EVALUATION OF SOIL PROPERTIES AT JENGKA RESEARCH STATION AFTER TWO YEARS ENRICHED WITH CARBON DIOXIDE EMISSIONS

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ABSTRACT

Carbon dioxide (CO2) contributes the major anthropogenic greenhouse gas (GHG), more than 70% of total (GHG) emissions. Adaptation methods are needed to reduce GHG emissions and forest can play an important role in sequestering carbon to mitigate climate change. Carbon sequestration occurs in forest and soils primarily through fixation of atmospheric C by photosynthesis. Experimental plots under the FACE (Free-Air CO2 Enrichment) study was set up at the Jengka Research Station in Pahang, Malaysia, to investigate the effects of increased atmospheric carbon dioxide on the forest ecosystem. The nutrient needs for plant growth are expected to increase in response to changes in CO2 and temperature, and the soil provides these nutrients for plant growth. This study provides information on changes in soil properties after two years exposure to carbon dioxide emissions. Increases in soil pH, moisture, nitrogen, organic carbon and exchangeable potassium were observed. While the levels of available phosphorus and exchangeable aluminum decreased after this area was enriched with CO2 gas.

Keywords: FACE, c-sequestration, greenhouse gas, CO2, soil properties

INTRODUCTION

Anthropogenic sources of man-made activities through burning, deforestation, agriculture and industrial operations have greatly increased atmospheric concentrations of water vapor and greenhouse gases (GHG). Increased greenhouse gas emissions cause heat to become trapped near earth surfaces, leading to global warming (Rajib *et.al.*, 2016). Carbon dioxide contributed the highest percentage, 76% of all greenhouse gases in 2010. This may be related to its high rate of 2.0 + 0.1 ppm per year compared to other greenhouse gases such as methane, nitrous oxide and fluorinated gases (IPCC, 2014). Although climate change is a slow process, its small changes over a long period of time have shown alarming signs, such as the melting of the ice on the North Pole, which led to sea-level rise and flood disasters in other parts of the world. Climate change caused by increased temperature, humidity and increased CO_2 has the potential to threaten food security through its effects on soil properties and processes (Brevik, 2013).

Forests can play an important role in reducing CO_2 emissions through sequestrating carbon in soils. Carbon sequestration is referred to the removal of atmospheric CO_2 through photosynthesis and the storage of fixed carbon in plant biomass (Lal, 2004). Subsequently, some of this plant biomass is indirectly sequestered carbon as soil organic carbon during decomposition processes (Navneet, 2017). Here we investigate the influence of increased atmospheric CO_2 on various soil parameters in the FACE system (Free-Air CO_2 Enrichment), which was carried out in a tropical forest in Pahang, Malaysia in order to understand the adaptation to climate change. Soil changes were also examined in the control plot without CO_2 elevation compared to the treatment with CO_2 fertilization in the FACE study area. The data after two years of gas release were discussed.

MATERIALS AND METHOD

Experimental sites

The study was conducted in a tropical forest ecosystem under the FACE system located at FRIM Jengka Research Station in Pahang, Malaysia. The hexagonal FACE system was built in 2017 and the released CO_2 concentration was in the range of 480-520 ppm per month. The control plot was setup 200 meters from the FACE area. Soil samples were taken before the start of treatment and after the gas release over a period of two years; in two depths, 0-10 cm and 10-30 cm. A similar sampling was also carried out in the control plot without CO_2 treatment.

Soil chemical analysis

The soil properties were analyzed at the FRIM soil chemistry laboratory. Total nitrogen was determined by Kjedahl micro-digestion followed by distillation and titration with 0.1 N hydrochloric acid. Organic carbon (OC) was quantified by the Wakley and Black rapid titration method. The available phosphorus (P) was extracted followed the Bray and Kurtz No.2 method and its concentration was determined in a UV-Vis spectrophotometer by the Denige Blue method. Soil moisture was determined by gravimetric method. Soil pH was measured with a pH meter using a 1: 2.5 ratio of soil: water suspension. The exchangeable potassium (K) was extracted with an ammonium acetate solution and its concentration was determined by an inductive couple plasma-optical emission spectrometer (ICP-OES). Exchangeable aluminum was extracted with potassium chloride solution and determined by titration method.

RESULTS AND DISCUSSION

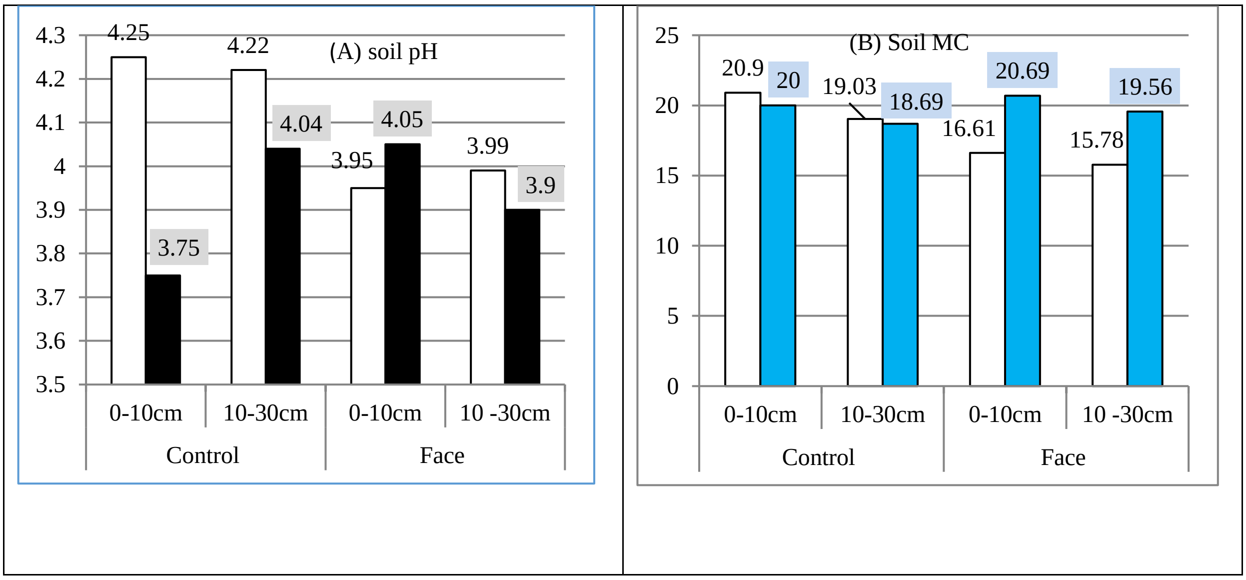
Soil pH

Tropical forests are a complex ecosystem. Changes in soil properties in forests are closely related to plants, the environment and the climate. The initial soil pH in the control plot was 4.22 - 4.25 while the FACE site recorded 3.95-3.99 pH before the CO_2 was released; showed that the soil in the trial plots was acidic. After two years of exposure to CO_2, the upper soil depth (0-10 cm) in the FACE area showed a slight increase in pH of 4.05, as shown in Figure 1A. The increase of soil pH may be due to the buffering of cation exchange with hydrogen ions and mineral solubility reaction (Fu *et. al*., 2009). However, a slight decrease in pH was observed at a depth of 10-30 cm. This may be due to the formation of carbonic acid through the reaction of CO_2 with water from the soil moisture. Zahra *et al*. (2020) found that CO_2 can be absorbed into the soil and forms carbonic acid when it comes into contact with water. Different trend was observed in the control plot where the soil pH showed a sharp decrease (4 -11%) after 2 years in both the soil layer. The decomposition of plant residues can lead to the formation of organic acids and causes a decrease in the pH value of the soil.

Moisture content

After 2 years of CO_2 emissions, the percentage of soil moisture in the FACE plot showed a 24% increase in both soil depths (Figure 1B). On the other hand, a slight decrease in the soil moisture content was observed in the control plot (0.18 - 4.3%). Plant growth may affect the need for additional water to replace the water lost due to increased temperature. However, the soil moisture showed no decrease in the site elevated with CO_2 under the forest ecosystem. The control plot maintained the soil moisture content in the range of 18.7 – 20%.

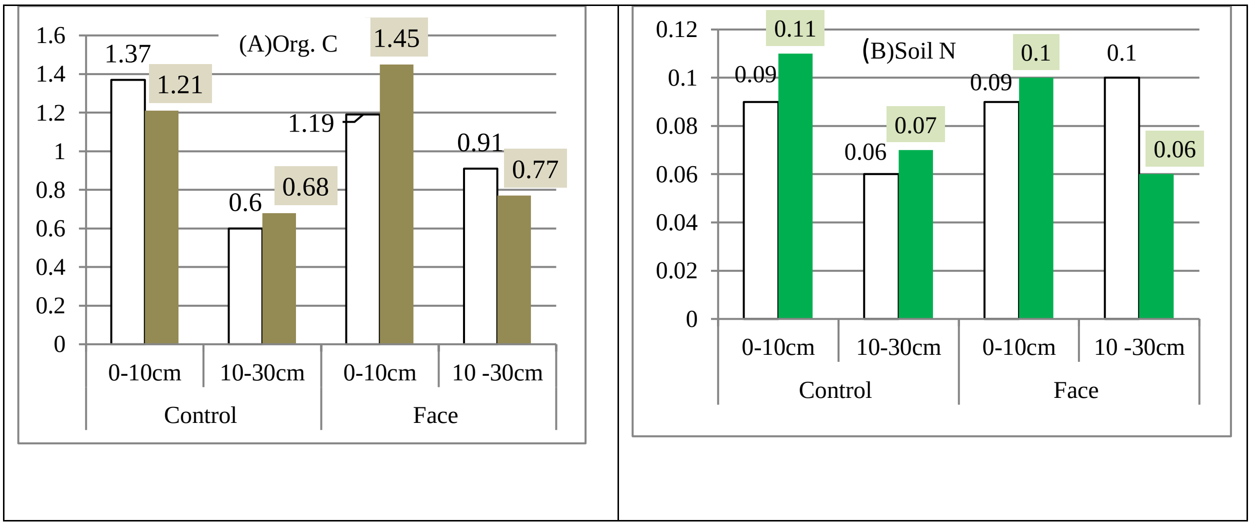
Figure 1: (A)Soil pH and (B) moisture content [%] in soil at FACE and control site
(White fill indicate initial ; color fill refer to after 24 months)



Soil organic carbon (C)

Before the start of the experiment, the soil of the FACE plot had a C content of 1.19% at a depth of 0-10 cm and increased by a further 22% after two years of CO_2 fertilization. The lower soil depth, however, shows a C decrease of 14% after the treatment (Figure 2A). The increase in the C content can be contributed by plants through dead leaves and roots which provides an indirect C input into the soil (Biose *et. al* .; 2016). Elevated CO_2 may increase environment temperature which can lead to fast decomposition of dead plant material and thus increase C level. This may suggest that soil in forest ecosystem able to sequester carbon in elevated CO_2 environment through the photosynthesis process and gives input to plant biomass. An opposite pattern was observed in the control plot with a 12% decrease in C in the top soil layer and a 16% increase in 10-30 cm depth. The decrease in soil C in the upper layer could be related to the decomposition of organic matter under normal tropical conditions.

Figure 2: (A) Organic carbon [%] and (B) nitrogen [%] content in soil at FACE and control site
(White fill indicate initial ; color fill refer to after 24 months)



Nitrogen (N)

An increase in N content was observed both in the depth of the soil in the control plot after a period of two years; the range of percent increase from 16-22% (Figure 2B). This can be related to an increase in "plant litter". A similar trend was found at depths of 0-10 cm at the FACE site with an 11% increaase in N content. However, the N concentration was reduced by 40% at a depth of 10-30 cm after the area was exposed to CO_2. The increase in N content in the top layer may be related to the decomposition of organic material that releases nutrients from plants. The percentage increase was observed less compared to the control plot. The greater reduction of N in the lower depth at the FACE site can be attributed to the fact that the decomposition of organic material did not occur quickly to release N. Phillips *et. al* (2011) and van Hees *et. al*. (2005) found that the increase in CO_2 in the atmosphere could increase the activity of microorganisms in the soil, resulting in faster breakdown of organic matter. However, this situation did not occur as expected. This could be related to the acidic pH of the soil, which was not ideal for microorganisms.

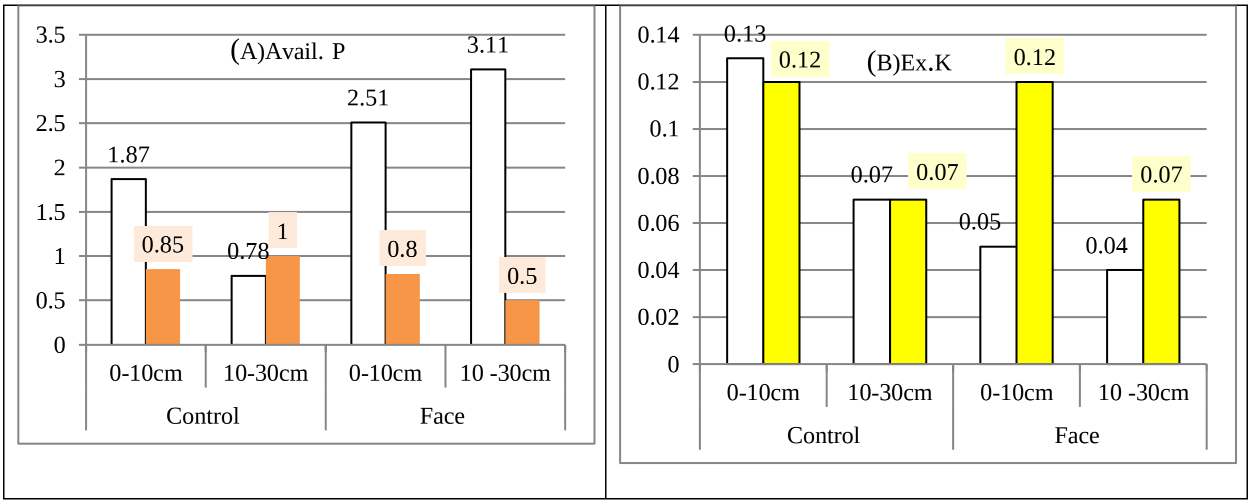
Available phosphorus (P)

The control site recorded a 54% decrease and a 28% increase in the available P in the upper and lower soil layers, respectively. Under acidic conditions, P may be less available for plant uptake. A similar trend was also observed at a depth of 0-10 cm at the site elevated with CO_2 (Figure 3A). The P content in the soil in the FACE plot showed a reduction of 68% and 84% at 0-10 cm and 10-30 cm depth, respectively. The decrease in P in the soil can be linked to an increased uptake of nutrients by plants (Adrien and William, 2003). Increased CO_2 induces plant growth, which leads to increased uptake of nutrients from the soil to support plant metabolism (Gavito *et. al*., 2001). The changes in the available P in the soil at the FACE site were greater compared to the control plot.

Exchangeable potassium (K)

The increase in CO_2 in the environment over 2 years showed a high increase in exchangeable K (75-140%) in all soil layers examined from the FACE site (Figure 3B). The rise in CO_2 may raise the temperature, which leads to the decomposition of organic matter to release nutrients. While the K amount in the control plot showed a slight decrease in the upper soil layer after two years, but no significant K change in the 10-30 cm layer.

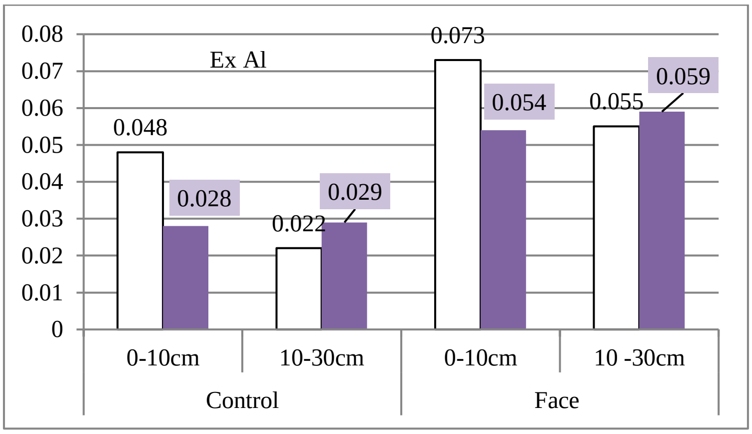
Figure 3: (A) Available P [mg/L] and (B) exchangeable K [cmol/kg] concentration in soil at FACE and control site
(White fill indicate initial ; color fill refer to after 24 months)



Exchangeable aluminum (Al)

After two years of inspection, both study sites showed a similar trend of exchangeable aluminium in the soil; Decrease in Al at a depth of 0-10 cm and increase in the amount of Al in a layer of 10-30 cm. However, the changes of exchangeable Al in the control plot are higher than in the FACE site. After 24 months, a 41% and 26% of exchangeable aluminium reduction was observed at 0-10 cm from the control and the FACE plot, respectively (Figure 4). While the Al content at 10-30 cm had risen to 32% and 0.9% in the control and in the elevated site with CO_2, respectively. An acidic pH affects the availability of exchangeable aluminum in the soil.

Figure 4: Exchangeable aluminium (Al) concentration (cmol/kg) in soil at FACE and control
(White fill indicate initial ; color fill refer to after 24 months)



CONCLUSION

During the gas release, CO_2 interacts with the soil matrix and water, which leads to changes in soil properties. Soil moisture, pH, organic C and exchangeable K were enhanced at depth of 0-10 cm under elevated CO_2 conditions after a period of two years. However, the opposite trend was observed in the control site under the tropical forest ecosystem. A similar pattern was found for N, available P and exchangeable Al in the soil of the control plots and fertilized with CO_2. There were an increase in N content and decerase in P and Al at the upper soil layer, although the study area was treated with or without CO_2 emissions. However, the effects were more for K and P in site with elevated CO_2 than in the control plot.

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