 1.01, and 0.48, insignificantly higher (P>0.05) than those of the control sample. Cadmium is easily transferred in this vegetable than any other metal. The intake of Cd was estimated at 9E-7 mg, representing approximately 0.009% of the referenced dose (R_fD), established to 0.001 mg kg^{-1}. Due to the gradual degradation of wetlands in Bamenda and the urgent need to secure and improve people's quality of life while simultaneously safeguarding the ecological benefits derived from the wetland, policy makers should integrate conservation and development in planning.

Keywords: Wetland; environmental quality; food security.

1. BACKGROUND OF THE STUDY

Wetlands and their allied resources contribute enormously to food production, and livelihoods. In Africa, most economies are largely agrarian-based with about 66% of wetlands used for agriculture [1,2]. However, achieving food security and environmental quality still remains a major concern [3,4]. Urban areas are characterised by a variety of human activities, which results to the discharge of a mixture of harzardous chemical substances into the environment. Similarly, the ever-growing land pressure aggravates the demand for arable farmlands. This has led to an increasing number of people invading wetlands for agricultural activities. In this fight for survival, they often engage in unsustainable use of these natural resources, causing degradation and other adverse effects.

If wetlands are not used sustainably, the functions, which support agriculture, as well as other food security components, ecosystem services, including water-related services, are undermined. Currently, the basis for making decisions on the extent to which, and how, wetlands can be sustainably used for agriculture is debatable. There is a general dearth of knowledge on the best agricultural practices to be applied within different types of wetlands and a lack of understanding on how to establish appropriate management arrangements that will adequately safeguard important ecosystem services [2].

Often, wetland policies are underpinned by a conservationist perspective that regards agriculture simply as a threat and disregards its important contribution to livelihoods.

As with any natural resource, the sustainable utilization of wetlands, which underpins the concept of wise use, requires a comprehensive understanding of developments at the interface between human societies and the natural world.

This requires consideration of a large number of extremely complex and interrelated issues and poses intricate technical, social and political problems. A key difference between sustainable and traditional natural resource management is in the evaluation of trade-offs in relation to all costs, benefits and risks [5]. To assist decision-makers, a wide range of methods, and tools has been developed. These include methods of environmental valuation [6,7], environmental and health impact assessment [8,9] and various methods of multi-criteria analysis [10].

For a reasonable sustainability planning, the multi-criteria approach is widely recognized to be appropriate [11]. Here, apart from the fact that stakeholder choices are rarely made with respect to just one criterion, it is not possible to express all criteria as monetary values but multidimensional, consequently, a Multi-criteria analysis (MCA) has been developed [12]. The main aim of MCA approaches is to incorporate both qualitative information and quantitative data, and encompass a broad range of variables. Ecological conditions of wetlands are classified on a qualitative scale varying from “natural” to “extensively modified”.

An assessment of possible hazards evaluates the potential consequences of implementing specific agricultural activities within a working wetland. It is based on an assessment of the risks both to existing livelihoods (i.e., in relation to the extent to which the wetland currently supports social welfare) and the current ecological condition of the wetland. This assessment must be undertaken within the context of the development pressure identified for the wetland and the likely benefits that will accrue.

The hazard rating is classified from "none" (i.e., class 5), very low (class 4), low (class 3) moderate (class 2) to "high" (i.e., class 1). However, evaluation of ecological hazards considers the uniqueness of the particular local, national and international scales.

In evaluating the ecological hazards, it is important to consider the "uniqueness" of the wetland at local, national and international scales. Adverse effects on groups that depend on consumption of the wetland's natural resources.

Bamenda is one of the most rapidly emerging municipalities in Cameroon with factories ranging from metallurgical, soap production, food processing, garage works, oil exchange services to traffic releases which generates huge amounts of wastes. The wastes are drained or deposited on soils or into water systems that supply wetland. The wetlands apart of their ecological importance are used for the cultivation of crops including vegetables consumed all over the country and beyond. Waste water irrigation is known to contribute significantly to the heavy metal content of soils [13,14]. Leafy vegetables are popular and preferred by the population of the area because of their vital dietary components and indispensability as ingredients in soups or sauces that accompany carbohydrate staples, and are increasingly in demand. In general, the vegetables have multifaceted importance in the livelihoods of the urban and peri-urban poor [15] but could accumulate heavy metals endangering health. This area has received little attention from the research and extension divisions.

The suitability of a wetland for the agricultural activities defined through identification of the development pressures is dependent on a complex combination of wetland attributes, as well as catchment characteristics and the broader socioeconomic setting in which the wetland is situated. Consequently, both biophysical and socioeconomic criteria need to be evaluated when considering the suitability of a wetland for the proposed agricultural activities.

This work synthesizes findings from multicriteria studies which addresses possible environmental and food security hazards' in vegetable gardens in urban wetlands of the Bamenda municipality, by evaluating the ecological and possible hazard assessment (soil heavy metal loads, and their accumulation in vegetables) approaches of the working wetland potential.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The area covered by this study includes urban and peri-urban wetlands in the Bamenda City Council of the North West Region of Cameroon (Fig. 1). It is bounded on the West, North and East by the Cameroon Volcanic Line (made up of basalts, trachytes, rhyolites and numerous salt springs). The geologic history of this area originates from the Precambrian era where there was vast formation of geosynclinal complexes, which became filled by clay-calcareous, and sandstone sediments [16] metamorphism [17]. It is part of the Bamenda escarpment and located between latitudes 5° 55''Nand 6° 30''N and longitudes 10° 25''Eand 10° 67''E. The town shows an altitudinal range of 1200 - 1700 m, and is divided into two parts by escarpments; a low lying gently undulating part with altitudes ranging from 1200 to 1400 m, with many flat areas that are usually inundated for most parts of the year, and an elevated part at 1400 to 1700 m altitude that forms the crest from which creeks, and streams, supplying the low lying parts take their rise.

This area has two seasons; a long rainy season, which runs from mid-March to mid-October and a short dry season that spans from mid-October to mid-March. It lies within the thermic and hyperthemic temperature regimes. Mean annual temperatures stand at 19.9°C. January and February are the hottest months with mean monthly temperatures of 29.1°C and 29.7°C, respectively. The Ustic and Udic moisture regimes dominate this area with the Udic extending to the south [16]. Annual rainfall ranges from 1300 – 3000 mm [18]. The area has a rich hydrographical network with intense human activities and a dense population along different watercourses in the watershed. The Rocks in the area are thus of igneous (granitic and volcanic) and metamorphic (migmatites) origin [19], which give rise to ferralitic soils [20].

The main human activity in and around this area is agriculture, which according to Grassfield Particpatory-Decentralised and Rural Development Project [20] involves over 70% of the population that use rudimentary tools. More than 81.7% of the active agricultural populations are involved in farming, 11.6% in fishing and 6.5% in grazing [20]. Farming and grazing involves the use of organic and fertilizers that is a potential source of pollution. The area equally harbours the commercial Centre that has factories ranging from soap production, and mechanic workshops to metallurgy, which may be potential sources of pollutants. An important vegetation type in this area is the raffia palm (*Raffia farinifera)* bush, which is largely limited to the wetlands (Valleysand depressions). *R. farinifera* provides raffia wine, a vital economic resource to the inhabitants who are fighting against the cultivation of these wetlands by vegetable farmers.

2.2 Assessing the Ecological Condition of a Wetland

Following [21], based on expert knowledge and comparing with undisturbed wetlands in the region; coupled to historical knowledge of the wetland users and local communities, the present ecological condition of the wetland was classified.

2.3 Environmental Quality and Food Security Assessment

Twenty-one topsoil samples (a control sample inclusive, from a wetland that does not receive effluents) were randomly collected within the wetlands (Fig. 1) and taken to the laboratory in black plastic bags. The soil samples were air-dried and screened through a 2-mm sieve. They were analysed for soil heavy metals (Cr, Mn, Pb and Cd) using the Atomic Absorption spectroscopy (AA-700 series with a detection limit of 0.0001mg/kg (in the Soil and Environmental Chemistry Laboratory of the University of Dschang Cameroon. The Two grams of each soil sample were digested in a mixture of HCl and HNO_3 in the ration 1:3. The solutions were then aspirated into the AAS set up for determination. A reference soil sample was used to ascertain the rate of recovery of the AAS machine. The reference soil sample was previously analysed as ordered by Pr. Cheo Emmanuel Suh of the University of Buea, Cameroon at the Activation Laboratories Limited in Canada using the ICP-MS equipment with a detection limit of 1%.

2.4 Vegetable Sampling and Analysis

Vegetable samples (*Solanum scarbrium*), which grow rapidly, producing high biomass and common in the area, were purchased and harvested directly from farms in the area of study corresponding to the soil collection.

After several cleanings with distilled water to remove heavy metals deposited on plant surfaces, the vegetable samples were weighed, air dried and later dried at 40°C in an oven. Two grams of each pulverized dried sample were digested with 10 mL of aqua regia. The solution was then aspired into an atomic absorption

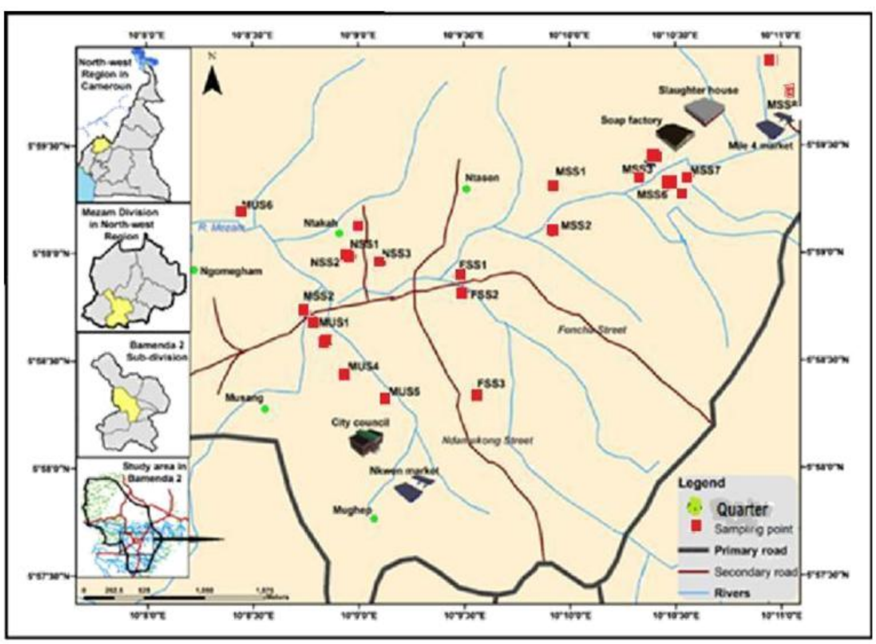

Fig. 1. Map of Bamenda municipality Cameroon, showing soil sampling points in wetlands

spectrophotometer with different lamps of 228.80 nm, 217.00 nm, 357.87 nm, and 279.48 nm for the determination of Cd, Pb, Cr and Mn, respectively.

2.5 Statistical Analysis

The degree of environmental quality (soil pollution) for each metal was calculated using the pollution load index (PLI) technique depending on soil metal concentrations.

PLI = Csoil (Samples)/Ccontrol [22]

where *Csoil* and *Ccontrol* are metal concentrations in soil samples and control, respectively. Based on PLI, soil contamination levels are classified into four grades: Pi < 1 (grade 1), unpolluted; 1 > Pi < 2 (grade 2), slight pollution; 2 > Pi < 3 (grade 3), medium pollution; Pi >3 (grade 4), heavy pollution [22].

Based on dry weight, the bio-accumulation factor (BAF), an index of the ability of the vegetables to accumulate a particular metal (food security) with respect to its concentration in the soil substrate [23], was calculated as follows:

BAF = Cplant/Csoil [24]

where *Cplant* and *Csoil* represent the heavy metal concentration in the edible part of vegetables and soils, respectively.

3. RESULTS AND DISCUSSION

3.1 Current Ecological Condition

The wetlands are floodplains of River Mezam located at an altitude of about 400 m above the sea level. The area is dominated by sandy loam soils and is flooded during the wet season. In the dry season, the water table is shallow; typically less than 50 cm below the ground surface. In the wetlands, many economic trees such as raffia *(Raffia faninera)* existed. These plants were/and are used for economic, social and cultural purposes [16,25]. These raffia bushes have largely been destroyed. The destruction of these raffias that serve as buffers in flood regulation exert additional burdens on the wetlands, especially during the rainy seasons. Some patches of the wetland are reclaimed for infrastructural development in defiance of existing national regulations. Semi aquatic and marshland plants species found in the wetlands during the study were mainly herbaceous and shrubby and most showed discoloration in patches throughout the wetland. Human activities involving cutting, of raffias and woody species resulted to an open vegetation with shrubs scattered all over the wetlands. Hyde and Wursten [26] noted similar vegetation composition in the mining-impacted sites in wetlands along Lake Victoria in East Africa. This could be indicative that, the areas have suffered some degree of disturbance. In some ponded areas close to the main river course, floating macrophytes were observed. Tita et al. [27] did not identify such plants in the urban segment of the Mezam River system nor made mention of them in ponded areas proxy to it. The latter reported that in 2007, the Nkoup River system was characterized by eutrophic species such as *Potamogeton spp* and *Ceratophyllum demersum* in the upstream segments considerably impacted by agriculture whereas the downstream and urban segments were dominated by floating and emergent species all of which accumulate and bioconcentrate significant amounts of metal pollutants. The fact that these plants were not reported in the agricultural wetlands in Bamenda Municipality is an indication that this wetland is under stress activities and, thus continually degrading. Diverse urban amenities with some having considerably noxious activities have come to existence within the environs of this agricultural wetland of the municipality. These activities either impinge directly through physical alteration and development and/or indirectly through widespread diverse chemical inputs on the agricultural soils. Acho-Chi [28] had commented on this alteration.

Currently 13.5 ha of the area are cultivated for market gardening. The farmers mostly use buckets and watering cans to convey water from streams to their farms, which are often far away from water sources. At times, they spontaneously construct irrigation channels for the canalisation of the main watercourse into their farms. A few use water pumps and dug up wells to complement the situation. Hydrological analysis indicates that current farmer and urban activities interventions have had medium impact on downstream flow regimes. Similarly, there have been adverse impacts on the water quality of the stream. Apart from vegetables cultivation, the wetlands are exploited for sand excavation, all which heavily impact the ecology of the wetland.

Using the definitions for ecological classification of wetlands, the current ecological condition of the wetlands is classified as “moderately modified.”

3.2 Environmental and Health Risk Assessment

3.2.1 Pollution load index and contamination grading

Table 2 summarises the pollution load indices and pollution grading's of the soil samples from the wetland gardens. The pollution load indices for Cr, Mn, Pb, and Cd were averagely 1.01, 1.14, 1.23 and 0.48, respectively using the control soil sample of this study as the background concentration with concentrations of 35.44 mg/kg, 0.07 mg/kg, 25.18 mg/kg and 0.00 mg/kg for Cr, Mn, Pb and Cd respectively. This indicates that the levels of the metals in the soils are slightly but insignificantly higher (P>0.05) than those of the control sample. Though higher, the insignificant difference is an indication that the level of contamination of the soils at moment is not a major problem. However, the indices at different sites were slightly different. The distribution of metals in farmlands at each site was mainly affected by the location of the farmland and agricultural practices. The results strongly agree with those of [29] of metals in soils studying levels of Metals in huckleberry along the banks of river Mezam but contrast those of [22] and [30] who reported significant higher levels of contamination by metals in China irrigated with wastewater. The higher level of contamination observed by them could be associated with the longstanding level of industrialisation of Beijing China as opposed to Bamenda Cameroon, which has few industries.

From the pollution grading, apart from Pb that showed slight pollution, the level of pollution associated with other metals was variable ranging from unpolluted through slight pollution to medium pollution.

3.3 Anthropogenic and Lithogenic Metal Inputs

The results indicated that (Fig. 2) there was significantly very little anthropogenic input of Cr and Pb in the soils of the study area. Contrarily, the amount of Cd added by anthropogenic activities outweighed that contributed by lithogenic activites. The main sources of this metal in soils of the area might not have been restricted to industrial effluents, but may include other municipal, domestic and agricultural sources. Studies in the area 15] had revealed high use of pesticides and fertilizers, which are all major sources of these elements.

3.4 Bioaccumulation Factor

The mean values of bioaccumulation factor (BAF) for the metals Cr, Mn, Pb and Cd in *Solanum scarbrum* stood at 0.0011, 0.82, 0.0012, and 0.1191, respectively (Table 3) with a trend of Mn>Cd>Pb>Cr. This indicates that Cr is the least accumulated metal while Mn and Cd are easily taken up. Tita et al. [29] had also reported the high rate of transfer of Mn from soils to vegetables in the area. A similar high transfer potential of Cd has been reported by [30] and [22] in China. The high transfer values for Cd and Mn from the soil to plants indicates a strong accumulation of the respective metals by food crops, particularly the leafy parts of the vegetables. Typically, the soil-to-plant transfer factor is one of the key components of human exposure to metals through the food chain. The results indicated that the BAF values were lower than those reported in literature by [30] and [22] in China which could be ascribed to differences in soil properties.

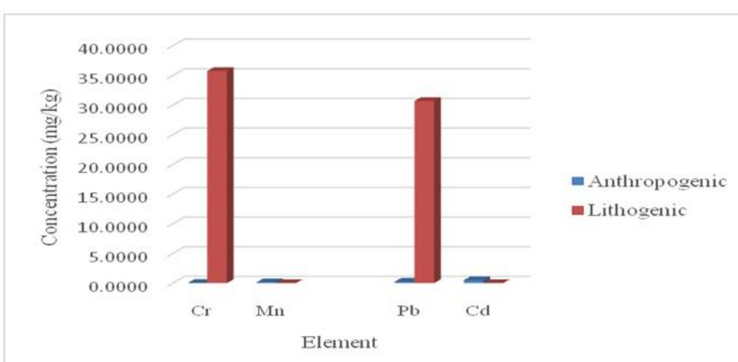

Fig. 2. Comparative levels of anthropogenic and lithogenic metal inputs in the wetland gaderns of Bamenda Municipality

Table 1. Guideline approach for assessing the ecological condition of wetlands

Description	Example	Possible desirable features	Possible negative features
Natural			
Natural habitats and functions are unmodified	Either no human interaction or only human intervention to maintain 'natural' system (e.g. nature reserves and natural parks where human populations are excluded	High biodiversity 'habitat for rare species' natural hydrological functions 'e.g. flood attenuations etc.). High aesthetic value.	Source of disease e.g. malaria and schistosomiasis. No natural resource exploitation available for local people.
Largely natural			
Few modifications. A small change from natural habitat and biota may have taken place, but the wetland 'natural functions' are essentially unchanged	Small amount of human intervention (e.g. fishing, hunting, and a collection of medicinal plants) but limited long-term impacts	People's livelihoods benefits from natural resources and the extraction is sustainable in the long-term	Source of disease e.g. malaria and schistosomiasis.
Moderately modified			
A small change of natural habitat and biota may have occurred but the basic ecosystem functions are still predominantly unchanged	Small land-use change (e.g. < 20 % of the wetland area) and/or minor modification to natural hydrological regimes	Some agricultural productions support some people livelihoods. Natural resource exploitation is still possible and sustainable	Limited water control, so crops/livestock at risks from flooding/droughts. High labour requirements to control weeds and other pests. Prevalence of disease may increase as people may spend longer time in wetland
Largely modified			
A large loss of natural habitat, biota and basic wetland functions has occurred	Significant land-use change (e.g. 21-75 % of the wetland area) and/or significant modification to natural hydrological regimes	Agricultural productions supports many people livelihoods	Significant reductions in natural resource exploitation. Loss of beneficial hydrological functions. Some soil erosion. Prevalence of disease may increase as people spend more time in wetlands.
Extensively modified			
The loss of natural habitat, biota and basic wetland functions (e.g. natural goods and services) is extensive.	Wetland ecosystem is very significantly altered from it perceived "natural" Condition. For example, extensive land-use change (e.g. >75 % of the wetland area) and highly modified hydrological regime (e.g. through drainage).	High and reliable agricultural productions support many people livelihoods. Reduced incidence of water related disease due to improved socioeconomic conditions.	Massive reduction in biodiversity. Loss of beneficial hydrological functions, possibly including pollution of water sources. Soil erosion. Low aesthetic value. Risk of diseases may still exist.

[a]In general, natural diverse habitats are highly valued and many wetlands have high biological diversity. However, in some wetland types, biodiversity is naturally low and human interventions (e.g., application of fertilizers to wet grassland to improve pasture or cutting and draining of peat bogs) will increase the diversity of communities and species in the wetland. Consequently, the number of species a wetland contains is not, in itself, a sufficient indicator of ecological condition

Table 2. Summary of pollution load indices (PLI) and pollution gradings of the soil samples from the wetland gardens in Bamenda Municipality, Cameroon

Site	Cr (mg/kg)	PLI	Pollution grade	Mn (mg/kg)	PLI	Pollution grade	Pb (mg/kg)	PLI	Pollution grade	Cd (mg/kg)	PLI	Pollution grade
Fuwambi Near Ntasen	36.43	1.03	Slight Pollution	0.04	0.57	Unpolluted	32.88	1.31	Slight Pollution	0.00	0.00	Unpolluted
Fuwambi near GTTC	36.00	1.02	Slight Pollution	0.06	0.86	Unpolluted	31.45	1.25	Slight Pollution	0.00	0.00	Unpolluted
Slap 1	35.62	1.01	Slight Pollution	0.06	0.86	Unpolluted	28.03	1.11	Slight Pollution	1.00	1.00	Slight Pollution
Slap 2	36.21	1.02	Slight Pollution	0.04	0.57	Unpolluted	31.43	1.25	Slight Pollution	0.00	0.00	Unpolluted
Slap 3	34.71	0.98	Unpolluted	0.15	2.14	Medium Pollution	31.13	1.24	Slight Pollution	0.31	0.31	Unpolluted
Slap 4	35.92	1.01	Slight Pollution	0.07	1.00	Medium Pollution	32.68	1.30	Slight Pollution	0.16	0.16	Unpolluted
Slap 5	34.84	0.98	Unpolluted	0.14	2.00	Medium Pollution	30.73	1.22	Slight Pollution	0.93	0.93	Unpolluted
Mile 4 market	36.26	1.02	Slight Pollution	0.08	1.14	Medium Pollution	28.23	1.12	Slight Pollution	1.27	1.27	Slight Pollution
Foncha right of road	34.98	0.99	Unpolluted	0.13	1.86	Medium Pollution	32.15	1.28	Slight Pollution	0.00	0.00	Unpolluted
Foncha left of road	36.14	1.02	Slight Pollution	0.05	0.71	Unpolluted	31.20	1.24	Slight Pollution	0.00	0.00	Unpolluted
Ndamukong	35.86	1.01	Slight Pollution	0.07	1.00	Medium Pollution	32.30	1.28	Slight Pollution	0.13	0.13	Unpolluted
Ntahkah inn	36.27	1.02	Slight Pollution	0.05	0.71	Unpolluted	29.33	1.16	Slight Pollution	0.27	0.27	Unpolluted
Ntahkah out	35.60	1.00	Slight Pollution	0.08	1.14	Medium Pollution	31.15	1.24	Slight Pollution	0.67	0.67	Unpolluted
Ntahkah before bridge	35.30	1.00	Unpolluted	0.12	1.71	Medium Pollution	30.73	1.22	Slight Pollution	0.47	0.47	Unpolluted
Mulang council junction	35.53	1.00	Slight Pollution	0.11	1.57	Medium Pollution	32.18	1.28	Slight Pollution	0.33	0.33	Unpolluted
Mulang left of road	35.34	1.00	Unpolluted	0.08	1.14	Medium Pollution	28.03	1.11	Slight Pollution	1.50	1.50	Slight Pollution
Mulang middle	36.07	1.02	Slight Pollution	0.04	0.57	Unpolluted	28.88	1.15	Slight Pollution	0.74	0.74	Unpolluted
Mulang 4 near houses	36.12	1.02	Slight Pollution	0.06	0.86	Unpolluted	30.53	1.21	Slight Pollution	1.29	1.29	Slight Pollution
Army Rescue	35.87	1.01	Slight Pollution	0.07	1.00	Medium Pollution	32.85	1.30	Slight Pollution	0.11	0.11	Unpolluted
Ngomegham	35.83	1.01	Slight Pollution	0.09	1.29	Medium Pollution	32.38	1.29	Slight Pollution	0.33	0.33	Unpolluted
Average	**35.75**	**1.01**	**Slight Pollution**	**0.08**	**1.14**	**Medium Pollution**	**30.91**	**1.23**	**Slight Pollution**	**0.48**	**0.48**	**Unpolluted**

Table 3. Bioaccumulation factor (BAF) for Cr, Mn, Pb and Cd in *Solanum scarbrum* in urban and peri-urban wetlands of Bamenda

Site	Cr soil mg/kg	Cr plant mg/kg	BAF	Mn soil mg/kg	Mn plants mg/kg	BAF	Pb soil mg/kg	Pb plant mg/kg	BAF	Cd soil mg/kg	Cd plant mg/kg	BAF
Fuwambi Near Ntasen	36.43	0.04	0.0011	0.04	0.08	2.00	32.88	0.03	0.0009	0.00	0.05	0.0000
Fuwambi near GTTC	36.00	0.07	0.0019	0.06	0.07	1.17	31.45	0.04	0.0013	0.00	0.02	0.0000
Slap 1	35.62	0.04	0.0011	0.06	0.05	0.83	28.03	0.02	0.0007	1.00	0.01	0.0100
Slap 2	36.21	0.02	0.0006	0.04	0.08	2.00	31.43	0.05	0.0016	0.00	0.05	0.0000
Slap 3	34.71	0.01	0.0003	0.15	0.05	0.33	31.13	0.03	0.0010	0.31	0.08	0.2581
Slap 4	35.92	0.06	0.0017	0.07	0.06	0.86	32.68	0.06	0.0018	0.16	0.02	0.1250
Slap 5	34.84	0.04	0.0011	0.14	0.04	0.29	30.73	0.04	0.0013	0.93	0.02	0.0215
Mile 4 market	36.26	0.02	0.0006	0.08	0.06	0.75	28.23	0.07	0.0025	1.27	0.03	0.0236
Foncha right of road	34.98	0.03	0.0009	0.13	0.06	0.46	32.15	0.07	0.0022	0.00	0.03	0.0000
Foncha left of road	36.14	0.02	0.0006	0.05	0.02	0.40	31.2	0.03	0.0010	0.00	0.05	0.0000

Site	Cr soil mg/kg	Cr plant mg/kg	BAF	Mn soil mg/kg	Mn plants mg/kg	BAF	Pb soil mg/kg	Pb plant mg/kg	BAF	Cd soil mg/kg	Cd plant mg/kg	BAF
Ndamukong	35.86	0.03	0.0008	0.07	0.04	0.57	32.3	0.04	0.0012	0.13	0.04	0.3077
Ntahkah inn	36.27	0.06	0.0017	0.05	0.08	1.60	29.33	0.02	0.0007	0.27	0.07	0.2593
Ntahkah out	35.60	0.02	0.0006	0.08	0.06	0.75	31.15	0.01	0.0003	0.67	0.08	0.1194
Ntahkah before bridge	35.30	0.08	0.0023	0.12	0.08	0.67	30.73	0.02	0.0007	0.47	0.07	0.1489
Mulang council junction	35.53	0.01	0.0003	0.11	0.06	0.55	32.18	0.04	0.0012	0.33	0.03	0.0909
Mulang left of road	35.34	0.04	0.0011	0.08	0.08	1.00	28.03	0.01	0.0004	1.5	0.05	0.0333
Mulang 4 near houses	36.12	0.02	0.0006	0.06	0.01	0.17	30.53	0.06	0.0020	1.29	0.02	0.0155
Army Rescue	35.87	0.08	0.0022	0.07	0.04	0.57	32.85	0.04	0.0012	0.11	0.08	0.7273
Ngomegham	35.83	0.07	0.0020	0.09	0.07	0.78	32.38	0.04	0.0012	0.33	0.08	0.2424
Mbelewa	35.44	0.03	0.0008	0.07	0.04	0.57	25.18	0.04	0.0016	0	0.08	0.0000
Average	**35.71**	**0.04**	**0.0011**	**0.08**	**0.06**	**0.82**	**30.73**	**0.04**	**0.0012**	**0.44**	**0.05**	**0.1191**

Table 4. Daily intake of heavy metals from the consumption of *Solanum scarbrum* cultivated in the urban and peri-urban wetland gardens of Bamenda Municipality

Site	Cr (mg/kg)	Daily intake (mg/kg)	Mn (mg/kg)	Daily intake (mg/kg)	Pb (mg/kg)	Daily intake (mg/kg)	Cd (mg/kg)	Daily intake (mg/kg)
Fuwambi Near Ntasen	0.04	0.0001	0.08	0.0002	0.03	0.0001	0.05	7E-7
Fuwambi near GTTC	0.07	0.0002	0.07	0.0002	0.04	0.0001	0.02	4E-7
Slap 1	0.04	0.0001	0.05	0.0002	0.02	0.0001	0.01	1E-7
Slap 2	0.02	0.0001	0.08	0.0002	0.05	0.0002	0.05	1.2E-6
Slap 3	0.01	0.0000	0.05	0.0002	0.03	0.0001	0.08	1.1E-6
Slap 4	0.06	0.0002	0.06	0.0002	0.06	0.0002	0.02	6E-7
Slap 5	0.04	0.0001	0.04	0.0001	0.04	0.0001	0.02	4E-7
Mile 4 market	0.02	0.0001	0.06	0.0002	0.07	0.0002	0.03	1E-6
Foncha right of road	0.03	0.0001	0.06	0.0002	0.07	0.0002	0.03	1E-6
Foncha left of road	0.02	0.0001	0.02	0.0001	0.03	0.0001	0.05	7E-7
Ndamukong	0.03	0.0001	0.04	0.0001	0.04	0.0001	0.04	8E-7
Ntahkah inn	0.06	0.0002	0.08	0.0002	0.02	0.0001	0.07	7E-7
Ntahkah out	0.02	0.0001	0.06	0.0002	0.01	0.0000	0.08	4E-7
Ntahkah before bridge	0.08	0.0002	0.08	0.0002	0.02	0.0001	0.07	7E-7
Mulang council junction	0.01	0.0000	0.06	0.0002	0.04	0.0001	0.03	6E-7
Mulang left of road	0.04	0.0001	0.08	0.0002	0.01	0.0000	0.05	2E-7
Mulang 4 near houses	0.02	0.0001	0.01	0.0000	0.06	0.0002	0.02	6E-7
Army Rescue	0.08	0.0002	0.04	0.0001	0.04	0.0001	0.08	1.5E-6
Ngomegham	0.07	0.0002	0.07	0.0002	0.04	0.0001	0.08	1.5E-6
Mbelewa	0.03	0.0001	0.04	0.0001	0.04	0.0001	0.08	5E-7
Average	**0.04**	**0.0001**	**0.0565**	**0.0002**	**0.04**	**0.0001**	**0.05**	**9E-7**

Oral Reference Dose RfD= 0.004, 0.001, 0.014, 1.5 for Pb, Cd, Mn and Cr respectively. (Source FAO/WHO, 2013)

3.5 Daily Intake of Heavy Metals through the Food Chain

The daily intake of heavy metals was estimated according to the average daily vegetable consumption (0.1995 kg dry matter for *Solanum scarbrum*). The estimated daily intake through the food chain (Table 4) was calculated for an adult of an average weight of 65 kg over a lifespan of 55 years (average lifespan in Cameroon). The daily intake values for the heavy metals were significantly low. The intake of Cd was estimated as 9E-7 mg, which represents approximately 0.009% of the referenced dose (R_fD), established to 0.001 mg kg^{-1} of body weight per day by [31].

The content of Cd intake found was lower than that reported in literature, which ranged between 0.0018 and 0.052 mg per day [32,33,34]. Cadmium is a dangerous element because it can be absorbed via the alimentary tract, penetrate through the placenta during pregnancy, and damage membranes and DNA. Once in the human body, it may remain in the metabolism from 16 to 33 years and is connected to several health problems, such as renal damages and abnormal urinary excretion of proteins. Decrease in bone calcium concentrations and increase of urinary excretion of calcium have also been attributed to exposure to Cd, eventually causing death. It also affects reproduction and endocrine systems of women [35]. Vegetables may contribute to about 70% of Cd intake by humans, varying according to the level of consumption [36].

The average daily intake of Pb was 0.0002 mg estimated at 5% of the RfD of 0.004 mg/kg of body weight per day set by [31]. The value is below those reported in literature for rice (0.025 and 0.521 mg/day) [32,33,34]. Lead is a very toxic element and it's reported toxic effects focus on several organs, such as liver, kidneys, spleen and lungs, causing a variety of biochemical defects. The nervous system of infants and children is particularly affected by the toxicity of this heavy metal. Adults exposed occupationally or accidentally to excessive levels of Pb exhibit neuropathology. Maihara and Favaro [37] have reported a strong association between Pb in human body and increase of blood pressure in adults. The daily intake of Cr was 0.0001 mg which is lower than the R_fD of 1.5 mg kg^{-1} per day established by [31]. This value was also significantly ($P< 0.01$) lower than that recommended by the US National Council [38] for Cr^{3+}, of 0.05 to 0.2 mg. The daily intake of Cr estimated in this work was also lower than that reported in literature, which ranges between 0.013 and 0.098 mg per day [39]; and [33,34]. Cr is an important element for the insulin activity and DNA transcription; however, an intake below 0.02 mg per day could reduce cellular responses to insulin [40].

4. CONCLUSION

The main focus of this study was to address possible environmental and food security hazards' in vegetable gardens in urban wetlands of the Bamenda municipality, by evaluating the ecological status of the wetland and possible hazard assessment from heavy metals. The wetlands of the municipality have been moderately modified with a loss and change of biota such as the *Raffia fanifera*. Pollution load indices varied considerably at the different sites, and ranged from unpolluted through slight pollution to medium pollution. The mean values of bioaccumulation factor (BAF) for *Solanum scarbrum*, stood at Cd>Mn>Pb>Cr, with respective values of1.23, 1.14, 1.01, and 0.48, insignificantly higher ($P>0.05$) than those of the control sample. Cadmium is easily transferred in this vegetable than any other metal. The intake of Cd was estimated at 9E-7 mg, representing approximately 0.009% of the referenced dose (R_fD), established to 0.001 mg kg^{-1}. Due to the gradual degradation of wetlands in Bamenda and the urgent need to secure and improve people's quality of life while simultaneously safeguarding the ecological benefits derived from the wetland, policy makers should integrate conservation and development in planning.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Adams M. Wetland and floodplain development in dry land Africa In: Binns and Tonny (Eds) People and Environment. Sussex, UK. John Wiley & sons, Ltd; 1995.
2. IWMI. Working wetlands: a new approach to balancing agricultural development with environmental protection. Water policy briefing issue 21, September 2006, Colombo, Sri Lanka.
   Available: http://www.iwmi.org. Accessed 21/10/2007.

3. Pinstrup-Andersen P. Food and agricultural policy for a globalizing world: preparing for the future. American Journal of Agriculture and Economics. 2002;84(5): 1201-1214.
4. United Nations (UN). World population prospects: The 2006 Revision. Department of Economic and Social Affairs, New York: United Nations; 2007.
5. Haimes YY. Sustainable development: A holistic approach to natural resource management. Water International. 1992; 17:187-192.
6. Barbier EB, Acreman M and Knowler D. Economic valuation of wetlands: A guide for policy-makers and planners. Gland Switzerland: Ramsar Convention Bureau. 1997;127.
7. Emerton L, Bos E. Value: Counting ecosystems as an economic part of water infrastructure. Gland, Switzerland and Cambridge, UK: The World Conservation Union (IUCN). 2004;88.
8. World Bank. Environmental Assessment Sourcebook. Technical Report No. 140, Volume-II. Washington, D.C.: World Bank; 1991.
9. World Health Organization (WHO). Environmental health indicators: Framework and methodologies. WHO/SDE/ OEH/99.10. Protection of the Human Environment, Occupational and Environmental Health Series. Geneva: WHO; 1999.
10. Harboe R. Multicriteria methods for decision-making in water resources systems. In Water resources management: Modern decision techniques, eds. M. Benedini, K. Andah and R. Harboe. Rotterdam, the Netherlands: A. A. Balkema Publishers. 1992;1-10.
11. Yerima BPK, Van Ranst E, Sertsu S, Verdoodt A. Pedogenic impacts on the distribution of total and available Fe, Mn, Cu, Zn, Cd, Pb and Co contents of vertisols and verticinceptisols of the Bale Mountain area of Ethiopia. African Journal of Agricultural Research. 2013;8(44):5429-5439
12. Stirling A. Multicriteria mapping: Mitigating the problems of environmental valuation? In Valuing nature: Economics, ethics and environment, ed. J. Foster. London: Routledge; 1997.
13. Devkota B, Schmidt GH. Accumulation of heavy metals in food plants and grasshoppers from the Taigetos Mountains, Greece. Agriculture Ecosystem and the Environment. 2000;78:85-91.
14. Mapanda F, Mangwayana EN, Nyamangara J, Giller KE. The effect of long term irrigation using wastewater on heavy metal contents of soils under vegetables in Harare, Zimbabwe. Agricuture Ecosystem Environment. 2005; 107:151-165.
15. Asongwe GA, Yerima BPK, Tening AS. Vegetables production and the livelihood of farmers in Bamenda municipality, Cameroon. International Journal of Current Microbiology and Applied Sciences. 2014;3(12):682–700.
16. Yerima BPK, Van Ranst E. Introduction to soil science, soil of the tropics. TRAFFORD Publishers, Victoria Canada. 2005a;397.
17. Yerima BPK, Van Ranst E. Major soil classification systems used in the Tropics: Soils of Cameroon. TRAFFORD Publishers, Victoria Canada. 2005b;295.
18. Ndenecho EN. Biological resource exploitation in cameroon: From crises to sustainable management. Unique Printers Bamenda Cameroon. 2005;181.
19. Kips P, Faure P, Awah E, Kuoh H, Sayol R, Tchieuteu R. Soils, land use and land evaluation of North West Province of Cameroon. Ekona: FAO/UNDP; 1987.
20. GP-DERUDEP. Grassfield participatory: Decentralized and rural development project. Baseline study of the North West Province. SIRDEP Bamenda Cameroon. 2006;298.
21. McCartney MP, Van Koppen B. Wetland contributions to rural livelihoods in United Republic of Tanzania. FAO-Netherlands Partnership Program: Sustainable Development and Management of Wetlands. Rome: Food and Agriculture Organization of the United Nations. 2004;42.
22. Liu WH, Zhao ZY Ouyangn E, Soderlund P, Liu GH. Impacts of sewage irrigation on heavy J. Z. metals distribution and contamination in Beijing, China. Environment International. 2005;31:805-812.
23. Ghosh M, Singh SP. A comparative study of cadmium phytoextrcation by accumulator and weed species. Environmental Pollution. 2005;133:365-371.
24. Cui YJ, Zhu YG, Zhai R, Huang Y, Qiu Y, Liang J. Exposure to metal mixtures and

human health impacts in a contaminated area in Nanning, China. Environment International. 2005;31:784-790.

25. Kometa SS. Wetlands exploitation along the Bafoussam Bamenda road axis of the western highlands of Cameroon. Journal of Hum Ecology. 2013;41(1):25-32.
26. Hyde M, Wursten B. 2007. Flora of Zimbabwe. Available:htpp://www.Zimbabweflora.co.zw Speciesdata/about.php
27. Tita MA, Magha A, Kamgang KVB. Occurrence of macrophytes in the Mezam river system in Bamenda (Cameroon) and their role in nutrient retention. Syllabus Review. Sci. Ser. 2012;3:1-10.
28. Acho-Chi C. Human interference and environmental instability addressing consequences of rapid urban growth in Bamenda. Environment and Urbanisation. 1998;10(2):161-174.
29. Tita MA, Tsala GN, Kamgang KBV. Levels of Metals in huckleberry (*Solanum scarbrum*) grown along the Mezam River banks in Bamenda, North West Cameroon: Implications for crop growth and human consumption. Syllabus Review Science Series. 2011;2(2):69-78.
30. Khan S, Cao Q, Zheng YM, Huang YZ, Zhu YG. Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. Environment Pollution. 2007;1–7.
31. FAO/WHO. Food and Agriculture Organization of the United Nations /World Health Organization. CODEX ALIMENTAIRIUS COMMISSION: Joint FAO/WHO Food Standards Programme, Rome. 2013;214.
32. Tripathi RM, Raghunath R, Krishnamoorthy TM. Dietary intake of heavy metals in Bombay city, India. Science of the Total Environment. 1997;208:149–59.
33. Santos EE, Lauria DC, Porto da Silverira CL. Assessment of daily intake of trace elements due to consumption of foodstuffs by adult inhabitants of Rio de Janeiro city. Science of the Total Environment. 2004;327:69-79.
34. Guerra F, Trevizam AR, Muraoka T, Marcante NC, Canniatti-Brazaca SG. Heavy metals in vegetables and potential risk for human health. Scientia Agricola. 2012;69(1):54-60.
35. World Economic Forum. Environmental sustainability index: An initiative of the global leaders of tomorrow environment task force. New Haven, Conn.: Yale Center for Environmental Law and Policy, Yale University. 2002;82.
36. Wagner GJ. Accumulation of cadmium in crop plants and its consequences to human health. Advances in Agronomy. 1993;51:173-212.
37. Maihara VA, Fávaro DIT. Toxic elements. In: Cozzolino, S.M.F., ed. Bioavailability of nutrients. Manole, Barueri, SP, Brazil (originally in Portuguese). 2006;629-660.
38. National Research Council [NRC]. Recommended Dietary Allowances. National Academy Press, Washington, DC, USA; 1989.
39. Biego GH, Joyeux M, Hartemann P, Debry G. Daily intake of essential minerals and metallic micro pollutants from foods in France. Science of the Total Environment. 1998;217:27-36.
40. Kohlmeier M. Nutrient Metabolism, Elsevier, San Diego, USA; 2003.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/20910