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Natural Gas Flaring Affects Microclimate and Reduces Maize (*Zea mays*) Yield

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ABSTRACT

It is a common saying by farmers in the oil producing area of Niger Delta that gas flaring is a major reason for low maize yield. This paper reports the impact of natural gas flaring on microclimate and maize yield in the Niger Delta, using Ovade flare site as a case study. Experimental sites were located at 500 m, 1 km, 2 km and 70 km (control) from the flare site. Soil physico-chemical properties, air and soil temperatures (10 cm & 20 cm depths) rainfall and relative humidity were monitored. Physiological parameters measured were emergence rate, growth rate, leaf area index (LAI) and yield. The experiment was carried out in the 2005 and 2006 planting seasons. Time series and ANOVA were some statistical tools employed in analysing the data. The results show that with rise in air and soil temperatures of the flare site, relative humidity, soil moisture and all the soil chemical parameters decrease toward the flare. The induced microclimatic condition, which impacted on the soil, reduced the yield of maize by 76.4%, 70.2% and 58.2% at 500 m, 1 km and 2 km, respectively. Maize production is not economically viable within 2 km from the flare site.

Key Words: Gas flaring; Flare site; Nigeria; Hydrothermal; Microclimate; Maize growth; Maize yield

INTRODUCTION

Environmental degradation in form of air, water and soil is associated with oil production in Nigeria (Akpobome, 2004). While oil spillage and effluent discharges are the major sources of land and water pollution by the oil industries, the air is polluted through gas flowing (Odjugo, 2004a, 2005 & 2007). Gas flaring is a common practice in the oil production process that is not restricted to Nigeria only. Libya for instance flares about 21% of its natural gas, while Saudi Arabia, Canada and Algeria flare 20%, 8% and 5%, respectively (Atevure, 2004). In 2002, Nigeria flared about 76% of its natural gas (Atevure, 2004) and about 60% in 2006 (Inyang, 2007). This implies that Nigeria has one of the worst rates of gas fearing in the world.

The flared gas has a lot of environmental implications. For instance, gas flaring is observed to reduce atmospheric quality through the release of pollutants like carbon (c), nitrogen dioxide (NO_2) sulphur dioxide (SO_2) and lead (Pb) among others into the atmosphere (Okoh, 2000; Obi, 2001; Odjugo, 2004b). Gas flaring is also reported to cause acid rain within the flare's microenvironment (Odjugo, 2002). Studies show that gas flaring significantly affects not only the microclimate but also the soil physico-chemical properties of the flare sites (Alakpodia, 2000; Odjugo, 2007). Another impact of gas flaring reported is the destruction of vegetation, wild life and ecological destabilization (Akpan, 1998; Hong, 2002; Ogbonanya, 2003). Gas flaring is found to have significantly affected the health of the inhabitants of Otujeremu, Igbide, Olomoro and Ubeji, causing ailments like respiratory, eye, skin and intestinal diseases (Efekodo, 2001; Odjugo, 2004a; Otuaga, 2004).

Gas flaring has been reported by many researchers to be a major cause of low agricultural productivity, fishing and hunting in the Niger Delta, thereby impoverishing the inhabitants (Alakpadia, 2000; Daudu, 2001; Aregbeyen & Adeoye, 2001; Odjugo, 2007). A critical look at these studies on gas flaring and agricultural productivity shows that they are not scientifically in-depth studies of the impact of gas flaring and crops production; rather they are based on the opinions solicited from respondents by mere use of questionnaires. The few scientific studies include those of Udoinyang (2005) and Akpabio (2006), which studied the impact of gas flaring on sweet potato and plantain yield, respectively. They showed that gas flaring reduced the production of these crops within 1 km of the flare sites. Yam and cassava production is not economically viable within 2 km radius of the flare site (Odjugo, 2007).

Although some researches have been carried out on the impact of gas flaring on crops production; none has studied the relationship between gas flaring and maize production. Whereas maize is the major cereal crop produced in the study area and most of the farmers

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complained the gas flaring as main reason of low maize productivity. The present study was designed to explore the impact of gas flaring on the microclimate and its effects on the growth and yield of maize (*Zea mays*) in Edo State, Nigeria.

MATERIALS AND METHODS

The experimental sites were located within the vicinity of Ovade flare site, in Edo State, Nigeria. Ovade experiences equatorial type of climate (Koppen's Af climatic classification) with annual mean rainfall of above 2000 mm, air temperature of 27^0C and relative humidity of above 80%. The soil type is that of yellow-reddish laterite.

Experimental, statistical and simulation are the three major approaches to crop weather investigation (Ayoade, 2002). The direct or experimental approach is employed in this study, because there are no secondary data on climatic elements or maize yield around the flare site. To generate the data needed, four experimental sites were systematically selected around the flare site in Ovade. Ovade flare site is purposefully selected, because Obi (2001) and Odjugo (2003) show that gas flaring takes place in the entire Niger Delta region of Nigeria, likewise its impact, so, any part of the region could be selected for study related to imparts of gas flaring. Sites 1 to 3 were within the flare vicinity, while the 4^{th} site was the control. Sites 1, 2, 3 and 4 were 500 m, 1 km, 2 km and 70 km, respectively away from the bund wall of the flare. The control site (Ekiadolor), which is 70 km northwest of the flare site was chosen, because Onuorah (2000) and Odjugo (2007) noted that the impact of gas flaring on the atmospheric quality is statistically insignificant beyond 15 km and 20 km radius of the flare site. Again both the experimental sites and control site are within the same climatic and soil zone, but the control site is not a crude oil production area, so any noticed differences could be attributed to the effect of the gas flaring.

In each experimental site, a land area of 15 m by 17 m, which had been lying fallow mainly with elephant grass and siam weed for over three years was demarcated. The experimental design employed was the randomised complete block split. Each experimental site was cleared on the 18-19/3/2005. As practised by the traditional farmers, fire was set on the farm on 26/3/2005. On the 29-30/3/2005, each site was demarcated into 3 replicates and each replicate measured 5 m by 15 m with inter-replicate spacing of 1 m. Each replicate in turn was divided into 3 plots of 5 m by 5 m, given a total of 9 plots in each site. A crop variety was planted in each plot. The first season planting took place on the 2/4/2005, while the second was 5/4/2006. The maize was harvested between 10-20/7/2005 and 15-21/7/2006 in the first and second planting seasons, respectively. The improved maize TZSRW-E (Tropical Zea Mays Stick Resistance White Early) variety was planted. This variety was selected, because it is the most preferred and widely planted by the local farmers in the study area. Three seeds were planted in a hole (Stand) using 60 cm by 90 cm spacing and this gave 48 stands per plot, 144 per replicate and 432 per site. Three weeks after planting (WAP), the crops were tinned to two per hole.

No fertilizer was applied in this study. This is to enable us monitor clearly how gas flaring affect the physico-chemical status of the soil. With this, any notable difference in the soil nutrient could be attributed to gas flaring.

The required weather instruments (Thermographs, hygrographs, raingauges & soil thermometers) were installed on 2/4/2005 and 5/4/2006 for each of the planting seasons and measurements started immediately. With the aid of the automatic thermograph and hygrograph, the 24 h measurement of the air temperature and relative humidity, respectively was made possible. With the raingauges, rainfall was measured daily while the soil temperature at 5 and 10 cm depth was measured three times daily using the soil thermometers. Soil moisture at 0-15 cm depth was determined gravimetrically. These depths were chosen, because they form the main root zone of the maize crop (Jang, 2002).

Physiological parameters measured were daily emergence rate by physical counting; weekly growth rate using the thread and metre rule and leaf area index (LAI) (Isodje, 2003).

LAI = Leaf Area Per Plant/Ground Area.

The soil nutrient status at 0-15 cm depth of each plot was analysed for particle size composition, organic matter, total nitrogen, phosphorus, soil exchangeable calcium, potassium, magnesium and sodium, pH and bulk density using notable standard methods as found in (Isodje, 2003). All the data collected were presented for analysis using tables, percentages, time series, product moment correlation and ANOVA. The time series was employed to analyse the trends displayed by the climatic parameters. To assess the nature of the relationship between the dependent variable (yield) and independent variables (climatic elements), the product moment correlation was used. While the ANOVA assisted in determining whether the observed differences are statistically significant. The differences in both climatic, growth parameters and yield for the two planting seasons were statistically the same so, the mean values of the two seasons is presented and analysed.

RESULTS AND DISCUSSION

Air temperature, soil temperature at 5 cm and 10 cm depths increased as one moves closer to the flare site (Table I). In contrary, soil moisture content (0-15 cm) and relative humidity increased with increasing distance from the flare site. Rainfall did not exhibit any regular pattern. Compare with the control site, which is the ecological climatic condition of the study area, shows that the flare actually modifies the microclimate (Table I).

The higher temperatures generated by the flare must have increased the evaporation rate (Odjugo, 2007), in sites

Table I. Heat load and aridity occasioned by gas flaring in relation to control site

Distance	Air temperature (°C)	Soil temperature 5cm (°C)	Soil temperature 10cm (°C)	Soil moisture 0-15 cm (g/g)	R.H (%)
500 m	+11.6	+8.8	+7.7	-9.3	-24.3
1 km	+9.2	+7.6	+6.0	-6.3	-18.1
2 km	+4.3	+3.9	+3.0	-2.8	-12.3

Table II. ANOVA for hydrothermal condition (P<0.05)

Parameters	F-value	F-critical
Soil temperature (5 cm)	18.77*	2.866
Soil temperature (10 cm)	26.62*	2.866
Air temperature	113.8*	2.866
Relative humidity	41.22*	2.866
Rainfall	0.05	2.866

*Significant at $p < 0.05$

Table III. Soil Physico-chemical and hydrothermal parameter (0-15cm depth)

Soil parameters	500m	1km	2km	70km
Sand (%)	84.3	82.2	79.0	76.3
Silt (%)	6.9	6.2	13.1	13.6
Clay (%)	8.8	11.6	11.9	10.1
pH	4.4	5.2	5.8	7.1
Organic carbon (%)	1.3	2.2	4.2	6.4
Total Nitrogen (%)	0.15	0.26	0.41	0.52
Calcium (meg/100g)	0.25	0.33	0.48	0.52
Magnesium (meg/100g	0.11	0.26	0.46	0.55
Sodium (meg/100g)	0.03	0.04	0.07	0.09
Potassium (meg/100g)	0.09	1.10	0.15	0.18
Phosphorus (ppm)	15.3	17.2	36.6	41.2
Bulk Density (g/cm^{-3})	1.8	1.7	1.3	1.1
Air temperature	39.4	37.0	32.1	27.8
Soil temperature	37.8	36.6	32.9	29.0
Soil temperature (10cm depth)	36	34.3	31.3	28.3
Soil moisture (moisture (0-15cm)g/g	13.7	16.7	20.2	23.0
Rain fall (mm)	257.7	261.7	277.4	268.1
RH. (%)	58.1	64.3	70.1	82.4

closer to the flare hence decreased the soil moisture and relative humidity. The air temperature is increased by 11.6°C at 500 m from the flare site, which further decreased to 4.3 (°C) at 2 km. On the other hand, the soil moisture was reduced between 2.8 and 9.3 g/g. The study also determined whether the observed differences in the hydrothermal condition of the experimental sites is statistically different using the ANOVA and the result is presented in Table II. At 5% ($p < 0.05$) the differences in soil-and air-temperatures and relative humidity are statistically significant. This shows that these variables are not the same at different distances from the flare site, proving that gas flaring significantly affected them. On the other hand, rainfall value shows that it is statistically the same at different distances from the flare site, so gas flaring did not affect the amount of rainfall.

The changed microclimate showed negative impact on the soil physico-chemical properties as shown in (Table III). The sand content in the soil samples and bulk density increased toward the flare, while the clay, silt and pH content decreased toward the flare site. The values of all the

Fig. 1. Nigeria showing experimental site

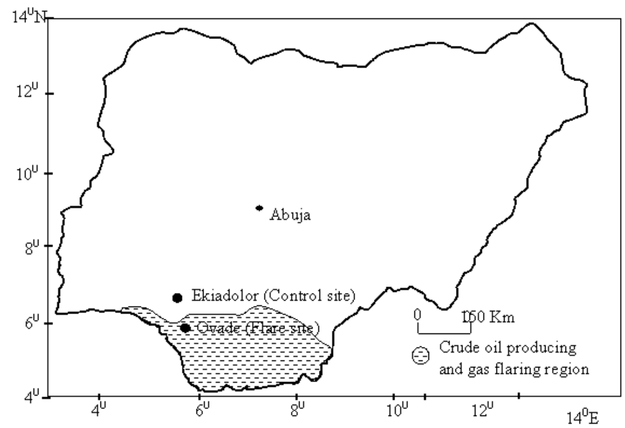


Fig. 2. The impact of distance from the flare site on percentage emergence of maize

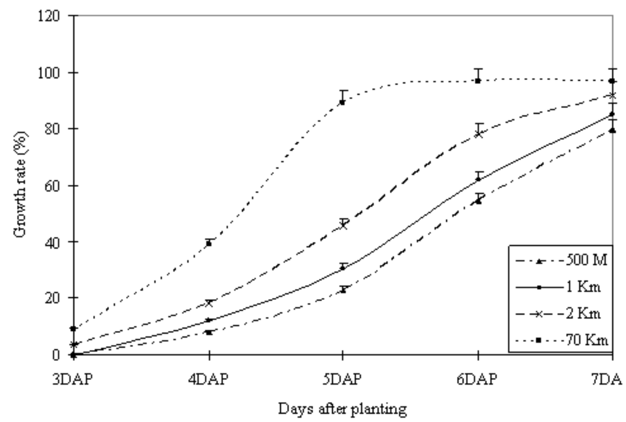
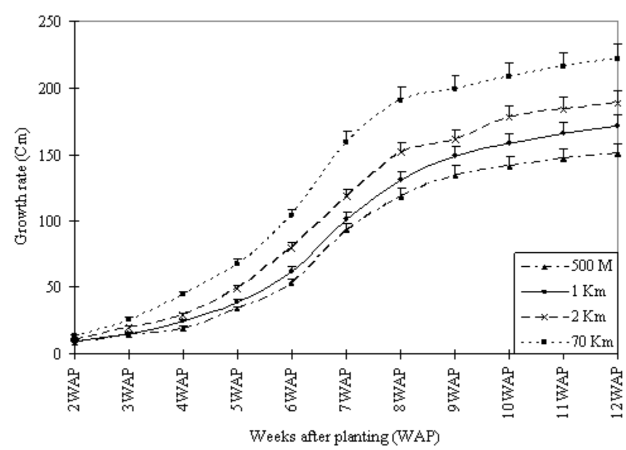


Fig. 3. The impact of distance from the flare site on maize growth rate



chemical parameters decreased toward the flare site. The result of the physico-chemical properties of the soil is a clear indication that the excessive heat generated by the flare did not only modify the microclimate but also the soil nutrient. The flare did not favour soil fertility. It did not only degrade the soil, it also impoverished it. The excessive heat either kill or scare away most of the micro-and macro-organisms that would have helped to improve the soil fertility through further breaking down of the soil particles, decaying and decomposition of the organic matters. Alakpodia (2000) and Akpobome (2004) showed that soils closer to flare sites are impoverished, because the heat from the gas flare disturbs the processes of eluviation and hydrolysis, which could have enhanced the formation of insoluble clay minerals.

It has been established in this study that gas flaring modified the microclimate. The microclimate in turn impacted negatively on the soil physico-chemical properties. The modified microenvironment actually affected not only maize emergence, but also the growth and the yield as shown in Fig. 2. Maize emergence rate was lowest in the hot, dry and most impoverished 500 m from the flare. This is followed by 1 km, 2 km and 70 km from the flare. The observed differences in the emergence rate with *F*-value of (24.52) are significantly higher than the critical value of (2.866) at $p < 0.05$. This clearly shows that the microclimatic condition created by gas flaring reduced the rate of maize emergence. The same pattern observed in the emergence is also noticed in the growth rate (Fig. 3) and leaf area index (LAI), in Fig. 4. The *F*-value of 28.61 is significantly higher than the critical value of 2.866 for growth rate, while LAI critical value of F=53.72 is significantly higher than the critical value of 2.866. These imply that both the growth rate and leaf area accumulation are significantly affected by gas flaring. Udoinyang (2005) Akpabio (2006) and Odjugo (2007) earlier observed that gas flaring reduced the growth and yield of plantain and root crops in the Niger Delta region of Nigeria.

The 500 m site recorded the least maize yield (524 kg ha^{-1}) followed by 1 km, (662 kg ha^{-1}), 2 km (921 kg ha^{-1}) and 70 km (2,218 kg ha^{-1}) (Fig. 5). The world average maize yield is 3600 kg ha^{-1}, while the African main yield is 1700 kg ha^{-1} (Onwueme & Sinha, 1999). While the yield of the control site is comparable to African average yield, those of the flare vicinity are far below either Africa or world mean yield. Odjugo (2003) noticed maize yield of 1850 kg ha^{-1} in Agbor, Delta State. Since the control site is the ecological condition of the study area, the yield in the three stations was compared with it in order to determine the degree of the flare's impact. The result shows that gas flaring at 500 m, 1 km and 2 km reduced the yield of maize by 76.4%, 70.2% and 58.2%, respectively. The *F*-value of 22 is significantly higher than the critical value of 2.866 at $p < 0.05$, which is a clear depiction of significant difference in maize yield among the flare sites. Jang (2002) suggested that any area, where environmental condition (s) reduce the yield of crops by 30% or more is not economically viable for cultivation. Gas flare reduced the yield of maize by between 58.2 and 76.4% showing that maize production is not economically viable within the 2 km radius of the flare bundwalls. An area with a radius of 2 km is 12.5 km^2. This implies that in

Fig. 4. The impact of distance from the flare site on leaf area index of maize

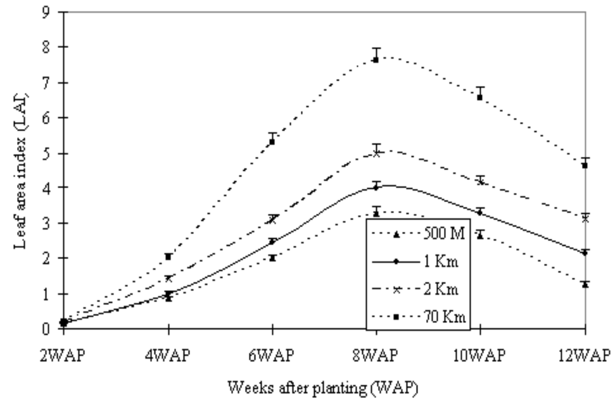
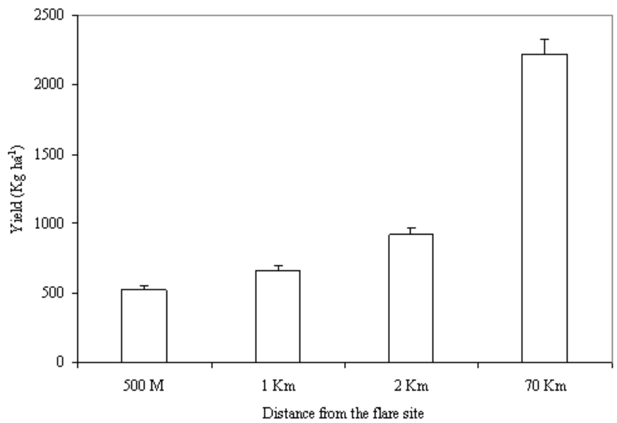


Fig. 5. The impact of distance from the flare site on maize yield



every flare site, 12.5 km^2 of arable land mass is not viable for the production of maize due to gas flaring. Akpabio (2006) shows that there are over 200 flare sites in the Niger Delta oil-producing region. This further shows that over 2500 km^2 out of the 117,396 km^2 (Enock & Okpara, 2004) in the Niger Delta region is not economically viable for maize production as a result of gas flaring.

CONCLUSION

The results show that the sand content of the soil, pH, bulk density, air and soil temperatures increased toward the flare site, while the reverse was the case with silt, clay, chemical properties of the soil and the relative humidity. Gas flaring increased air temperatures by between 4.3 and 11.6^{O}C and reduced soil moisture content by 2.8 and 9.3 g/g. The poor nutrient status, the high soil bulk density, soil and air temperatures and low soil moisture content induced by gas flaring were some of the factors found to have inhibited not only the emergence of maize but also the growth and yield closer to the flare. Maize yield was (524 kg ha^{-1}) at 500 m, followed by 1 km, (662 kg ha^{-1}), 2 km (921 kg ha^{-1}) and 70 km (2,218 kg ha^{-1}). The flare therefore reduced the maize yield by 76.4%, 70.2%, 58.2% at 500 m, 1 km and 2 km, respectively. It could be confidently said that maize production is not economically viable within 2 km radius of the flare site. This again confirms the claims of the farmers that gas flaring has drastically reduced the yield of maize in the study area.

It is therefore recommended that for optimum yield of maize within the Niger Delta where gas flaring is taking place, maize must not be cultivated within 2 km of the bund wall of the flare sites.

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