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Evaluation of Maize (*Zea mays*) Growth on Arable Soils Proximal To Gas Flaring Site in Egbema, Imo State, Southeastern Nigeria

Research Article

Nwagbara MO*, Irondi OA

Department of Soil Science and Meteorology, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria

***Corresponding author:** Moses O Nwagbara, Department of Soil Science and Meteorology, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria; E-mail: monwagbara@yahoo.com

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Abstract

The effects of gas flaring on arable soils and growth indices of maize (*Zea mays*) in Egbema were examined. A purposive transect sampling technique at marked distances (10m, 50m, 100m, 200m and control 40km) away from a flare site was used. Soil samples were collected from five marked distances at 0 -15cm and 15 – 30cm depths while part of the 0 – 15cm samples was used for maize poly-bag test crop experiment. Oba Super maize hybrid was used as planting material using RCBD replicated thrice. Results gave mean values of 0.66, 1.06, 1.46, 1.79, and 2.66 for emergence rate; 3.37cm, 4.85cm, 9.97cm, 8.09cm and 13.12cm for maize height; and 1.69cm2, 2.75cm2 3.07cm2, 4.06cm2 and 11.33cm2 for leaf area at 10m, 50m, 100m, 200m and 40km respectively. ANOVA was employed for statistical data analysis. Maize growth parameters at 10m, 50m, 100m, and 200m showed a decrease trend of data at closer distance to the flare, which could be as a result of increase in soil temperature and reduced soil moisture at the flare site. The control (40km away), showed increase data in all the parameters monitored. For increased growth and yield, maize plots should be sited at least 30km away from gas flaring sites.

Keywords: Gas flaring; Arable soils; Maize; Growth indices; Flare site

Introduction

Gas flaring, which is a means of safely disposing of waste gases through the use of combustion [1], is a common sight in the Niger Delta Region of Nigeria. This is the crude oil and natural gas producing region of the country. Here, gas flaring involves the use of open flare (both horizontal and vertical) to burn off unwanted associated gas that are extracted from the earth along with the crude [2]. An open flare is a type of flare that emits direct flames, thereby increasing thermal radiation to the surrounding community. The flares associated with gas flaring give rise to atmospheric contaminants which return to the earth as dry deposits or via acid rain. These contaminants include oxides of Nitrogen, Carbon and Sulphur (NO_2, CO_2, CO, SO_2), particulate matter, hydrocarbons and ash, photochemical oxidants, and hydrogen sulphide (H_2S) [3-5]. Acid rain is formed when sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) combine with atmospheric moisture to form sulphuric oxide and nitric oxide respectively. The contaminants and acid rain acidify the soil, hence depleting soil nutrient. It has been found out that the nutritional values of crops which are proximal to gas flaring sites are reduced [6]. In some cases, there is no vegetation in the areas surrounding the flare due partly to the tremendous heat that is produced and acidic nature of the soil [7]. Also, gas flaring has been confirmed to have raised the average global temperature by about 0.5 $^{\circ}$C in the last century [8,9]. Acid deposition and intense heat from gas flares are known to have deleterious effects on the fertility and productivity of the surrounding soils at gas flare sites. The obvious signs of these can be noticed in the poor vegetation growth and scorched soils around the sites. There could be about 100% loss in yield of crops cultivated 200m away from the flares, 40% loss in yield of crops at 600m away and 10% loss in yield for crops planted 1000m away [10].

Population growth in developing countries is driving a rapid increase in the demand for food and fibre. At the same time, rising population density in rural areas and increased demand on lands with arable soils for industrial activities have diminished farm size. Arable land is land under temporary crops cultivation, or land under permanent crops and is replanted after each harvest [11].

Maize (*Zea mays* L.) belongs to the Family *Poaceae* and is utilized worldwide for both industrial and food purposes. It is also a very important food grain for humans and animals [12]. About half of global maize production is grown in developing countries, where maize flour is a stable food for poor people and maize stalks provide dry season feed for farm animals [13]. In industrial countries, maize is largely used as livestock feeds and raw materials for industrial products. In sub-Saharan Africa, maize is a staple food for an estimated 50% of the population and provides 50% of the basic calories [13]. It is an important source of carbohydrate, protein, iron, vitamin B and minerals. Maize is the third most important cereal crop following wheat and rice in the world production of cereals [14]. Also, it is one of the major staples consumed in Nigeria [15]. It has a lot of industrial uses including its use as feed for domestic animals. In Nigeria, it is grown in most ecological areas especially in the Niger Delta region where oil exploration and industrial activities are predominant [16-19].

From the foregoing, gas flaring adversely affects the environment. Equally, maize is an important crop of the people of the Niger Delta Region of Nigeria. However, there is paucity of information on the effects of gas flaring on growth rate and yield attributes of maize planted proximal to gas flaring site in Egbema, a community in the Niger Delta Region of Nigeria. This study therefore aims at evaluating the growth performance of maize in arable soils proximal to a gas flaring site in Egbema, Imo state, Southeastern Nigeria.

Materials and Methods

Study Area

Soil samples were collected from the vicinity of Assa-Egbema horizontal flare jet and Awara-Egbema (control) much outside the flare jet (40km away), both in Egbema Community of Imo State Southeastern Nigeria which lies between latitudes 5˚14'N and 5˚35'N and longitudes 6˚25'E and 7˚6'E. The area has an annual rainfall total which ranges from 2250 mm and the annual mean temperature is about 27.0 ˚C Soil types are ultisol (USDA Soil Classification) derived from coastal plain sand [20]. The geological material is coastal plain sands (Benin formation). The area is generally low-lying with an altitude of 50 m above sea level. It is of Rainforest vegetation and Humid Tropical climate. The area is not rich in nutrient due to high rainfall that promotes leaching of basic ions away from the reach of plants into deeper horizons. The land is a rich source of mineral deposits such as crude oil and natural gas, which makes part of the area a gas flaring zone. Agriculture constitutes a major socio-economic activity in the area with the continuous planting of cassava (*Manihot esculenta*) and maize (*Zea mays*) as well as oil palm (*Elaeis guinaensis*). Also, many youths are engaged as workers, though mostly casuals, with multinational oil companies in the host community.

Sample Collection and Preparation

A transect sample technique was employed in sample collection. Soil samples were collected from different location points marked as A, B, C, D within the horizontal flare jet and point E (control) much outside the flare vicinity at distances of 10m, 50m, 100m, 200m and 40km respectively away from the bound wall of the flare jet. This means ten (10) representative sample spots. The control, which is about 4km away from the flare site, was chosen because [21] noted that the impact of gas flaring on soil and atmospheric quality is statistically insignificant beyond 15km and 20km radius of the flare site. Samples were collected from 0-15cm topsoil and 15- 30cm subsoil depths. The samples were bagged in a polythene bags and labelled appropriately against each spot of collection. Samples were air-dried for five days at room temperature and later sieved using 2mm mesh prior to laboratory analysis. Part of the 0 -15cm samples was used for planting maize (*Zea mays*) pot experiment. This depth was chosen because that is the main root zone of maize crops [22].

Laboratory Analysis

The prepared samples from 0-15cm topsoil and 15- 30cm subsoil depths were analyzed for selected physico-chemical properties of the soil. They were analyzed using notable standard procedures as found in [23] as follows:

Soil temperature was determined by immersing the bulb of mercury-in-glass thermometer into the marked distances (i.e. 10m, 50m, 100m, 200m and 40km) and depths (0-15cm and 15-30cm) in-situ for three minutes each and readings (in °C) taking appropriately. Particle size analysis was determined using Bouyoucous hydrometer method according to the procedure of [24] where sodium hexametaphosphate (calgon) solution was used as a dispersing agent. Bulk Density estimated using determined in undisturbed cone by the method described by [25] and was calculated thus:

$$eb = \frac{Ms}{Vt}$$

$$\%\,BS = \frac{TEB}{ECEC}\ x\,\frac{100}{1}$$

Where:

$eb = Bulk\ density$

$Ms = Mass\ of\ oven\ dried\ soil\ (g)$

$Vt = Totoal\ soil\ volume\ (cm3)\ assumed\ to\ be\ equal\ to\ volume\ of\ cylinder\ cal.from:$

$$Vt = \pi x^2 h$$

Total porosity was calculated from the result of bulk density and particle density as follows:

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$$Total\ porosity, F = \frac{1 - eb}{es} \ x \frac{100}{1}$$

Where:

$F = Total\ porosit$

$eb = Bulk\ density$

$es = Particle\ density\ (Assumed\ to\ be\ 2,65g/cm_3)$

The moisture content was determined by gravimetric method as

$$\%\ Moisture\ Content\ (MC) = W2 - \frac{W3}{W3} - W2\ x\ \frac{100}{1}$$

Where:

$W1 = Weight\ of\ core\ ring$

$W2 = Weight\ of\ sample\ and\ core\ ring$

$W3 = Weight\ of\ oven\ dried\ soil$

The soil pH was determined in a suspension of soil/water of 1:25 and was measured using a glass electrode pH meter as was described by [26]. Organic carbon was determined by the method of wet oxidation according to [27]. Organic matter was determined by multiplying organic carbon with Van Bemmelen factor of 1.724. Available Phosphorus was determined using Bray II extraction method. Total nitrogen was determined using the modified micro-Kjedahl digestion method [28]. The exchangeable bases were determined from ammonium acetate (NH_4OAc) leachate of the soil [29]. Exchangeable calcium and magnesium were determined by the EDTA (Ethylene Di Amine Tetra-acetic Acid) versanate titration method. Exchangeable sodium and potassium were determined by the flame photometer method [30]. Exchangeable acidity (Al^{3+} + H^{+}) were determined by leaching the soil with 1NKCl and titrating with 0.05NaOH [26]. Exchangeable Cation Exchange Capacity was determined by the summation of the total exchangeable bases (TEB) and total exchangeable acidity (TEA). It is expressed in meq/100g soil. Percentage Base Saturation was calculated thus:

$$\%\ BS = \frac{TEB}{ECEC}\ x \frac{100}{1}$$

Where:

$BS = Base\ Saturation$

$TEB = Total\ Exchangeable\ Bases$

$ECEC = Exchangeable\ Cation\ Exchange\ Capacity$

Data Presentation and Analysis

Data collected were analyzed and presented in tables and charts. Analysis of variance (ANOVA) was employed in data analysis and means for statistical significance were separated using least significance difference at 5% probability level according to [30,31].

Results and Discussion

Results of the physical and chemical laboratory analyses of the soil samples are shown in Tables 1 and 2. In Table 1, sand content (94.24%) increased towards the flare, which may be due to low organic matter content of soils close to the flare site and/or due to the nature of Southeastern Nigerian soils [32]. The observed decreased values of silt (3.64%) and clay content (2.12%) in Table 1 closer the flare could be as a result of acidic by-products of gas flaring like soot, dry deposition and acid rain.

The observed decrease in soil temperatures (56 °C, 43.5 °C, 41 °C

Table 1: Soil Physical Properties.

Sample ID	Depth (cm)	Bulk Density (g/cm³)	Porosity (%)	ST (°C)	MC (%)	Mechanical Analysis %Sand	%Silt	%Clay	Silt/Clay Ratio	TC
10m	0 - 30	1.37 (0.01)	48.29 (1.75)	56 (2.00)	2.85 (0.11)	94.24 (2.43)	3.64 (0.11)	2.12 (0.18)	1.39 (0.14)	Sand
50m	0 - 30	1.34 (0.02)	49.62 (2.11)	43.5 (1.80)	5.00 (2.52)	92.68 (3.09)	2.82 (0.07)	2.18 (0.19)	1.06 (0.25)	Sand
100m	0 - 30	1.32 (0.03)	50.18 (3.08)	41 (2.08)	5.50 (0.63)	91.68 (1.91)	6.32 (0.22)	2.00 (0.21)	13.54 (0.27)	Sand
200m	0 - 30	1.29 (0.02)	51.94 (3.36)	34 (2.00)	5.68 (1.07)	88.18 (1.66)	10.48 (0.30)	1.34 (0.14)	7.39 (0.33)	Sandy Loam
40km (Control)	0 - 30	1.21 (0.04)	54.53 (1.82)	27 (1.00)	6.42 (1.79)	79.74 (1.72)	3.50 (0.25)	16.76 (0.21)	0.21 (0.23)	Loamy Sand

Key: BD = Bulk Density, MC = Moisture Content, ST = Soil Temperature, TC = Textural Class, Values in Bracket = Standard Deviation

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Table 2: Soil Chemical Properties.

Sample ID	Depth	pH		OC	OM	TN	Av. P	Exch. Bases (Meq/100g)				TEB	Exch. Acidity		C/N	ECEC	%BS
	(cm)	H20	Kcl	(%)		(%)		Ca	Mg	K	Na	(Cmol/kg)	H^+	Al^{3-}	Ratio		
10m	0 – 30	4.84 (0.38)	4.16 (0.11)	0.42 (0.03)	0.82 (0.36)	0.38 (0.18)	0.38 (0.21)	0.03 (0.04)	0.02 (0.04)	0.03 (0.03)	0.08 (0.02)	0.12 (0.12)	0.37 (0.03)	-	1.24 (0.03)	0.66 (0.33)	34.8 (0.34)
50m	0 – 30	4.95 (0.46)	3.33 (0.25)	0.69 (0.11)	1.18 (0.24)	0.49 (0.26)	0.67 (0.21)	0.05 (0.04)	0.05 (0.03)	0.05 (0.04)	0.08 (0.03)	0.22 (0.04)	0.37 (0.05)	-	1.41 (0.28)	0.59 (0.30)	37.2 (0.31)
100m	0 – 30	5.71 (0.15)	4.43 (0.24)	0.98 (0.45)	1.46 (0.32)	1.06 (0.25)	1.24 (0.25)	0.10 (0.17)	0.02 (0.03)	0.04 (0.02)	0.03 (0.03)	0.37 (0.03)	0.38 (0.05)	-	0.92 (0.44)	0.59 (0.20)	39.9 (0.38)
200m	0 – 30	5.79 (0.18)	4.39 (0.19)	0.96 (0.04)	1.65 (0.23)	0.94 (0.25)	1.36 (0.27)	0.08 (0.03)	0.05 (0.01)	0.06 (0.03)	0.03 (0.04)	0.31 (0.05)	0.37 (0.18)	-	1.04 (0.04)	0.67 (0.30)	43.0 (2.00)
40km (Control)	0 – 30	6.25 (0.17	5.17 (0.24)	4.25 (0.20)	7.33 (0.32)	1.04 (0.27)	1.80 (0.17)	0.61 (0.23)	0.61 (0.24)	0.46 (0.35)	0.19 (0.23)	3.45 (0.35)	1.25 (0.23)	-	3.79 (0.25)	4.70 (0.36)	73.1 (4.03)

Key: OC = Organic carbon, TN = Total Nitrogen, C/N Ratio = Carbon/Nitrogen Ratio, TEB = Total Exchangeable Bases, Av. P = Available Phosphorus, TEA = Total Exchangeable Acidity, BS = Base Saturation, pH = PondusHydrogenum, ECEC = Effective Cation Exchange Capacity, Values in Bracket = Standard Deviation

Table 3: Effects of five Distances away from a Flare Site on Maize Emergence Rate.

	% Emergence/Days after Planting (DAP)					
Distance	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Mean**
10m	0	0	0.66	1.00	1.66	0.66
50m	0^{NS}	0.33^{NS}	1.33^{NS}	1.66^{NS}	2.00^{NS}	1.06
100m	0.33^{NS}	0.66^{NS}	0.66^{NS}	2.00^{NS}	2.66^{NS}	1.46
200m	66^{NS}	1.00^{NS}	2.00^{NS}	2.33^{NS}	3.00^{NS}	1.76
40km (control)	1.66*	2.66*	3.00*	3.00^{NS}	3.00^{NS}	2.66
SD	0.688	1.036	0.992	0.745	0.607	
LSD (0.05)	0.66*	1.50	0.89	1.11	0.56	

* = Significant at p (0.05), ^{NS} = not significant at p (0.05), SD = Standard Deviation

and 34 °C) at 10m, 50m, 100m, and 200m respectively, away from the flare (Table 1) could be due to the burning of crude oil products via gas flaring. This activity might have increased the temperature of the surrounding soils. The increased mean bulk densities closer the flare (1.37g/cm^3, 1.34g/cm^3, 1.32g/cm^3, 1.29g/cm^3) for 10m, 50m, 100m and 200m respectively as shown in Table 1, could be attributed to heat radiated from the flare, thus resulting to soil compaction, and decreased organic matter content of the soils in the flare site. This agrees with the findings of [33], which states that bulk density decreases with increase in organic matter of the soil. Also, the decrease in moisture content, 2.85%, 5.00%, 5.50%, and 5.68% for 10m, 50m, 100m, and 200m respectively, closer the flare site could be due to heat radiated by the flare. This observation is in line with the studies of [34], which showed that the heat generated by the flare increased evaporation rate in soils closer to the flare sites. Hence, the decrease in soil moisture content close to the flare whereas the control (6.42%) increased (Table 1). Porosity also decreased with distance towards the flare site: 48.29%, 49.62%, 50.18% and 51.94% for 10m, 50m, 100m, and 200m respectively. This is attributable to the high bulk density and decreased organic matter content closer the flare site as when compared with that of the control (54.53%).

Table 2 shows that the low pH values of 4.84, 4.95, 5.71, and 5.79 at 10m, 50m 100m and 200m respectively, away from the flare site could be due to acidic products of gas flaring deposited on the soil via acid rain. This observation is in line with the studies of [1], which found out that gas flaring releases acidifying substances such as soot particles and H_2S which cause a decrease in soil pH giving rise to increased soil acidity whereas the control, 40km away has a pH value of 6.25. The observed lower values of organic carbon (0.42%) and organic matter (0.82) at 10 m away from the flare site could be attributed to the excessive heat that either kills or scares away most of the micro and macro organisms that help to improve the soil fertility and soil processes through breaking down of the soil particles, decaying and decomposition of organic matter. This observation is in line with studies of [33] and [34], which concluded that gas flaring

Table 4: Effects of Five Distances away from the Flare Site on Maize Height (cm).

	Weeks after planting (WAP)				
Distance	**2**	**4**	**6**	**8**	**Mean**
10m	3.10	3.33	3.48	3.58	3.37
50m	4.3*	4.70*	5.13*	5.26*	4.85
100m	5.86*	6.73*	7.56*	7.76*	6.97
200m	7.03*	7.86*	8.56*	8.93*	8.09
40km (control)	9.26*	12.00*	15.06*	16.16*	13.12
SD	2.396	3.337	4.444	4.847	
LSD (0.05)	0.46	0.83	1.01	0.71	

* = Significant at p (0.05), NS = not significant at p (0.05), SD = Standard Deviation

Table 5: Effects of Five Distances away from the Flare Site on Maize Leaf Area (cm2).

	Weeks after planting (WAP)				
Distance	**2**	**4**	**6**	**8**	**Mean**
10m	1.30	1.71	1.81	1.97	1.69
50m	1.97*	2.73*	2.98*	3.35 NS	2.75
100m	**2.09***	3.03*	3.26*	3.91 NS	3.07
200m	2.78*	4.22*	5.42*	6.24 NS	4.66
4km (control)	9.82*	6.95*	12.45*	16.12 NS	11.33
SD	3.521	2.011	4.265	5.692	
LSD (0.05)	0.46	0.76	1.34	19.83	

* = Significant at p (0.05), NS = not significant at p (0.05), SD = Standard Deviation

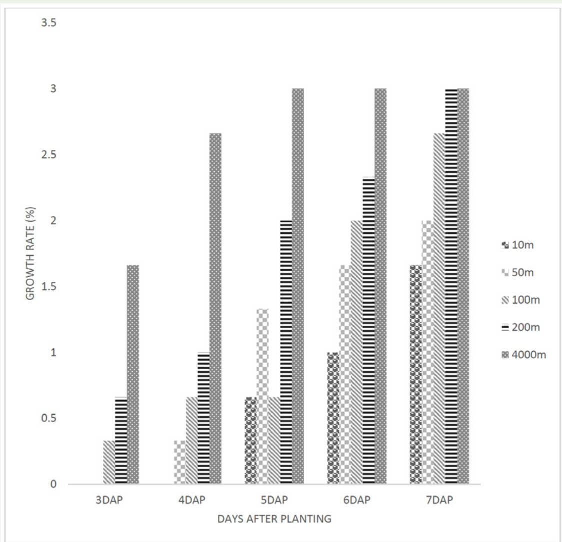

Figure 1: Percentage Maize Emergence Rate as Influenced by Distances away from Flare Site.

disturb the processes of eluviation and hydrolysis in soils close to the flare site, which would have enhanced the formation of insoluble clay minerals. As the organic carbon increases away from the flare site, so also is the value of the organic matter. Also, decreased soil organic matter content nearer the flare site could be attributed to increased temperatures which increased rate of decomposition [35].

Maize Poly-Bag Experiment

From Table 3 and Figure 1, maize seeds sown with soils 10m, 50m, 100m, 200m from flare site emerged 3 -7 days after planting (DAP) while the control (40km away from flare site) emerged 3 - 5 days after planting (DAP) with mean values 0.66, 1.06, 1.46, 1.76, 2.66. Maize emergence was lowest in the hot, dry and most impoverished 10m

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distance away from the flare site. This is followed sequentially by 50m, 100m, 200m, and 40km (control). At 5% ($P<0.05$) the difference in means are not significant from 2 - 8 weeks after planting (WAP).

Plant height was lowest in 10 m away from the flare site followed by 50 m, 100 m, and 200 m, and was highest in 40 km with mean values of 3.37 cm, 4.85 cm, 6.97 cm, 8.09 cm, 13.12 cm for 10 m, 50 m, 100 m, 200 m, and 40 km respectively (Table 4). At 5% ($p<0.05$) the difference in means for 2-8 WAP is statistically significant. This shows that these variables are not the same at different distances away from the flare site, confirming that gas flaring influence on this parameter was significant.

From Table 5, maize leaf area was lowest in 10m distance from the flare, followed sequentially by 50m, 100m, 200m and 40km with mean values 1.69cm^3, 2.75cm^3, 3.07cm^3, 4.66cm3, and 11.33cm^3 respectively. At 5% ($p<0.05$) the difference in means for 2-6 WAP was statistically significant while the 8 WAP was not. The 10m distance away data recorded the least emergence rate, plant height and leaf area with mean values of 0.66, 3.37cm, and 1.69cm2 respectively, while the data for the 40km (control) distance away were relatively very high with mean values of 2.66 for emergence rate, 13.12cm for plant height, and 11.33cm2 for leaf area. This implies that both the growth rate (Plant height) and leaf area accumulation are significantly affected by gas flaring. This is in agreement with the observations of [36], [37] and [38]. They said that gas flaring reduces the growth and yield of maize near a flare site. Growth reduction in the seeds of maize planted with soils nearer the flaring site as observed in this study, could be attributed to one or a combination of the following factors: disruption of plant-water relation, toxicity of living cells, reduced oxygen exchange between the atmosphere and the soil thus affecting root functioning, nutrient immobilization, heavy metal build up, and alteration in the physical, chemical and biological properties of soils. These factors could have led to reduction in biomass, morphological aberrations and other observed field abnormalities including dieback, leaf chlorosis, leaf fall/drop, necrotic patches, bleaching as well as withering. This agreed with earlier reports of [16].

Conclusion

Growth parameters of soils at closer proximity to the flare site showed poor physical features when compared with the 40km (control). Poor nutrient status of the soil, high bulk density and low moisture content induced by gas flaring were some of the factors that may have inhibited not only the emergence of maize but also the growth in soils closer to the flare. The results of maize emergence rate, height and leaf area and correlation with selected soil properties at 10m, 50m, 100m, 200m and 40km respectively correlated positively. Equally, the maize planted with the 10m soil sample away from flare showed lowest mean values in the features monitored while those planted with the 40km (control) soil sample away from flare showed highest mean values in all the features monitored. The study has therefore shown that gas flaring around arable soils has a highly significant effect on the performance of maize plant in the study area. This is evidenced in the reduction of the viability and subsequent poor emergence and overall yield of maize, the effect being proportional to the distance of arable soils proximal to the flare site. It could therefore be concluded that maize production is not economically viable and profitable at close proximity to gas flaring site.

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