



## Air Quality Indexing, Mapping and Principal Components Analysis of Ambient Air Pollutants around Farm Settlements across Ogun State, Nigeria

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### Abstract

The focus of this study was to portray the spatial pattern of air quality across seasons in the eight sampled farm settlements using air quality indexes and assess the clusters of monitored air pollutants. The concentrations of air pollutants were determined using *in-situ* portable gas detectors and particulate counter. The AQI for each criteria pollutants (CO, O<sub>3</sub>, TSP, PM<sub>10</sub>, SO<sub>2</sub>, and PM<sub>2.5</sub>) was calculated using AQI formulae of the United States Environmental Protection Agency and mapped using the Inverse distance weighting (IDW) interpolation method in the Geographic information systems (GIS) environment. Principal component analysis (PCA) was used to group the parameters and estimate the interrelationships between the loadings of the parameters in each component. The AQI ranges of pollutants which deviated from the acceptable good status are CO (71.98 – 238 and 88.85 – 220.93), NO<sub>2</sub> (10.14 – 107.07 and 10.84 – 72.88) and PM<sub>2.5</sub> (12.90 – 70.85 and 12.56 – 54.02) for the dry and wet seasons, respectively. There were five and four PCs with eigenvalues > 1, accounting for 69.75% and 61.73% of the total variance during the wet and dry season, respectively. The parameters in each component are as follows; PC1 - TSP, PM<sub>10</sub>, PM<sub>2.5</sub>, Bacteria and fungi; PC2 - CO and Temperature; PC3 - relative humidity and O<sub>3</sub>; PC4 - CO<sub>2</sub>; PC5 - NO<sub>2</sub> and SO<sub>2</sub> for the wet season and PC1 - TSP, PM<sub>10</sub>, PM<sub>2.5</sub>, Bacteria and fungi; PC2 - NH<sub>3</sub> and NO<sub>2</sub>; PC3 - CO<sub>2</sub> and O<sub>3</sub>; PC4 - Temperature and relative humidity during the dry season. Biomass burning, engine exhausts and fine-particulate related activities are sources of air pollution and such may pose negative implication to human health and environment. Therefore, the use of alternative biomass disposal, regular servicing of processing engines and the wearing of protective wears against dust are recommended.

**Keywords:** Agricultural activities; Air pollution; Health risks; GIS; Ogun

## Introduction

Nigeria possesses vast agricultural resources such as the expanse of arable land, well-distributed rainfall and warm temperatures throughout the year, which continue to support agricultural activities [1]. However, with the production of more cash crops, food crop suffered a great decline which led the country to food scarcity for the ever-increasing population [2–3].

Many agricultural practices like deforestation, slash-and-burn farming, the use of chemical fertilisers, herbicides, insecticides, vaccines and antibiotics, antimicrobial drugs and biotechnologies have been reported to jeopardise environmental sustainability [4] through the significant contributions to the emission of various elemental pollutants to the atmosphere [5].

Air pollution is one of the main contributors to environmental (global warming, transboundary transport of smoke, acid rain, ozone layer depletion) and health (breathing and cardiovascular disorders, exacerbation of asthma, impaired lung capacity and premature death) [6–8] issues. Given the adverse environmental and health effects of air pollution, there is a need for assessment and continuous monitoring of air quality for environmental sustainability. Air Quality Index (AQI) is a form of air pollution assessment which utilises a calculated rating and standard method through the use of five parameter pollutants (criteria air pollutants; NO<sub>2</sub>, ground-level ozone, CO, SO<sub>2</sub> and PM), to understand the atmospheric levels and identify the health risks to exposed humans.

Geographic information systems (GIS) serves numerous purposes in air quality issues by providing methods used in the collection, processing, analysis, and modelling of data. The generated results give better interpretation and visualisation, including advanced beneficial and relevant information [9–10]. GIS is now highly recognised for its role in monitoring and maintaining large volumes of spatially referenced data [11–12]. GIS data modelling involves mathematical and

statistical procedures used to analyse complex data and relationships such as patterns and trends by transforming them into simple convenient designs for estimation and predictions for unmonitored spaces [9, 13]. One of such models is kriging which has become useful in a spatial model of air quality in form of air quality maps.

Attention has been drawn from likely air pollution sources and activities in the rural and semi-urban areas, probably because of less vehicular traffic and minimal industrial activities [14]. Besides, spatial representation and mapping of AQI mapping in Nigeria have solely cut across the urban areas analysing different land-use types and especially traffic-related air pollutants [6, 15–16]. The available studies describing farm settlements (FS) in Nigeria were published more than 40 decades ago [17–20], except Oyebojani et al. [21]. Also, there are no available articles that have mapped both the land coverage of FS and even the air quality, making it almost impossible to access secondary sources of data on FS in Nigeria.

Therefore, this study computed spatial AQI scores across two seasons in the FS; and showed the apportioned sources of monitored air quality parameters using the principal component analysis.

## Materials and methods

### 1) Study area

The study was conducted in Ogun State (Figure 1), located in the southwestern region of Nigeria. The geographical coordinates of the area are 7°00' – 7°30'00" N and 3°00'00" – 3°30'00" E with a total land area of 16,980 km<sup>2</sup> and a total population of 3,751,140. The area has a climate classified under the tropical climatic region. The northern, southern and central parts of the State consist mainly of derived savannah, mangrove swamp and rainforest belt, respectively. The rain starts in March and ends in November, with the remaining months representing the dry season. The annual rainfall varies across the state, with

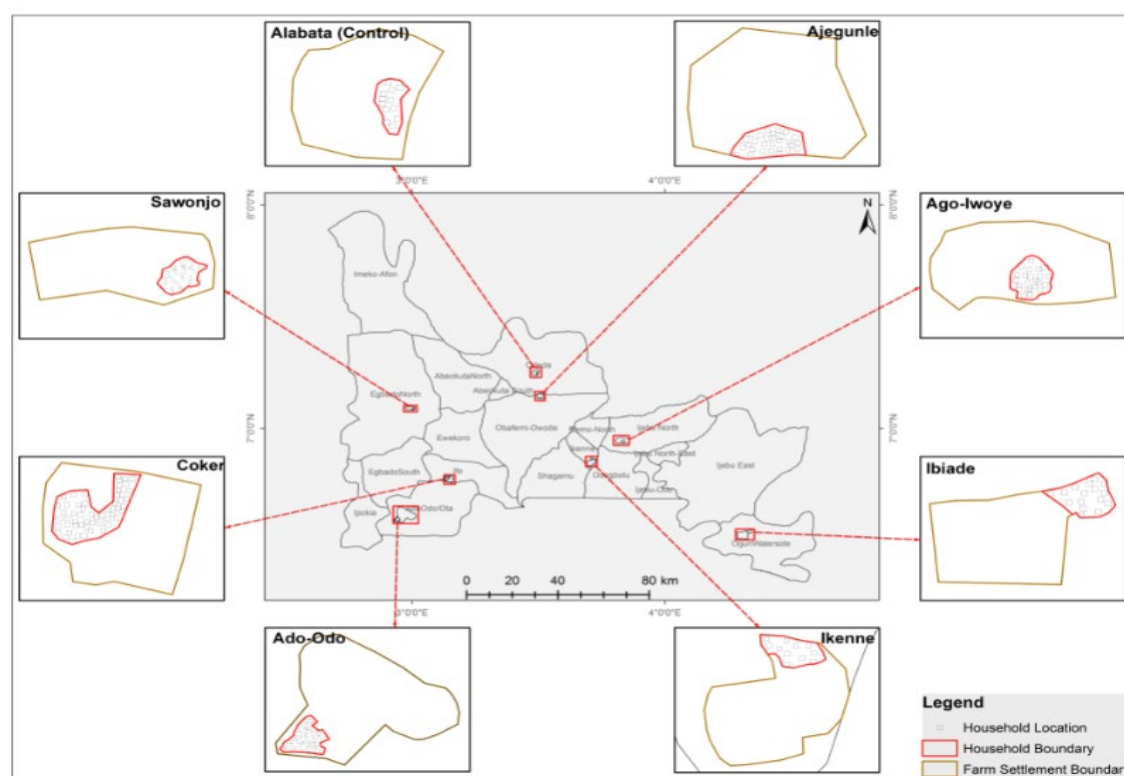
an average of 128 mm in the southern part of the State and 105 mm in the northern part with relative humidity ranging between 76% and 95%, respectively [22–23]. Ogun State has a vibrant agricultural potential and relatively at an advantage in six major cash crops: cocoa, cassava, kola, cotton, oil palm and rice.

Farm Settlement (FS) is a scheme that involved the acquisition of large expanse of land by the government to encourage rural development. The government provides small farmers with capital resources and land for commercial farm operations. The Regional Government of Western Nigeria established the eight FS and modelled them according to the concept of Israeli Moshavim concept [20] with the attempt to provide a model for farmers in the immediate and neighbouring communities to learn the modern techniques and methods of scientific farming between 1959 by Chief Obafemi Awolowo to the end of the First Republic in Nigeria in the year 1966 [24–25]. The study took place at seven of the eight FS,

which were still in operation (Ado-Odo, Ikenne, Ago-Iwoye, Sawonjo, Ibiade, Ajegunle, Coker) and Alabata Community which served as the Control site.

## 2) Sampling techniques and estimation for sample sizes

From a total of 454 households across all the FS, the Yamane formulae [26] was used to calculate the appropriate sample size. A total of 213 households was calculated, but 211 household heads consented to their houses being used for air quality assessment/monitoring. Besides, 12 sampling sites within a non-farm settlement to serve as Control were included. The total sample size was proportionally allocated across the FS. The sampling positions were recorded with the aid of a highly sensitive hand-held receiver of the Global Positioning System (GPS). The sampled points and maps of each farm settlements, including the Control (Alabata), are presented in Figure 1.



**Figure 1** Distribution of the study areas (FS) across Ogun State.

### 3) Meteorological parameters

The temperature (°C) and relatively humidity (%) at each sampling points were measured using an *in-situ* Weather Station (VENTUS W155).

### 4) Air quality sampling procedure

The levels of volatile organic compounds (VOCs), ammonia (NH<sub>3</sub>), carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), ozone (O<sub>3</sub>), nitrogen dioxide (NO<sub>2</sub>), sulphur dioxide (SO<sub>2</sub>), total suspended particulate (TSP), particulate matter of 10 microns (PM<sub>10</sub>), particulate matter of 2.5 microns (PM<sub>2.5</sub>), aerosolised bacteria and fungi assessment were conducted twice a day (morning and evening) during the wet and dry season using portable active in situ samplers. The VOCs was monitored using TVOC SP 2000 (15063564), SO<sub>2</sub> was monitored with Sulphur dioxide meter Z-1300, CO with EXTECH Instruments, NO<sub>2</sub> with Nitrogen dioxide meter Z-1400, O<sub>3</sub> with GRI Instruments Co., Ltd. (JY15090019) WASP-XM, NH<sub>3</sub> and CO<sub>2</sub> using Tester iSP Sample Pump and particulate matter (PM<sub>10</sub> and PM<sub>2.5</sub>) using Thermo Scientific MIE pDR-1500 PM monitor. Also, bacteria and fungi were monitored and counted using the settle-plate method described by Napoli et al. [27] and Wemedo et al. [28]. The gaseous samplers were switched off and on for zeroing. At the same time, each particulate parameter was monitored after changing the filter paper of the sampler to take a new reading at different sampling points. Three replicate readings were taken at the sampling points, and the averages were finally recorded for each site.

### 5) Air quality index

The AQI is a numerical manipulation that generates a single number that reports the quality of air and its effects on human health [29] using ground-level ozone, SO<sub>2</sub>, NO<sub>2</sub>, CO, PM<sub>2.5</sub> and PM<sub>10</sub> commonly referred to as criteria air pollutants [30]. The studies of Adedeji et al. [6]

and Olujimi et al. [31] also employed the AQI to ascertain the health impacts of air pollutants on the health of the exposed populace. Air Quality Index was done based on dose-response relationships of pollutants to obtain breakpoint concentrations [32] using the concentration of each pollutant in Eq. 1.

$$I_p = \frac{I_{HI} - I_{LO}}{BP_{HI} - BP_{LO}} (C_p - BP_{LO}) + I_{LO} \quad (\text{Eq. 1})$$

Where; C<sub>p</sub> = the rounded concentration of pollutant p, I<sub>p</sub> = the index for pollutant p, I<sub>HI</sub> = the AQI value corresponding to BP<sub>HI</sub>, I<sub>LO</sub> = the AQI value corresponding to BP<sub>LO</sub>, BP<sub>HI</sub> = the breakpoint that is greater than or equal to C<sub>p</sub>, and BP<sub>LO</sub> = the breakpoint that is less than or equal to C<sub>p</sub>. The different categories of break-points used for the individual air pollutants' AQI calculations are presented in the Supplementary Material (SM) 1.

### 6) GIS analysis

The study involved integrating data from in-situ measurements of air pollutants into digital map layers to determine the spatial variations. The Global Positioning System (GPS) (Garmin) tool helped identify various households in which the data were obtained and processed in excel format for use in GIS software (ESRI, ArcMap 10.5). Following the generation of spatial objects and their attributes, geospatial analysis (kriging) technique [6] was performed to calculate the value of each cell at locations without sample data. Inverse distance weighting (IDW) of Interpolation method in a GIS environment is based on the theory of spatial dependents, where the level of relationships dependence between nearby and distant features are centred. Hence, AQI of six air pollutants obtained from the seven farm settlement households in Ado-Odo, Ikenne, Ago-Iwoye, Sawonjo, Ibiade, Ajegunle, Coker and Alabata (Control site) in Ogun State, Nigeria for wet and dry seasons were used to map the spatial patterns in the study area using IDW.

## 7) Data analysis

Mean daily and seasonal values of criteria air pollutant concentrations were calculated using the Microsoft Excel, 2016, which was then entered into the self-designed AQI Microsoft Template for calculation of AQI values. Besides, principal component analysis was used to group and identify the possible sources of the monitored air quality parameters (observed variations among the monitored parameters during seasons). Risk maps were produced using the ArcMap 10.1 based on the spatial autocorrelation among the measured and predicted locations using the kriging method.

## Results and discussion

### 1) Air quality index mapping

The spatial and seasonal AQI maps for CO, NO<sub>2</sub> and PM<sub>2.5</sub> across the study areas are presented in Figures 2 – 4 and those for O<sub>3</sub>, PM<sub>10</sub> and SO<sub>2</sub> are in SM 2 – 4, respectively. During the dry season, the AQI score for CO (Figure 2) was moderate (71.98) at Alabata (Control) with unhealthy and very unhealthy patches, unhealthy for sensitive groups (146.46) with patches of unhealthy sparsely scattered at Ago-Iwoye. Also, Ajegunle (193.52) and Ikenne (196.77) were generally unhealthy with patches of very unhealthy levels. The remaining locations had very unhealthy CO AQI levels ranging between 217.80 and 238 at Ado-Odo and Ibiade, respectively. Although, there are patches of unhealthy levels at Ado-Odo, Ibiade and Sawonjo. The average NO<sub>2</sub> AQI levels (Figure 3) showed that at Coker (21.76), Ajegunle (50), Alabata (10.14), Sawonjo (11.62), Ado-Odo (21.90) and Ibiade (11.05) the AQI levels were good. Although patches of unhealthy levels and spread of moderate levels across Ibiade, patches of moderate levels at Ado-Odo, patches of moderate and unhealthy to sensitive groups at Sawonjo were observed. Besides, the average NO<sub>2</sub> AQI status at Ago-Iwoye was moderate (52.19), while Ikenne had unhealthy levels

(107.07). SM 2, 3 and 4 show the good AQI levels for O<sub>3</sub>, PM<sub>10</sub> and SO<sub>2</sub> across all the sampled locations. The O<sub>3</sub> AQI ranged from 8.75 at Ago-Iwoye to 13.11 at Ajegunle, the PM<sub>10</sub> AQI varied between 1.49 at Alabata and 13.44 at Ikenne, and the SO<sub>2</sub> AQI scores ranged from 9.14 at Alabata to 39.46 at Sawonjo. Figure 4 displayed the moderate (60.15 at Ikenne – 70.85 at Ago-Iwoye) for PM<sub>2.5</sub> AQI levels in all the sampled locations except at Alabata, which showed a good score (12.90) with patches of moderate levels.

In the wet season, the average CO AQI levels (Figure 2) were very unhealthy across almost all the locations except at Alabata ranging between 217.60 at Ajegunle and 220.93 at Ikenne. Although Alabata had patches of unhealthy for sensitive groups and very unhealthy, it was averagely moderate (88.85). The AQI levels of O<sub>3</sub>, PM<sub>10</sub> and SO<sub>2</sub> (SM 2, 3 and 4, respectively) reflected good levels. The scores of O<sub>3</sub> ranged from 8.61 (Ajegunle) to 12.41 (Sawonjo), the least level for PM<sub>10</sub> is 1.13 (Alabata), while the highest is 24.06 (Ikenne), SO<sub>2</sub> also ranged between 11.95 (Ikenne) and 32.64 (Coker). Six locations had averagely good PM<sub>2.5</sub> levels ranging between 12.56 (Alabata) and 34.66 (Ajegunle), with patches of moderate levels at Ibiade. Ikenne (53.05) and Coker (54.02) had moderate levels with patches of good levels. The good AQI levels for NO<sub>2</sub>; 10.84 (Alabata), 11.01 (Ikenne) and 29.14 (Coker) with moderate patches at Coker, generally moderate values ranged between 56.98 (Ado-Odo) and 72.88 (Ajegunle).

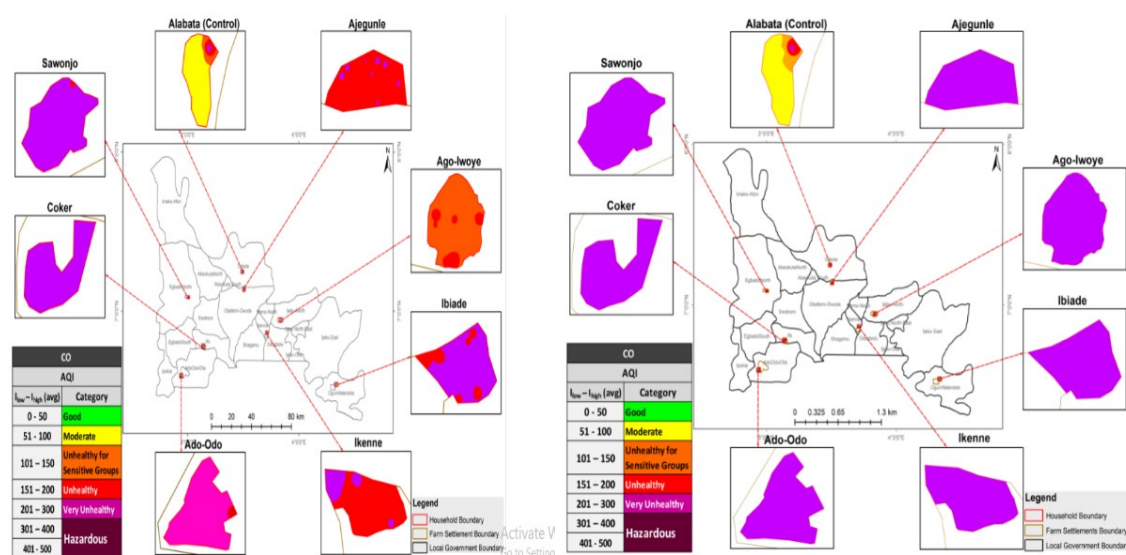
Going by the AQI scoring, CO, NO<sub>2</sub> and PM<sub>2.5</sub> deviated from the good status and hence are at poor levels capable to impact negatively on human health. According to the submission of Smith [33], moderate CO levels are known to induce dizziness, headache and throat irritation in exposed humans, thereby affecting human comfort. However, at elevated levels, CO can react with haemoglobin forming carboxyl-haemoglobin because of its higher affinity to

haemoglobin than oxygen [34], denying the bloodstream of oxygenated blood [35] to cause hypoxia, ischemia and cardiovascular disorders. The studies of Peel et al. [36] and Moshammer et al. [37] provided epidemiological proof of impaired lung function in children and the occurrence of other respiratory illnesses as results of exposure to elevated concentrations of CO, SO<sub>2</sub> and NO<sub>2</sub>. Acute and chronic toxicity of CO induces common respiratory symptoms [38–39]. Acute CO poisoning in developed countries has also resulted in death, most especially in fire-related poisoning [40]. CO is a by-product of incomplete combustion of fossil fuel [34], biomass burning in an agricultural setting is similar combustion which gives off CO. Although, King and Hungria [41] have also proved that ambient CO is dependent on the cultivated plant roots in an agricultural ecosystem.

NO<sub>2</sub> at low concentrations irritates the respiratory system upon deep penetration into the lungs thereby inducing respiratory diseases, cough, dyspnea, bronchospasm, wheezing and pulmonary oedema. Also, at higher concentrations,

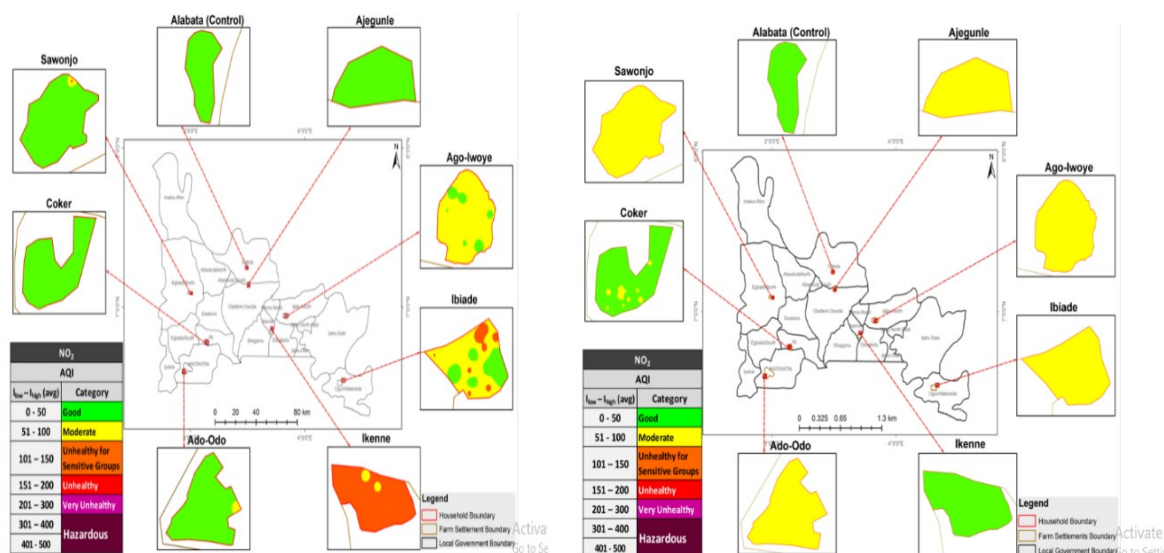
immune response producers - CD8<sup>+</sup> and NK cells may be affected, the sense of smell may be impaired and other non-respiratory systems such as eyes and throats may severely suffer [42]. The major source of NO<sub>2</sub> in literature is traffic/vehicular exhaust [34] such as tractor and other farm machinery operations within the agricultural area. Besides, milling and grinding machines also possess the ability to emit such traffic-related air pollutants.

The PM<sub>2.5</sub> tend to penetrate deeply into the lungs to pose a great health risk [43] affecting the second bronchial passage and leading to acute nasopharyngitis [44]. People with compromised health are especially vulnerable to more severe impacts when exposed to dust suspensions [34, 45]. The sources of PM<sub>2.5</sub> in the agricultural settings can either be a single or combined such as field operations, animal feeding lots, farm equipment exhaust, unpaved road, crop residue burning, processing and production activities, pesticides usage and air turbulence [46–47].

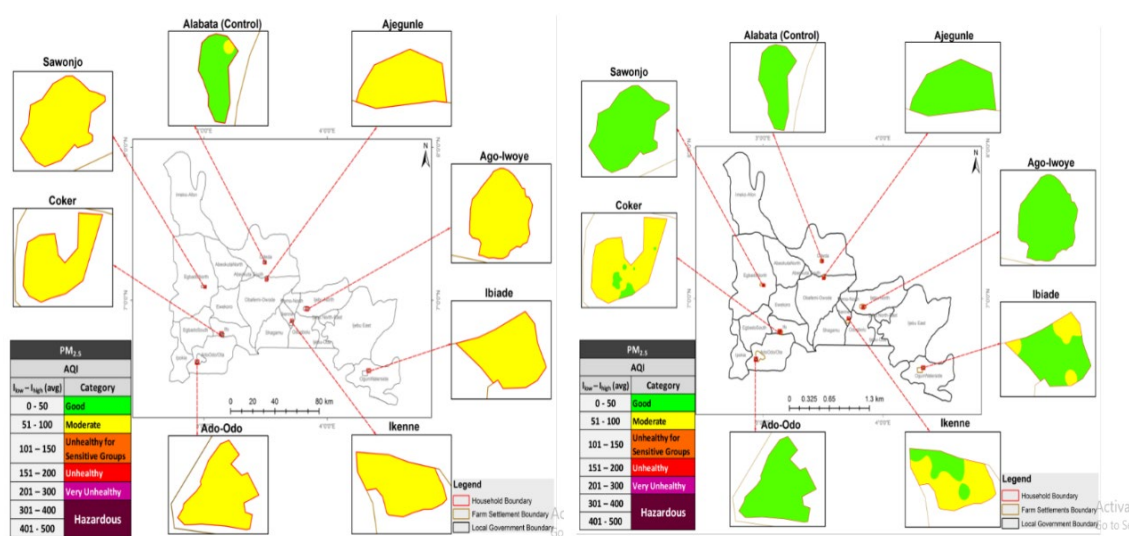


**Figure 2** AQI of CO in the study locations during dry and wet seasons, respectively.





**Figure 3** AQI of  $\text{NO}_2$  in the study locations during the dry and wet seasons, respectively.



**Figure 4** AQI of  $\text{PM}_{2.5}$  in the study locations during the dry and wet seasons, respectively.

## 2) Association and source identification of the monitored parameters

The PCA was carried out to assess how the monitored parameters are clustered by generally showing the level of variation between the parameters (Table 1). The total variance of the average parameter levels and the rotated component matrix at the farm settlements during the wet season and dry season is shown in Tables 2 and 3. The total variance showed that there are five components with initial eigenvalues of more than 1. These five components, whose eigenvalues are  $> 1.0$ , accounted for 69.75% of the total variance. After the varimax rotation, the first

principal component (PC1 - 5) explained variations of 31.65%, 10.28%, 9.08%, 8.01% and 7.68%, respectively.

These rotated component matrices, therefore, revealed that particulate (TSP,  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  and bioaerosol (bacteria and fungi) have high positive loadings in the first principal component with factor loadings 0.84, 0.87, 0.93, 0.93 and 0.93, respectively. Similarly, temperature has a relatively high value in the second principal component with a weak factor loading of 0.48. In the third principal component, relative humidity and  $\text{O}_3$  display moderate factor loadings 0.65 and 0.58, respectively. Also, in the fourth

principal component, CO<sub>2</sub> has a moderate loading of 0.62 while NO<sub>2</sub> and SO<sub>2</sub> have moderate factor loadings of 0.69 and 0.51, respectively in the fifth principal component.

Tables 3 and 4 show the total variance and rotated component matrix respectively for the air pollutants during the dry season. Table 3 shows that there are four components with initial eigenvalues of more than 1.0, accounting for a total variance of 61.73%. PC1, PC2, PC3 and PC4 accounted for 32.82, 11.76, 9.35, 7.80% of the variance, respectively. Results, therefore, imply that particulate matter (TSP, PM<sub>10</sub> and PM<sub>2.5</sub>) and bioaerosol (bacteria and fungi) have high loadings in the first component with factor loadings 0.84, 0.85, 0.95, 0.95 and 0.95 respectively. PC2 showed high loading for VOC, NO<sub>2</sub> and NH<sub>3</sub> with moderate to high factor loading values of 0.50, 0.68 and 0.70, respectively. Also, CO<sub>2</sub> and O<sub>3</sub> have moderate factor loading values of 0.60 and 0.62, respectively in PC3, the only parameter in PC4 with a relatively high value but a weak factor loading of 0.47 is temperature. However, VOC and NH<sub>3</sub> (wet season), relative humidity, CO, CO<sub>2</sub> and SO<sub>2</sub> (dry season), was not substantially related to the other pollutants in terms of emission

source because they did not form any coherent components and hence, should not be aggregated with them.

The results of the PCA showed that air pollutants concentration across the FS were highly influenced to a large extent by particulate matter-related activities during both seasons. PM is produced from agricultural field operations and animal production activities [21]. This observation is in tandem with the study of Forero et al. [48] which stated that TSP is released during planting 6.2 times higher than land tilling and other wind events. The components of particulates are diverse [49], and this explains the reasons for having PM and bioaerosols in the same group. Ibe et al. [50], established that to solve the PM menace, anthropogenic point sources of PM are very relevant. Also, temperature and relative humidity were sources of variations in PC2 and PC3, respectively, during the wet season. Air pollutants behaviour is often influenced by rainfall, which is related to relative humidity because of the scavenging effects on particulate concentrations and the impact of temperature to determine the motion and speed of air pollutants [51–52].

**Table 1** Variance explained by the components for the wet season

Factors	Initial eigenvalue			Extracted sums of loading		
	Eigenvalue	% Variance	Cumulative %	Eigenvalue	% Variance	Cumulative %
1	4.43	31.65	31.65	4.43	31.65	31.65
2	1.56	11.13	42.78	1.56	11.13	42.78
3	1.42	10.14	52.91	1.42	10.14	52.91
4	1.22	8.74	61.65	1.22	8.74	61.65
5	1.13	8.09	69.75	1.13	8.09	69.75
6	0.92	6.54	76.28			
7	0.82	5.88	82.16			
8	0.75	5.36	87.52			
9	0.66	4.69	92.21			
10	0.56	4.00	96.21			
11	0.48	3.42	99.62			
12	0.05	0.38	100			
13	0.00	0.00	100			
14	0.00	0.00	100			



**Table 2** Rotated component matrix for the wet season

Parameters	Principal components (Wet season)				
	1	2	3	4	5
Temperature	0.21	<b>0.48</b>	-0.17	-0.50	-0.29
Relative humidity	-0.19	0.19	0.65	0.21	-0.22
VOC	0.26	0.24	-0.54	0.34	-0.15
NH <sub>3</sub>	0.09	0.34	0.34	-0.44	0.00
CO	0.43	0.49	-0.16	0.08	-0.40
CO <sub>2</sub>	0.05	0.44	-0.02	<b>0.62</b>	-0.11
O <sub>3</sub>	0.04	0.48	<b>0.58</b>	0.24	0.21
NO <sub>2</sub>	0.05	0.35	-0.18	-0.24	<b>0.69</b>
SO <sub>2</sub>	-0.02	0.39	-0.36	0.09	<b>0.51</b>
TSP	<b>0.87</b>	0.06	0.12	-0.15	-0.007
PM <sub>10</sub>	<b>0.84</b>	0.15	0.06	-0.19	-0.12
PM <sub>2.5</sub>	<b>0.93</b>	-0.22	0.06	0.12	0.14
Bacteria	<b>0.93</b>	-0.22	0.06	0.12	0.14
Fungi	<b>0.93</b>	-0.22	0.06	0.12	0.14

**Table 3** Variance explained by the components for dry season

Parameters	Eigenvalue	% Variance	Cumulative %	Eigenvalues	% Variance	Cumulative %
1	4.59	32.82	32.82	4.59	32.82	32.82
2	1.65	11.76	44.58	1.65	11.76	44.58
3	1.31	9.35	53.93	1.31	9.35	53.93
4	1.09	7.8	61.73	1.09	7.8	61.73
5	0.99	7.13	68.86			
6	0.95	6.79	75.65			
7	0.85	6.09	81.74			
8	0.79	5.67	87.41			
9	0.70	4.98	92.39			
10	0.50	3.6	95.99			
11	0.31	2.23	98.23			
12	0.24	1.77	100			
13	0.00	0.00	100			
14	0.00	0.00	100			

**Table 4** Component matrix for dry season

Parameters	Principal components (Dry season)			
	1	2	3	4
Temperature	0.19	0.18	0.12	<b>0.47</b>
Relative humidity	0.22	0.39	-0.37	-0.41
VOC	0.42	<b>0.50</b>	0.32	-0.25
NH <sub>3</sub>	-0.04	<b>0.70</b>	-0.14	0.09
CO	0.34	0.31	-0.24	0.26
CO <sub>2</sub>	0.18	0.16	<b>0.60</b>	-0.39
O <sub>3</sub>	0.15	0.15	<b>0.62</b>	0.48
NO <sub>2</sub>	0.09	<b>0.68</b>	-0.09	-0.04
SO <sub>2</sub>	-0.07	0.16	-0.35	0.41
TSP	<b>0.84</b>	0.04	0.11	0.01
PM <sub>10</sub>	<b>0.85</b>	-0.10	0.16	0.09
PM <sub>2.5</sub>	<b>0.95</b>	-0.16	-0.16	-0.02
Bacteria	<b>0.95</b>	-0.16	-0.16	-0.02
Fungi	<b>0.95</b>	-0.16	-0.16	-0.02

## Conclusions

The study assessed the AQI of criteria air pollutants across eight rural settlements (seven farm settlements and control). Remarkable seasonal and spatial AQI variations of PM<sub>2.5</sub>, CO and NO<sub>2</sub> across the study areas were observed, and the AQI was poor. These air pollutants are known to have negative impacts on human health. The PCA also revealed the relationship and source of the air pollutants investigated. Similarly, PCA grouped particulate matter and bioaerosol into one coherent group with relatively high loading for both seasons. There is a need for critical, pro-active measures and an established system for continuous air quality monitoring to achieve clean air for rural residents including farmers. This study recommends the creation of awareness on potential health risks of farmers' exposure to these pollutants and discourages incessant burnings of wastes. The contribution of this study is the provision of data that can assist in facilitating the management of air pollutions arising from extensive farming activities in the study areas.

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