Study on the impact of air quality in agricultural and health sectors

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Abstract. This study focused on the impact of air quality in agricultural and health sectors. The impact of CO\textsubscript{2} on the agricultural crops was conducted by using literature review and the impact of air quality was conducted using secondary data to calculate the Air Quality Index (AQI), derived from some monitoring stations available in Indonesia. Numerous studies showed that the elevated CO\textsubscript{2} decreased the agricultural productivity. Maize yields decreased by 15\% in areas which used irrigation system and 8\% in areas which used rainfed. Maize yields had already experienced severe losses without increasing CO\textsubscript{2} concentrations. It decreased by 21\% for irrigated maize and 26\% by rainfed maize. In addition, it turned out that other elevated pollutants, such as SO\textsubscript{2}, NO\textsubscript{2}, SPM, O\textsubscript{3}, CH\textsubscript{4}, PM\textsubscript{2.5}, PM\textsubscript{10} and TSP also occurred in the atmosphere. These pollutants’ effects might harm human being in term of health concern. The USEPA had developed a tool, called the Air Quality Index (AQI) calculator to calculate the pollutants’ concentrations in a daily basis. This tool’s function to inform how clean or polluted the air that we breathed was with the health effects based on the concentrations of each pollutant. The AQI also provided the information on sensitive groups, health effects and cautionary statements. Based on the air daily data which derived from Board of Meteorology, Climatology and Geophysics (BMKG) of Indonesia, the AQI in Indonesia varied from good, moderate to unhealthy categories; with level of health concern was respiratory diseases, such as asthma.

1. Introduction
The purpose of this study was to identify the impact of air quality on agricultural and health sectors. These both sectors might be related to each other. Good agriculture made healthy human beings. The sources of agricultural pollutants might be similar with or different from air pollutants. Yet, both agricultural and health sectors got impacted with the same target, human beings.

CO\textsubscript{2} is composed of one atom of carbon and two atoms of oxygen. It is a heavy colorless, odorless and non flammable gas. It is produced during respiration by the decomposition of organic substances; when carbon is burned; or when people and animal breathe out. The US Department of Energy (USDOE) [1] mentioned that the primary sources of CO\textsubscript{2} were divided into two sources: natural CO\textsubscript{2} sources and man made (anthropogenic) CO\textsubscript{2} sources. The greates natural CO\textsubscript{2} sources was derived from the ocean. Other sources came from animal and plant respiration, decomposition of organic matters, forest fires, and emissions from volcanic eruptions. In addition, CO\textsubscript{2} deposits found in rock layers within the Earth’s crust. Meanwhile, the anthropogenic CO\textsubscript{2} sources came from our daily

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activities, such as powerplant, transportation, industries, chemical production, petroleum production, and agricultural practices. The USDOE had identified more than 4,000 stationary sources which emit over 3,000 million metric tons of anthropogenic CO$_2$ per year in USA and some parts in Canada (Figure 1). The blue color represented the electric power which generated the largest emitter of anthropogenic CO$_2$.

![Figure 1. Stationary anthropogenic sources of CO$_2$ by industry in USA and some parts in Canada [1].](image)

Figure 2 above showed the diagram of stationary anthropogenic of CO$_2$ emission. The largest contributor was the electrical production which was about 73%. The elevated CO$_2$ concentrations in the atmosphere could increase water use efficiency in crops and mitigate yield losses due to climate...
change [2]. A study reported that yields from wheat, maize, soybean, and rice at levels of CO₂ remained at concentration of 2000 levels would experience severe decline in yields due to higher temperature and drier conditions. But, when all four crops grown at doubled CO₂ concentrations, the crop productivity and yield varied. According to the study, maize experienced yield losses due to the large part of the plant was already greater efficiency in photosynthesis using CO₂ than other crops. Maize yields decreased by 15 % in areas which used irrigation system and 8 % in areas which used rainfed. Maize yields had already experienced severe losses without increasing CO₂ concentrations. It decreased by 21 % for irrigated maize and 26 % by rainfed maize. This study also mentioned that the elevated CO₂ concentrations on plant nutrition could lead to the reduction of nutrients, such as iron, zinc and protein content [2]. Another study which was conducted in Ethiopia [3] revealed that CO₂ emissions had a negative impact on agricultural performance. The impact of CO₂ emissions induced reduction in agricultural factor productivity led to a decrease in production of agricultural traded and non-traded crops, except livestock production.

The impact of elevated CO₂ concentrations on plants in the mid to high latitudes of northern hemisphere showed that the increase of CO₂ concentrations accounted for 98% of water use efficiency on plants. Plants growing at higher altitudes showed higher increase in water use efficiency and more sensitive to the CO₂ increase than plants at lower altitudes. Meanwhile, plants growing at low temperature environments were slightly more sensitive to CO₂ increase than those at higher temperature environments. The research also showed that there was no significant relationship between precipitation and plants’ water use efficiency in response to the atmospheric CO₂ increase. In addition, the research reported that altitude and temperature, both impact the water use efficiency in response to the elevated CO₂. Yet, the size of the impact was physically small and could be omitted from ecological models [4].

Agricultural pollutants which important and generally occurring of these pollutants were ethylene, fluorides, ozone, peroxycylic nitrates (PAN) and sulfur oxides. Their effects upon animals and plants could be best described by the reaction of biologic materials to pollutant concentration and exposure time. The following four criteria were recognized: (1) interference with enzyme systems (2) change in cellular chemical constituents and physical structure (3) retardation of growth and reduction in production from altered metabolism, and (4) acute immediate tissue degeneration [5]. Meanwhile, the sources of air pollutants in the atmosphere were sulfur dioxide (SO₂), nitrogen dioxide (NO₂), Suspended Particulate Matter (SPM), pH of precipitation, ozone (O₃), green house effect, particulate matter (PM₁₀), particulate matter (PM₂.₅) and Total Suspended Particulate (TSP).

2. Methodology
This study focused on literature review on CO₂ impact on agricultural crops and utilized secondary data for air quality which obtained from Board of Meteorology, Climatology and Geophysics (BMKG) of Indonesia to calculate the Air Quality Index (AQI) in Indonesia.

Each of the following pollutant measurement was conducted by BMKG and most of them were analysed at Air Quality Laboratory of BMKG in Indonesia, except for the green house gas which was analysed at NOAA Laboratory. SO₂ measurement was conducted using Passive Sampler with passive gas method. Samples were analysed using an ion chromatography. NO₂ measurement was conducted using Passive Sampler with passive gas method and analysed using a spectrophotometer. SPM sampling was conducted using a High Volume Sampler (HVS) and samples were analysed using an analytical balance. pH of precipitation was measured using an Automatic Rain Water Sampler (ARWS) with Wet and Dry Deposition method. These samples were analysed using an ion chromatograph. O₃ measurement was conducted using an Ozone Analyzer and UV Photometric method. The pollutants measured in Green House Effect were CO₂ and CH₄. Samples were measured using an Analyzer Picarro G3010 with Cavity Ring Down Spectroscopy (CRDS). These samples were analysed using an Air Kit Flask Sampling. PM₁₀, PM₂.₅ and TSP were particles in the air with size less than 10 microns, less than 2.5 microns and less than 100 micrometers, respectively.
The quality standard for pollutants was presented in Table 1. The Air Quality Index (AQI) was identified using a tool developed by The US Environmental Protection Agency (USEPA) [7] called the Air Quality Index Calculator which available online on www.airnow.gov. The AQI could be calculated by using equation 1 [8].

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} (C_p - BP_{Lo}) + I_{Lo}$$

(1)

Where:
- \( I_p \) = the index for pollutant \( p \)
- \( C_p \) = the truncated concentration of pollutant \( p \)
- \( BP_{Hi} \) = the concentration breakpoint that is greater than or equal to \( C_p \)
- \( BP_{Lo} \) = the concentration breakpoint that is less than or equal to \( C_p \)
- \( I_{Hi} \) = the AQI value corresponding to the \( BP_{Hi} \)
- \( I_{Lo} \) = the AQI value corresponding to the \( BP_{Lo} \)

The AQI was used to report air quality in daily basis. It informed us about how clean or polluted the air was with the health effects which might become our concern. The AQI focused on health effects that we might experience within hour after breathing polluted air. The AQI with level of health concern was classified into 6 categories along with its meanings presented in Table 2 and Table 3, respectively.

**Table 1. Quality Standard of Pollutants\(^a\)**

| Pollutant | Concentration amount | Units      |
|-----------|----------------------|------------|
| SO\(_2\)  | 0.14                 | ppb        |
| NO\(_2\)  | 0.08                 | ppb        |
| SPM       | 230.00               | \(\mu\) gram/m\(^3\) |
| pH        | 5.60                 | -          |
| O\(_3\)   | 120.00               | ppb        |
| PM\(_{10}\)| 150.00               | \(\mu\) gram/m\(^3\) |
| PM\(_{2.5}\)| 65.00               | \(\mu\) gram/m\(^3\) |
| TSP       | 230.00               | \(\mu\) gram/m\(^3\) |

\(^a\)BMKG of Indonesia [6]

**Table 2. Classification of The Air Quality Index with Level of Health Concern\(^a\)**

| Air Quality Index | Level of Health Concern | Colors         |
|-------------------|-------------------------|----------------|
| 0 - 50            | Good                    | Green          |
| 51 - 100          | Moderate                | Yellow         |
| 101 - 150         | Unhealthy for sensitive group | Orange      |
| 151 - 200         | Unhealthy               | Red            |
| 201 - 300         | Very unhealthy          | Purple         |
| 301 - 500         | Hazardous               | Hazardous      |

\(^a\) USEPA [7]
Table 3. Classification of The Air Quality Index with Level of Health Concern with its meaning

| Air Quality Index | Level of Health Concern | Meaning |
|-------------------|-------------------------|---------|
| 0 - 50            | Good                    | Air quality is considered satisfactory. |
| 51 - 100          | Moderate                | Air quality is acceptable; however for some pollutants there may be a moderate health concern for every small number of people who are unusually sensitive to air pollution. |
| 101 - 150         | Unhealthy for sensitive group | Members of sensitive groups may experience health effects. The general public is not likely to be affected. |
| 151 - 200         | Unhealthy               | Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects. |
| 201 - 300         | Very unhealthy          | Health alert: everyone may experience more serious health effects. |
| 301 - 500         | Hazardous               | Health warning with emergency conditions. The entire population is more likely to be affected. |

* USEPA [7]

3. Results and Discussion

Based on the previous studies, the results showed that the elevated CO₂ could increase crop water use efficiency and reduce crop productivity. Yet, another study showed that there was no significant relationship between precipitation and plants’ water use efficiency with the elevated CO₂.

Table 4. The AQI based on the average pollutant’s concentrations from several stations located spreadly in Indonesia in 2016 up to May 2017

| Pollutant | Concentration | Unit       | AQI<sup>b</sup> | AQI Category<sup>b</sup> | Sensitive Group<sup>b</sup> |
|-----------|---------------|------------|------------------|--------------------------|-------------------------------|
| SO₂       | 0.0033 ppb    | 47 Good    | People with asthma are the group most at risk. |
| NO₂       | 0.0368 ppb    | 152 Unhealthy | People with asthma or other respiratory diseases, the elderly, and children are the groups most at risk. |
| SPM       | 77.6659 µ gram/m³ | - | - | - |
| pH        | 5.1336        | - | - | - |
| O₃        | 17.0000 ppb   | 16 Good    | Children and people with asthma are the groups most at risk. |
| CO₂       | 400.0000 ppb  | - | - | - |
CH$_4$ 1870.0000 ppb - - People with respiratory or heart disease, the elderly and children are the groups most at risk.

PM$_{2.5}$ 18.3623 µ gram/m$^3$ 64 Moderate People with respiratory or heart disease, the elderly and children are the groups most at risk.

PM$_{10}$ 19.2691 µ gram/m$^3$ 18 Good People with respiratory disease are the group most at risk.

TSP 0.0000 µ gram/m$^3$ - - -

$^a$ BMKG of Indonesia [6]
$^b$ USEPA [7]

Table 5. The AQI with Level of Health Concern in Indonesia$^a$

| Pollutant | AQI Category$^b$ | Sensitive Group$^b$ | Health Effects Statements$^b$ | Cautionary Statements$^b$ |
|-----------|------------------|---------------------|-----------------------------|--------------------------|
| SO$_2$    | Good             | People with asthma are the group most at risk. | None | None |
| NO$_2$    | Unhealthy        | People with asthma or other respiratory diseases, the elderly, and children are the groups most at risk. | Greater likelihood of respiratory symptoms in active children, the elderly, and people with lung disease, such as asthma; possible respiratory effects in general population. | Active children, the elderly, and people with lung disease, such as asthma, should avoid prolonged or heavy outdoor exertion; everyone else, especially children, should reduce prolonged or heavy outdoor exertion. |
| O$_3$     | Good             | Children and people with asthma are the groups most at risk. | None | None |
| PM$_{2.5}$| Moderate         | People with respiratory or heart disease, the elderly and children are the groups most at risk. | Unusually sensitive people should consider reducing prolonged or heavy exertion. | Unusually sensitive people should consider reducing prolonged or heavy exertion. |
| PM$_{10}$ | Good             | People with respiratory disease are the group most at risk. | None | None |

$^a$ BMKG of Indonesia [6]
$^b$ USEPA [7]

The AQI based on the average pollutant’s concentrations from several stations located spreadly in Indonesia in 2016 up to May 2017 was presented in Table 4. The results showed that based on its
concentrations, the AQI varied from 16 to 152 for each pollutant. The AQI categories varied as well from good, moderate to unhealthy, with sensitive group of people with asthma and respiratory or heart diseases. The AQI only calculated PM$_{2.5}$ (24hr average), PM$_{10}$ (24hr average), CO (8hr average), SO$_2$ (1hr average), SO$_2$ (24 hr average), O$_3$ (8hr average), O$_3$ (1hr average), and NO$_2$ (1hr average). The AQI also provided the health effects and cautionary statements presented in Table 5.

4. Conclusion
This study identified the impact of air quality in agricultural by conducting some literature reviews and the impact of air quality in health sectors by calculating the AQI using AQI Calculator in Indonesia. Studies showed that the elevated CO$_2$ decreased the agricultural productivity. Meanwhile, the air pollutants in the atmospheres such as SO$_2$, NO$_2$, SPM, O$_3$, CO$_2$, CH$_4$, PM$_{2.5}$, PM$_{10}$ and TSP had an impact on human’s health. The air quality for health sector used the Air Quality Index (AQI) Calculator to inform how clean or polluted the air that we breathed was with the health effects based on the concentrations of each pollutant. The AQI in Indonesia was in good, moderate to unhealthy categories.

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