Exploration of the Relationship between air Quality as an Environmental Factor on well-being and performance of working Oxen in semi-arid climate of Nigeria

Babatunde Akeem Sikiru[1*], John Olayinka Makinde[2], Isiaka Munirat Ambali[3], and Nahari Maryam Adam[4]

[1]Department of Animal Science, Federal University of Agriculture Zuru 872101, Zuru, Kebbi State, Nigeria.
[2]Department of Animal Science, Federal University Gashua, Nigeria.
[3]Department of Crop Science, Federal University of Agriculture Zuru 872101, Zuru, Kebbi State, Nigeria.
[4]Department of Biology, Federal University of Agriculture Zuru 872101, Zuru, Kebbi State, Nigeria.

***Corresponding author:** akeembaba01@gmail.com

ABSTRACT

Smallholder farmers in arid and semi-arid climates rely on draught animals, highlighting the importance of understanding the welfare and well-being of the draught animals. This study was carried out to investigates the interplay between air quality, physiological responses, and work performance of oxen in semi-arid conditions. The Air Quality Index (AQI) ranges from 28.64 to 48.26, averaging 39.02. Respiration rates vary from 17.06 to 21.45 bpm (mean: 19.07 bpm), while pulse rates range from 26.90 to 86.42 bpm (mean: 54.03 bpm). Rectal temperatures span from 33.47°C to 41.25°C (mean: 37.41°C). Field capacity ranges from 1135.63 kg to 2373.99 kg, with an average of 1737.04 kg, and ploughing efficiency from 0.46 m2/min to 2.28 m^2/min (mean: 1.24 m^2/min). Draught Animal Power (DAP) varies from 11.35 mW/ha to 46.36 mW/ha, averaging 20.77 mW/ha. The results showed that weak correlations exist between AQI and pulse rate, ploughing efficiency, and DAP ($p<0.05$), but not with respiration rate and rectal temperature ($p>0.05$). The study concluded that further research on air quality and physiological responses and performance of oxen are warranted as part of comprehensive animal welfare and management strategies for working oxen under semi-arid climate conditions.

Keywords: Draught animals; Semi-arid climate; Oxen well-being; Air quality index (AQI); Draught animal performance metrics.

1.0. INTRODUCTION

Oxen and other draught animals are critical components of smallholder farming operations in the semi-arid climate of Nigeria (Sikiru et al., 2023). This necessitate study that can provide valuable insights into the relationship between environmental conditions, physiological responses, and performance of working oxen in semi-arid climates, these were carried out in this study analytical methods of correlation. This study explored correlations between air quality index

(AQI) and physiological responses including the rate of respiration, pulse rate, rectal temperature as measures of well-being as well as the impact of air quality on performance metrics including field capacity, ploughing efficiency, draught animal power output of the oxen. It is important to investigate environmental impacts on animals' well-being because it has been reported that ambient air pollution exposure in sequence can cause pulmonary inflammation and oxidative stress, followed by haemostasis changes, pulmonary inflammation contributing to systemic changes which can affect cardiovascular system (Li et al., 2008).

The importance of studying environmental impacts on animal well-being cannot be overstated because existing research suggests that exposure to ambient air pollution can have a cascading effect (Manisalidis et al., 2020). It can trigger pulmonary inflammation and oxidative stress, followed by changes in blood clotting and further inflammation, ultimately affecting the cardiovascular system (Miller, 2020). This highlights the need for a comprehensive understanding of how environmental factors in semi-arid regions, beyond just air quality, influence the health and performance of working oxen. However, there are gaps in current knowledge which necessitate further research on the influence of additional environmental factors such as air pollution, temperature extremes, water availability, dust levels on oxen well-being, and performance. Furthermore, investigating the long-term consequences of chronic exposure to these conditions is essential. By addressing these knowledge gaps, it will be possible to develop effective strategies to improve the welfare of working oxen, ultimately contributing to the sustainability and productivity of smallholder farms in Nigeria's semi-arid regions.

2.0. METHODS

2.1. Data Collection

Data were collected on air quality, physiological responses, and work performance of oxen under semi-arid conditions over an 18-day period. The study involved three teams of crossbred (Yankanaji) working oxen (2 oxen per team) in Zuru, located at geographical coordinates 11.4384° N, 5.2319° E.

2.2. Air Quality Measurement

Air quality was assessed using an Android-enabled software known as Air Quality ver.3.2, developed by FFZ Srl (www.ffz.it). The software measures air quality by considering the presence of different obnoxious chemicals and other substances with relevant health risks such as PM10, PM2.5, NO_2, CO, SO_2, NO, O_3, and benzene. These particles, particularly PM10 and PM2.5, are microscopic in nature and can penetrate deep into the lungs, potentially causing respiratory problems, heart disease, and even cancer (Manisalidis et al., 2020).

2.3. Physiological Responses and Field Performance Characteristics

The physiological responses of the oxen were monitored during work periods including the rate of respiration measured as breaths per minute. The pulse rate was measured using stethoscope (Littmann Classic III stethoscope), while the rectal temperature was measured using a Medline digital clinical rectal thermometer (model MDS9950). Non-invasive methods for quantifying heat stress in farm animals were implemented as described by Sejian et al. (2022). The field performance characteristics of the oxen were assessed during work periods, and these include field capacity measured in kilograms (kg) ploughing efficiency measured in meters squared of area covered by the oxen per minute (m^2/min) using measurement of the area ploughed and time taken, and the draught animal power measured in milliwatts per hectare (mW/ha). All the field performance characteristics were determined as reported by Sikiru et al. (2023).

2.4. Monte Carlo Simulation

Data recorded over the 18-day period were subjected to Monte Carlo simulation to generate data for a 60-day period. The simulation process involved assigning normal probability distributions to each variable, generating random values within those distributions, and iteratively combining them to create 60-day scenarios. This approach provided a comprehensive understanding of the potential range of outcomes and how air quality might affect the oxen's well-being and work performance. The simulation employed a normal distribution for each variable to accommodate the central limit theorem, which states that the sum of many independent random variables will tend towards a normal distribution as the number of variables increases, crucial in Monte Carlo simulations (Chopin, 2004).

2.5. Statistical Summary Analysis

The data exploration was carried out implementing a descriptive statistical analysis conducted to explore and summarize the collected data aimed to gain an understanding of the distribution and central tendency of the variables included in the study. For each variable, including Air Quality Index (AQI), physiological responses (rate of respiration, pulse rate, and rectal temperature), and performance metrics (field capacity, ploughing efficiency, and DAP). The count provides the total number of observations for each variable, the mean represents the average value of all data points for the variable, the standard deviation measures the variability or spread of data points around the mean, while the lowest and highest observed value for the variable were the minimum and maximum, respectively.

2.6. Correlation Heatmap Analysis

The correlation heatmap analysis was carried out using the Pearson correlation coefficient to evaluate the relationships between all pairs of variables in the dataset. This was used to generate visual representation that can help in identifying any significant correlations between air quality (AQI), and both physiological responses and performance metrics. The Seaborn's heatmap function was used for generating the visualization of the correlations in a heatmap, the annotations were included to display the correlation values, providing immediate insights into the strength and direction of the relationships.

2.7. Scatter Plot Analysis

For a detailed exploration of the relationships between AQI and individual physiological and performance variables, scatter plots were generated. Each plot displayed AQI on the x-axis and one of the following on the y-axis: rate of respiration, pulse rate, rectal temperature, field capacity, ploughing efficiency, and DAP. These plots were employed as instrument in visually inspecting the data for trends, patterns, or outliers that might not be evident from the correlation analysis alone. Similarly, Seaborn's scatter plot function was used for generating the scatter plots, to facilitate a direct visualization of the correlation due to changes in physiological responses and performance metrics.

3.0. RESULTS

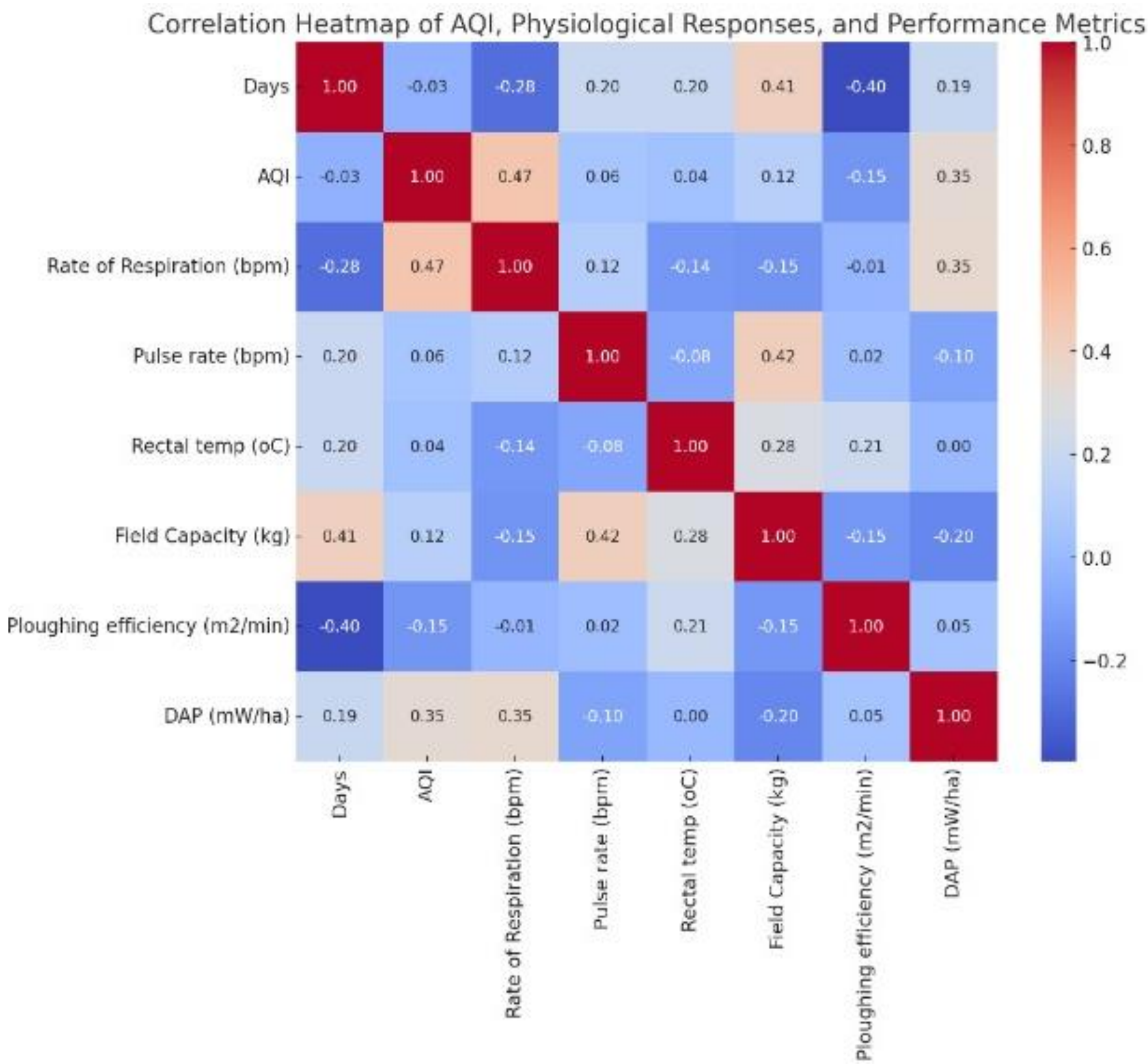
3.1. Summary of descriptive statistics

The Air Quality Index (AQI) ranges from approximately 28.64 to 48.26, with a mean of 39.02, indicating variations in air quality during the observation period. The rate of respiration varies from 17.06 bpm to 21.45 bpm, with a mean value of 19.07 bpm. The pulse rate has a wider range, from 26.90 bpm to 86.42 bpm, and mean value of 54.03 bpm. The rectal temperature spans from 33.47 °C to 41.25 °C, with a mean of 37.41°C, highlighting temperature fluctuations among the oxen. The field capacity shows a range from 1135.63 kg to 2373.99 kg, with an average capacity of 1737.04 kg. The ploughing efficiency is between 0.46 m^2/min, and 2.28 m^2/min, averaging at 1.24 m^2/min. While the Draught Animal Power (DAP) measured in mW/ha, also varies significantly from 11.35 mW/ha to 46.36 mW/ha, with a mean of 20.77 mW/ha.

3.2. The correlation heatmap

The correlation heatmap provides insights into how different variables are related to each other. While there were correlations between the AQI and some of the variables, there were no significant correlations between the AQI and some of the variables. The heatmap showed that there was no strong correlation between AQI and the physiological responses of the oxen, such as the rate of respiration, pulse rate, and rectal temperature ($p>0.05$). This suggests that, within the observed range of AQI values, there was no clear linear relationship with these physiological metrics. Similarly, the correlation between AQI and performance metrics including the field capacity, ploughing efficiency, and DAP (mW/ha) was not also significant ($p > 0.05$).

The correlation heatmap showed that there is a weak positive correlation between the Air Quality Index (AQI) and the rate of respiration, as the AQI increases, the rate of respiration also tends to increase. There is a moderate positive correlation between the AQI and pulse rate, as the AQI increases, the pulse rate also tends to increase. There is a weak positive correlation between the AQI and rectal temperature, as the AQI increases, the rectal temperature also tends to increase. There is a weak negative correlation between the AQI and ploughing efficiency, as the AQI increases, ploughing efficiency tends to decrease. However, there is a moderate positive correlation between ploughing efficiency and DAP (Draught Animal Power), as ploughing efficiency increases, DAP also tends to increase (Figure 1).



ISSN: 2821-9007 (Online)

Figure 1: The correlation heatmap showing relationship between the air quality index, rate of respiration, pulse rate, rectal temperature, field capacity, ploughing efficiency, and draught animal power output of the oxen. The figure is a correlation heatmap which shows the strength and direction of the relationships between various physical responses and performance metrics. The scale on the right side of the heatmap goes from -1 to 1, where -1 indicates a negative correlation, 0 indicates no correlation, and 1 indicates a positive correlation. There is a weak positive correlation between the Air Quality Index (AQI) and the rate of respiration. This means that as the AQI increases, the rate of respiration also tends to increase.

3.3. The scatterplot

The scatter plots provide a visual examination of the relationship between Air Quality Index (AQI) and each of the physiological and performance metrics for the working oxen. The scatterplot indicated that breathing dirty air may not be the main cause of an increased rate of respiration, there could be other factors that are causing both the AQI and the rate of respiration to increase (Figure 2).

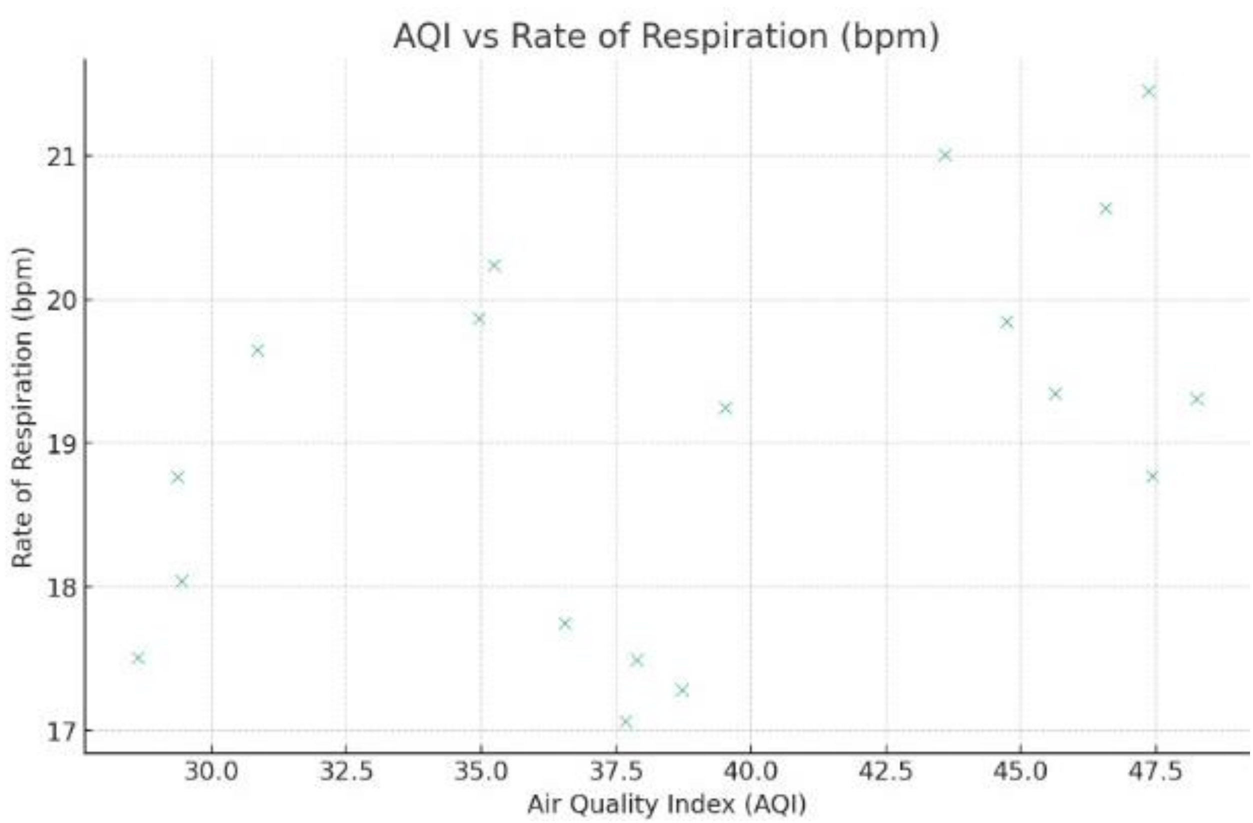


Figure 2: The scatterplot showing relationship between the air quality index and rate of respiration of the oxen. The x-axis of the graph shows the Air Quality Index (AQI), ranging from 30.0 to 47.5. The y-axis shows the rate of respiration in breaths per minute (bpm), ranging from 17 to 21. The data point show a slight upward trend and it suggest that there is a weak positive correlation between air quality and rate of respiration, although the figure showed that as the AQI increases, the rate of respiration also tends to increase slightly.

For the pulse rate, the data points showed a slight upward trend which is a suggestion that there is a weak positive correlation between air quality and pulse rate, as the AQI increases, the pulse rate could also tend to increase slightly (Figure 3).

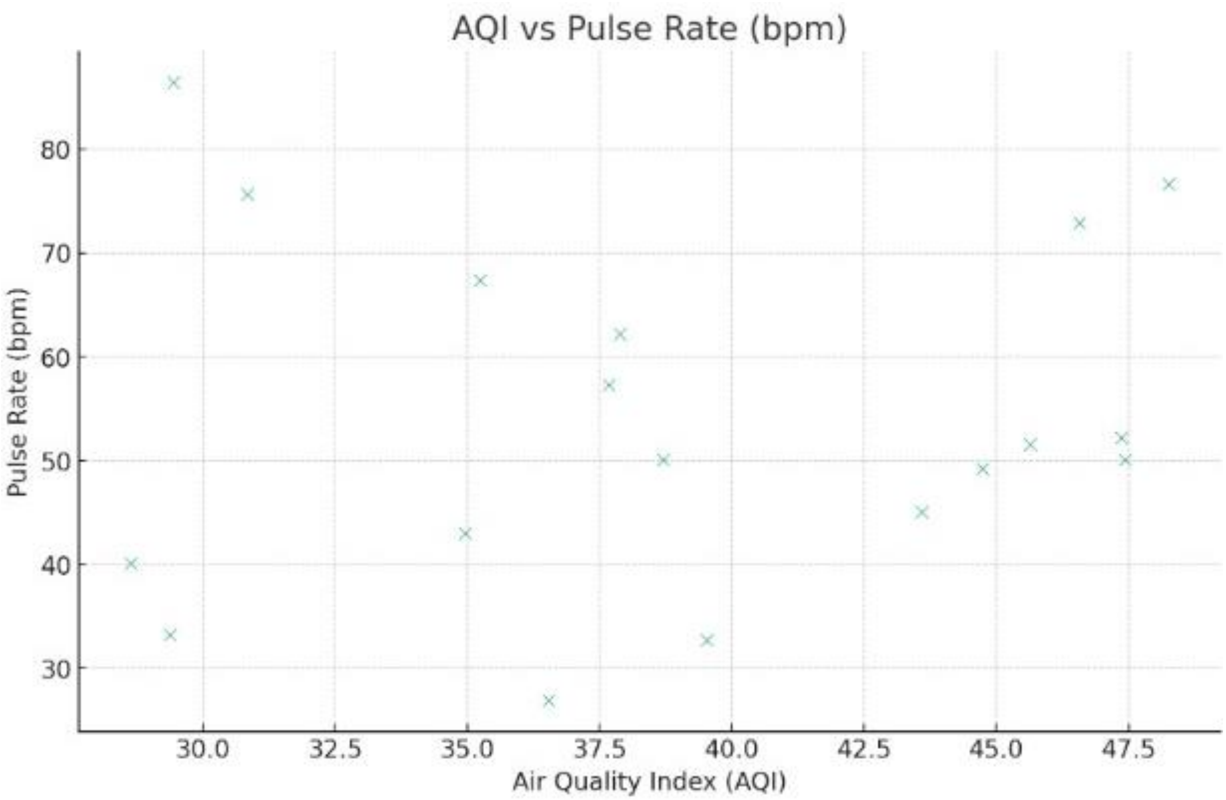


Figure 3: The scatterplot showing relationship between the air quality index and pulse rate of the oxen. The figure shows the relationship between Air Quality Index (AQI) and pulse rate, the x-axis represents the AQI, ranging from 30.0 to 47.5, while the y-axis represents the pulse rate in beats per minute (bpm), ranging from 40 to 80.

ISSN: 2821-9007 (Online)

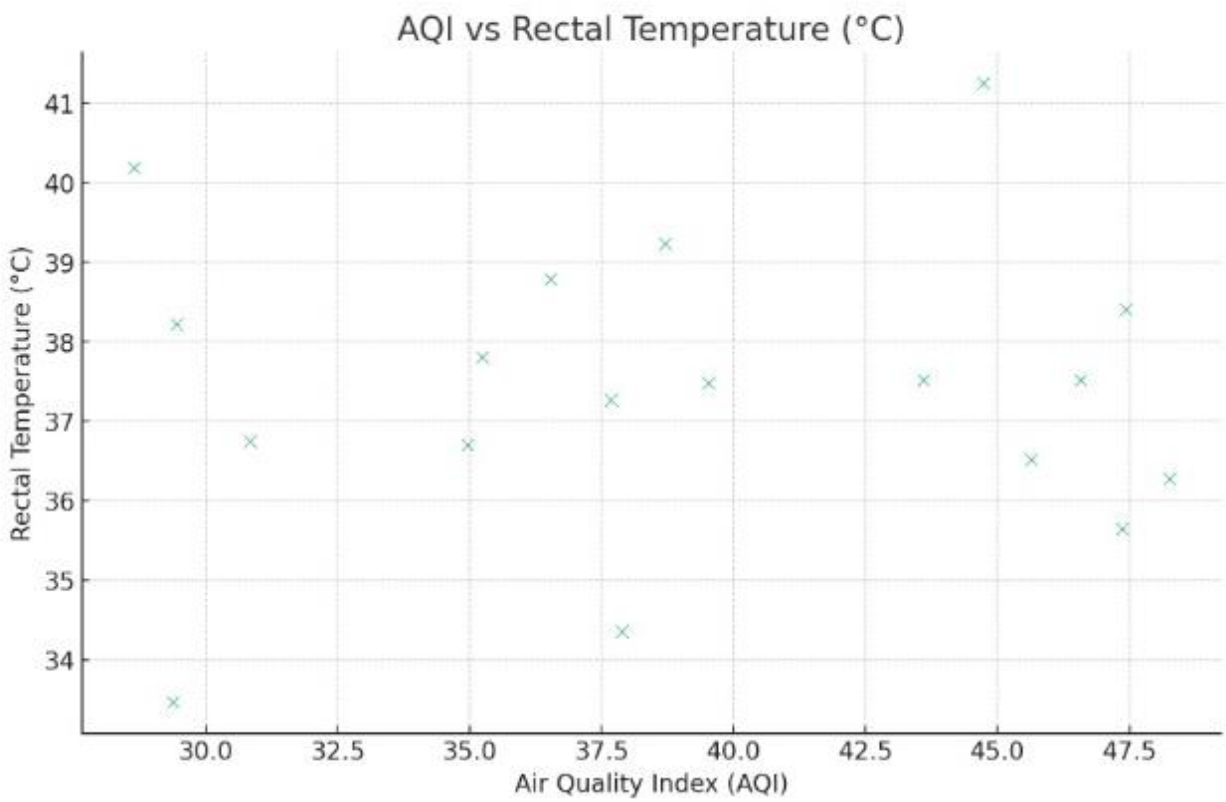


Figure 4: The scatterplot showing relationship between the air quality index and rectal temperature of the oxen. The x-axis shows the Air Quality Index (AQI), ranging from 30.0 to 47.5. The y-axis shows the rectal temperature in degrees Celsius (°C), ranging from 34 to 41.

For the rectal temperature and AQI, the scatterplot showed no clear pattern, but the plot suggests that there is no correlation between AQI and rectal temperature which means there is no evidence that AQI influences rectal temperature (Figure 4). Similarly, the scatter plots for these performance metrics against AQI also do not show a distinct pattern or relationship. While there are variations in these metrics, there was no significant correlation between AQI, and the variables ($p>0.05$). While the data points showed no clear pattern to suggest a correlation or an anti-correlation between the field capacity and the AQI, it is possible that there could be a relationship between field capacity and AQI outside of the range depicted (Figure 5).

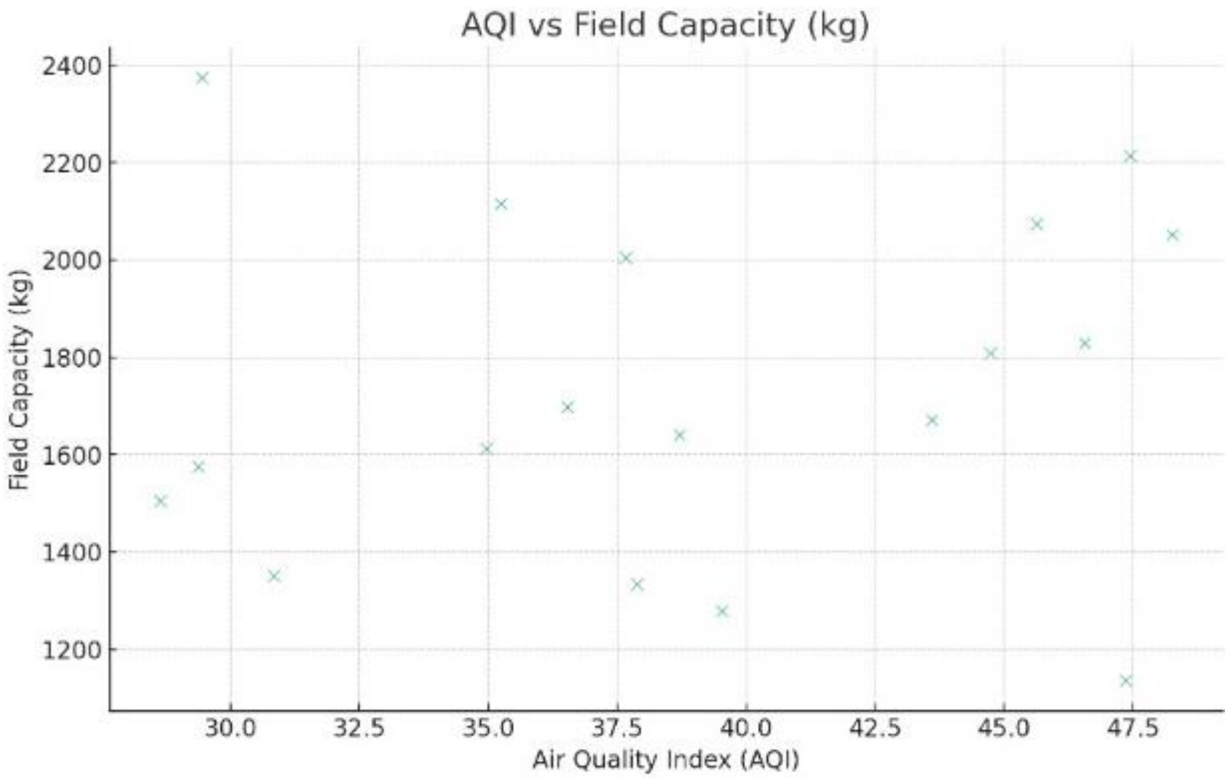


Figure 5: The scatterplot showing relationship between the air quality index and field capacity of the oxen. The figure indicate the Air Quality Index (AQI) on the x-axis ranging from 30.0 to 47.5 level, while the y-axis shows the field capacity, ranging from 1200 kg to 2400 kg.

There are several data points plotted on the graph indicating the relationship between AQI and ploughing efficiency in a downward trend suggesting that there could be a weak negative correlation between air quality and ploughing efficiency. In other words, as the AQI increases, the ploughing efficiency might tend to decrease slightly (Fig. 6).

The data points plotted on the graph showed a slight upward trend for the AQI and DAP which suggests that there might be a weak positive correlation between AQI and DAP that could be interpreted that as the AQI increases, the DAP might also tend to increase slightly (Fig. 7).

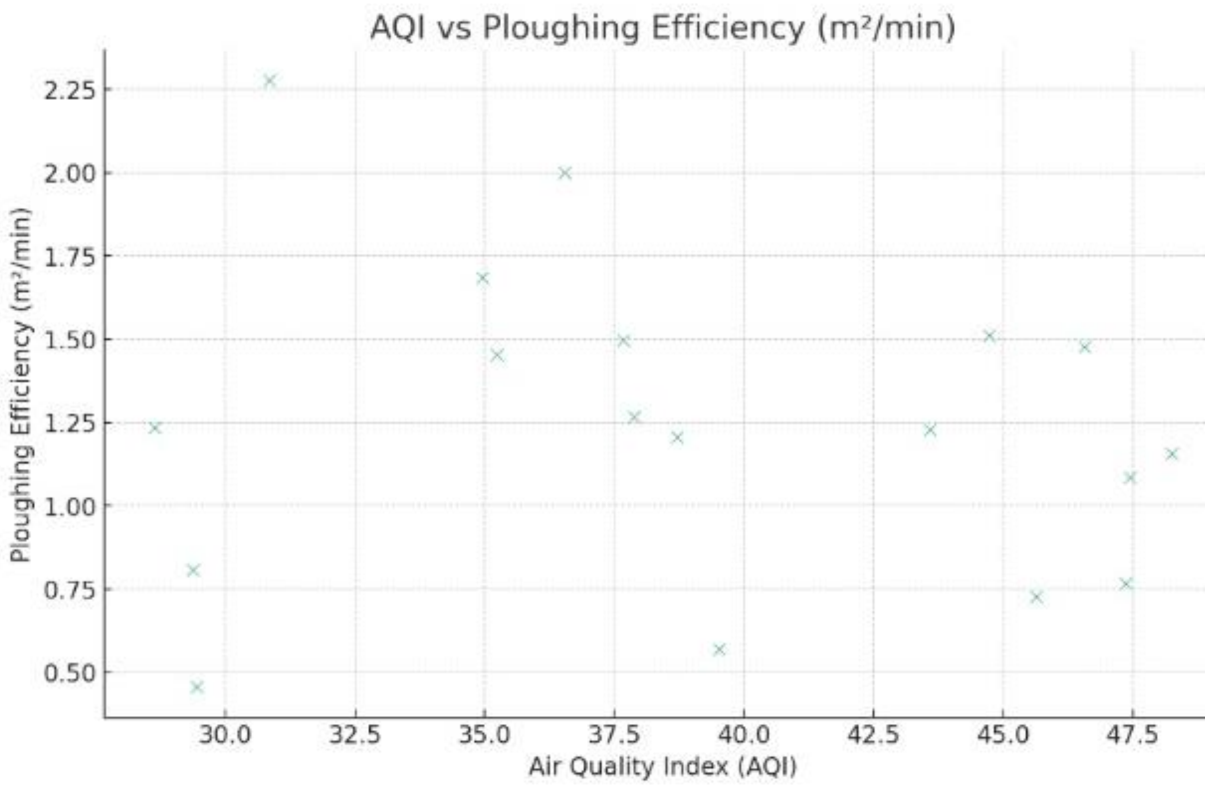


Figure 6: The scatterplot showing relationship between the air quality index and ploughing efficiencey of the oxen. The x-axis of the graph shows the Air Quality Index (AQI), ranging from 30.0 to 47.5. The y-axis shows the ploughing efficiency in square meters per minute (m^2/min), ranging from 0.5 to 2.25.

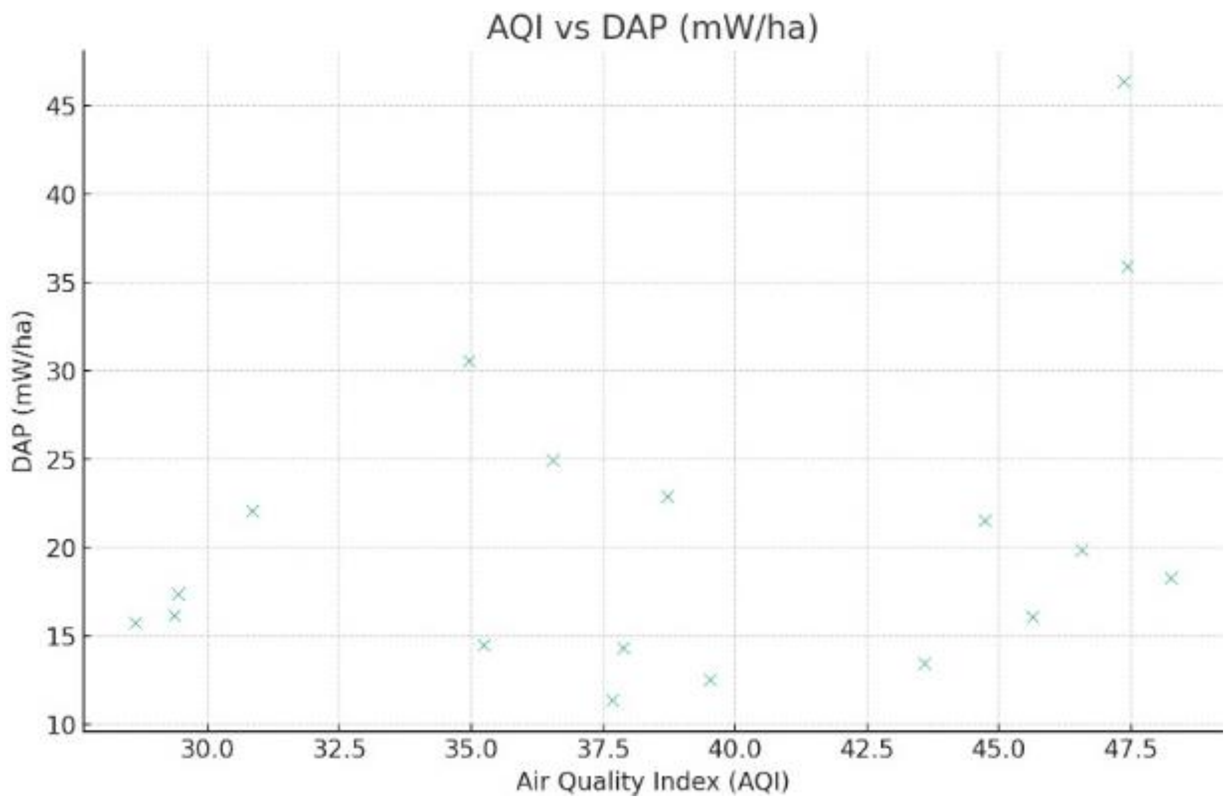


Figure 7: The scatterplot showing relationship between the air quality index and draught animal power output of the oxen. The x-axis of the graph shows the Air Quality Index (AQI), ranging from 30.0 to 47.5. The y-axis shows the DAP, ranging from 15 to 45 (mW/ha).

4.0. DISCUSSION

The exploration carried out in this study suggests that there is limited direct correlation between AQI and both the physiological responses and performance metrics of working oxen under the conditions observed. This implies that while air quality is an essential factor for overall well-being, its impact on the specific physiological and performance metrics recorded may be influenced by a complex interplay of factors beyond just AQI. Although, slight positive correlation between AQI and pulse rate increase was observed in the working oxen in this study. The increased pulse rate, often measured as heart rate (HR), is a significant factor in cardiovascular health and disease which has been associated with various physiological and pathological outcomes, influencing both the structure and function of the cardiovascular system (Pope et al., 1999). This suggest that exposure to air pollution could be associated with changes in heart rate and rhythm, which can lead to autonomic dysfunction and potentially increase the risk of cardiopulmonary mortality and other cardiac events, with susceptibility heightened in individuals with pre-existing conditions or certain genetic predispositions. In conclusion, the observed increased pulse rate could have significant implications for cardiovascular health of the oxen highlighting a gap in research findings and establishment of management strategies for working oxen.

The increase in pulse rate was also weakly associated with reduced work efficiency under poor air quality which could have significant implications for health and productivity of the oxen. This shows that the study provided a comprehensive overview of the adverse effects of air pollution on cardiovascular and pulmonary function, which in turn can affect an individual's ability of oxen to perform tasks efficiently. This could have several implications, firstly, exposure to higher concentrations of air pollution could be associated with higher resting blood pressure and lower ventilatory function, as indicated by a study that found significant associations between air pollution and a higher resting heart rate, higher systolic and diastolic blood pressure, and reduced exercise capacity (Cakmak et al., 2011). This suggests that air pollution could directly impact cardiovascular health of the oxen which is critical for maintaining physical stamina and work efficiency.

Secondly, poor air quality has been linked to decreased productivity even under office settings in a study which found that poor indoor air quality, due to inadequate mechanical ventilation systems, led to symptoms of lethargy in 75% of office workers, with temperature being strongly correlated with working performance (Wyon, 2004). This implies that not only does air pollution affect physical health but could also has a direct correlation with cognitive functions and work performance of the oxen. Furthermore, it has been demonstrated that indoor air pollution can reduce productivity by 6-9%, with the higher value obtained under field validation (Rahman et al., 2014). This reduction in productivity is significant and suggests that even at pollutant levels that do not affect the perception of air quality by the respondents such as oxen in this present study, there can be substantial impacts on work performance such as ploughing efficiency and draught animal power output. Lastly, a meta-analysis supports an inverse relationship between heart rate variability (HRV), a marker for a worse cardiovascular prognosis, and particulate air pollution (Pieters et al., 2012). This indicates that particulate matter exposure can lead to reductions in HRV of working oxen, which could be associated with adverse cardiovascular outcomes in the oxen that could potentially contribute to decreased work efficiency in terms of ploughing efficiency and draught animal power. These implies that the relationship between increased pulse rate and reduced work efficiency under poor air quality are multifaceted and could affect both physical health and cognitive function of oxen which underscore the importance of maintaining good air quality in environments to protect cardiovascular health and ensure optimal work performance of the oxen. Premised on the observation above, there is a need to consider exploration of other environmental such as the Temperature humidity index, health status, workload, and animal management as factors that could be playing roles in the well-being and performance of working oxen in the study area. This holistic approach to well-being focusing on these factors for the promotion of the well-being of working oxen under semi-arid climate conditions would be essential and could further shed light on better understanding to improve air quality as part of comprehensive animal welfare and management strategies for working oxen.

LIMITATIONS OF THE STUDY

The study's limitations include the relatively short data collection period of 18 days, which may not capture longer-term trends and variations in air quality and its effects on oxen performance. Variability in the calibration and precision of measurement instruments which could also influence the results. Future studies should consider longer observation periods and incorporate a wider range of environmental variables to enhance the robustness of the findings.

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