Evaluating peri-urban market gardening and shallow well quality for irrigation: a case study from Lagos, Nigeria

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Abstract: Urban agriculture is vital for food security and environmental sustainability. The study evaluated peri-urban market gardening and the quality of shallow well water for irrigation purpose. The result shows a significant relationship between gender of farmers and occupation; education and income at p = .000. The mean value of bicarbonate, calcium and pH exceeded their detection level in about 66.7%, 60% and 53.3%, respectively. Kelly ratio ranged from 0.03 to 0.12 meq/L with a mean value above the computed KR in about 20%. Magnesium ratio, percent sodium exceeded the mean value in about 50% and 33.3% respectively in Ojo. Unlike Amuwo-Odofin, it is about 55.6% and 33.3%, respectively. The pattern of salinity and sodium hazard shows that approximately 66.7%, 26.7% and 6.7% of the shallow wells indicate low, medium and high salinity respectively. The paper recommended monitoring of irrigation water quality and runoff control. Regulation of agricultural activities and protective measures against pollution of water sources were also recommended.

Keywords: irrigation; Kelly ratio; magnesium hazard; market gardening; percentage sodium; peri-urban; shallow well; sodium adsorption ratio; SAR; Nigeria.

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1 Introduction

The continuous rise in population growth, rapid rate of urbanisation and poor planning by the concerned agencies and stakeholders in urban and peri-urban areas in the developing countries pose a major challenge to the urban planning process. Considering this trend, there has been an increasing rate of rural-urban migration in most developing countries. This phenomenon has contributed to the current rise in poverty, food insecurity and malnutrition. Consequently, the global efforts about the eradication of hunger and the concern about the capacity of agriculture to meet future food needs. This study is very important because of the daily influx of people into Lagos state, Nigeria from the different states, including the neighbouring countries. Similarly, the opportunity of securing a white collar job in the urban area is highly competitive. Hence, the majority of these migrants resorts in peri-urban agriculture. One of the Millennium Development Goals (MDGs) is to eradicate extreme poverty and hunger by 2015. Urban agriculture is one of the major strategies employed by urban farmers to reduce the poverty level and improve food security globally (Averbeke, 2007). According to Bettina and Belevi (2001), there are six major processes of urban agriculture namely; agricultural practices, soil quality management, irrigation, animal feeding, public health management and urban planning and policy.

Many definitions of urban agriculture abound in literature (Tinker, 1994; Smit, 1996; Aldington, 1997; FAO, 1999; Mougeot, 1999; Quon, 1999). Bettina and Belevi (2001) argued that urban agriculture comprised of the production, processing and distribution of diverse food crops, including vegetables and animal products within the intra-urban or at the fringe (peri-urban) of an urban area. The major aim is targeted towards food production (for personal consumption or sale) and/or higher income. Urban agriculture plays a very significant role in contributing to the socioeconomic status of the urban households (Tefera, 2010). It is also responsible for food supply to more than 800 million urban dwellers globally (Zezza and Tasciotti, 2010). In addition, urban agriculture also plays a vital role in sustainable resource management, especially in solving some urban environmental problems such as solid and liquid waste treatment or reuse. Urban agriculture also increased the nutritional status of the urban dwellers and also reduces significantly the problems of urban household food insecurity (Maxwell, 1994). Despite the immense contributions of urban agriculture to the eradication of extreme poverty, hunger and food security, the effects of urban agriculture on surface and groundwater resources due to irrigation pose a major environmental and health challenges to the teeming population that relies on surface and groundwater for their respective needs. Irrigation of agricultural lands accounted for about 70% of the global water consumption (WWAP, 2006; Vineesha and Singh, 2008). According to statistics, irrigation accounts for almost 85–90% of all withdrawals in Asia, the Middle East, North Africa and sub-Saharan Africa (WWAP, 2012). Although irrigation is essential for food security, it has been reported that irrigation of agricultural lands is responsible for surface and groundwater quality deterioration due to pesticides, pollutants, nutrients, sediments and salinisation among others (WWAP, 2006; Foster and Candela, 2008; GWP, 2012). Similarly, raw water used for irrigation contains certain impurities, such as salts and minerals that are harmful for human as well as for plant growth (Akoteyon, 2014). Poor irrigation water qualities are very complex. They include salinity, permeability, toxicity and miscellaneous (Ayers and Westcot, 1985). Each of these problems may affect crop singly or in a combination of two or more. Several irrigation water quality schemes have been proposed by many authors. Most of the classification schemes are based on two or more factors. For instance, the United State Salinity Laboratory's (USSL, 1954) classification technique which considers water quality with respect to the total salinity, sodium hazard and sodium adsorption ratio (SAR). Others include, total dissolved solids (TDS), percentage of sodium (%Na), residual sodium carbonate (RSC) and magnesium ratio (MR) among others. Poor irrigation water qualities are very complex. They include salinity, permeability, toxicity, and miscellaneous (Ayers and Westcot, 1985). Each of these problems may affect crop singly or in a combination of two or more. Several irrigation water quality schemes have been proposed by many authors. The majority of the classification schemes are based on two or more factors. For instance, the USSL's (1954) classification technique which considers water quality with respect to the total salinity, sodium hazard and SAR. Others include, TDS, Na, RSC, and MR among others. Irrigation of agricultural lands accounted for about 70% of the water used globally (WWAP, 2006; Vineesha and Singh, 2008). For example, in Asia, the Middle East, North Africa and sub-Saharan Africa irrigation accounts for almost 85–90% of all withdrawals (WWAP, 2012).

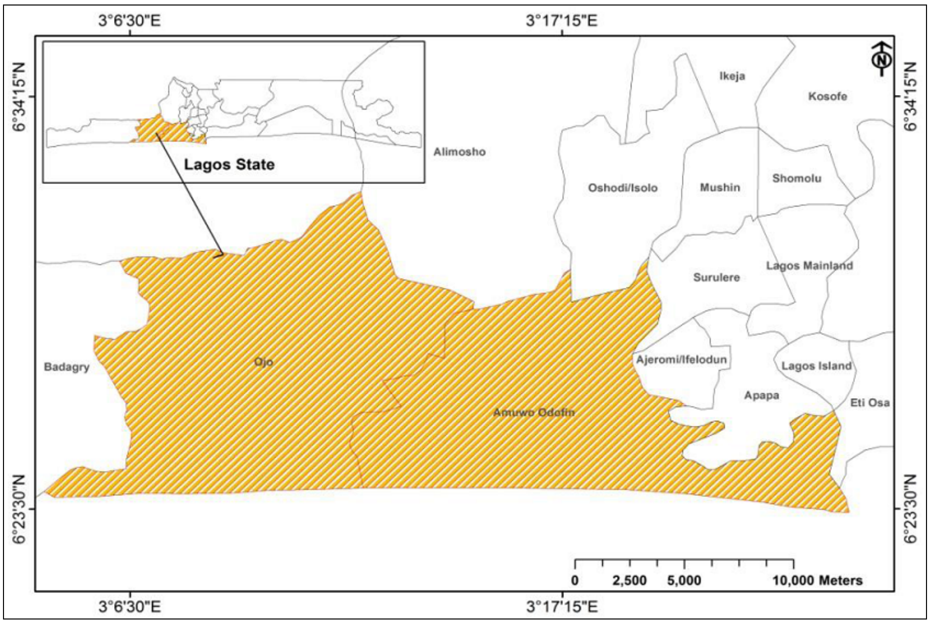
Although irrigation is essential for food security, it has been reported that irrigation of agricultural lands is responsible for surface and groundwater quality deterioration due to pesticides, pollutants, nutrients, sediments and salinisation among others (WWAP, 2006). Therefore, the formulation of sound and effective agricultural policies that will guarantee sustainable environment should be enforced at all levels (local, state and federal). Also, proper legislation of the urban agricultural activities must be secured in order to regulate access to land and water resources. This will help to minimise the deleterious effects urban agricultural activities on water resources.

Several authors have carried out research on the contribution of urban agriculture both qualitatively and quantitatively across the globe. For instance, Mankoe and Mtapuri (2012), Tefera (2010), Kutiwa et al. (2010), Averbeke (2007), Bettina and Belevi (2001), Gbadegesin (1995), Fasona and Adedayo (2004) and Olawepo (2008) examined the diverse nature of urban agriculture in the area of animal rearing and market gardening. Similarly, Lawal and Aliu (2012) studied the operational pattern of urban agriculture in Lagos. Adedayo (2010) examined the contributions of irrigation activities in vegetable farms to the incidence of malaria infection in Lagos, Nigeria. Similarly, the literature abounds on groundwater suitability for irrigation purpose the world over. Hussain et al. (2010), Arabi et al. (2010), Hulya and Nakoman (2010), Nata et al. (2009) are among others. However, most of the authors have not considered an integrated assessment of urban market gardening vis-a-vis the suitability of the irrigation water quality for crop cultivation. Therefore, this study seeks to fill this gap in knowledge.

2 The study area

Amuwo-Odofin local government area (LGA) is located approximately on longitudes 3°14’W and 3°12’W and on latitudes 6°29’N and 6°27’N. It is bounded by Ajeromi/Ifelodun LGA in the East, Oshodi/Isolo in the North, the Badagry Creek to the South and Ojo LGA in the West. The LGA occupies about 134.6 km^2 area of land. The population is estimated at about 318.166 (NPC, 2006) (Figure 1). Unlike Ojo LGA, it is located on longitudes 2°55’W and 2°12’W and on latitudes 4°15’N and 4°17’N. The LGA is bordered by Amuwo-Odofin LGA in the East, Alimosho to the North, the Badagry Creek to the South and Badagry LGA in the West. The population is about 598,071 (NPC, 2006) (Figure 1).

Figure 1 The study area (see online version for colours)



The climate of the area is characterised by two major seasons, namely the dry season spanning between November and March while the wet season covers between April to October. The mean temperature is about 27°C with annual average rainfall of about 1,532 mm (Adetoyinbo and Babatunde, 2010). The major vegetation comprises of the tropical swamp forest (fresh waters and mangrove swamp forests and dry lowland rain forest) (FEPA, 1997). The drainage pattern is characterised by Lagoon, creek, barrier islands and sand beaches. The major river is Yewa River. The geology of the area is underlain by recent sedimentary rock composed mainly of alluvial materials (Longe, 2011). Major farming activity in the area is vegetable/market gardening. Other human activities include fishing, trading among others (Odumosu, 1999). The major crops planted includes, vegetables and lettuce while others crops include, garbage, onions, spinach etc. Major source of irrigation water is from shallow wells that are usually flooded during wet season.

3 Materials and method

3.1 Social survey on peri-urban farming

The social survey used for this study was conducted in July, 2012 covering four peri-urban farm sites around Navy gate Okokomaiko and LASU post service area of Ojo LGA (see Plate 1) and vegetable farms around Finniger and Abule-Ado in Amuwo-Odofin LGA (Plate 2).

Plate 1 Peri-urban farm sites in Ojo LGA (see online version for colours)

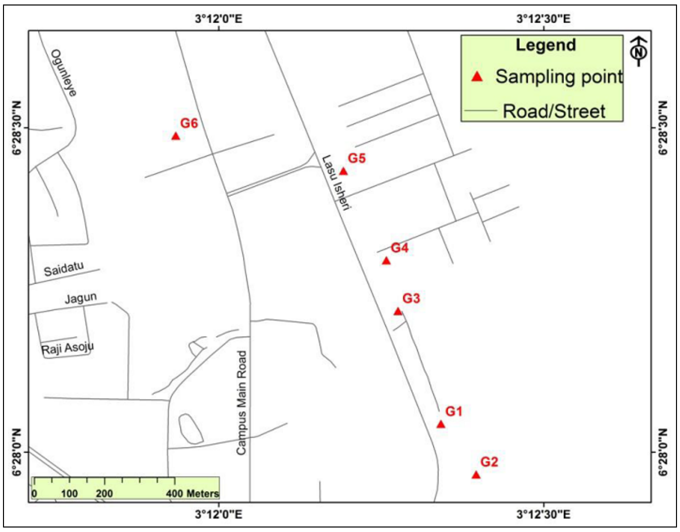
Plate 2 Peri-urban farm sites in Amuwo-Odofin LGA (see online version for colours)

A total of 150 peri-urban farmers were sampled using structured questionnaires to collect information on their farming activities. A non-random sampling method was employed in the selection of the farm sites while the quota sampling technique was used in the social survey to collect relevant data on Peoria-urban agriculture in the study area. The survey questionnaire consists of three sections: socio-demographic characteristics of peri-urban farmers, nature of peri-urban farming activities and the contributions/challenges of peri-urban farming.

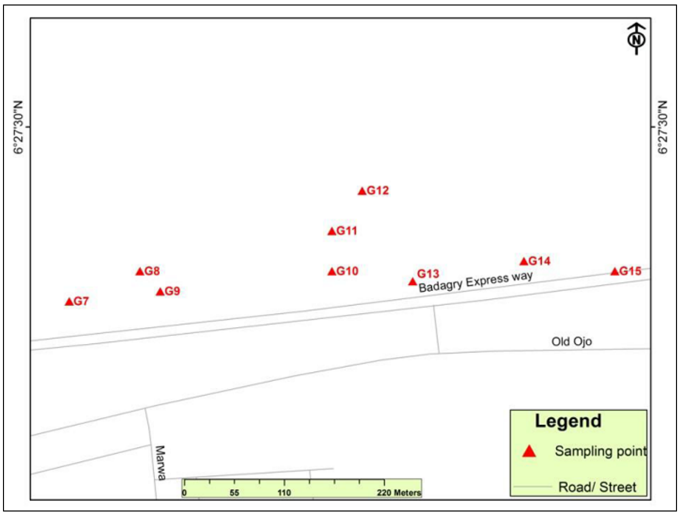
3.2 Assessment of irrigation water quality

For the assessment of irrigation water quality, a total of fifteen shallow wells was sampled during the wet season of July, 2012 using random sampling techniques. The water samples were properly labelled e.g. G1-6 represents samples from Ojo LGA while G9-15 represents samples from Amuwo-Odofin LGA. Samples from the shallow wells were stored in plastic bottles after being rinsed with the shallow well water to be sampled and were taken to the department of chemistry, University of Lagos for laboratory analysis. Electrical conductivity (EC), pH and TDS were measured using the direct field measurement technique with the aid of portable hand held meters [EC-Dist 3 (HI98303, Hanna model), (PH-102, RoHS model) and TDS/TEMP HM digital model respectively]. Titrimetry method was employed for the analysis of bicarbonate, calcium, carbonate and chloride. The atomic absorption spectrophotometer (AAS) HI 98180 model was used to analyse magnesium, potassium and sodium while sulphate ion was determined with the aid of spectrophotometer, HACH DR/2000 model using standard procedures (APHA, 1998). The coordinates of the sampling locations were recorded by global positioning system (GPS), Garmin map (76CSX model) and were exported in an ArcMap 10 software environment to generate maps of the study area. Thereafter, the coordinates were plotted to generate maps of the sampling locations (Figure 2).

Figure 2 (a) Sampling locations in Ojo LGA (b) Sampling locations in Amuwo-Odofin LGA (see online version for colours)



(a)



(b)

3.3 Irrigation water quality indices

Appropriate irrigation water quality indices were employed to assess the suitability of shallow well water quality for cultivation. The indices include Kelly ratio (KR), magnesium ratio (MR), sodium percentage (% Na) and sodium absorption ratio (SAR) as stated in equations (1) to (4).

1 Kelly (1963) expressed KR (Kelly's ratio) as:

$$KR = Na / Ca + Mg \quad (1)$$

2 Szabolcs and Darab (1964) expressed MR (magnesium ratio) as:

$$MR = Mg / Ca + Mg \times 100 \quad (2)$$

3 Todd and Mays (1995) expressed % Na (percentage sodium) as:

$$\%Na = Na + K / Ca + Mg + Na + K \times 100 \quad (3)$$

4 Richards (1954) expressed SAR as:

$$SAR = \left(Na / \surd (Ca + Mg) / 2\right) \quad (4)$$

where Na – sodium, Ca – calcium, Mg – magnesium, K – potassium. All the ionic concentrations are in milliequivalent per litre (meq/L).

3.4 Data presentation and analysis

Both the descriptive, bivariate and indices were applied for the data analysis using the Statistical Package for Social Sciences (SPSS) 17.0 version and AquaChem Software 2012.1 version respectively. The results of the analysis were presented in tables, charts and map formats. Kelly's ratio was plotted using bar chart with the aid of excel software 2003 edition. Magnesium ratio and % Na were mapped using pie chart with the aid of ArcMap 10 software while sodium hazard (SAR) and salinity hazard (conductivity) were mapped using Wilcox diagram with the aid of AquaChem 2012.1 version.

4 Results and discussion

4.1 Socio-demographic characteristics of urban farmers

The socio-demographic characteristic of the interviewed farmers is presented in Table 1.

Table 1 Socio-demographic characteristics of respondents

Variables	*n*	*(%)*
Gender		
Male	125	(83.3)
Female	25	(16.7)

Table 1 Socio-demographic characteristics of respondents (continued)

Variables	*n*	*(%)*
Age		
< 20 years	19	(12.7)
20–30 years	35	(23.3)
31–40 years	62	(41.3)
> 40 years	34	(22.7)
Marital status		
Single	28	(18.7)
Married	120	(80.0)
Others	2	(1.3)
Ethnic group		
Hausa	40	(26.7)
Igbo	105	(70.0)
Yoruba	5	(3.3)
Education		
Primary	81	(54.0)
Secondary	40	(26.7)
No formal education	29	(19.3)
Occupation		
Yes	136	(90.7)
No	14	(9.3)
Income		
Daily (< ₦1,000)	69	(46.0)
Weekly (₦1,000–₦5,000)	58	(38.7)
Monthly (above ₦5,000)	23	(15.3)

According to gender, 83.3% of the farmers are males while the remaining 16.7% represents the females. A similar result was reported by Lawal and Aliu (2012). This finding supports the belief that men are the main breadwinners of the family. However, a study carried out by Mankoe and Mtapuri (2012) and Jacob et al. (2000) was at variance with the current result. With respect to age, the age group between 31 and 40 years is actively engaged in urban agriculture. The second largest age group is between 20–30 years, followed by age group above 40 years. This is also confirmed by Lawal and Aliu (2012) that mature young farmers participate actively in urban agriculture due to the need for food security. Based on marital status, 80% of the farmers are married while 18.7% and 1.3% are single and others (e.g. divorced, widowed, etc.) respectively. The pattern of the ethnic background of the farmers revealed that, the majority (70.0%) represents the Igbo while 26.7% and 3.3% accounts for Hausa and Yoruba ethnic background. This finding implies that, urban farming activities are predominantly practiced by migrants (Igbo’s) from the Southeastern Nigeria in the study area.

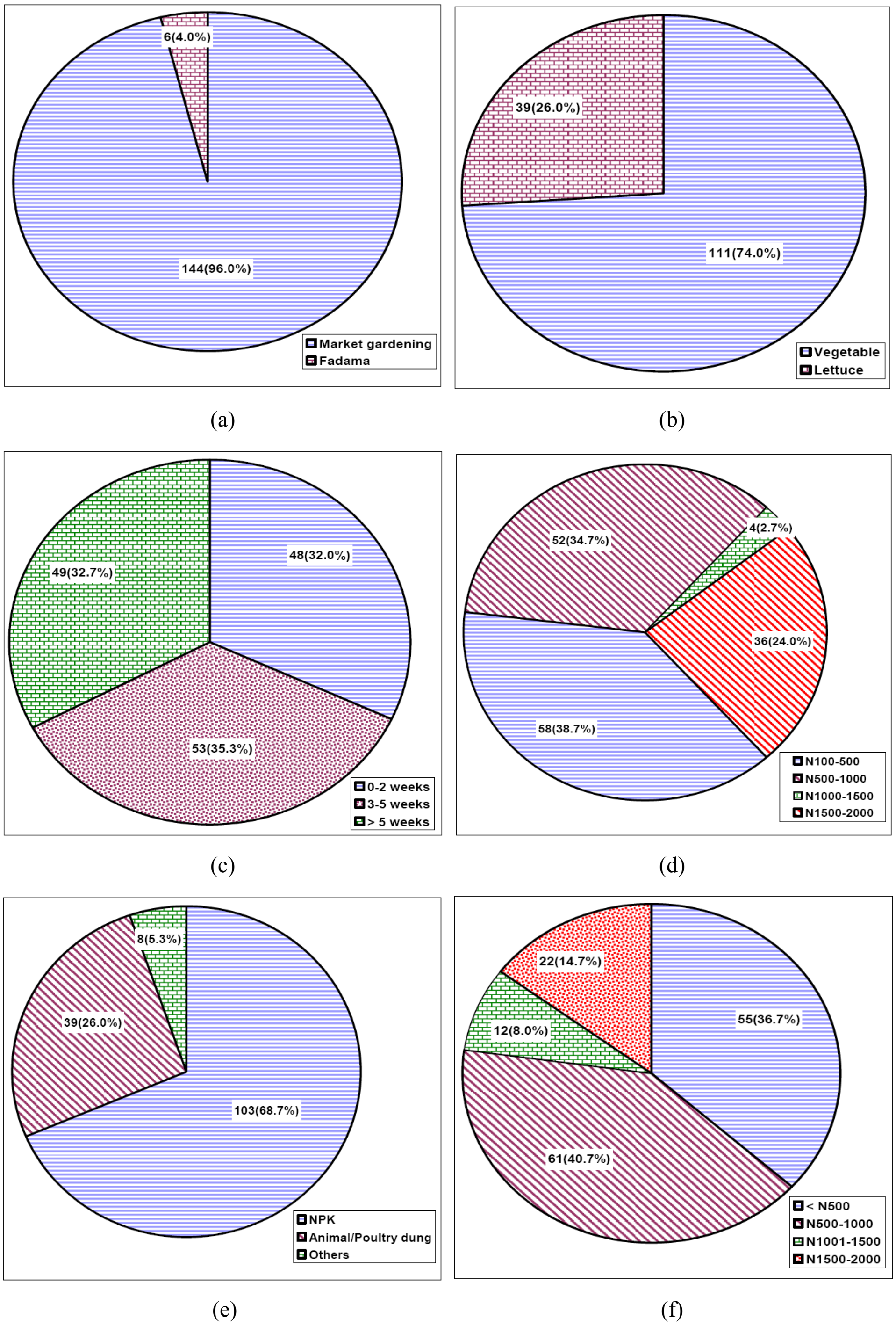
Statistics show that Nigeria is a literate country with an estimated adult literacy rate of about 56.9% with some variations among the states. For instance, Lagos accounts for about 92.0% compared to Borno state with only 14.5% adult literacy (UNESCO, 2012). Variations across the regions show that, the urban and rural areas are estimated at about 74.6% and 48.7% respectively. In terms of gender, the male and female represents 65.1% and 48.6%, respectively (UNESCO, 2012). In the study area, more than half of the urban farmers interviewed had primary school education, whereas; about 26.7% and 19.3% had a secondary and no formal education respectively. Thus, the literacy level of the urban farmers in the area serves as an impetus that will help equip the farmers with the knowledge, skills and attitudes needed for economic self-sufficiency, poverty reduction and sustainable development. The major occupation among the interviewed farmers shows that, more than three-quarter of the respondents are fully engaged in urban agriculture while 9.3% are not fully engaged in farming activity as their main occupation.

With respect to the income level of the urban farmers, the income shows that 46% of the farmers make below ₦1,000 per day while 38.7% earn between ₦1,000–₦5,000 per week while 15.3% make above ₦5,000 per month. Based on the current exchange rate of about ₦230.00 which is equivalent to US $1.00, a larger proportion of the farmers are generating below the poverty line income on a monthly basis. This has been reported by Rogerson (1993). Thus, it implies that most of the urban farmers in the study area only generate the minimum income required for the survival of their family.

4.1 Nature of urban farming

The nature of urban farming activities in the study area shows that, market gardening is the main type of farming, with about 96%, while only 4% of the farmers engaged in fadama farming [Figure 3(a)]. Similarly, the analysis of the crop types revealed that, about 74% of the farmers cultivate vegetable while the remaining 24% grow lettuce [Figure 3(b)]. The spatial variations across the study area indicate that, Lasu post service and Abule-Ado farm sites recorded the highest and the lowest proportion respectively. This variation further confirms the varied ethnic background in the study area since most Igbo's prefer the cultivation of fluted pumpkin *Telfairia occidentalis* unlike the Hausa's who prefers the cultivation of lettuce. The gestation period of the crops cultivated shows that almost three-quarters of the crops grown are matured for harvest within a month. The breakdown of this proportion indicates that, about 32% and 35.3% of the crops cultivated requires 0–2 and 3–5 weeks for maturation while the remaining 32.7% require above one month prior to harvesting [Figure 3(c)]. The cost of seed procurement shows that, about 38.7% of the farmers spend between ₦100–₦500 on seed. Approximately 34.7% of the farmers spend between ₦500–₦1,000 [Figure 3(d)]. This proportion shows that the cost implications of the purchase of seed are very low. However, it was observed that almost one-quarter of the farmers spend between ₦1,500–₦2,000. This amount is relatively high compared to the proportion of the farmers that make above ₦5,000/month. It could be inferred that this category of farmers relies on hybridised seeds from far locations in order to ensure optimum yield. Similarly, it can also be deduced that, this category of farmers represents those with secondary school education who have a better knowledge on the importance of quality seed in crop production.

Figure 3 (a) Type of farming (b) Type of crop (c) Duration of crop maturation (d) Cost of seedling (e) Type of fertiliser (f) Cost of fertiliser (see online version for colours)



Farmers' knowledge on the type of fertiliser for the cultivation of vegetable shows that, almost three-quarters of the farmer's uses nitrogen, phosphorus and potassium (NPK) fertiliser. Unlike animal/poultry dung, approximately 26% applies it for growing vegetable [Figure 3(e)]. With the cost of buying fertiliser, about 40.7% of the farmers spend between ₦500–1,000 for the purchase of fertiliser while 36.7% spend less than ₦500 [Figure 3(f)]. Though the cost incurred on the purchase of fertiliser per month is relatively low, this could be attributed to government's subsidy on the supply of fertiliser to farmers in the area. Further analysis revealed that, some 14.7% of the farmers spend between ₦1,500–2,000/month on fertiliser. This amount is relatively high based on the observation made in respect to cost expended on seed. Perhaps, it could be as a result of lack of access to the supply of fertiliser by this group of farmers' who have to buy from their counterpart's. Thus, the slight difference in the cost.

4.2 Nature of peri-urban farming activities

The nature of peri-urban farming activities in the study area shows that the farm size is predominantly below two plots (i.e. 120 m × 60 m) (Table 2). The dominant type of farm ownership is mainly free/inherited from parents while the incidence of pest on the farms account for about 90%. The measure of pest control shows that the majority of the farmers representing 84.75% applied garmalin-20 for the control of pests on their farms while some 15.3% of the farmers do not adopt any measure for pest the control.

Table 2 Basic farm operation characteristics

Variables	*n*	*(%)*
Farm size		
Below two plots	150	(100.0)
Type of ownership		
Free/inherited from parents	150	(100.0)
Incidence of pest		
Yes	135	(90.0)
No	15	(10.0)
Pest control method		
Use garmalin	127	(84.7)
None	23	(15.3)

4.3 Bivariate analysis of peri-urban farming variables

The relationship between gender of farmers and occupation showed a dependent relationship ($\chi^2 = 12.353$, p = .000). Males were the major urban farmers in the area. This result implies that urban farming as an occupation is dependent on gender (Table 3).

Table 3 Gender relationship with occupation of farmers

Variable	*Gender*	*Yes*	*No*	*Chi square (χ^2)*
Occupation	Male	118 (94.4)	7 (5.6)	$\chi^2 = 12.353$ p = .000
Female	18 (72.0)	7 (28.0)		

The chi-square analysis of the relationship of education and income of farmers indicate a dependent relationship between the educational status of farmers and their income ($\chi^2 = 30.479$, p = .000) (Table 4). This result shows that the farmer's income is dependent on educational status.

Table 4 Relationship of education and income of farmers

Variable	*Education*	*Supplement income*	*Subsistence*	*Commercial*	*Chi-square (χ^2)*
Income		Daily (< ₦1,000)	Weekly (₦1,000–₦5,000)	Monthly (> ₦5,000)	$\chi^2 = 30.479$ p = .000
	Primary	40 (49.4)	33 (40.7)	8 (9.9)	
	Secondary	8 (20.0)	17 (42.5)	15 (37.5)	
	No formal education	21 (72.4)	8 (27.6)	0 (0.0)	

Similarly, the chi-square test between educational status of farmers and the way they perceive the use of fertiliser showed a dependent relationship ($\chi^2 = 14.581$, p = .001) (Table 5). This result implies that education attainment is a major factor that may influence the knowledge of the application of fertiliser in crop cultivation.

Table 5 Relationship of education and farmer's perception about the use of fertiliser

Variable	*Education*	*Yes*	*No*	*Chi-square (χ^2)*
Fertiliser	Primary	76 (93.8)	5 (6.2)	$\chi^2 = 14.581$ p = .001
	Secondary	39 (97.5)	1 (2.5)	
	No formal education	21 (72.4)	8 (27.6)	

Further analysis on the relationship between the farm locations and cost incurred on seedling showed a dependent relationship ($\chi^2 = 25.26$, p = .000) (Table 6). Similarly, there is a dependent relationship between farm locations and cost of application of fertiliser ($\chi^2 = 26.64$, p = .000) (Table 6). The analysis revealed that, the spatial location of the farm site has influence on the cost of seed/fertiliser.

Table 6 Relationship of farm locations and cost of seed and fertiliser procurement

Seedling	*Location*	*100–500*	*500–1,000*	*1,000–1,500*	*1,500–2,000*	*Chi-square (χ^2)*
	Ojo	41 (38.8)	31 (29.0)	0 (0.0)	35 (32.7)	$\chi^2 = 25.26$ p = .000
	Amuwo-Odofin	17 (39.5)	21 (48.8)	4 (9.3)	1 (2.3)	
Fertiliser	*Location*	*<500*	*500–1,000*	*1,001–1,500*	*1,500–2,000*	*Chi-square (χ^2)*
	Ojo	48 (44.9)	31 (29.0)	7 (6.5)	21 (19.6)	$\chi^2 = 26.64$ p = .000
	Amuwo-Odofin	7 (16.3)	30 (69.8)	5 (11.6)	1 (2.3)	

4.4 Contribution of urban agriculture

The benefits accrued from urban farming show those family members of the urban farmers representing 61.3% benefitted directly from the farming activity, whereas 36.7% and 2% of the buyers and others claimed direct benefit respectively (Table 7). In respect to the contribution of urban agriculture, about 72% of the farmers asserts that, urban agriculture plays a major role in the survival of their household. In addition, some 17.3% claimed urban agriculture serve as a source of employment while 5.3% each confirms that it supplement income and also support food security (Table 8). In terms of the support farmers required from government to enhance their farming activities, the support range from financial assistance, provision of fertiliser and farmland in the order of 46.7%, 45.3% and 8% respectively (Table 9). The result revealed that, financial assistance and the provision of fertiliser constitute the major support the farmers required from the government. The low proportion of farmers requesting for farmland from government further supports the findings that majority of the farmers either got the farmland free or inherited it from their parents or family. Though 100% of the farmers claimed to have obtained the farmland free or inherited it from their parents. This does not preclude that some token amount in the form of rent will not be made by the farmer. Hence, it is assumed that the proportion of farmers in this category constitutes the small fractions of the farmers that required government assistance in respect of farmland.

Table 7 Direct beneficiary from urban agriculture

Variables	*n*	*(%)*
Family	92	(61.3)
Buyers	55	(36.7)
Others	3	(2.0)

Table 8 Contribution of urban agriculture

Variables	*n*	*(%)*
Play a major role in household survival	108	(72.0)
Supplement income	8	(5.3)
Supports food security	8	(5.3)
Source of employment	26	(17.3)

Table 9 Support required from the government

Variable	*n*	*(%)*
Financial assistance	70	(46.7)
Provision of fertiliser	68	(45.3)
Provision of farm land	12	(8.0)

4.5 Physico-chemical parameters of shallow well water

The level of detection and the descriptive statistics of the physico-chemical parameters of shallow well water is presented in Table 10. The result shows that the physico-chemical parameters: pH, EC and TDS varied between 7.2 and 7.8, 80 and 774 μScm^{-1} and

53.3 and 518 mg/l respectively. The corresponding mean values are in the order of 7.5, 302.9 μScm^{-1} and 202.4 mg/L^{-1} respectively. The coefficient of variation (%) indicate that, aside from pH, EC and TDS are heterogeneous in nature. Thus, the need for routine monitoring of these two parameters based on their wide variability. The spatial variations of EC and TDS indicate that about 33.3% of the sample locations each exceeded the mean value at locations G_4, G_6–G_7, G_9 and G_{11}. The relatively high concentration of EC and TDS in these locations might result from the leaching of organic and inorganic fertiliser that is used for the cultivation of vegetable at the various farm sites.

Table 10 Level of parameter detection and descriptive statistics of shallow well water quality

Code	*pH*	*EC*	*TDS*	Ca^{2+}	Mg^{2+}	Na^{2+}	K^+	HCO_3^-	SO_4^{2-}	CO_3^-	Cl^-
G_1	7.51	221	146	40	12	3.01	1.7	4	6	10	32
G_2	7.57	202	135	24	8	2.52	1.28	2	6	12	20
G_3	7.34	227	150	38	14	2.96	1.42	6	7	14	26
G_4	7.41	365	244	54	22	4.52	2.65	4	8	10	40
G_5	7.3	198.9	133.1	22	10	2.16	1.17	4	6	14	28
G_6	7.46	391	263	62	18	6.34	2.51	3	10	8	46
G_7	7.75	704	471	52	20	9.08	4.29	4	20	16	38
G_8	7.46	231	155	38	12	3.16	1.86	2	7	10	36
G_9	7.57	774	518	64	16	12.15	3.29	4	16	10	50
G_{10}	7.7	234	156	44	16	2.98	1.17	6	6	14	40
G_{11}	7.59	312	208	46	14	3.72	1.56	4	8	12	28
G_{12}	7.31	193.7	129.7	14	6	2.28	0.91	2	7	8	20
G_{13}	7.43	213	142	26	12	2.39	0.92	2	8	10	18
G_{14}	7.21	196.7	131.8	18	8	1.89	0.65	6	8	14	22
G_{15}	7.17	80	53.3	10	4	0.56	0.18	4	3	6	8
Mean	7.5	302.9	202.4	36.8	12.8	3.9	1.7	3.8	8.4	11.2	30.1
Min	7.2	80	53.3	10	4	0.6	0.2	2	3	6	8
Max	7.8	774	518	64	22	12.2	4.3	6	20	16	50
C.V(%)	2.3	63.6	63.7	46.7	39.9	76.3	63.3	37.5	50.7	25.1	38.4

Notes: Min – minimum, Max – maximum, C.V – co-efficient of variation

pH is an indicator of the degree of acidity or basicity of the water. The benchmark for pH of irrigation water is between 6.5 to 8.4 (Sarkar and Hassan, 2006). Studies have shown that, value above this range may be toxic or cause nutritional imbalance in soil or plants. It may also affect irrigation equipment. The pH values in the study area are within the permissible guideline for irrigation. Similar findings by various authors have been reported to be within the prescribed guideline for crop cultivation (Khan et al., 1989; Zaman and Mohiuddin, 1995). The EC is an indicator of salinity. Salinity usually result from high quantity of salts in the irrigation water, especially in the crop root zone. It has an effect on crop yield, slow growth and also pose difficulty to plants in extracting adequate water from the soil. Prolonged salinity has also been reported to cause crusting of seed beds, excessive weeds, drowning of the crops, rotting of seeds and poor crop stand (Ayers and Westcot, 1976). TDS is also an indicator of the build up of salt in soil after irrigation. An increase in the concentration of TDS reduces plant growth and crop yield as a result of increase in osmotic potential of the soil solution, thus resulting in stunted growth and huge losses in crop yield (Hussain et al., 2010).

4.6 The characteristics of the cations in shallow well

The major cations Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} varied between 10 and 64, 4 and 22, 0.6 and 12.2, 0.2 and 4.3 mg/L^{-1} while the mean value are in the order of 36.8, 12.8, 3.9, and 1.7 mg/L^{-1} respectively (Table 9). The C.V (%) indicates that all the cations are homogeneous in nature except for Na^{+} and K^{+} ions that shows wide variability .These parameters require routine monitoring to reduce or control its effects on plants and the soil. Studies have shown that, large concentration of sodium with carbonate, chloride or sulphate results in alkali and saline soils respectively (Sarkar and Hassan, 2006). The presence of high Na^{+} and its reaction with the soil reduces soil permeability leading to the development of alkali soil. In addition, the presence of Ca^{2+}/Mg^{2+} salt in irrigation water retards the effects of Na+ therefore, increasing the soil's permeability (Sarkar and Hassan, 2006). The presence of Na+ in irrigation water also enhances soil dispersion and consequently the structural breakdown of the soil. Imbalance in the concentration of calcium and magnesium irrigation water quality may also result to toxic symptoms while high concentrations of potassium can result in the deficiency of magnesium and iron.

4.7 The characteristics of the anions in shallow well water

The major anions HCO_3^{-}, SO_4^{2-}, CO_3^{-} and Cl^{-} ranged from 2 and 6, 3 and 20, 6 and 16 and 8 and 50 mg/L^{-1} respectively. The corresponding mean value is; 3.8, 8.4, 11.2 and 30.1 mg/L^{-1}. The C.V shows that all the parameters are homogeneous with the exception of SO_4^{2-} that is slightly variable in the study area. Sarkar and Hassan (2006) reported that irrigation water rich in bicarbonate results in precipitation of insoluble calcium and magnesium leaving behind higher sodium proportion with an increase in the SAR value in the soil. Similarly, bicarbonate if present in large quantity may affect irrigation water with significant implication on the uptake and metabolism of nutrients. The presence of sulphate salts in irrigation water limits the uptake of calcium and increase the absorption of sodium and potassium, thus resulting in the disturbance in the cationic balance of the plant. Chloride toxicity is also a major problem with irrigation water quality. Usually, chloride is not adsorbed or held back by soils, thus, it moves readily with the soil-water. Once the concentration of chloride exceeds the tolerance of the crop, it results to leaf burn or drying of leaf tissue (Ayers and Westcot, 1976).

4.8 Assessment of irrigation water quality

The variation in the Kelly ratio irrigation index is presented in Figure 4. The KR index ranged from 0.03 and 0.12 meq/L with a mean value of 0.06 meq/L. The mean value exceeded the computed KR in about 20% of the sample locations at G_7, G_9 and G_{12}. Though, the computed KR index is within the maximum permissible guideline of 1.0 meq/L for irrigation purpose (Kelly, 1963). Again, proper monitoring of Na^{+}, Ca^{2+} and Mg^{2+} ions in the study area is required so as to eliminate soil permeability problem (Sarkar and Hassan, 2006).

Figure 4 Computed Kelly ratio in the study area (see online version for colours)

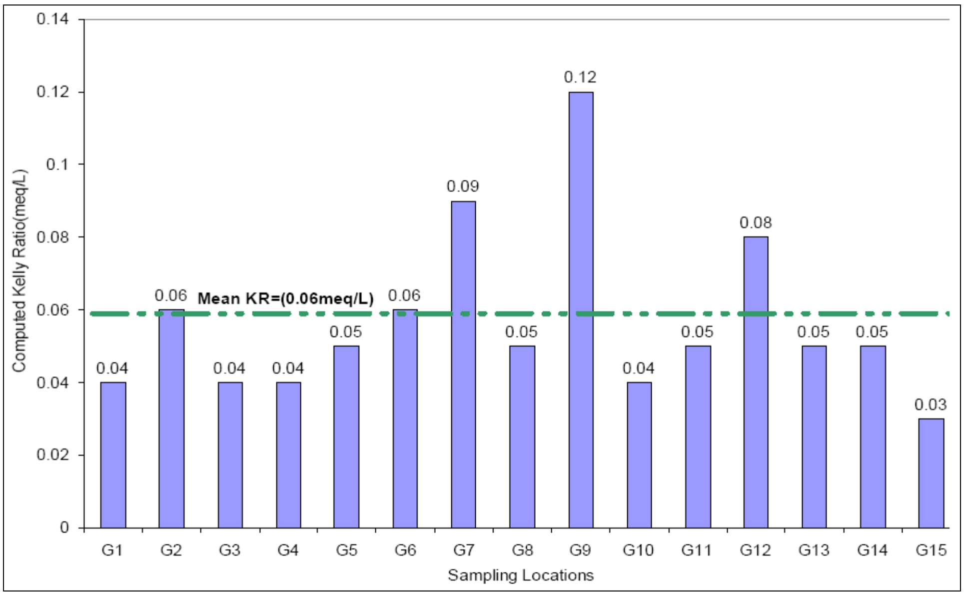
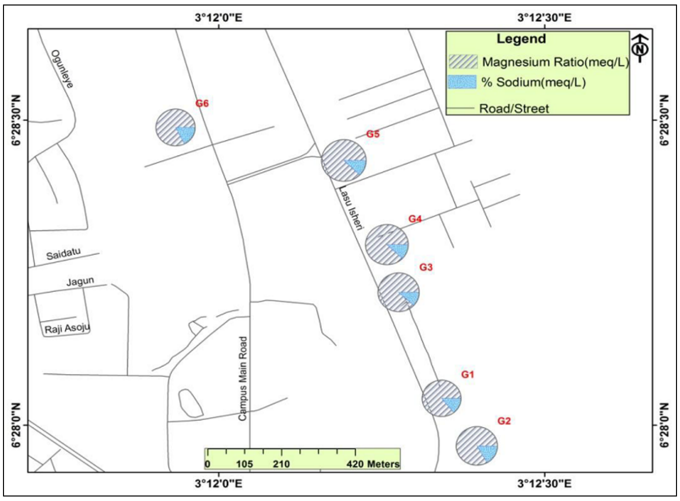


Figure 5(a) shows the spatial variations of magnesium ratio and % sodium in Ojo LGA. The MR varied from 32.38 and 42.83 meq/L while % Na ranged from 5.14 and 7.12 meq/L. The corresponding mean values are 36.96 and 6.05 meq/L. Sarkar and Hassan (2006) and Mridha et al. (1996) reported a low Kelly ratio around the Pabna district in the Ganges River floodplain and inferred that the examined irrigation water quality is suitable for crop cultivation. The computed value of MR and %Na indices exceeded the mean value of MR and %Na in about 50% and 33.3% from locations G_3–G_5 and G_2 and G_6 respectively.

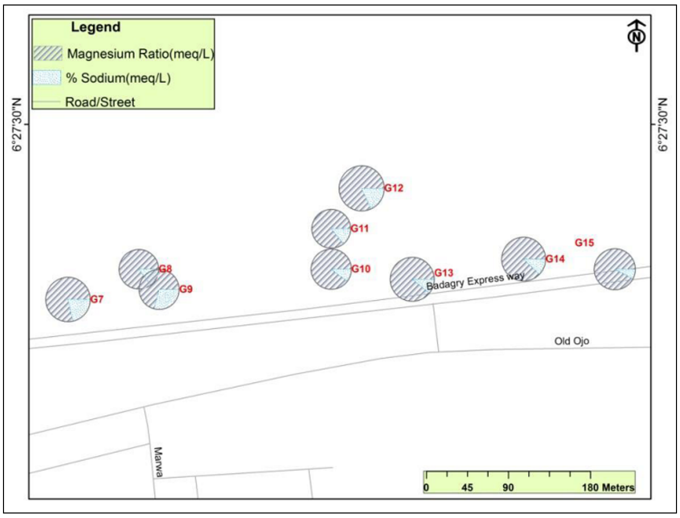
Unlike the variations of magnesium ratio and % sodium in Amuwo-Odofin LGA, magnesium ratio ranged from 29.19 and 43.21 meq/L while %Na is between 3.38 and 11.96 meq/L. The mean values are 37.76 and 6.94 meq/L respectively [Figure 5(b)]. About five sample locations representing 55.6% from G_7, G_{12}–G_{15} had their mean value above the computed MR while approximately 33.3% of the sample locations from G_7, G_9 and G_{12} had their mean value above the computed %Na in the area.

Szabolcs and Darab (1964) suggested that MR value above 50meq/L is harmful and unsuitable for irrigation because it adversely affects crop yields. Despite the low MR in the study area, routine monitoring of magnesium and calcium ions are necessary in some of the shallow wells, especially in Amuwo-Odofin LGA in order enhance optimum crop yield. Rao et al. (2012) argued that high concentration of Mg^{2+} and Na^{+} in irrigation water damage soil structure with significant effect on crop yield. Similarly, irrigation water requirement based on %Na is considered unfit if it exceeds 60 meq/L. The result shows that, the computed %Na index are within the maximum guideline for irrigation in the study area. However, some of the shallow wells have a relatively high value above the mean value. Therefore, adequate and proper monitoring with respect to Na^{+}, K^{+}, Ca^{2+} and Mg^{2+} in the study area.

Figure 5 (a) Spatial variations of magnesium ratio and percent sodium, Ojo LGA
(b) Spatial variations of magnesium ratio and percent sodium, Amuwo-Odofin LGA
(see online version for colours)



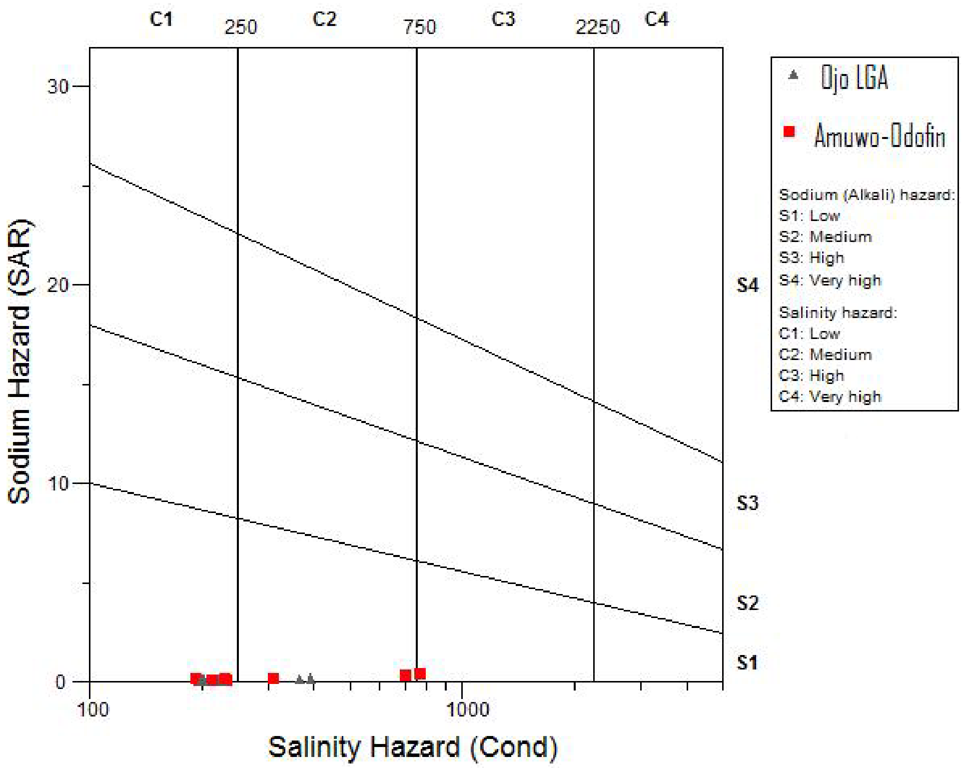
(a)



(b)

The sodium and salinity hazard were assessed using the USSL (1954) technique. The classification scheme classified sodium hazard (S) into four sub-zones as; low-sodium hazard (S1, <10), medium-sodium hazard (S2, 10 to 18), high-sodium hazard (S3, 18 to 26), and very-high sodium hazard (S4, >26), representing good, moderate, poor, and very poor irrigation water quality respectively. Similarly, the salinity hazard (C) was divided into four sub-zones given as: low salinity hazard (C1, <250 μS/cm), medium-salinity hazard (C2, 250 to 750 μS/cm), high-salinity hazard (C3, 750 to 2,250 μS/cm), and very-high-salinity hazard (C4, >2,250 μS/cm) corresponding to good, moderate, poor, and very poor water classes respectively. SAR is an important index for the determination of irrigation water quality for crop production. The computed SAR varied between 0.05 and 0.5 meq/L with a mean value of 0.19 meq/L. The spatial pattern of salinity and sodium hazard in the study area is shown in Figure 6. The pattern indicates that, approximately 66.7% of the shallow wells from locations G_1 to G_3, G_5, G_8, G_{10}, and G_{12}–G_{15} fall within zone C1 (low salinity) whereas about 26.7% and 6.7% belong to zone C2 (medium salinity) and C3 (high salinity) respectively. Generally, the computed SAR shows that all the samples are suitable for irrigation purpose. However, the mean values of samples from locations G_6, G_7 and G_9 exceeded the computed SAR index in about 20% in the study area. High SAR affects the rate of infiltration of water. A study carried out by Sarkar and Hassan (2006) shows that SAR of the irrigation water quality is suitable for crop cultivation.

Figure 6 Spatial pattern of salinity and sodium hazard in the study area (see online version for colours)



5 Conclusions

The social survey on peri-urban agriculture in the study area shows that the male are more actively engaged in peri-urban farming. The pattern of ethnic background indicates that, the Igbos are the predominant ethnic type. The income level of the urban farmers, reveals that, they only generate the minimum earning required for the survival of their family. Farmers' knowledge on the application of fertiliser for crop cultivation shows that, almost three-quarters of the farmers uses NPK fertiliser. Significant relationship were found between gender of farmers and occupation, education and income of farmers, educational status of farmers and their perception on the use of fertiliser, farm locations and cost incurred on seedling/cost of fertiliser at p = .000. The CV indicates that all the measured parameters except pH, EC and TDS are heterogeneous in nature. The EC and TDS exceeded the mean value in about 33.3% each of the sample locations. The mean value of HCO_3^-, Ca^{2+}, pH, $Mg^{2+}/CO_3^-/Cl^-$, EC, TDS/Na^{2+}/K^+ and SO_4^{2+} exceeded their detection level in about 66.7%, 60%, 53.3%, 46.7%, 40%, 33.3% and 20% respectively. This suggests that the water quality is gradually deteriorating hence; adequate protection must be put in place to check the rate of water quality deterioration. In addition, application of organic and inorganic fertiliser, insecticides/pesticides should be monitored to avoid runoff into the shallow wells used for irrigation.

Kelly ratio varies from 0.03 to 0.12 meq/L with a mean value above the computed KR in about 20%. Magnesium ratio, percent sodium exceeded the mean value in about 50% and 33.3% respectively in Ojo. Unlike Amuwo-Odofin, it is about 55.6% and 33.3%, respectively. The spatial pattern of salinity and sodium hazard shows that about 66.7%, 26.7% and 6.7% of the shallow wells are low, medium and high salinity respectively. This implies that the CA, Mg, and Na are relatively higher compared to other parameters in the study area.

Thus, there is a need for proper monitoring of fertiliser to check the level of dissolved salts in the soil. The paper concluded that the computed irrigation water quality indices of the study area are suitable for crop cultivation. The paper suggested the need for government to encourage urban farmers by assisting them in the provision of farm inputs at very subsidised rates. Also, periodic monitoring of irrigation water quality testing and runoff control technique to check the washing away of fertiliser, and insecticides/pesticides into water bodies were also recommended. Policy wise, government should regulate urban agricultural activities, access to land and water resources and put in place measures that will protect pollution of water sources to ensure the sustainability of these vital resources.

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