TITLE : IMPACT OF ELEVATED ATMOSPHERIC CARBON DIOXIDE (CO_2) LEVEL ON NUTRITIONAL QUALITY OF LEAFY VEGETABLES THROUGH REAL TIME MONITORING.

FULL NAME OF SPEAKER : DK DR **RAFIDAH** PG HJ **PETRA**

INSTITUTION : UNIVERSITI TEKNOLOGI BRUNEI (UTB), BRUNEI DARUSSALAM.

Project Title (1 out of 2):

Background :

- Over the past decades, the concentration of atmospheric CO_2 level has increased due to the increased burning of fossil fuels and forest fires either naturally occurring or human-made.

- The increased concentration of CO_2 level in the atmosphere can either be beneficial or harmful to crops cultivation.

- Plants synthesize CO_2 from the atmosphere, combined with water and sunlight, as a source of energy in terms of carbohydrates $(C_6H_{12}O_6)$.

Fig. 1 Photosynthesis in plant.

- J. Dong et al. [1] reviewed the benefits of elevated CO_2 level which promotes the growth of various vegetables, which includes root vegetables, fruit vegetables and leafy vegetables.

- However, very high concentration of CO_2 level in the atmosphere can also be harmful on the nutritional quality of crops, specifically leafy vegetables [1, 2].

- In recent years, the occurrence of forest fire in ASEAN countries such as Brunei, Malaysia, Indonesia and Vietnam has seriously increased. Factors causing the forest fire incidences are due to climate factors such as prolonged extremely dry period, coupled with improper land management, poor water management and man-made slash and burn activities.
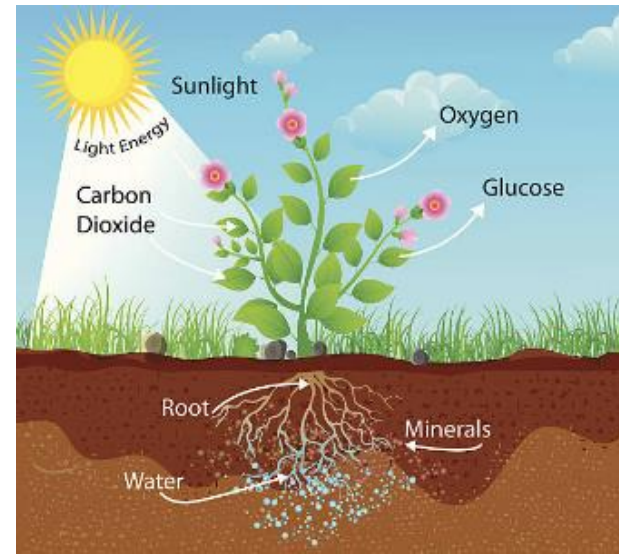
Project Title (2 out of 2):

Background :

- Lack of information on the condition of the affected areas exacerbated the situation even further.

- With the recurring hazy season in the ASEAN region due to uncontrollable forest fire lead to the increased level of CO_2 in the atmosphere, risking the growth quality of crops.

- The proposed project is in connection with the Networked ASEAN Peat Swamp Forest Communities (NAPC), which targets cultivation areas for leafy vegetables farming.

Targets:

- The motivation of the proposed project is to provide reliable data to farmers in Brunei Darussalam on the concentration of carbon dioxide (CO_2) level in the atmosphere, on a real-time basis.

- Several experiments are planned to be carried out, investigating the quality and nutritional contents of leafy vegetables, with their response to different concentrations of CO_2 levels.

Fig. 2 Haze season in Brunei Darussalam at: (a) Peatland area, and (b) City center.
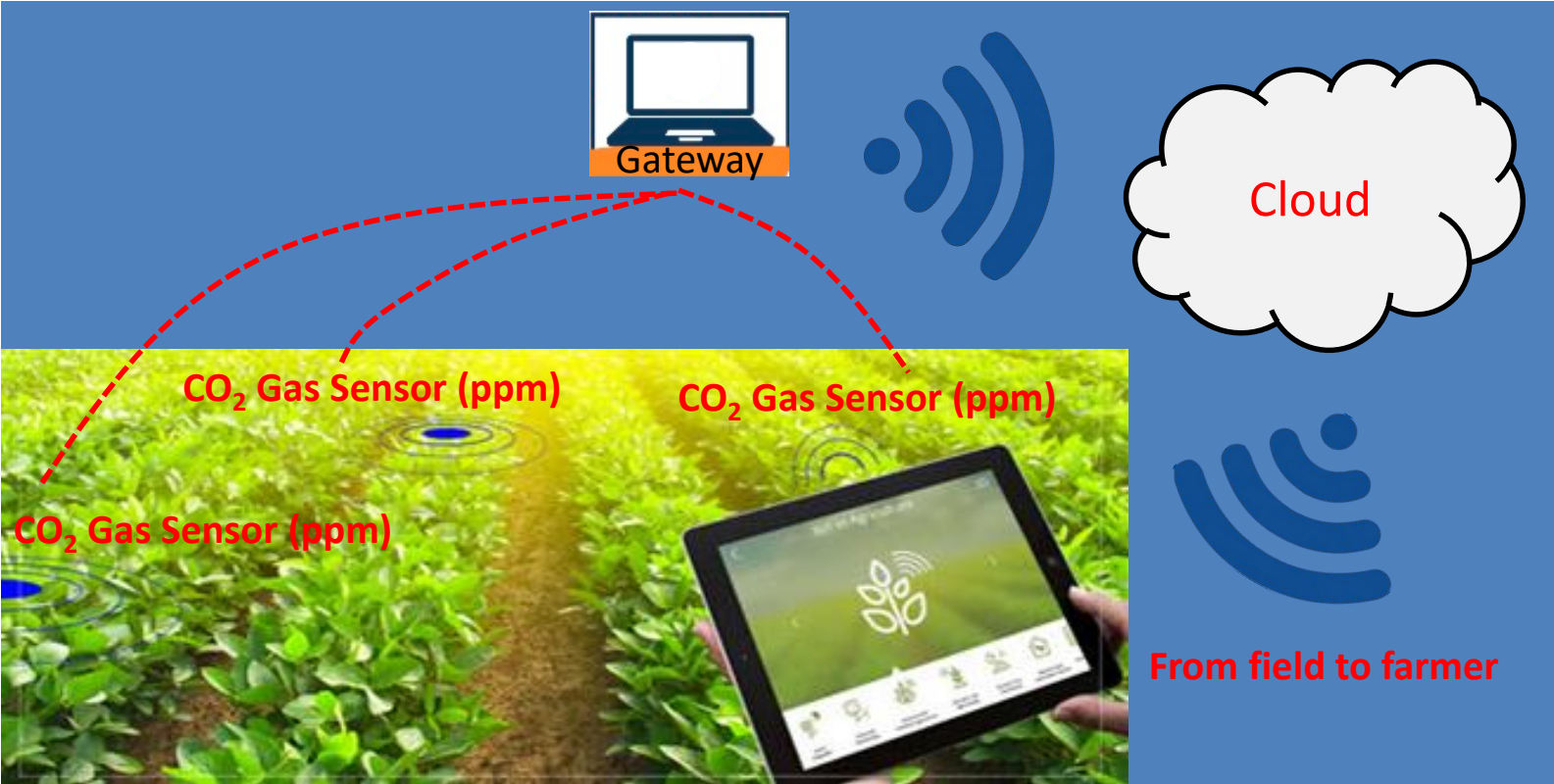
Proposed Method (1 out of 3):

- In this project, the atmospheric carbon dioxide (CO_2) level is to be monitored and measured through real-time application.

- Carbon dioxide (CO_2) gas sensor is to be used as an instrument to measure the atmospheric air quality using an IoT-based solution.

Fig. 3 AN YING Smart Farming CO_2 sensor.

Fig.4 LIBELIUM Smart Environment Pro.

Gateway

Cloud

CO$_2$ Gas Sensor (ppm)

CO$_2$ Gas Sensor (ppm)

CO$_2$ Gas Sensor (ppm)

From field to farmer

Parts-per-million (**ppm**) is the ratio of one **gas** to another.

Fig.5 Schematic diagram of IoT – based farming.

Proposed Method (2 out of 3):

The data acquired from the CO_2 gas sensor is used to investigate the effect on the growth and nutritional contents of leafy vegetables.

In this project, **spinach** is chosen as a case study.

World-famous for:

Delicious taste

High nutritional contents

Spinach is **HIGH** in Anti-oxidant, Zinc, Iron, Calcium, Fiber, Vitamins A, C, E, K and many more. And, spinach is **LOW** in fat and cholesterol.

Objective: To identify acceptable range of values of CO_2 level in the atmosphere, with respect to the concentration of the nutritional contents.

Based on the data acquired from the CO_2 gas sensor.

Carrying out experiments to measure the concentration of the following:

1) Anti-oxidant

2) Iron

As a response to the level of CO_2 in the atmosphere, gathered from the real-time monitoring system – farmers can take necessary actions to protect the crops.

Scientific and Technological Impact:

- Enhance understanding and knowledge of researchers to the effect in the increased of CO_2 level in the atmosphere towards vegetation.

- Open new gate for R & D in the area of agriculture, environmental sensing, clean energy, Big Data and nanotechnology application.

Societal Impact:

- Potential improvement in public health and welfare, economical resilience, access to better facilities and improved people standard of living in general.

- Implementing the farm-to-table and table-to-body concept in ensuring food safety and food freshness.

- Provide research/experimental facilities for local researchers/trainees/students that can be used as example and replicated in other locations that will help improve local research activities and contributions.

Impact (2 out of 2):

Collaborative Impact:

- Establish education and R & D capacity and stronger collaboration in technology related to smart agriculture among ASEAN countries and beyond.

- Provide facilities to engage various stakeholders in working together to reduce the problem of air pollution and its effect, not only to agriculture but can also be expanded to other sectors, within Brunei and beyond.

- Allow collaboration between traditional farmers and technologist, which is expected to create knowledge exchange between parties according to each other expertise and contribution.

Output/Outcome (1 out of 2):

Scientific Outcome:

- Development of prototype of integrated system to assist farmers in making decision on the increased concentration of CO_2 in the atmosphere.

- Providing database that gives information on the resilience or susceptibility of various vegetation towards different level of CO_2.

- Creating experimental platform to study possible solutions in counteracting the effect of elevated CO_2 level in the atmosphere, such as through the use of nanotechnology.

Societal Outcome:

- The set of data to be used by farmers and agricultural authority to improve the country's food production.

- Compliance in open burning fire policy especially in fire-prone agricultural areas.

- Activities to raise awareness of the effect of elevated CO_2 caused by open-fire burning.

Output/Outcome (2 out of 2):

<mark>Collaborative Outcome:</mark>

- Stronger multidisciplinary research collaboration within the project team.

- Initiate collaboration with stakeholders from agricultural and environmental agencies, local farmers and governmental policy makers.

- Initiate partnership with other ASEAN countries particularly those who are facing the same issue in haze and air pollutions.

Conclusion (1 out of 2):

- Elevated CO_2 levels have important impact on agriculture. This may be positive or negative.

- Having an amount of CO_2 in the atmosphere promotes plant growth for high yield. However, further increased gives reverse effect as it decreases the nutritional quality of the vegetable crops, especially leafy vegetables (according to a study [1, 2]).

- The objective of the project is to investigate the effect of increased CO_2 level in the atmosphere towards the growth and fertility of leafy vegetables through real time monitoring system.

- Spinach is proposed in this project due to its richness in nutritional contents and being worldwide favourite.

- The project is proposed to be carried out using current technological approach, by integrating commercialized CO_2 gas sensor and collecting the data through IoT-based monitoring system.

- This technology can be applied and useful for farmers who cultivate their crops outdoor, where the vegetable farms are readily exposed to the increased polluted environment.

- The proposed project is very much in-line with Brunei Darussalam's 2035 vision and the Sultan calls for the country to be sufficiently secured with food production through agricultural sector [3, 4].

- The data acquired from the proposed project can be utilized for global food security under future climate change.

References:

[1] J. Dong, N. Gruda, S. K. Lam, X. Li and Z. Duan, "Effects of Elevated CO_2 on Nutritional Quality of Vegetables: A Review", *Frontiers in Plant Science*, vol. 9(924), August 2018.

[2] Y. Fu, L. Shao, H. Liu, H. Li, Z. Zhao, P. Ye, P. Chen, H. Liu, "Unexpected decrease in yield and antioxidants in vegetables at very high CO_2 levels", *Environmental Chemistry Letters*, vol. 13(4), December 2015.

[3] Brunei Darussalam. Gov.bn. *Wawasan Brunei 2035*. [Online]. Available: https://www.gov.bn/SitePages/Wawasan%20Brunei%202035.aspx

[4] A. Zin. *HM Calls for More Efforts to Develop Agriculture*, The Bruneian, June 28, 2019. Accessed on October 6, 2019 [Online]. Available: https://www.thebruneian.news/hm-calls-for-more-efforts-to-develop-agriculture/

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