# Relationship of satellite-derived atmospheric $CH_4$ concentrations with agriculture sector $CH_4$ emissions in Turkey

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**Abstract.** In this study, bottom-up annual $CH_4$ emissions from agriculture (rice cultivation, enteric fermentation and manure) were calculated with the IPCC Tier 1 approach on county-level, and province totals were obtained for the first time in Turkey. Konya, which produces the highest annual $CH_4$ emissions (117 Gg $CH_4$/yr), is followed by Izmir, and Manisa provinces. TROPOMI-derived $CH_4$ measurements for a year from December 2018 to November 2019 were used to estimate the monthly and annual concentrations (ppb) for counties and provinces in Turkey. The monthly average $CH_4$ concentrations were between 1855-1870 ppb, and the highest levels were observed between June and September, which also coincides with the agricultural processes cause $CH_4$ emissions. TROPOMI $CH_4$ concentrations and agriculture-related $CH_4$ emissions agreed for provinces of İzmir, Aydın, Tekirdağ, Mersin, Adana, Hatay, Osmaniye, Kilis, Mardin and Şırnak, but conflicts for Ardahan, Van, Ağrı, Kars and Erzurum. The results indicated agreement with agricultural $CH_4$ emissions in western and southern parts of Turkey rather than northern and eastern parts.

**Keywords:** $CH_4$, Remote Sensing, Agriculture, TROPOMI

## 1. Introduction

Today, climate change is among the global environmental problems that requires our immediate attention. The United Nations Framework Convention on Climate Change (UNFCCC) defines greenhouse gases as "both natural and human-sourced; gas formations that absorb and re-emit infrared radiation in the atmosphere" (FAO 2014). Human activities and natural events increase the concentrations of these greenhouse gases in the atmosphere, causing global warming. Methane ($CH_4$) is a greenhouse gas and contributes to global warming. $CH_4$ is released into the atmosphere from swamps as natural sources, and extraction of natural gas and oil, production and transportation of coal, livestock and other agricultural practices, stubble burning, and organic waste decay in municipal solid waste storage areas as anthropogenic sources.

The greenhouse effect of $CH_4$, which has a life span of 12 years in the atmosphere, is 21 times higher than carbon dioxide (IPCC 2015). With industrialization, atmospheric $CH_4$ concentration has reached from 720 to 1800 ppb and global $CH_4$ emission are estimated as 550 ± 60 Tg/yr (Palmer et al. 2018). Global $CH_4$ sources can be listed as follows; Swamps 22%, Quarries and natural gas 19%, Enteric Fermentation 16%, Rice Farming 12%, Stubble Burning 8%, Waste Storage 6%, Animal manure 5%, Sewage systems 5%, Termites 4%, Hydrates 3% (Saunois et al. 2020). IPCC estimated as 50% of the total $CH_4$ emissions are from anthropogenic sources (IPCC 2015). The agriculture and livestock sector have the biggest share among the anthropogenic sources and approximately 60% of $CH_4$ emissions are from anthropogenic sources (IPCC 2015). The 7th National Communication of Turkey stated that $CH_4$ emissions increased from 1990 until 2016 in all sectors (MoEU 2018). However, the highest increase was seen in the agricultural sector with 21.5% and nearly 60% of total $CH_4$ emissions are from this sector in 2016 (MoEU 2018). The greenhouse gas emission has increased from 475 Mt $CO_2$ eq to 522 Mt $CO_2$ eq globally from 1990 to 2012 due to paddy fields (Tubiello et al. 2014). Research has shown that seed type, (Wang, Neue, and Samonte 1997), the number of aerenchymas, applied agriculture practices (Hou et al. 2012, Hussain et al. 2015) use of nitrogenous fertilizers (Taşlıgil 2013) or compost material (Denier Van Der Gon et al. 2002) and irrigation method (Arunrat et al. 2021) affect $CH_4$ emissions in paddy agriculture. On the other hand, it was stated that the increase in animal husbandry reflected an 8% increase in global $CH_4$ emissions resulting from gas extraction in livestock (IPCC 2015). Feed quality, feed and energy amount that the animal consumes affect the production of $CH_4$, as well as the age, weight and gender (Koyuncu and Akgün 2018, Yu et al. 2018). $CH_4$ emissions from manure caused either from anaerobic conditions during storage or the manure spread on the pastures (Koyuncu and Akgün 2018). These emissions depend on the manure content, manure amount, anaerobic degradability, and temperature (Masse et al. 2016, Benchaar and Hassanat 2019, Balde et al. 2016).

TROPOMI has higher accuracy in atmospheric $CH_4$ measurements compared to other satellites due to its high spatial resolution and global coverage (Lorente et al. 2021). Puliafito et al. (2020) stated that satellite $CH_4$ retrievals, including TROPOMI, can show local $CH_4$ concentrations in line with the $CH_4$ emissions from agricultural activities.

The aim of this study is to examine the correlation between the satellite-derived atmospheric $CH_4$ concentrations and the agricultural $CH_4$ emissions in Turkey. The county-level $CH_4$ emissions were estimated from agricultural sources, and spatial and temporal correlation of these emissions with atmospheric $CH_4$ concentration were investigated.

## 2. Methodology

The rice cultivation is done in 27 of the 81 provinces of Turkey, whereas livestock activities carried out in every province. Therefore, this study covers all counties and provinces in Turkey. It was observed that the rice production of the paddy plant, planted in April-May, was ceased in July-August (**GDoTGB** 2019). Although it varies from region to region, the livestock are grazed in the pastures generally starting from May to the end of September. The study period was selected as a 12-month period (December 2018- November 2019) to investigate the annual changes and the effect of these emissions on $CH_4$ concentrations.

In the study, $CH_4$ emissions from agriculture was calculated with IPCC Tier 1 methodology. Annual emissions were calculated by multiplying the Activity Information (AI) with appropriate Emission Factors (EF) The calculations were performed with specific emission factors for the Eastern European region from the IPCC (Shukla et al. 2019). The used emission factors are 1.56 kg $CH_4$ ha/day for rice cultivation, and 58 kg $CH_4$ beef cattle/yr, 93 kg $CH_4$ dairy cow/yr, 5 kg $CH_4$ sheep/yr, for livestock. The parameters used in the $CH_4$ emission calculations from manure are given in Table 1.

**Table 1.** The parameters used for $CH_4$ emission calculation from manure (Seyhan and Badem 2018**,** TIGEM 2017, Gavrilova et al. 2019)

| | Cattle | Dairy Cow | Sheep | Poultry |
|---|---|---|---|---|
| Average Animal Weight (kg) | 900 | 700 | 35 | 4 |
| Manure Production (kg/day) | 6.840 | 4.690 | 0.290 | 0.032 |
| Total solid content (% TS) | 14.5 | 14.5 | 30.0 | 28.0 |
| Organic matter content (%OM) | 77.5 | 77.5 | 80.0 | 80.0 |
| Biogas potential of manure ($m^3$/kg OM) | 0.25 | 0.25 | 0.40 | 0.20 |
| $CH_4$ content of biogas (%) | 65 | 65 | 65 | 60 |

TROPOMI on Sentinel–5P is a spectrometer provides 7×7 $km^2$ and 7×3.5 $km^2$ spatial resolution, making it possible to identify $CH_4$ emission sources (Palmer et al. 2018). TROPOMI includes the SWIR (short wavelength infrared rays) spectral band which measures atmospheric $CH_4$ concentration with a wavelength of 2.3 µm (Hu et al. 2018, Jacob et al. 2016).

TROPOMI $CH_4$ retrievals were processed monthly, average and standard deviations along with data counts over Turkey were calculated via R. Using the average atmospheric $CH_4$ concentrations, spatial distribution maps were prepared for all counties and provinces of Turkey using ArcGIS. Satellite-derived $CH_4$ concentrations and monthly changes were compared with annual $CH_4$ emissions calculated for each county and province for three categories: rice cultivation, enteric fermentation and manure from livestock.

## 3. Results

The maximum atmospheric $CH_4$ concentration was observed at August-September for Turkey similar to other studies (Fiore, Jacob, and Field 2002). $CH_4$ emissions from agricultural sources (enteric fermentation, rice cultivation and manure) are at peak levels between June and September, similar to $CH_4$ concentrations observed (Figure 1). $CH_4$ emissions are high in September due to animal and their manure because of the warming weather. When the change in $CH_4$ concentration is analyzed, there was an increase from March to October, and decrease after October. Monthly averages of $CH_4$ concentrations varied between 1850 (May) and 1872 ppb (August-September).


**Figure 1.** The domain-wide monthly atmospheric $CH_4$ concentrations and months with emission activity (lower).

Monthly $CH_4$ concentration averages showed an increase from August to November especially in the Southeastern Anatolia (Figure 2). The clustering analysis with respect to months and provinces indicated four groups from high to low concentrations; August-October, November-January, June-July, February-May (Ceylan 2019). Generally, the highest concentrations are observed in the western (İzmir, Çanakkale, Edirne, Tekirdağ, Eskişehir) and southeastern parts (Adana, Hatay, Gaziantep, Şanlıurfa) of Turkey. The lowest concentrations are in the northeastern (Ardahan, Kars, Erzurum) and eastern parts (Ağrı, Van, Hakkari). The provinces of Gümüşhane, Bayburt, Artvin, Ağrı, Erzurum, Ardahan, Bitlis and Van have low atmospheric $CH_4$ concentrations throughout the year. The increase in atmospheric $CH_4$ concentration is striking in the summer and autumn seasons (Figure 2). The monthly temperature changes in Turkey showed increase about 2-3℃ on average in November of 2019 across all regions except northeastern parts (Kars, Iğdır ve Erzurum) experiencing a decrease (TSMS 2019). Hence, the $CH_4$ concentration was increased in the northeastern part.

The atmospheric $CH_4$ concentrations and agricultural $CH_4$ emissions were both observed similarly low for some provinces like Artvin, Giresun, Bitlis at the northeastern part. (Figure 3). $CH_4$ concentrations were lower than expected in Konya and Erzurum although $CH_4$ emissions from enteric fermentation and manure were high due to intense cattle breeding (Figure 3). Lower $CH_4$ concentrations can be related to temperature, ozone, hydroxyl radical levels, land use changes in the region (Thompson, et al. 1992).

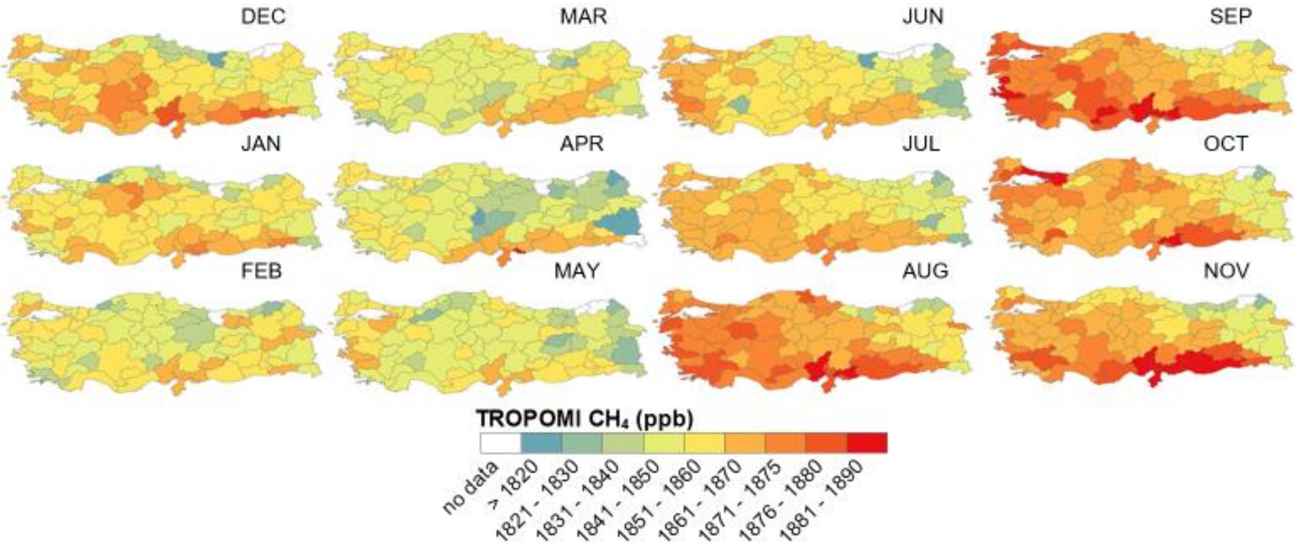


**Figure 2.** Average monthly atmospheric $CH_4$ concentrations on provincial basis.

County-level annual $CH_4$ concentrations and agriculture-related emissions showed similar spatial distribution for west and southeastern parts (Figure 4) similar to province-level results. The agriculture-intense regions were better identified with counties and higher $CH_4$ concentration regions were observed in Hatay, Mersin, Adana, Konya, Eskişehir, Ankara, İzmir, Aydın and Çanakkale (Figure 4). However, the counties with high agricultural activity in north and northeastern parts did not showed high atmospheric $CH_4$ concentrations. This result can be attributed to colder temperatures in those regions. The counties with maximum $CH_4$ concentrations were better identified with monthly averages (Ceylan 2019).

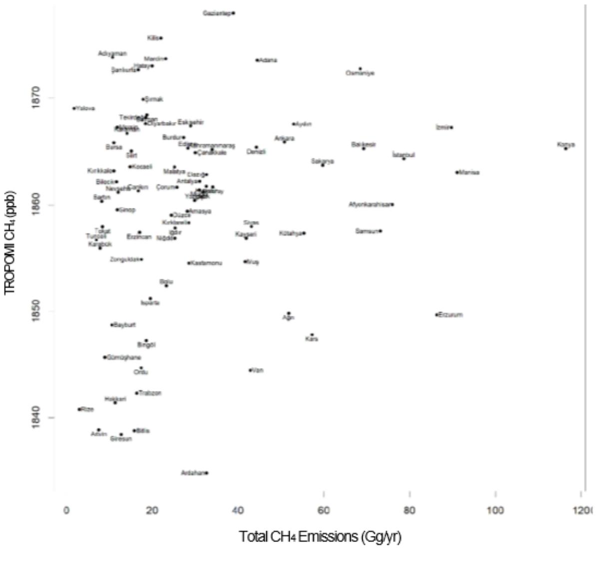


**Figure 3.** Annual agriculture-related $CH_4$ emissions versus $CH_4$ concentrations for 81 provinces of Turkey

## 4. Conclusion

The aim of this study is to show the change of $CH_4$ concentrations and the effect of selected agriculture emission sources on this change. The agricultural $CH_4$ sources across Turkey and its spatial distribution using satellite $CH_4$ concentrations were investigated. The $CH_4$ emissions from agricultural and livestock were calculated using TUIK agriculture statistics (TUIK 2018) and IPCC Tier 1 methodology for all counties in Turkey. TROPOMI $CH_4$ retrievals were processed and monthly and annual average $CH_4$ concentrations were calculated on county and province levels. $CH_4$ concentrations were very low in winter months (December, January and February) Subsequently, the compatibility of spatial distribution of retrievals with emission estimations was examined. When our emission estimations and TROPOMI $CH_4$ concentration were examined, the contribution of $CH_4$ emissions from agriculture to $CH_4$ concentration can be seen for most provinces.

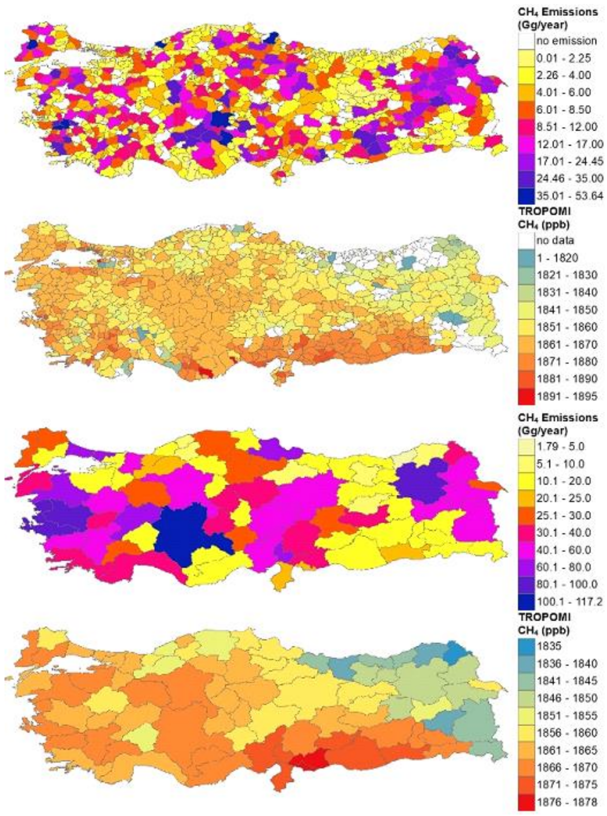


**Figure 4.** Annual atmospheric $CH_4$ concentrations and agriculture-related $CH_4$ emissions for counties (upper) and provinces (lower)

The annual average $CH_4$ concentrations showed the highest concentrations in dominantly over north eastern part of Turkey. Therefore, it was concluded that $CH_4$ sources have a high effect on $CH_4$ concentrations for that region.

In this study, TROPOMI $CH_4$ concentrations were investigated on county and province levels for the first time for Turkey. This gives a chance to follow-up emissions of $CH_4$, an important greenhouse gas without routine measurements, and spatio-temporal change of $CH_4$ concentrations. To improve our understanding, a longer study interval and a fine-gridded study area combined with high-resolution land use information will give better resolution indicating agricultural areas within the counties.

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