



ASEAN FOOD SECURITY INFORMATION SYSTEM

Global warming and Food Insecurity

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As our world is developing and progressing in every aspect especially the advance of technology and information, this enables humans to acknowledge and realize that food system which primarily focuses on the mass production without considering the environmental impact is one of the key factors that cause global warming and severe climate change nowadays. The news and information regarding to the phenomenon of global warming and climate change that people receive each day causes them to be worried and gain more attention to deal with this phenomenon more seriously whether what are the causes of these changes and how to protect or alleviate the impact of global warming and climate change. The examples of this phenomenon that people are interested and researched include the melting of polar ice caps resulting from the increase of global temperature, climate change which caused severe or heavy storm in many countries and caused a lot of damages in many years, climate change that caused severe drought or the disappearance of coastlines affected by rising sea levels. The previous studies and research on technologies in the past found that the phenomenon caused by the increasing of earth's temperature called "Global warming" resulting in changes in the world's climate.

Global warming was affected by excessive greenhouse gas emissions, of which one fourth of human activities that was the main drivers of greenhouse gas emissions was used for agricultural land for food production to meet customer demand increasingly due to world population growth. This production type called mass production is agriculture which simply focuses on production volume. If there is no rules or regulation imposed to control and mitigate the amount of greenhouse gas emissions from human activities, it is expected that human-induced greenhouse gas emission will cause more than half of the amount of greenhouse gas emission released on earth within 2050. This implies that global warming and climate change will be more severe and have more impact to the livings on earth as the phenomenon of global warming does not only cause higher temperature or hotter weather conditions but also causes extreme weather such as extreme drought, extreme flood, rain delay, extreme cold in winter leading to snowfall in the area that has never snowed before. Thus, this phenomenon causes farmers to change or adjust their planting season according to the amount of the rainfall each year. Further details and information regarding global warming, greenhouse gas emission in agricultural sector and the impact of greenhouse gas emission in agriculture and food security as well as recommendation to mitigate greenhouse gas emission will be provided to the reader to gain more insight and understanding of global warming phenomenon.

I. Global warming and Greenhouse Gas

Global Warming refers to a phenomenon occurring as the earth is unable to dissipate heatwave from the sun normally which leads to the rise of average temperature such as air temperature, ocean temperature. This will cause the world's climate to change and will affect life on earth. Main determinants that cause climate change are originated from external factor caused by solar energy, Earth's orbit and internal factors such as changes in atmospheric composition. It is believed that the cause of climate change nowadays is from changes in atmospheric composition mostly originated from human activities and it is believed that the rise of average temperature on earth is resulted from the phenomenon of greenhouse effect caused by the accumulation of greenhouse gas in the atmosphere that increased than usual. The added greenhouse gas will cause atmosphere to absorb more heat which will lead to the change in earth-atmosphere energy balance and continuously impact the future. ⁽¹⁾

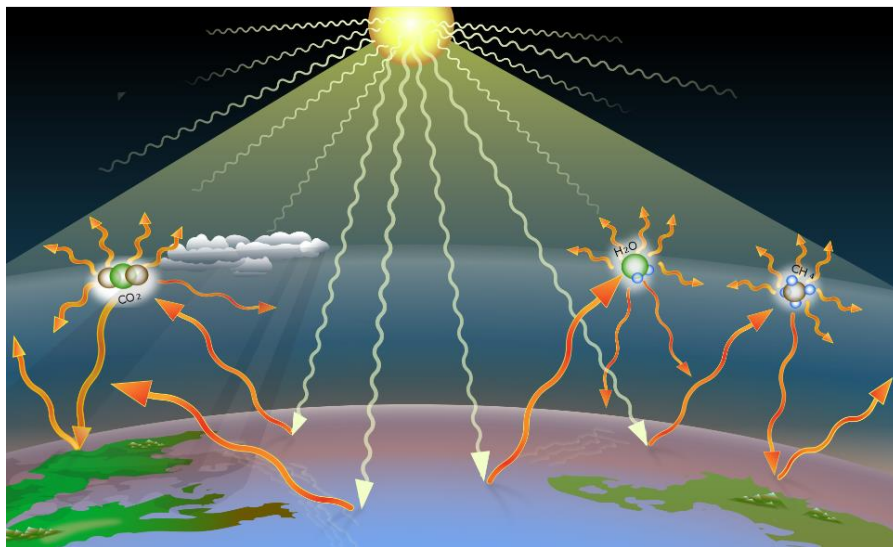


Figure 1: The greenhouse effect of solar radiation on the Earth's surface caused by the emission of greenhouse gases

Source: https://en.wikipedia.org/wiki/Greenhouse_gas

Greenhouse Gas refers to gas which is the composition of the earth's atmosphere that enveloped the earth as a greenhouse. It acts like a shield to protect and trap sunlight emitted to the earth's surface and absorb some sun's heat itself so that earth's temperature is appropriate for the living things. However, humans have caused dramatic changes in temperature nowadays by using certain chemical products in the various activities and some gases also caused greenhouse gas effect. The more greenhouse gas is emitted into the atmosphere, the more earth's atmosphere stores heat as well. As a result, world's temperature is higher which will affect ecosystems and destroy the earth's defense or deplete ozone layer to become thinner as the ozone layer helps block harmful radiation called Ultraviolet (UV) light. Greenhouse gas can occur naturally and be produced by human activities. The important types of greenhouse gas are Carbon dioxide (CO₂), Methane (CH₄), Nitrous oxide (N₂O), Chlorofluorocarbons (CFCs), and Hydrofluorocarbons (HFCs). ⁽²⁾

- 1) **Carbon dioxide (CO₂)** is the most abundant gas in the atmosphere produced by natural sources and human activities such as burning of fossil fuels from energy production for industry, transportation, and electricity. Additionally, deforestation also contributes to the release of carbon dioxide as there are no trees and forests absorbing carbon dioxide and stored carbon is released to the atmosphere as carbon dioxide.
- 2) **Methane (CH₄)** can be occurred naturally and produced from human activities such as from rice production, livestock farming, decomposition of organic matter, organic waste (in nature and landfill), burning from biomass, coals, and natural gas.

- 3) **Nitrous oxide (N₂O)** is naturally-occurring gas through lightning, volcano eruption, composted animal manure, etc. Normally, this gas exists naturally from the ocean and decomposition of organic matter in the soil by bacteria. Recently, the amount of nitrous oxide has increased due to the impact of agricultural sector (from applying fertilizer with nitrogen-related compounds) and industries that use nitric acid in the production such as Nylon fiber industry, chemical and plastic industry, manufacture that produces nitric acid, sulfuric acid, metal plating, and explosive industry. It is also caused by burning of fossil fuels and other organic matters. Nitrous oxide can be used directly as an accelerator of aerosol.
- 4) **Chlorofluorocarbons (CFCs)** is a man-made synthetic substance used in the industries which consist of carbon (C), chlorine (Cl), and fluorine (F). It has been used extensively in various industries for instance, refrigerants in the refrigerator and air conditioner equipment, foam, spray packaging, fire extinguishing agents, and cleansing agents in the electronics industry.
- 5) **Hydrofluorocarbons (HFCs)** is used as refrigerants for commercial and household usage as well as in the air conditioner. It is also used as blowing agents for foams, solvents, fire extinguishing agents, and accelerator of aerosol. Although HFCs is emitted in the small amount, it will have high impact.

Annual Greenhouse Gas Emissions by Sector

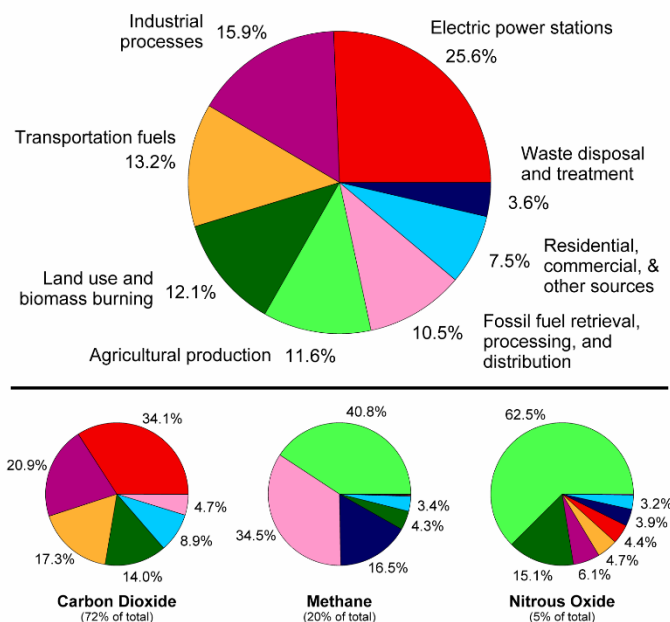


Figure 2: GHG emissions by human activities are classified into eight subsections (2000)

Source: <https://th.wikipedia.org/wiki/แก๊สเรือนกระจก>

II. Agricultural Sector and Greenhouse Gas Emission

Since the industrial revolution era, carbon dioxide and other important greenhouse gas were emitted from natural sources and human activities increasingly. Fuel burning and deforestation corresponding to human activities or deforestation to increase the area for food production or agricultural land to meet increasing and growing demand rapidly of food industry and food production are a crucial cause of the increase in greenhouse gas emission in the atmosphere. Furthermore, the increase of methane emission in the atmosphere is also caused by rice farming, usage and changes in wetland area, livestock farming, digestion in animal stomach and intestine, manure management, loss of gas and fuel from pipeline, as well as gas emission from landfill or enclosed waste stabilization pond that release gas through the drainpipe. The use of

Chlorofluorocarbons (CFCs) related components in refrigerators and air conditioners as well as halon is in fire extinguishing systems and manufacturing process, agricultural activities including fertilizer application also contributes to nitrous oxide emission. ⁽³⁾

According to the committee of Intergovernmental Panel on Climate Change (IPCC), risks from global climate change are resulted from greenhouse gas emission. Agricultural sector gets support from various organizations and member countries to drive greenhouse gas mitigation in the agricultural areas because agricultural sector also contributes to global warming by emitting greenhouse gas and being a carbon sink. In addition, Food and Agriculture Organization (FAO) has a strong interest to reduce greenhouse gas emission by using agricultural area as a carbon sink. This method was also promoted in the United States of America and started to trade carbon from agricultural area that carries out agricultural activities without tillage or reduced tillage and using the agricultural land to grow grass. This is considered as effective approach, low cost and can be implemented immediately.

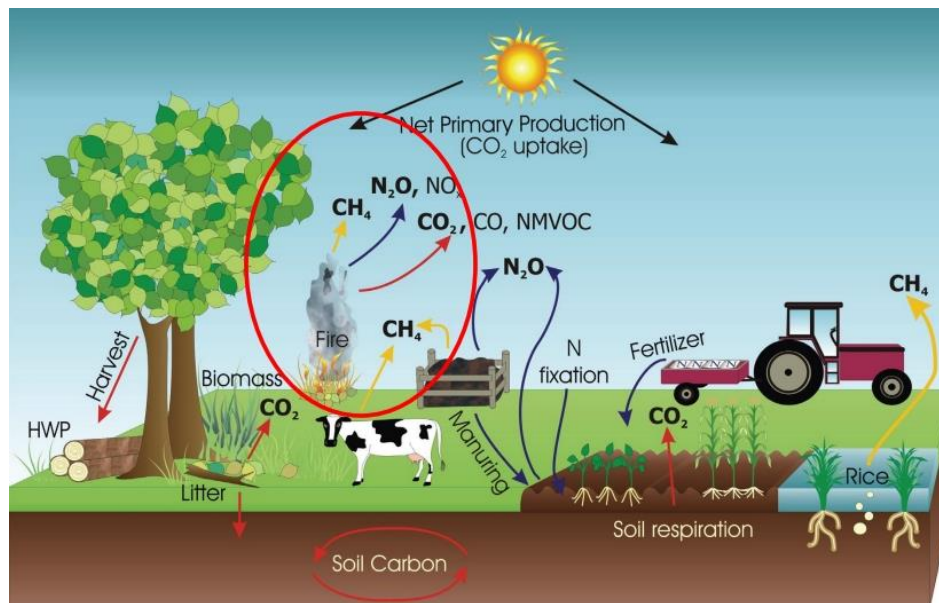


Figure 3: Greenhouse gas emissions from agricultural activities

Source: https://www.researchgate.net/figure/The-main-on-farm-agricultural-greenhouse-gas-emission-sources-removals-and-processes-in_fig1_281439963

Globally agricultural area is approximately 5,023 million hectares or 40-50% of global land surface. Greenhouse gas emitted mainly from agricultural area includes Methane (CH_4), Nitrous oxide (N_2O), and small amount of Carbon dioxide (CO_2). The amount of greenhouse gas emission in 2005 was accounted for 10-12 percent of the amount of greenhouse gas emissions produced from human activities around the world, most of which were caused by decomposition of organic matter and burning crop residue. Methane occurred from decomposition of organic matter with limited amount of oxygen from animal digestion, manure or residue fermentation, and rice field. While Nitrous oxide was produced by transforming of nitrogen compound in the soil and animal manure which mostly occurred from applying nitrogen fertilizer more than plant need. Previously, the emission of greenhouse gas in the agricultural had drastically increased due to population growth. This led to the increasing demand for food or higher demand with limited production area resulting in forest encroachment to expand agricultural land. Soil degradation was also another factor that led to the excessive use of nitrogen fertilizer especially in developed countries resulting in the increasing methane and nitrous oxide emissions. This was accounted for three-fourth of greenhouse gas emission from agriculture around the world. Therefore, greenhouse gas mitigation in agricultural sector played an important role in global greenhouse gas reduction. ⁽⁴⁾

Although greenhouse gas mitigation is not currently the first priority to deal with, the expansion of agricultural area tends to increase rapidly. The use of agricultural area as a source of to release greenhouse gas has risen. The author will focus on 2 major activities which are rice production and livestock farming because the products of these activities have high potential, and those activities are the main source of methane and nitrous oxide emission the most.

1) Greenhouse gas emission in rice field

Rice farming is considered as a major source of greenhouse gas emission which is approximately 100 million tons per year globally. Especially, Asia continent, the largest rice production in the world, can supply rice production to population up to one-third of the world population and releases greenhouse gas from rice production around 46-63 million tons per year. Greenhouse gas emission from the rice field includes methane and nitrous oxide. Normally the more methane occurs in the soil, the more methane is emitted to the atmosphere. The accumulation of methane and nitrous oxide is caused by flooding rice field for a long time. This is a storage of aerobes and organic matter such as plant and animal residues, manure, and compost under flood water. Those organic matter will be decomposed by aerobes in flooded condition and absence of oxygen. This will evaporate from flooded water and emit methane to the atmosphere. As farmer intends to gain high yield and do not read the fertilizer label or follow the instruction on how to use fertilizer properly, excessive application of nitrogen fertilizer in the rice field harms the environment as rice cannot absorb excessive nutrients and left into the soil. Those will be decomposed by aerobes and release nitrous oxide in the atmosphere. Additionally, inappropriate post-harvest management of rice straw such as burning of rice straw and stubble can cause carbon dioxide in the atmosphere as well.

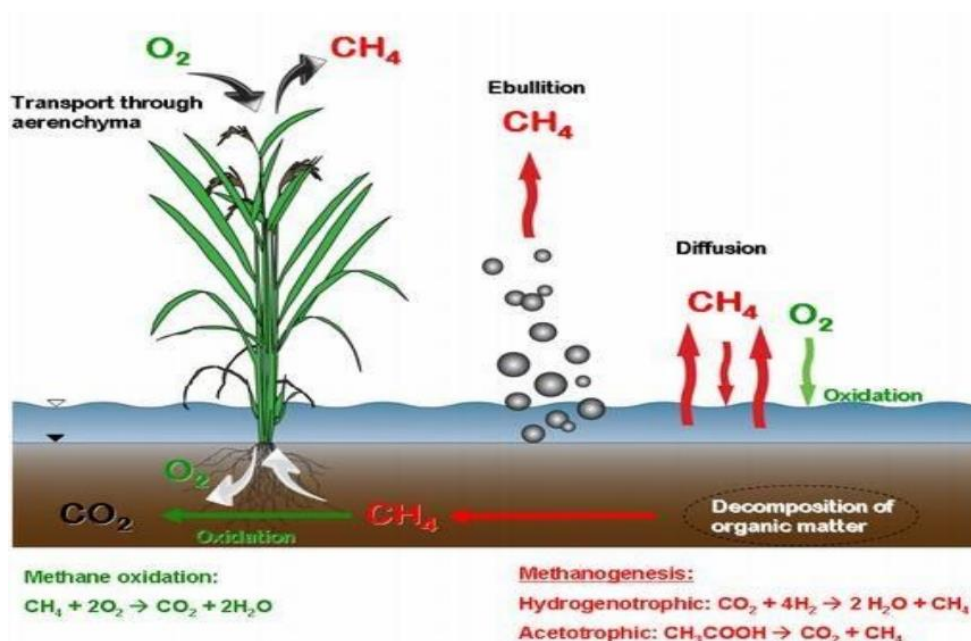


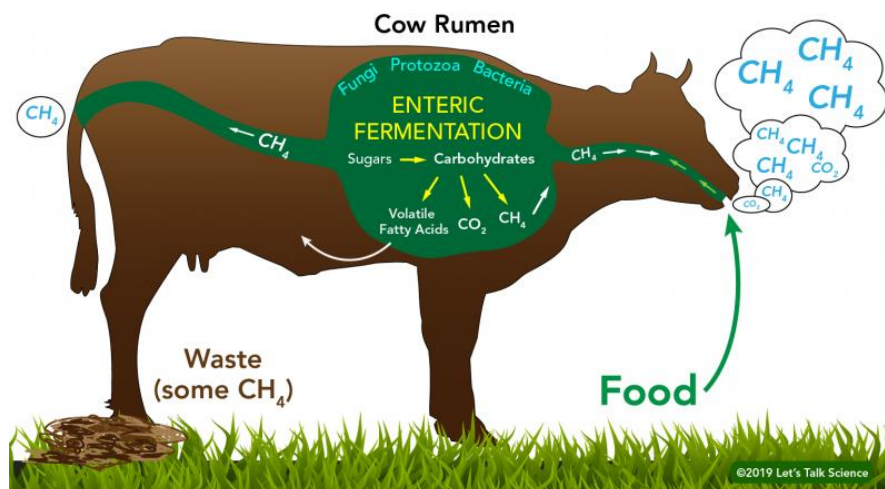
Figure 4: Greenhouse gas emissions in rice fields

Source: http://www.thai-explore.net/search_detail/result/6061

2) Greenhouse gas emission in livestock farming

Due to the world growth, demand for meat and dairy product of world's population tends to increase every year. FAO estimates that global demand for meat has risen double from 229 million ton in 2000-2001 to 465 million tons in 2050 and demand for dairy product has increased twice from 580 million tons in 1999/2001 to 1,043 million tons in 2050. Global livestock farming has grown more rapidly than other agricultural sectors and has emitted greenhouse gas up to 40% of overall agricultural sector. The greater number of populations grows, the more demand for livestock products

increases especially the large-scale commercial livestock farming such as beef cattle, dairy cattle, swine, chickens for meat and egg production. The amount of animal waste from farming each day also contributes to nitrous oxide and diet digestion in ruminants causes methane as well as inappropriate pasture management also leads to greenhouse gas emission. In addition, the growth of feed industry over the past two decades drove the increase in demand for animal feed. This resulted in deforestation and forest burning to expand livestock farming area and grow more feed grain that caused carbon dioxide such as planting corn or maize which was the staple food of animal. Forest area has drastically decreased and turned to pasture and planting area of feed grains and forests that were originally absorbing carbon dioxide would be destroyed. Greenhouse gas would increase from chemical reaction by using nitric acid to deal with animal manure management resulting in nitrous oxide which was greenhouse gas that was able to cause global warming approximately 265 times higher than carbon dioxide. Animal manure would also be beneficial for farmers to use as a fertilizer for planting feed grains.



Greenhouse gas has the ability to absorb heat energy as infrared radiation. If the amount of infrared radiation is appropriate, it can help maintain the average temperature of the world. On the other hand, if the amount of gas is excessive, it will increase the average temperature of the world or global warming particularly, carbon dioxide resulted from burning or agricultural technology, methane caused by decomposition of organic matter, and nitrous oxide originated from fertilizer application in agriculture. ⁽⁵⁾

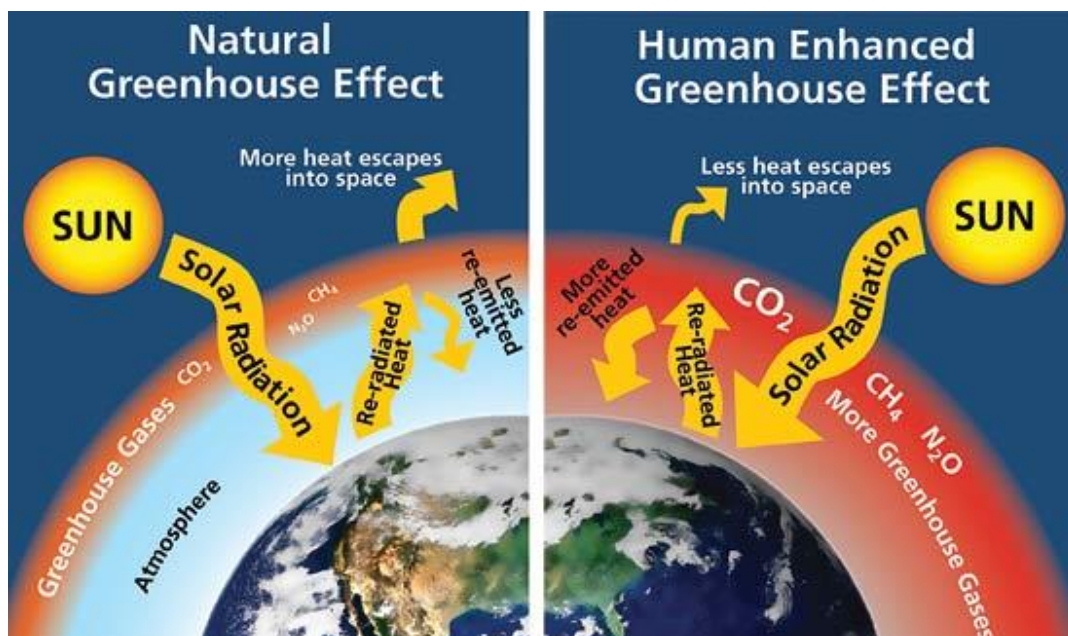


Figure 6: Natural and Human Enhanced Greenhouse Effect

Source: <https://climatechange.lta.org/get-started/learn/co2-methane-greenhouse-effect/>

Global warming or climate change resulted from greenhouse gas is the crucial determinant that causes damage to agricultural sector. Climate change currently stimulates abnormality and damage to crop production increasingly. In the past decade, the average temperature has increased 0.8 degree Celsius and expects to rise about 0.9-3.5 degree Celsius in 2100. Climate change negatively affects to the growth and cultivation of many crops and farmers have to face serious impact on various agricultural production especially in the production of crops, livestock, and fishery for example, ecosystem changes, seasonal variation which caused uncertainty of cultivation period, unusual rainfall, flood, drought, soil degradation, outbreak of weeds, diseases and pests. Consequently, farmers cannot cultivate and produce enough food to meet increasing demand. For example, severe climate change caused by the increase of average temperature, phenomenon of prolonged drought (El Nino) and severe flooding occurred more often. It also increases temperature during flowering stage and affects photosynthesis in the plants resulting in lower yield.

Climate change causes problems of sustainable water management, for example, reserving water will be more difficult when it cannot estimate the amount of heavy rainfall for a long time or water reservation in dry season will be more difficult due to prolonged drought. Additionally, climate change provides chances to create new plant diseases and changes of plant and pest disease as increased temperature affects pest population in the tropics resulting in the increase of pest population and damage. For example, the problem of locusts attacking crop production is more severe as locusts are forced to gather during the abnormal dry weather and gathering of locusts encourages them to move fast and needs more various food. Changes in humidity and higher temperature according to changes of heavy rain will increase the amount of water evaporation in the atmosphere and this will allow crops to retain moisture on the leave surface and relative humidity well. This condition easily results in plant diseases. Moreover, drought also affects plant disease incidence and severity level of diseases caused by the virus more easily. The rise of sea level creates risks especially in low-lying coastal areas and estuaries which affect majority of people to be at risk because that area could produce a lot of food and risks from saltwater intrusion in agricultural area caused crop damage as occurred in Vietnam and Thailand. Furthermore, higher temperature causes warmer temperature in water used for aquaculture resulting in damage of sea and freshwater fishing areas due to lower production quantity and changes in natural ecosystem will have serious impact on food security and economy of the country. The occurrence of wildfire has expanded to many countries in the prolonged

drought during the year affected by global warming. This will become more severely and decrease yield of overall agricultural sector. Particularly, agricultural production in terms of food will be more difficult to produce while demand for food has increased due to population growth. Lower production in agricultural sector caused higher prices and food will become more difficult to afford or may lead to food scarcity resulting in food insecurity issue.

IV. The impact of greenhouse gas on food security

Food security is related to human livelihood in every country. However, as climate change currently occurs, food production system that focuses on mass production and does not concentrate on sustainability will affect food security in all aspects including crop cultivation, livestock and fishery farming, and waste management from food production system that is more difficult to produce. Demand for food has increased corresponding to the growth of world population but food production tends to decrease, and the price is high which will affect food insecurity. As a result, population with low income will be starving and will be affected even more. Nowadays, food production system in agriculture is at risk when the world temperature rises approximately 2 degree Celsius from impact of climate change and more than 189 million people suffer from hunger and starvation. If the average temperature increases up to 4 degree Celsius, the number of people who have to face this hardship will jump to 1.8 billion people especially when the number of population are up to 8 billion people, we need to be aware of how to produce enough food without destroying the planet together with supporting the environment as well. However, if there is no cooperation from anyone, food insecurity and starvation will exist in unprecedented level. ⁽⁶⁾

World Food Day is on October 16th in every year organized to promote knowledge transfer, understanding and cooperation for people to afford to food and nutrition correctly. On the other words, this means to help vulnerable population who have difficulty to afford food to get ready to deal with climate crisis. Building sustainable food system needs to be developed in every part from raw materials, crop cultivation, livestock and fishery farming, processing, transportation, distribution, consumption, waste management, and packaging. All of these are factors that affects sustainable development of the world while unsustainable food production system is also crucial factor driving climate change as well. ⁽⁶⁾



Figure 7: Global warming and Food Insecurity
Source: UN Thailand, 2022

Another problem now is “Food Loss”. Food production has emitted a lot of greenhouse gas while some food is not consumed and becomes food waste in which not small proportion is eliminated along the way as the packaging is not attractive to consumer in spite of similar nutrition. “Food waste” mostly caused by consumption without awareness. Every year, more than 900 million tons of food are thrown away and fermented food waste has created methane which is more severe greenhouse gas than carbon dioxide approximately 20 times. The amount of greenhouse gas released from other activities along value chain of food system is also high such as vehicles or food truck driven by fossil fuels, frozen food delivery system to the freezer in the supermarket. Food supply is linked to the climate for example, crops and animals need water, sunlight, soil and appropriate temperature to grow. Therefore, when extreme weather occurs, risks for food insecurity has increased. Climate fluctuation is another major cause of extreme food production crisis and is a driving factor which contributes to food insecurity level every year. Food starvation tends to increase in areas where people work in agricultural sector for a living including the country where agricultural system is sensitive to the amount of rainfall and temperature fluctuation. ⁽⁶⁾

In the past 10 years, there were the frequency and severity of extreme weather as well as economic has slow down. The pandemic caused by livestock was such as Avian Influenza or bird flu, and Lumpy skin disease and COVID-19 pandemic ignited fear and panic of people around the world. Russia-Ukraine war caused higher food production cost and the increase of energy price. The impact of these crises led to the decrease of ability to produce food in many countries and refraining from exporting to reduce risks for supplying sufficient food in the country. This could worsen food shortage resulting in the biggest increase of food insecurity in decades. As most of those people who lived in the risky and environmental degradation condition, this problem did not simply have the effect on food but also clean water for consumption as well. Degradation from human activities affected 34 percent of agricultural areas and in the next decade, it was expected that global agricultural production will decrease up to 30 percent due to climate change impact. While it was estimated that the number of world population would expand to 9 billion people within 2050 implying that food production was needed to increase for supplying everyone in the world. ⁽⁶⁾

V. Recommendation for greenhouse gas mitigation and global warming impact

1) Greenhouse gas mitigation in agricultural sector

Reduction of greenhouse gas in agricultural sector both from rice farming and livestock farming cannot be successful unless there is cooperation between farmers and government in each country to support and strengthen climate resilience for sustainable food production around the world. Providing knowledge with technologies to present and compare pros and cons clearly so that farmers will acknowledge the importance and risks of climate change. The practices to promote farmers become more resilience to climate change and reduce risks from greenhouse gas emission in farming require both treatment and preventive measures to ensure food security, livelihood, and development as well as knowledge improvement in terms of infrastructure and ecosystem. Especially in the application of local wisdom, local people have better understanding than academic experts in terms of adaptation because local people know how to adjust themselves. Therefore, using local wisdom to climate change is important to implement activities and practices of greenhouse gas mitigation in agriculture. The author would like to propose the ways to reduce greenhouse gas emission in agriculture that every country can select and implement according to the landscape as follows. ⁽⁴⁾

1.1 Promoting and supporting agricultural farming to be carbon sink by encouraging farmers to do proper farming activities and management without threatening for security and aligning with sustainable development. Agricultural activities that play a role in carbon sequestration and greenhouse gas reduction include 1) managing pasture to cover crop by transforming pasture to be cover crop 2) conservative tillage that are researched agricultural areas in the United Kingdom and found that new way of farming by doing no-trill farming but making the hole in the soil for seeding instead can reduce up to one-third of greenhouse gas emission and help store carbon in the soil.

Digging a small hole for planting seeds required only one drilling machine to run through the whole farming area in one time. This approach disturbs the amount of soil less than normal planning which requires various planting machines and has multiple planting steps including tilling, sowing, covering, and compacting the soil. Thus, no-trill farming approach can save machinery cost and reduce air pollution from burning diesel fuels of machinery. This approach also helps store carbon from decomposition of dead plants in the soil. ⁽⁷⁾ 3) Agroforestry system is a systematic land resource management combining with forestry, agriculture, animal husbandry, and aquaculture and fisheries. On the other words, it is inclusive agricultural approach that combines plants and animal within the same areas in a proper and balanced way so that this system is similar to forest ecosystems in terms of complexity and biodiversity. Crop and animal production will increase effectiveness of the use of natural resources in the soil and in the nature as a holistic way. This results in various crop production and circulation of food nutrition with a balanced, consistent and sustainable approach in the long-run. In summary, agroforestry system will improve soil capability to absorb water, preserve underground water and reduce the loss of soil surface. ⁽⁸⁾

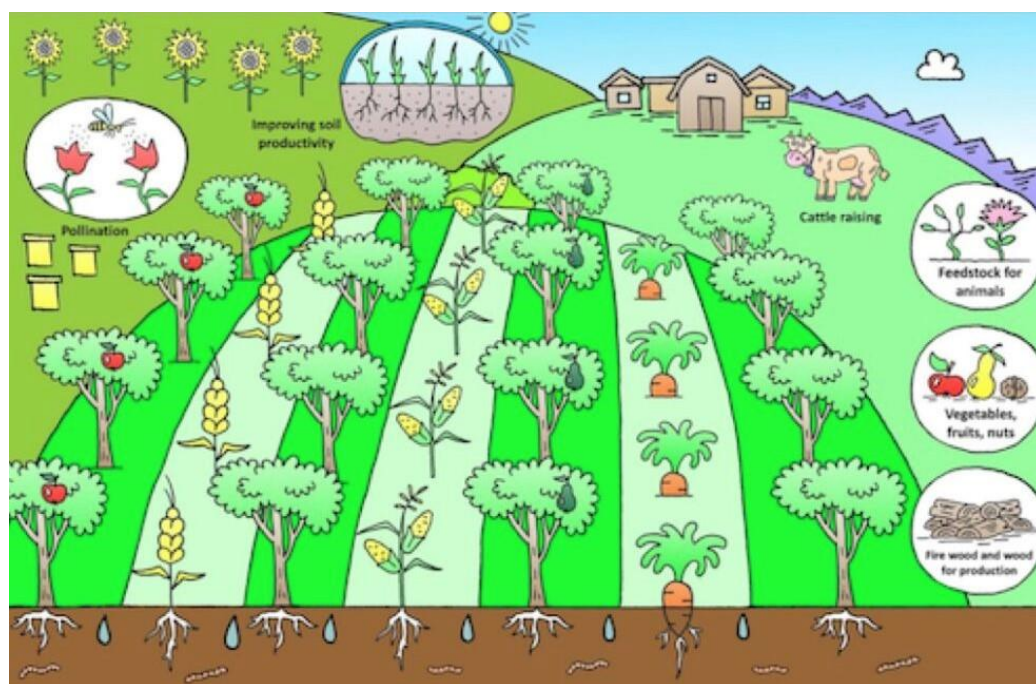


Figure 8: Agroforestry

Source: <https://www.flickr.com/photo/zoienvironmemt/46847834374>

1.2 Promoting and supporting farmers to reduce methane emission and nitrous oxide from agricultural activities. Reduction of greenhouse gas from fermentation of animal digestive system can be managed by doing manure management such as aerobic fermentation including dry fermentation in which drying period depends on various factors such as relative humidity in the air. Methane emission can be decreased by using animal manure to produce biogas and using as fuels. Moreover, it needs to promote farmers to raise livestock in a barn, improve feeding method and animal food additives, improve animal manure and nitrogen fertilizer in the soil to prevent nitrification process.

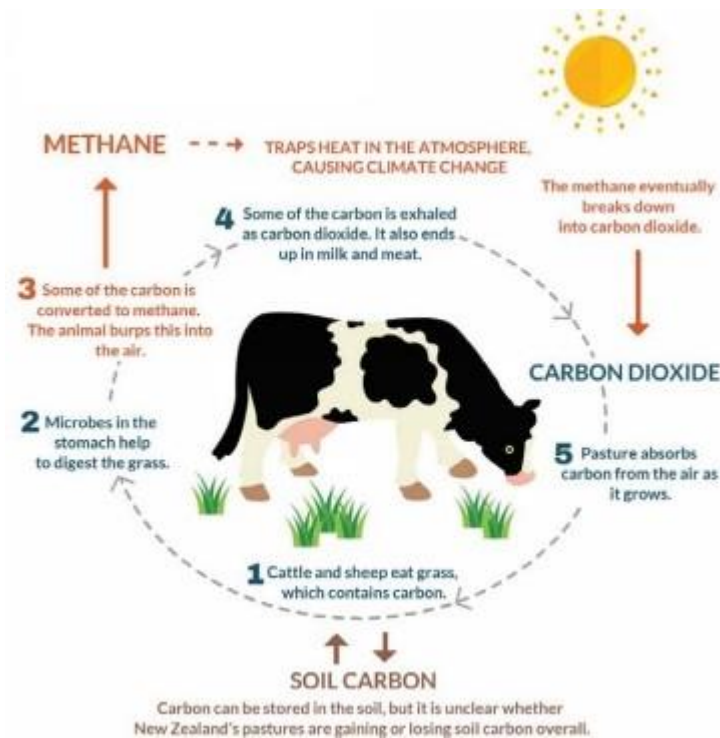


Figure 9: Reducing greenhouse gas emissions in the livestock sector

Source: <https://environment.govt.nz/facts-and-science/climate-change/agriculture-emissions-climate-change/>

1.3 Promoting and encouraging farmer to reduce nitrous oxide in agricultural area by giving recommendation for farmers to use the proper amount of nitrogen fertilizer and follow instructions on the fertilizer label as well as apply fertilizer when the plant needs. Recommendation on the fertilizer label will help farmers to apply appropriate amount of chemical fertilizer. Applying fertilizer in the right time when the plants need can reduce excessive fertilizer application especially nitrogen fertilizer which caused nitrous oxide. As a result, appropriate fertilizer application from the recommendation can help mitigate greenhouse gas (nitrous oxide) and save production cost at the same time.

It is shown that the guideline to reduce greenhouse gas emission in agricultural sector as stated above is the approach that can mitigate greenhouse gas and has a potential in terms of production cost compared to other activities in the sector. Additionally, it is also a way to reach long-term climate objectives. However, the effectiveness of agricultural activities may differ if it is implemented with agricultural system of other countries due to differences in cultivation patterns, area and climate conditions, as well as plant and animal species. Therefore, there is no greenhouse gas reduction approach that can be applied in all cases, and it should have further study and consideration to select suitable agricultural activities before implementing in the country in terms of social, environmental and economic condition in each country. ⁽⁴⁾

2) Promoting and supporting to use rice technologies to mitigate greenhouse gas emission

Rice is a cereal grain that world population consumes as the staple food especially in the Asia. Rice is the third-highest production in the world after wheat and maize. For rice plating method, farmers usually flooded water in the rice field and this is another factor that caused greenhouse gas by producing methane which is the cause of global warming. Growing rice by using a lot of water can result in water storage in the future. Technologies that can be applied for rice production to help farmers reduce greenhouse gas emission and sustainably produce food corresponding to the demand around the world are as follows:

2.1 Laser Land Leveling (LLL) is the technology to adjust the level of rice field by smoothening the land surface or using other appropriate methods using technology of each country. This will help farmers to manage water conveniently and efficiently, help the use of pesticides to be distributed evenly, reduce fertilizer use, the number of weed and water use in rice production up to 30-50% as well as increase rice yield and quality. ⁽⁹⁾

2.2 Alternate Wetting and Drying (AWD): normally if water is flooded for a long time, rice field will become a place that gathers pests and plant diseases. Consequently, farmers have to use pesticides to deal with those problems later resulting in soil degradation. The alternate wetting and drying is a method that irrigates water to rice stalk during the growth of rice stems and drains water of the rice field in some period in which water level in the rice field will be 10-15 centimeters lower than soil surface (by measuring from a water pipe under the surface). When water is lower than soil surface until the topsoil is cracked, this allows the air above to penetrate into the soil and roots are grown and sprout a new root. As a result, methane is not produced and emitted from the rice field. AWD is also help save water use as well. ⁽⁹⁾



Figure 10: Growing rice by reducing greenhouse gas emissions

Source: <https://erdi.cmu.ac.th/?p=1148#CMU>

2.3 Soil test based fertilizer application or effective fertilizer management: using excessive fertilizer caused soil degradation and affected rice quality. Thus, proper fertilizer application according to the rice and soil needs was required. Farmers should collect soil sample from the rice field to analyze soil nutrition and soil health so that farmers can apply tailor-made fertilizers according to soil analysis in the proper period when rice is needed with appropriate amount of fertilizer. This technology can reduce overuse of fertilizer especially for nitrogen fertilizer which is the source producing nitrous oxide in the rice field and also decrease production costs to farmers. ⁽⁹⁾

2.4 Rice straw and stubble management technology both for post-harvest and pre-planting management in next rice season especially stubble management in flooded area: farmers in general usually burn rice straw and stubble because decomposing rice straw and stubble naturally takes a long time which is not corresponding to some planting areas as farmers can grow rice many times in a year. However, burning rice straw and stubble destroys soil nutrients such as nitrogen, phosphorus, and potassium in which 93 percent of nitrogen and 20 percent of phosphorus are destroyed resulted in soil degradation, air pollution, PM2.5 particles and greenhouse gas that affect the environment. Therefore, if farmers stop burning rice straw and stubble and use rice stubble for other purposes such as compressed into straw bales for feeding animal, transforming to various products for selling, using as material for mushroom farming or material for composting. Ploughing rice straw and stubble and

using microorganisms to decompose rice straw or stubble will increase soil organic matter. This will be useful in growing crops, making the soil to be loamy and absorbing water well. ⁽⁹⁾

Technologies for rice planting as recommended by the author above should have further study if you would like to apply these technologies and should adjust it properly according to the activities, environment, social and economic context of each country.

3) Promoting and supporting the use of technology in beef and dairy cattle farming for greenhouse gas reduction

Currently, consumption demand for beef and dairy cattle has risen due to the increase in world population which encourages beef and dairy farming to increase beef and dairy production to meet consumer's need. This resulted in the increased number of beef and dairy cattle rapidly which accelerated greenhouse gas emission from cattle digestive system and waste in each day. This is a source of methane emission that released to the atmosphere increasingly. The author would like to recommend farming technologies of beef and dairy production that can reduce greenhouse gas emission so that the country can produce food and meet the world need sustainably as follows:

3.1 Improving the digestive efficiency of cattle by using dietary supplement and improving food recipe or using substances to inhibit or slow down the multiplication of bacteria that causes methane gas in animal feed such as tannic acid in raw material of seaweed, lemongrass, fat, and oil which inhibits methanogen in animal stomach to reduce greenhouse gas emission and nitrogen excretion rate together with increasing food production. For example, the study and research publication showed that seaweed in the species of *asparagopsis* inhibited methane. *Asparagopsis* and other seaweed species had special cells that stored bromoform. When taking this red seaweed through the freeze-dried process and combining with animal feed, it helped protect the combination of carbon and hydrogen atoms that caused methane gas in cattle stomach. From this approach, cattle would produce more propionate (Fatty acid which helped generate glucose in metabolism process) which increased efficiency of animal body. ⁽¹⁰⁾

3.2 Exploration of changes in manure management and storage methods such as aeration and fermentation of buffalo manure can reduce the amount of methane. Methane gas from animal manure could use as energy sources as dairy digester technology can transform animal manure to natural gas to run electric generator within farms and utilize within the community. Biogas production from animal manure was in many forms. Currently, there is technology invention that are widely used and biogas production technology uses anaerobic biodegradation process in fermented manure pond divided by degradation rate of organic matter level which are low rate and high rate of animal manure as follows: **1) Low rate anaerobic reactor** requires a wide spread area as it needs to install a lot of equipment because it takes time to store high water **2) High rate anaerobic reactor** has a rapid degradation rate as the system has combining, retaining, and preserving good quality of bacterial sludge for a long time by designing to fix bacterial sludge in the middle or combine as a chunk and take the sludge that has been gone with water flow into the system. The fermented manure pond is small and has the ability of receive large amounts of waste. ⁽¹¹⁾

3.3 Pasture management and reduced tillage for growing new forage crop: as each tillage will release a lot of carbon in the soil. If there is good pasture management or creating permanent pasture along with agroforestry system, growing forest or food crop to cover soil surface, using forage crop varieties that can live for many years, have deep and dense root system including growing grass with legume plants that allow the plants to use nitrogen in the air as a source of food and nutrition for the plants, these will increase the ability of soil to store carbon more than emitting in the form of carbon dioxide.

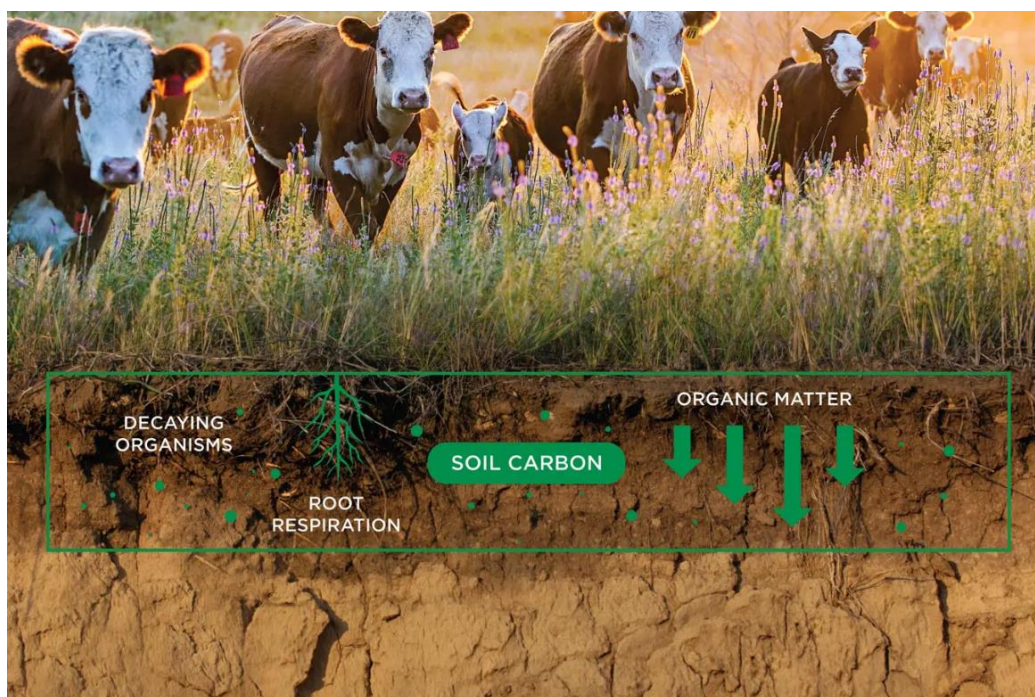


Figure 11: Carbon Farming- Extracting CO₂ from Air and Storing it in Soil

Source: <https://www.cleanfuture.co.in/2021/06/09/carbon-farming-co2-from-air-soil/>

3.4 Improving cattle breed for high productivity, fast growing, high quality of feed conversion ratio and lactation ratio. For example, the study found that bacteria that produced methane in cattle stomach was related to cattle genetic. Scientists could breed cattle that had fewer bacteria in their stomachs and would finally get cattle breeding that produce lower methane. Additionally, they could genetically modified dairy cattle to be more resistant to global warming. It was reported that AgResearch company in New Zealand had modified genetic of dairy cows to replace dark patches on the skin with gray patches instead so that cattle could absorb less heat from the sunlight, reduce the stress and reduce methane production in the cow's stomach from heat inside the animal body. ⁽¹²⁾

3.5 Improving and developing farm management systems by maintaining the farm equipment, improving farm environment for food hygiene. There should be a barn for beef and dairy cattle for habitat to shelter and escape the heat from the sun, available waste management, or producing compost according to academic principles by using animal manure or organic waste and by-products from agriculture to reduce methane emission caused by fermenting cattle manure in the absence of oxygen condition. Eliminating a place that can cause disease outbreaks and modifying farms to be more environmentally friendly leading to sustainable agricultural system.

For technologies of beef and dairy cattle production as presented earlier, if you would like to use these technologies applying in your farm, you should do further study and consideration for appropriateness corresponding to agricultural activities, environment, society and economy of each country.

4) Government initiatives for greenhouse gas mitigation

4.1 Government should drive greenhouse gas reduction in agriculture into greenhouse gas mitigation plan in the national level by transferring technologies, concepts, and knowledge to the targeted farmers. Public media production is recommended for disseminating knowledge to farmers and related agencies such as academic journals, newspapers, local radio, television, and websites that mainly shared activities. Government could impose a policy on greenhouse gas reduction and climate change in direct and indirect way. The policy could be in the form of a voluntary agreement by using according to the situation and suitability of the country. Data used for decision making includes

observing and measuring the storage and emission rates of greenhouse gas within the farm of each country so that this can be accepted by farmers

4.2 Government should recommend and support agricultural activities in terms of technical assistance and appropriate planting method. There should be a selection of agricultural activities supporting greenhouse gas reduction for each country. Assessment of carbon change in agricultural areas and greenhouse gas emissions must be considered as a greenhouse gas accounting using the estimation method developed by Intergovernmental Panel on Climate Change (IPCC). Measurement technique of greenhouse gas emission must comply with measurable, reportable, and verifiable (MRV) method. However, government should find easy and low-cost approach especially when using remote sensing technology with on ground observation and using the model for prediction. Further study is required to impose additional standard and the leakage of other agricultural activities that emit greenhouse gases

4.3 Government should create financial incentives to motivate farmers to join the project and implement greenhouse gas reduction policy. Government should expand policy framework to cover more agricultural activities and amend rules and regulations of farmer's registration in the project in the easy and flexible way because farmers in developing countries are smallholder farmers who live in countryside and make a living depending on agriculture and natural resources. This farmer groups will be affected most from disaster created by humans. Moreover, smallholders are excluded due to financial or social status. Consequently, they cannot get access to knowledge, help, support, funding, and innovation. Therefore, government in each country urgently needs to help farmers who are affected from global warming impact to gain knowledge, adjust themselves, get access to the information and funding sources so that they are aware of the current crisis and give support and cooperation to develop sustainable food production system. ⁽⁴⁾

Source

1. <http://climate.tmd.go.th/content/file/11>⁽¹⁾
2. <https://dmcrth.dmcr.go.th/manpro/detail/11697/;https://web.ku.ac.th/schoolnet/snet6/envi3/mirror/mirror.htm>⁽²⁾
3. <https://th.wikipedia.org/wiki/แก๊สเรือนกระจก>⁽³⁾
4. <http://prp.trf.or.th/trf-policy-brief>⁽⁴⁾
5. <https://actionforclimate.deqp.go.th/>⁽⁵⁾
6. <https://thailand.un.org/th>⁽⁶⁾
7. <https://www.sdgmovement.com/>⁽⁷⁾
8. <https://www.bio100percent.com/knowledge/agro-forestry/>⁽⁸⁾
9. <https://erdi.cmu.ac.th/?p=1148#CMU>⁽⁹⁾
10. In vitro evaluation of feeding North Atlantic stormtoss seaweeds on ruminal digestion - <https://bit.ly/3hdmjiW>⁽¹⁰⁾
11. <https://webkc.dede.go.th/testmax/node/188>⁽¹¹⁾
12. <http://www.tgo.or.th/2020/index.php/th/post>⁽¹²⁾