Spatial Mapping Of Agricultural Green House Gas Emission For Implementing Paris Agreement On Climate Change In Vietnam

Thao Thanh Tong (1), Hang Thi Thanh Doan (1), Man Minh Duc Le (1), Duyen My Chau Nguyen (1), Long Ta Bui (1)

[1]Hochiminh City University of Technology, 268 Ly Thuong Kiet Street, District 10, Vietnam
Email: 1552348@hcmut.edu.vn; 1552117@hcmut.edu.vn; 1552220@hcmut.edu.vn; nguyenduyen91@hcmut.edu.vn; longbt62@hcmut.edu.vn

KEYWORDS: *Greenhouse gas, Paris Agreement, inventory, CMAQ, spatial maps*

ABSTRACT

Vietnam signed in Paris Agreement and is trying to aim the target of controlling the increase in temperature in this century. To achieve this mission, Vietnam planned to decrease 8% of national greenhouse gases (GHGs), especially agriculture needs to reduce 20% of GHG emissions by 2020. Objectives of this study are figuring out the amount of GHG emissions releasing from agricultural sectors and building hourly spatial map of O_3 concentrations for regional area by applying the Community Multiscale Air Quality (CMAQ) model. The case study of this research is Dong Thap province which is ranking the third in producing rice and the second in aquatic products in Vietnam. The results show that $CO_{2\text{-eq}}$ in agriculture is mainly produced by cultivation (58%), especially rice crops, followed by 40.2% emissions come from straw burning. Furthermore, the spatial maps of O_3 display that there is a decrease in the ozone concentration during the day from 1:00 to 24:00 on 13 February 2017. The highest value is 78.0376 µg/m^3 at 5:00 a.m and the lowest value (32.8207 µg/m^3) is belonged to 22:00. In conclusion, IPCC method is effective in inventorying the annual amount of emissions released by agriculture and can be applied for developing countries. Furthermore, hourly concentration of pollutants can be determined by CMAQ model and this result is useful for air quality management.

1. INTRODUCTION

1.1. Significance of research

Climate change is a global environmental problem which has been attracting attention of all researchers all over the world. Every country take the responsibility to reduce the negative impacts of climate change. In order to find an effective alleviation, root cause of this problem was identified – Greenhouse Gas (GHG). While almost people think and believe that GHG emissions are mainly produced by industry, however, in global scale agriculture, which is ranking at the second place after energy consumption, is emitting more GHG emissions than industry. This fact is also occurring in Vietnam, especially Vietnam is one of the most countries are famous for exporting rice and agricultural products. Agriculture is not only impacted by climate change, but also takes the responsibility for releasing the GHG emissions. According to The Fifth Assessment Report of IPCC (2014), agriculture released 24% of total GHG emissions while industry emitted less than 20%, and 44% of agricultural GHG emissions come from Asia (IPCC, 2014). There was an announcement that showed GHG emissions rate increased as much as twice during last 50 years and it is predicted to rise by 30% up to 2050 (The IPCC Fifth Assessment Report, 2014). In the 2017

United Nations Climate Change Conference (COP23), which organized in Bonn city, Germany, considered that worldwide agriculture could help in controlling the amount of emissions released into the atmosphere.

According to Announcement No.2 of the MONRE, agricultural production is the largest source of greenhouse gas emissions and is expected to continue to increase in the coming years. For the production activities of the sector, wet rice production emissions account for more than 57% of the GHG emissions of the industry as a result of large emissions of methane (CH_4) and oxide (N_2O), followed by blanket livestock which has a strong development. Many reports in Vietnam showed that agriculture is one of the main sources in releasing GHG emissions. In 1994, agriculture produced more than 50 million tons of $CO_{2\text{-eq}}$ which contributed 50.5% of GHG emissions in Vietnam. That amount increased up to 80,58 million tons in 2005, with the main cause is cultivation, especially in paddy fields and in 2011, 5,3 billion tons of GHG emissions was emitted from agricultural activities in Vietnam (iasvn.org, 2018). Inventory the GHG emissions released by agriculture is an important in achieving the target of mitigating with climate change in Vietnam. CO_2 emissions have been observed to rise at a cumulative annual growth rate of 7.94% and 5.26% for agriculture and fisheries sectors, respectively.

Therefore, minimizing the amount of GHG is the most important mission for environmental researchers. Vietnam signed in Paris Agreement at COP21 in 2015 and is trying to aim the target of controlling the increase in temperature. Particularly, the global temperature should not be risen more than 2°C by this century. To achieve this goal, Vietnam planned to decrease 8% of national greenhouse gases by 2030 (*Plan For Implementation Of The Paris Agreement* dated 2016), especially agriculture needs to reduce 20% of GHG emissions by 2020 mentioned in *Decision No.1775/QD-TTg* dated 2012. In detail, *Decision No.3119/QD-BNN-KHCN* dated 2011 requires cultivation needs to decrease 10.03% GHGs; livestock reduces 25.84% and aquaculture cuts 23.32%. In plan activities, government announced that inventorying GHGs is compulsory. This mission can be completed via application of IPCC calculation, which is used in this research. However, inventorying the amount of GHG emissions is not enough for mitigating the impacts on human health. The transportation and dispersion of GHGs should be considered to recorgnized the affected scope to protect citizens because polluted air not only cause respiratory problems, but also decrease the human's life-span. In Southeast Asia, the region includes Vietnam, outdoor air pollution was estimated to contribute to 712,000 deaths in 2010 (Lim, 2012, Wang, 2012). Similarly, Ho Chi Minh City (HCMC) is the most dynamic area as a social, cultural and economic center of Vietnam (B.Q.Ho, 2017). Consequently, environment has become polluted, and the citizens have to face many environmental problems.

In a recent study of relationship between air pollution and human health, over 90% children less than five years old in HCMC were infected to respiratory disease (HEI, 2012). According to World Economic Forum in 2012, Vietnam is one of 10 countries which has the worst air pollution in worldwide (WEF, 2012) and in urban area as HCMC, traffic is the major contributor to air pollution (B.Q. Ho, 2011). Many studies related to air quality management in HCMC have been done recently, including "Air pollution forecast for Ho Chi Minh City, Vietnam in 2015 and 2020" to simulate pollutants over HCMC (NOx, CO, SO_2, O_3, but not PM10) (B.Q.Ho, 2011). Moreover, *Decision No.985a/QD-TTg* dated 2016 highly recommends international cooperation in researching, establishing model for assessing the dispersion of emissions and predicting air quality.

Additionally, in atmosphere, there is a dispersion and transformation of emissions. That means the emissions can react with others to create a new pollutants, such as ozone which is the product of chemical reaction between CH_4, CO, NOx, Non-methane Volatile Organic Compounds (NMVOC) under sunlight condition. The highest level of ozone pollution appears during the sunny weather periods (WHO, 2018). Ozone at ground level acts similarly to a strong greenhouse gas. Tropospheric ozone affects the climate beyond increased warming, having impacts on evaporation rates, cloud formation, precipitation levels, and atmospheric circulation. Tropospheric ozone causes smog. WHO (2018) recommends the 8-hour average concentration for protecting public health of ozone is $100ug/m^3$, decreased $20ug/m^3$ compared to criteria in 2005 because the ozone impacts are emergency. California has one hour outdoor ozone standard is 0.09ppm (Climate & Clean Air Coalition, 2018). Spare The Air (2015) provides the AQI for ozone in ambient air. The AQI comes from 101 to 150 is unhealthy for sensitive groups (elder, children, pregnant). Corresponding with AQI 101-150 is the range of ozone 8-hour average concentration which is between 0.071ppm and 0.085ppm.

Therefore, calculating the amount of emissions released by agricultural activities and researching the dispersion of pollutants in atmosphere are extremely important in inventorying and management of GHGs.

To approach ozone concentration and dispersion via CMAQ model, which can calculate hourly average concentration of pollutants and display the transportation of emissions in atmosphere.

1.2. Objectives

The research amis to quantify the amount of GHGs released by agriculture in Dong Thap province, Vietnam in 2017 and hourly display the dispersion of ozone in 12 districts of scope of study in 24 hours.

2. STUDY AREA

Dong Thap is bordered by Pray Veng province (Cambodia) in the North; Vinh Long and Can Tho in the South; An Giang in the West; and Long An and Tien Giang in the East. Dong Thap has a tropical climate which includes two seasons: dry season (from May to November) and wet season (from December to April). Dong Thap is chosen for this research due to the high contribution in national agricultural development. The average agricultural growth rate is 4.73% per year. The exported rice in 2016 reached 3.39 million tons/year (ranking at third place in Vietnam), aquatic products 491,486 tons (ranking at the second place). Besides, the province has many advantages in developing livestock, especially poultry. Last but not least, aquaculture is also plays a vital role in Dong Thap's agriculture area with 5,835 ha area (2016). Fish, especially catfish is known as one of main revenue of residences in Dong Thap, shrimp is also mentioned as an important aquatic species.

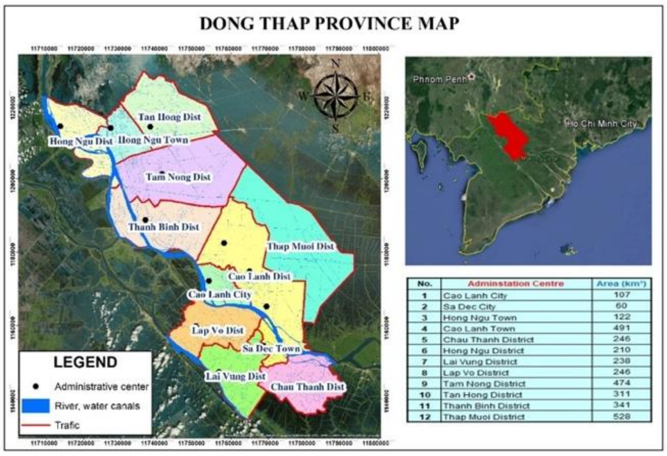


Figure 1. Administrative map of Dong Thap province

3. DATA AND METHOD

3.1. Data

The primary agricultural data including area of three kinds of crop (rice, maize, sweet potato), number of five livestock species (buffalo, cattle, swine, goat, poultry) and aquaculture area is provided by Statistic Yearbook of Dong Thap Province (2017).

Furthermore, in IPCC equations, the emission factors (EF) and default values are required. The authors got those values from Appendix of IPCC Volume 4.

Table 1. Emission Factor of Crops (IPCC, 2006)

Crops	EF (kg CH_4 ha-1 day-1)
Rice, Maize, Sweet Potato	1.3

Table 2. Default Values of Livestock Breeding Calculation (IPCC, 2006)

Livestock Species	Buffalo	Cattle	Swine	Goat	Poultry
Enteric Fermentation EF ***(kg CH_4 / year)***	55	47	1	5	-
Manure management EF ***(kg CH_4 / year)***	2	2	7	0.22	0.02
Default value for Nitrogen Excretion ($N_{rate(T)}$) ***(kg N/1000 kg animal mass/day)***	0.32	0.34	0.42	1.37	0.82
Typical Animal Mass (TAM) ***(kg)***	450	250	60	-	-
Default value for Nitrogen Loss due to volalisation of NH_3 and NO_x from manure management ($Frac_{GasMS}$) ***(%)***	45	45	40	-	-

3.2. Method

This is a combination between four softwares: WRF (Weather Research and Forecasting), WCT (Weather and Climate Toolkit), CMAQ (The Community Multiscale Air Quality Model) and GIS. In detail, WRF, CMAQ and GIS are three main components, WCT takes responsibility for supporting in treating output data from CMAQ and WRF before entering into GIS. The key software is CMAQ and three others are responsible for input data, analyzing results.

- *WRF software* is a model used for simulating and forecasting the regional weather with highly recommended use due to the correction of outputs at current. WRF (Weather Research and Forecast) software plays an important role in supplying input data for CMAQ. Moreover, WRF is currently known as the most modern and correct meteorological data model.
- *CMAQ model*

CMAQ model is applied for expressing the dispersion of emissions to others regions from source. This model requires the input data includes: emission data at each point of study area in each hour (IPCC calculating results combine with GIS tool), meteorological data (WRF software). The emission data and meteorological data need to have similar scope study with the cell size of grid is 3km x 3km. This diagram (EPA, 2017) shows clearly the process of CMAQ (Figure 1.13). In this paper, despite of using SMOKE and Agriculture, greenhouse gas emissions taken from IPCC method above is applied as emission inventory. The input data format for running model is presented below.

After achieving the amount of emissions released by agriculture and meteorology of studied region, these two data will be input data of CMAQ. However, there is a preparation of emission data in formatted file. The emission data per hour is set for each cell of the grid which covers Dong Thap province with additional information such as latitude and longtitude. Totally, the authors need 24-hour emission data on 13 February 2017. The users can put as much as possible the diverse kind of emissions/pollutants users have.

The input data for CMAQ running including four main files: met (meteorological data), icbc consists of ICON (initial condition) and BCON (boundary condition), emis (emission), ocean.

Table 3. Requirement for running CMAQ

Requirement	
Domain	Dong Thap province area (Resolution 3km x 3km)

Meteorological data	WRF (Weather Research and Forecasting model)
Emission inventory data	IPCC method

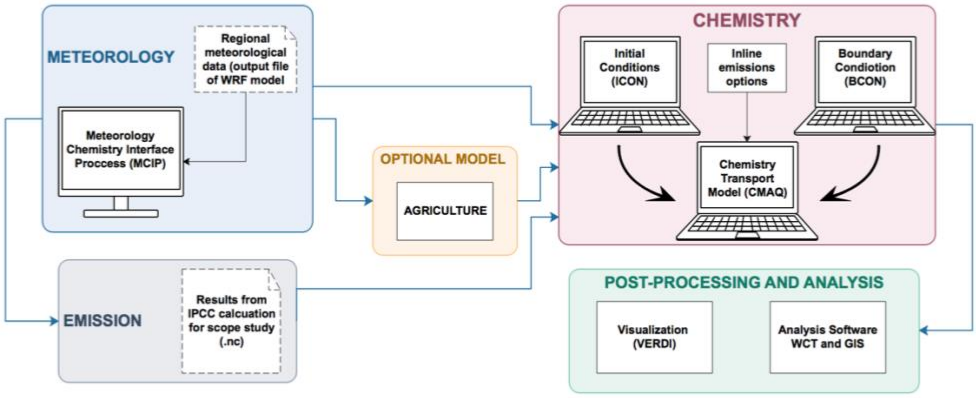


Figure 2. Running CMAQ process (EPA, 2017)

To provide the emission data for CMAQ, IPCC (2006) equations are applied. Particularly, agricultural GHGs are calculated in for sectors: cultivation, livestock, aquaculture and biomass burning. In that, equations for straw burning sector is taken from Gradded et al., (2009).

Table 4. IPCC equations in inventorying agricultural GHGs

Sector	Equations
Cultivation	$\mathbf{CH_{4Rice} = \sum_{I,j,k}(EF_{i,j,k} \times t_{i,j,k} \times A_{i,j,k} \times 10^{-6})}$ (IPCC, 2006) Where: $CH_{4\ Rice}$: annual methane emissions from rice cultivation, Gg CH_4 yr^{-1} $t_{i,\ j,\ k}$: cultivation period of rice for i, j, and k conditions, day $A_{i,\ j,\ k}$: annual harvested area of rice for i, j, and k conditions, ha yr^{-1} i, j, k: represent different ecosystems, water regimes, type and amount of organic amendments, and other conditions under which CH_4 emissions from rice may vary
Livestock	**Enteric fermentation** $\mathbf{ECH_4=EF_{(T)} \times (N_{(T)} / 10^6)\ (GgCH_4/year)}$ (IPCC, 2006) Where E: Methane emissions from enteric fermentation, ($GgCH_4$ / year), 1Gg = 1000 tons N (T): number of animals (single) EF (T): emission factor (kg CH_4 / year) **Manure management** *CH4 emission from manure management* $\mathbf{CH_{4Manure} = EF_{(T)} \times (N_{(T)} / 10^6)}$ ($GgCH_4$/year) (IPCC, 2006) Where: $CH_{4Manure}$: CH_4 emissions from manure management, for a defined population, Gg CH_4/yr $EF_{(T)}$: emission factor for the defined livestock population, kg $head^{-1}$ yr^{-1} $N_{(T)}$: the number of head of livestock species/category T in the country T: Species/category of livestock

	N_2O emission from manure management $$N_2O_D = [\ \Sigma_s(\Sigma_T N_T \text{ x } Nex_T \text{ x } MS_{TS}) \text{ x } EF_{3S}] \text{ x } 44/28$$ (IPCC, 2006) NT: number of animals $M_{S\ (T,\ S)}$: the rate of excrement is processed according to the system S $EF_{3\ (S)}$: emission factor of treatment system S (kg N2O- N / kg N), $EF_{3(S)}$ = 0.01 (kg N2O- N/kg N) (developing countries and climate zone with high temperature (over 28°C)) 44/28: conversion factor from N_2O to N emissions Nex_T: average N emissions per year, (kg N / year) MS (%) = 2.0% $$Nex_T = N_{rate\ (T)} \text{ x } TAM/1000 \text{ x } 365$$ (IPCC, 2006) Where $N_{rate\ (T)}$: default N excretion rate, kg N/1000 kg animal mass/day TAM : typical animal mass for livestock category, kg *N losses due to volatilization from manure management* $$N_{volatilization\ -MMS} = [\ \Sigma_s(\Sigma_T N_T \text{ x } Nex_T \text{ x } MS_{TS}) \text{ x } (Frac_{GasMS}/100)]_{(T,S)}$$ (IPCC, 2006) Where $N_{volatilization}$: amount of manure nitrogen that is lost due to volatilisation of NH_3 and NOx, kg N yr^{-1} N_T : number of head of livestock species/category T in the country Nex_T : annual average N excretion per head of species/category T in the country, kg N $animal^{-1}$ yr^{-1} MS_{TS} : fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless $Frac_{GasMS}$: percent of managed manure nitrogen for livestock category T that volatilises as NH_3 and NOx in the manure management system S, %
Aquaculture	$$CH_{4EmissionWWflood} = P \text{ x } E\ (CH_4)_{diff} \text{ x } A_{flood\_total\_surface} \text{ x} 10^{-6}$$ (IPCC, 2006) Where $CH_{4EmissionWWflood}$: total CH_4 emissions from flood land, Gg CH_4 yr^{-1}, 1Gg = 1000tons P : the number of days without ice cover during a year = 365 days yr^{-1} $E\ (CH_4)_{diff}$: average daily diffusion emissions = 0.63 kg CH_4 ha^{-1} yr^{-1} $A_{flood\_total\_surface}$: total reservoir surface area, icluding flooded land, lakes and rivers
Straw burning	**Straw production weight** $$Q_{st} = Q_p \text{ x } R \text{ x } k$$ (Gradded et al., 2009) Where Q_{st} : total straw production burned on fields, tons Q_p : rice production, tons R : straw fraction (R=Wr/Wh; Wr dry weight of straw, kg; Wh rice weight, humidity 14%, kg), R≈0.92 k : fraction of straw burned on the fields compared to total straw produced, k=1.33 **Emissions from biomass burning** $$E_i = Q_{st} \text{ x } E_{FI} \text{ x } F_{co}$$ (Gradded et al., 2009)

	Where E_i : emissions produced from burning straw on the fields (tons) E_{FI} : emission factor I from straw burning on the fields, g/kg, (ECO_2 = 1464; ECO = 34.7; ENOx = 3.1) F_{co} : fraction of straw burned on the fields = 0.8

After calculating hourly Ozone concentration in CMAQ model, WCT and GIS are used for analyzing the results and building spatial maps. Additionally, due to the requirement of convert the unit of emission from ppmV to µg/m^3, the temperature and press are necessary. To get these two layers, the WRF output is also the input of WCT tool. Then Raster Calculator is used to convert the unit of emissions according to equation below (Scribd, 2014), the results will be multiplied with 1000 to get ug/m3 unit.

$$\mathbf{ppmV = (mg/m3) \times (273.15 + {}^{o}C) / (12.187) \times (MW)}$$

Where

ppmV: ppm by volume

mg/m^3: milligrams of gaseous pollutant per cubic meter of ambient air

MW: molecular weight of gaseous pollutant

^{o}C: ambient air temperature in degrees Centigrade

In this study, due to the temperature output in WRF is in degrees Kelvin, the author does not need to plus temperature with 273.15.

4. RESULTS AND DISCUSSION

4.1. Agricultural GHGs in Dong Thap province in 2017

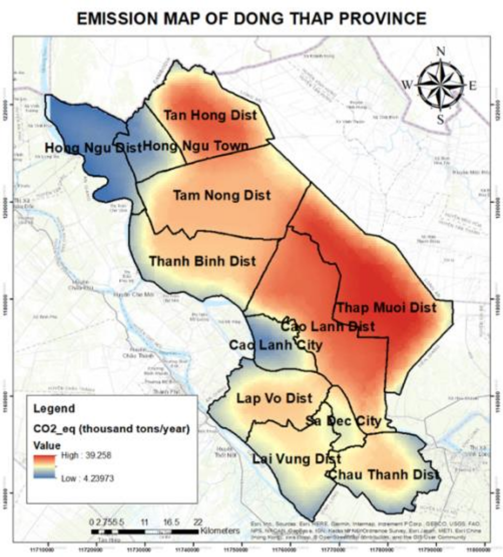


Figure 3. Emissions map of Dong Thap province

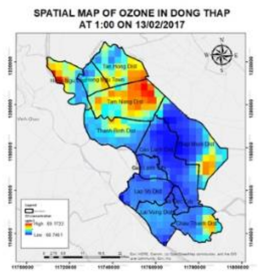
Totally, Dong Thap province released 11,169.56 tons $CO_{2\text{-eq}}$ in 2017 via cultivation, livestock, aquaculture and biomass burning. Especially, emissions are mainly released from cultivation and straw burning that are also the major activities in agricultural sector. In details, Thap Muoi and Cao Lanh districts took the first and second places in emitting $CO_{2\text{-eq}}$. Additionally, the largest amount of $CO_{2\text{-eq}}$ came from cultivation is 6,478.19 thousand tons (accounts for approximately 58% of regional GHGs), followed by 40% of straw burning while that of aquaculture is nearly 1,000 tons. Although livestock releases more emissions than aquaculture, this sector is a small source compared to cultivation and agricultural waste combustion.

4.2. Hourly O_3 concentration on 13 February 2017

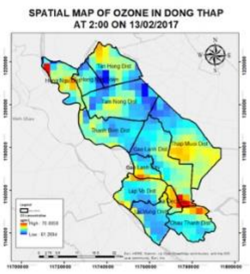
The concentration of Ozone ranges from 32.8207 µg/m^3 to 78.0376 µg/m^3. Although the value of ozone does not exceed the allowed concentration in ambient in QCVN 05:2013/BTNMT (200 µg/m^3 in one hour), this amount of O_3 impacts on human health, especially sensitive groups. Furthermore, the resident is living in the area for long time, so the exposure is needed to be concerned.

Table 5. Hourly Ozone concentration on 13 February 2017 from 1:00 to 24:00

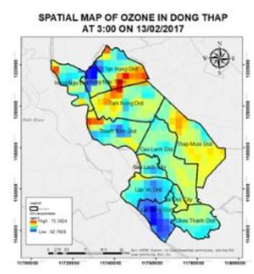
Hourly Ozone concentration on 13 February 2017 from 1:00 to 24:00



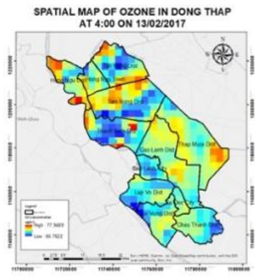
1:00



2:00

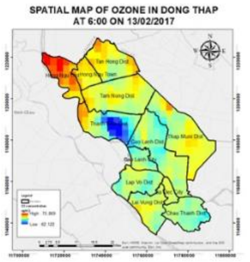


3:00

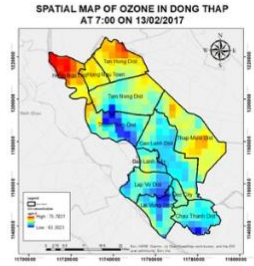


4:00

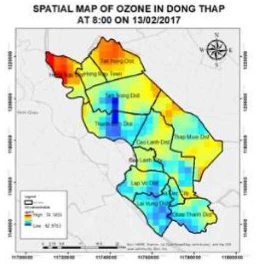
5:00



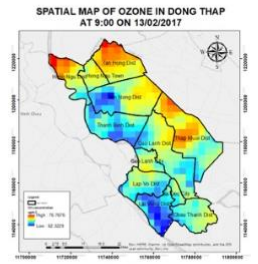
6:00



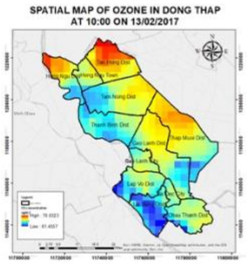
7:00



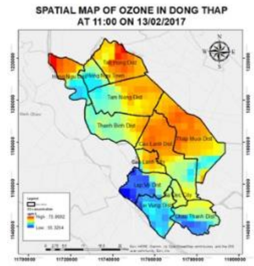
8:00



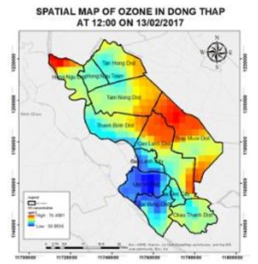
9:00



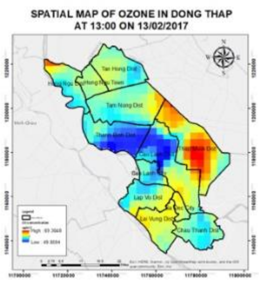
10:00



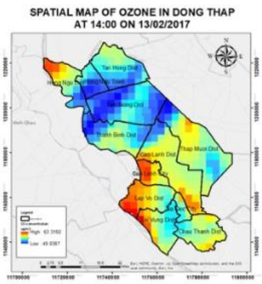
11:00



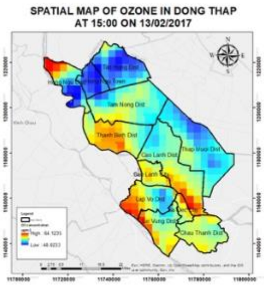
12:00



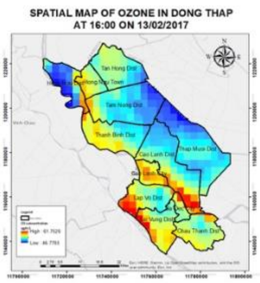
13:00



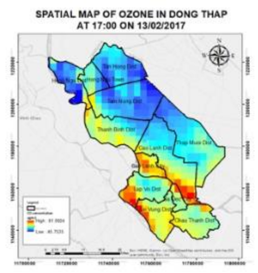
14:00



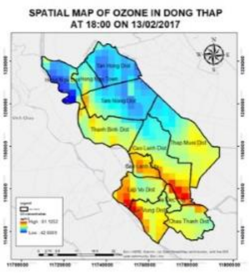
15:00



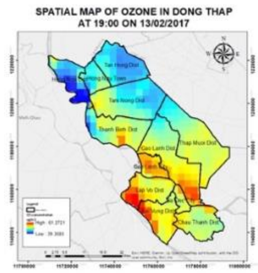
16:00



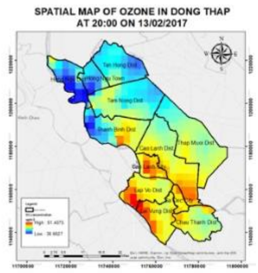
17:00



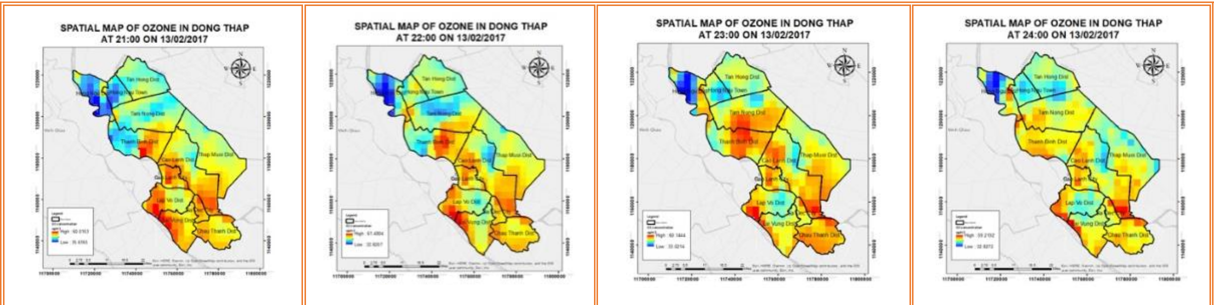
18:00



19:00



20:00



21:00 22:00 23:00 24:00

The lowest value is at 22:00 and the highest is belonged to 5:00. During a day, there is a moving of center emissions, which is the highest point of total emission in hour. The direction shown from spatial map is from the North to the South of scope study.

On the first half of the day (from 1:00 to 12:00) the highest concentration of O_3 in each hour are higher than 70 µg/m^3 and the lowest concentration is approximately 51 µg/m^3 (at 12:00). The emission spreads during the time and reach the largest scope at 11:00. There is a move of center emission from Tan Hong district and Hong Ngu district to the East region which includes Thap Muoi district and Cao Lanh district. At 1:00 the highest points of emission are in Tan Hong and Hong Ngu districts, until 12:00 Thap Muoi and Cao Lanh are the two centers of emissions.

The emission continues to move to the South and the West of Dong Thap in the rest of 13 February (from 13:00 to 24:00). At 13:00 the emissions are concentrating at Thap Muoi district. From 14:00 up to 19:00, Cao Lanh city, Lap Vo district, Sa Dec city, Lai Vung district have to face with high ozone concentration while the atmosphere in Chau Thanh district is still fine. Thanh Binh is impacted at 15:00 only. From 20:00 to the end of the day the ozone covers both of Thanh Binh district and Chau Thanh district. Comparing to the period from 1:00 to 12:00, the ozone concentration in the second half of 13 February is less than, especially in night. The highest concentration is 69.3048 µg/m^3 (13:00) and the lowest is 32.8207 µg/m^3 at 22:00.

5. CONCLUSIONS

The GHGs released by agricultural sectors calculated by IPCC (2006) equations are 11,170 thousand tons in Dong Thap province in 2017. In 12 districts, Thap Muoi district and Cao Lanh district release 2.332 million tons and 1.875 million tons $CO_{2\text{-eq}}$ respectively. These two districts emit the largest amount of emissions in Dong Thap. Thereby, rice cultivation is considered to create the largest CO_2 (6.478 million tons $CO_{2\text{-eq}}$) into the environment because of accounted for the highest proportion (58%) in Dong Thap province. Rice is evaluated as the main producer of GHG emissions in cultivation term. Flooded paddy fields emit 6.425 million tons $CO_{2\text{-eq}}$, account for 99% of emissions from cultivation in Dong Thap. The second sector is biomass burning, which generates 4.492 million tons GHGs and accounts for more than 40% of regional CO2-eq in 2017. CMAQ model is modern and highly helpful in displaying the transference, distribution of emissions. The value of ozone ranges from 32.8207 ug/m^3 to 78.0376 µg/m^3 and in Verdi the concentrations of O_3 are between 0.014 ppmV and 0.071 ppmV. The highest value of O_3 occurs at 5:00 and the lowest value is belonged to 22:00.

REFERENCES

B.Q. Ho, A. Clappier, G. Francois. (2011). Air pollution forecast for Ho Chi Minh City, Vietnam in 2015 and 2020. *Air Qual Atmos Health*, 4, 145-158.

B.Q. Ho. (2017). Modeling PM10 in Ho Chi Minh City, Vietnam and evaluation of its impact on human health.

Climate & Clean Air Coalition. (2018). Tropospheric ozone. [online] Available at: https://www.ccacoalition.org/ru/slcps/tropospheric-ozone [Accessed 1 Jun. 2019].

EPA (2017). *Overview of Greenhouse Gases | US EPA*. [online] US EPA. Available at: https://www.epa.gov/ghgemissions/overview-greenhouse-gases [Accessed 19 Oct. 2018].

Gadde B., Bonnet S., Menke C., and S Garivate (2009). Air pollutant emissions from rice staw open field burning in India, Thailand and the Phillipines. Journal of Environmental Pollution, Vol. 157, pp.1554-1558.

HEI. (2012).Effects of Short-term Exposure to Air Pollution on Hospital Admissions of Young Children for Acute Lower Respiratory Infections in Ho Chi Minh City, Vietnam. Health Effects Institute, Boston, MA.

Iasvn.org (2018). *Phát thải khí nhà kính của ngành nông nghiệp | Vien Khoa Hoc Ky Thuat Nong Nghiep Mien Nam*. [online] Iasvn.org. Available at: http://iasvn.org/tin-tuc/Phat-thai-khi-nha-kinh-cua-nganh-nong-nghiep-gia-tang-4955.html [Accessed 10 Sep. 2018].

IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Agriculture, Forestry and Other Land Use (AFOLU), Volume 4.

IPCC (2013): Climate Change 2013: The Physical Science Basis. Contribution of Group Working I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A.Nauels, Y. Xia, V. Bex and P.M. Midgley (eds)]. Cambrigde University Press, Cambrige, United Kingdom and New York, NY, USA, 1535 pp.

Lim. (2012). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet, 380 (2012), 2224-2260.

Scribd. (2014). Air Dispersion Modeling Conversions and Formulas: Converting Atmospheric Pollutant Concentrations. [online] Available at: https://www.scribd.com/document/255193581/Conversions-and-Formulas [Accessed 6 Jan. 2019].

Spare The Air (2015). Spare The Air: Air Quality Index (AQI). [online] Sparetheair.com. Available at: http://www.sparetheair.com/aqi.cfm [Accessed 1 Jun. 2019].

US EPA. (2017). Health Effects of Ozone Pollution | US EPA. [online] Available at: https://www.epa.gov/ground-level-ozone-pollution/health-effects-ozone-pollution [Accessed 1 Jun. 2019].

Wang. (2012).Age-specific and sex-specific mortality in 187 countries, 1970–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet, 380 (2012), 2071-2094.

WHO (2018). Ambient (outdoor) air quality and health. [online] Available at: https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health [Accessed 1 Jun. 2019].