Spatial Estimation for Gas Flaring and Natural Gas Waste from Oil Production using Remote Sensing and GIS Techniques / Original Article

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التقدير المكاني لحرق الغاز ونفايات الغاز الطبيعي الناتجة عن إنتاج النفط باستخدام تقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية

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الجامعة التكنولوجية، كلية الهندسة المدنية، قسم هندسة الجيوماتيك، بغداد|العراق.

Abstract

This study aims to provide a comprehensive geospatial gas flaring intensity and emission doses analysis throughout oil production areas in Iraq based on remote sensing and GIS-based interpolation methods. Satellite image and spatial data were combined to create a map of flaring locations, refinery locations, and associated CO_2-equivalent emissions. The results show that there is a clear spatial variation in the intensity of the emissions ranging from northern regions towards the oil fields in the south near Basra, Rumaila and West Qurna, where refinery density and high flaring activities are observed. Interpolation modelling suggests that the majority of Iraq's GHG emissions are concentrated in these areas, and in some localised areas, emissions are significantly higher than very high limits. The study shows the potential of reducing emissions by flaring reduction and gas recovery projects and how GIS can be used to quantify environmental impacts resulting from hydrocarbon operations. The results offer scientific evidence for making energy policy and utilizing energy resources sustainably, which will help Iraq reduce routine gas flaring to zero by 2030.

Keywords Natural Gas, Oil Production, Remote Sensing, GIS Techniques Geomatics, gas flaring.

المستخلص

تهدف هذه الدراسة إلى تقديم تحليل شامل لكثافة حرق الغاز وجرعات الانبعاثات في جميع مناطق إنتاج النفط في العراق، وذلك بالاعتماد على تقنيات الاستشعار عن بُعد وأساليب الاستيفاء القائمة على نظم المعلومات الجغرافية. وقد جُمعت صور الأقمار الصناعية والبيانات المكانية لإنشاء خريطة لمواقع حرق الغاز، ومواقع المصافي، وانبعاثات ثاني أكسيد الكربون المكافئة المرتبطة بها. حيث تُظهر النتائج وجود تباين مكاني واضح في كثافة الانبعاثات، يمتد من المناطق الشمالية باتجاه حقول النفط في الجنوب قرب البصرة وخاصة حقل الرميلة وغرب القرنة، حيث تُلاحظ كثافة عالية للمصافي وأنشطة حرق الغاز المكثفة. وتشير نماذج الاستيفاء إلى أن غالبية انبعاثات الغازات الدفيئة في العراق تتركز في هذه المناطق والتي تتجاوز فيها الانبعاثات الحدود القصوى المسموح بها بشكل ملحوظ. تُبين الدراسة إمكانية خفض الانبعاثات من خلال مشاريع الحد من حرق الغاز واستخلاصه، وكيف يُمكن استخدام نظم المعلومات الجغرافية لتقييم الآثار البيئية الناتجة عن عمليات استخراج الهيدروكربونات. تُقدم النتائج أدلة علمية لوضع سياسات الطاقة واستخدام مواردها بشكل مستدام، مما سيساعد العراق على خفض حرق الغاز الروتيني إلى الصفر بحلول عام 2030.

الكلمات المفتاحية: الغاز الطبيعي، إنتاج النفط، الاستشعار عن بعد، تقنيات نظم المعلومات الجغرافية، الجيوماتيك، حرق الغاز.

1. Introduction

Enterprises in the south region work mainly with oil, while in the north region, gas is developed along with oil Figure (1). The main products of the gas production industry are natural gas (combustible natural gas (natural), gas condensate, liquefied natural gas (combustible natural liquefied gas) and regasified liquefied natural gas (combustible natural regasified gas).[1]

Natural gas is a gaseous mixture consisting of methane and heavier hydrocarbons, nitrogen, carbon dioxide, water vapor, sulfur-containing compounds, inert gases. Methane is the main component of natural gas, other components are found in trace amounts.[2,3]

Gas condensate is a liquid mixture consisting of paraffinic, naphthenic and aromatic hydrocarbons of a wide fractional composition, containing impurities of non-hydrocarbon components, obtained as a result of separation of a gas condensate mixture.[4,5]

Distinguish between unstable and stable gas condensate. Unstable gas condensate - gas condensate containing dissolved gaseous hydrocarbons, sent for processing in order to remove impurities and release hydrocarbons. Natural gas production that meets the requirements. Impurities include water (aqueous solutions of corrosion and / or hydrate inhibitors), chloride salts, sulfur compounds and mechanical impurities.[6]

Stable gas condensate - gas condensate obtained by cleaning unstable gas condensate from impurities and separating hydrocarbons from it ITS 29-2017 Natural gas production- ITS 29-2017 Natural gas production that meets the requirements of GOST R 54389-2011 (clause 9 of GOST R 53521).

Liquefied natural gas (LNG) - natural gas liquefied for storage or transportation.

The process of converting LNG from a liquid to a gaseous state is called regasification, which results in regasified LNG (combustible natural regasified gas).

According to preliminary data from the Ministry of Oil (Iraq), gas consumption in the domestic market in 2015 decreased compared to 2014 by 4.0% and amounted to 441.1 billion m3 Natural gas production, which is mainly due to a decrease in gas supplies to power plants Iraq.

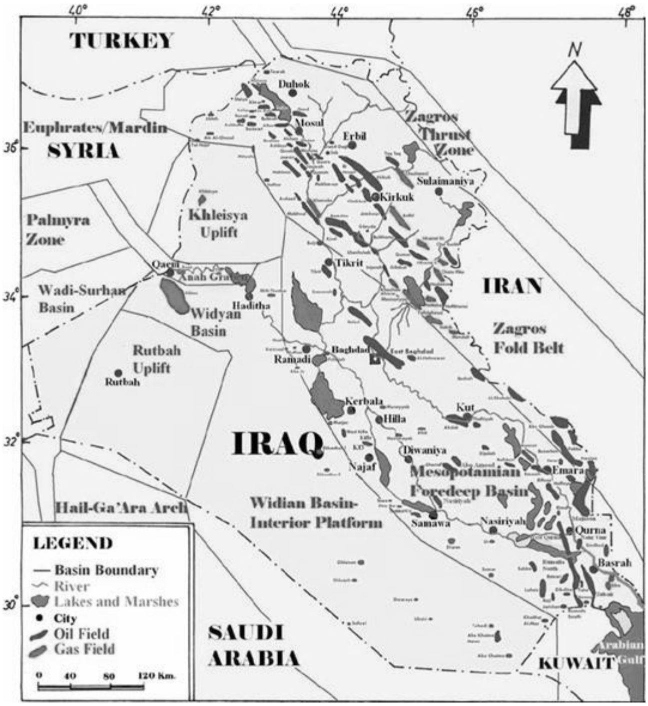


Figure 1: Location map of Iraqi wells, and oil fields.[7]

2. Volumes of Gas Flaring

Iraq is developing its facilities for gas collection and distribution, as Iraq concentrates on rising gas production by cutting flaring volumes. Iraq fosters collaborations with IOCs to meet its targets for gas output and reverse the current trends in the process, as sanctions, regional tensions and the lack of incentives for foreign operators have been derailed.

From early 2018 to late 2022, the additional output is expected to be mainly used for domestic fuel and power consumption in Iraq, raising its gas production of 23 mcm (812 mcf) per day. The production is expected to increase further by 2022 with the rise of the giant Miran-Bina Bawi project Figure (2).

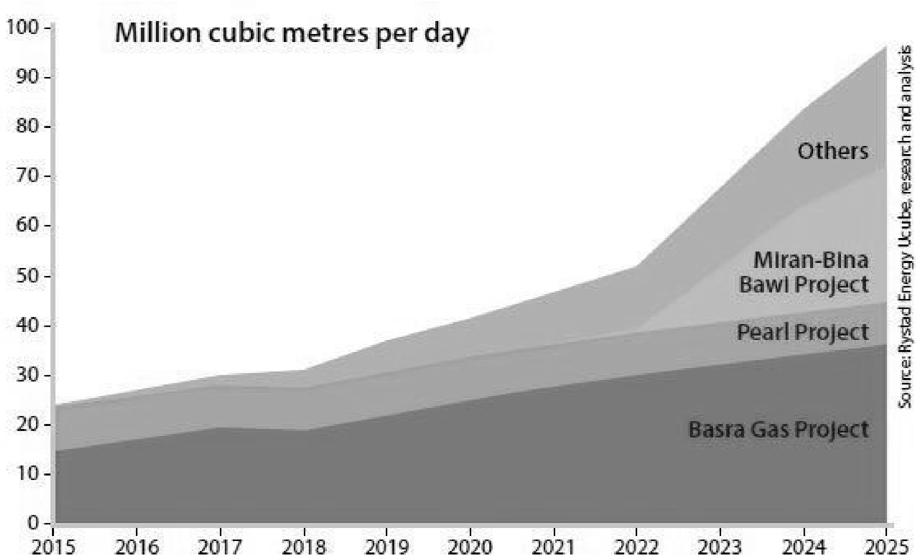


Figure 2: Iraq gas output, split between major projects; Basra Gas Project, Pearl and the Miran-Bina Bawl Project. Iraq gas production.

3. Calculations of volumes

Preliminary statistics indicate that by December 2018 Iraq's federal oil production amounted to 4.45 mbpd compared to approximately 4.2 mbpd in early January 2018. The KRI output increased by approximately 105 kbpd from 360 kbpd in January to 465 kbpd by December. Combined, Iraq has 4,915 mbpd operating capacity with 185 kbpd under-utilized. With respect to exports Figure (3), the SOMO has ended the year to hit a 3,726 mbpd level with a 3,63 mbpd sold by Ceyhan and Trucking17 through Basra's southern ports and by Turkey, throughout the rest.

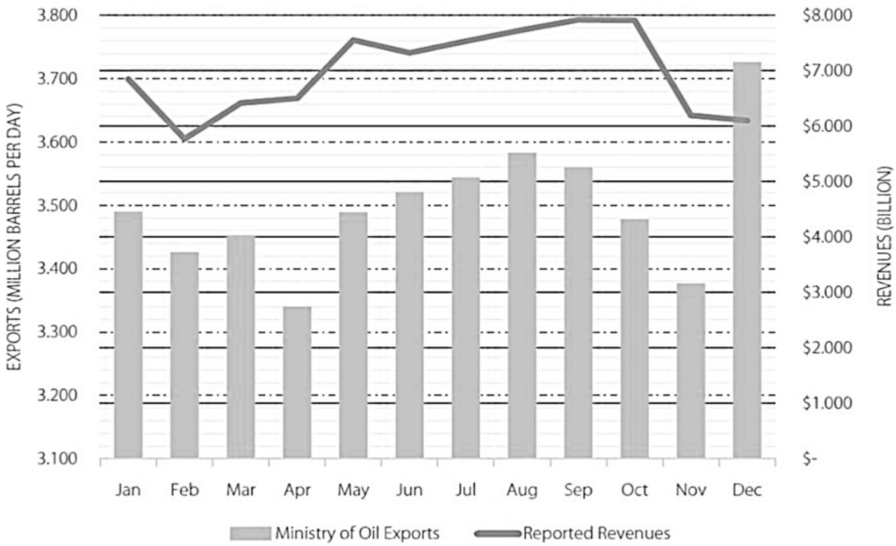


Figure 3: Iraq's 2018 Oil Exports & Revenues[8]

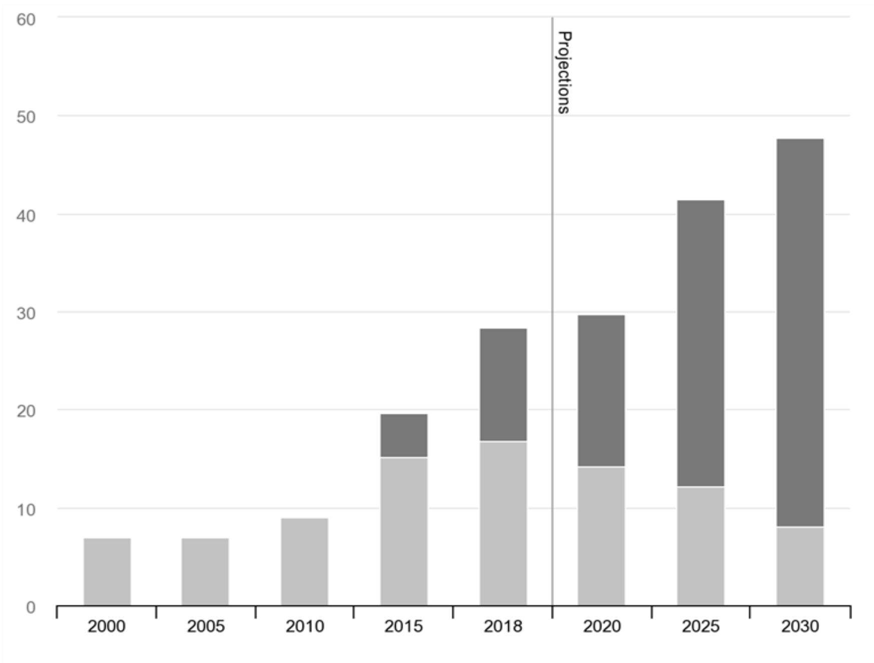


Figure 4: Iraq, 2000-2030 natural gas produce and flaring

The volume of associated gas generated alongside the rise in oil output has also increased as shown in Figure (4). However, this gas has not kept pace for capture and processing. The failure to use its gas resources means the country has increased the gas deficit and now Iraq relies on Iranian imports to meet rising demand, added a variety of vulnerabilities to the energy infrastructure in Iraq. Payment problems, for example, led Iran last summer to cut exporters and considerably worsen Iraq's electricity scarcity during peak seasonal demand.

4. Environmental Issues of the Industry

Technological processes of the main and auxiliary production of hydrocarbon raw materials have an impact on the natural environment: atmospheric air, water and land resources due to emissions and discharges of pollutants, the formation and treatment of production and consumption waste Figure (5). The main types of environmental impact include:

1. Emissions of pollutants into the atmosphere at gas fields and gas collection points;
2. Emissions of pollutants into the atmosphere during technological maintenance of gas control stations and gas pipelines;
3. Discharges of waste water into evaporation ponds and filtration fields;
4. Possible pollution of the environment with wastes of the main and auxiliary production.

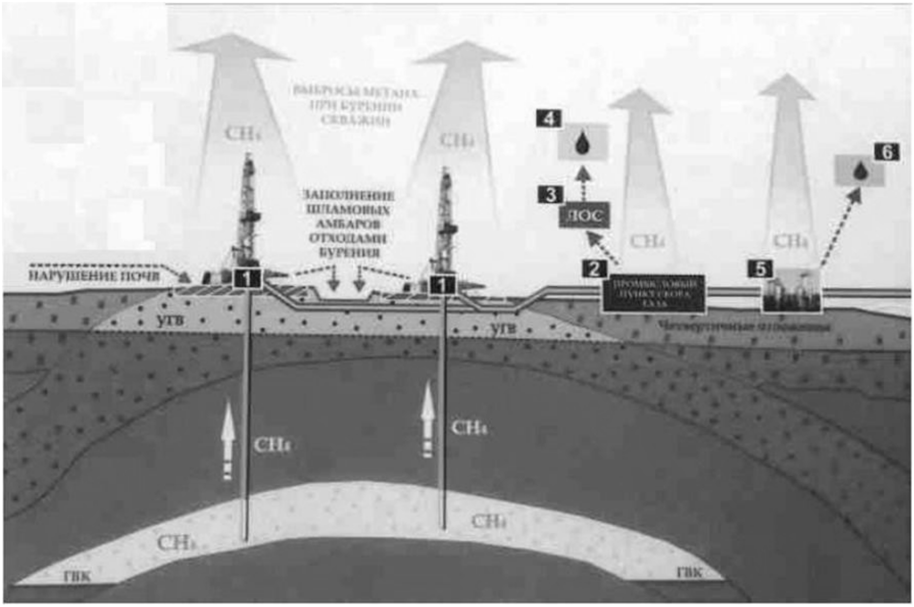


Figure 5: Environmental issues of the industry

5. Flare Installations

The flare unit is designed to burn off-grade gas and gas condensate mixtures formed during the operation of equipment or emergency discharges. At gas and condensate production facilities, horizontal and high-altitude flare units are used to burn hydrocarbon mixtures and waste gases after blowing (during commissioning, after workover) of wells in gas fields, gas pipelines after capital repairs, process equipment at gas fields and gas treatment plants, dust collectors at compressor stations.

Horizontal flare units are located in special earthen pits at a distance of about 100 m from the wellhead. The well spout is connected to the barn by a horizontal pipe, the end of which is brought out above the ground. Combustion occurs in an open torch from the ground surface, and pollutants are dispersed in the vertical part of the torch. The temperature of the combustion products is 900-2000 ° C, depending on the combustion mixture, the excess air ratio is 1- 1.5.

In high-altitude flare units (high and low pressure), the flare burners are located at the top of the flare stack. Only combustible components rise along the flare stack, and combustion occurs in the atmosphere above the flare stack head.

When operating hydrogen sulfide-containing deposits, it is preferable to use high-altitude flare units to increase the degree of dispersion of pollutants. The design of the flare units ensures soot-free combustion of gas mixtures under certain conditions for gas outflow. Since the mode of gas discharge into flare systems can vary in a wide range, the composition of emissions (soot / soot combustion) must be determined by calculation for each specific case (type of routine operation).

Efficient mixing of hydrocarbon mixtures with air is ensured by using a flare burner with the separation of the gas flow into separate streams using a large number of burners or with a large number of outlets.

There are also several types of flare systems:

a) A flare system for the removal of warm humid vapors - the gas is burnt through this flare constantly, periodically or in emergency situations in the following order:
   - Periodic use during maintenance or repair;
   - Use in emergency situations when pressure relief valves are activated or accidental emergency shutdown;

b) Low pressure flare - at an early stage in the operation of the fuel gas system, a separate, independent low pressure flare may be installed, which will be used in the period before the construction of the main flares. Gas discharge to the low pressure flare can be carried out either periodically or in case of emergency. Permanently operating flare units can operate from reservoirs of unstabilized condensate, from a methanol recovery unit, etc .;

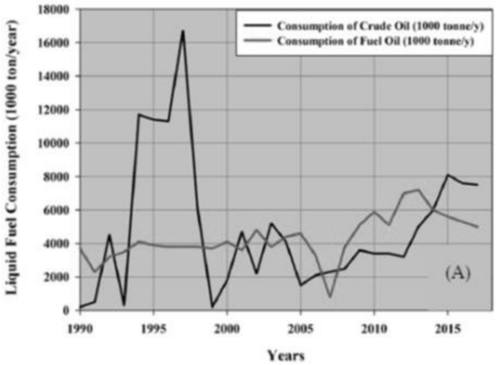
c) Cold / dry gas flare system - the system consists of flare and drainage headers together with associated drainage tanks and flares for burning gases and liquids. Dry gas flare headers collect cold liquids - drains that do not contain water or its vapors;

d) Boil-off flare system - a separate, independent low pressure flare is required for the LNG storage and offloading area due to the very low emission pressure from the system. The capacity of this system must be sufficient to cope with evaporation during operations in the LNG storage area. Vapors that can arise in the event of emergencies (failure of the control valve of the relief valve or overturning of the vessel) will be released to atmosphere through the safety valves of the LNG storage tank.

6. Levels of Environmental Impacts for the Gas Field as a Whole

6.1 Energy Consumption

The volume of energy resources (gas, heat and electricity, water) consumed by a gas producing company for gas production and preparation for transportation largely depends on the reservoir pressure level of the field being developed and the method of gas compression in the declining production mode as shown in Figure (6) a and (6)b. The enterprise strives to extract the maximum possible volume of hydrocarbon raw materials from the fields being developed and to the maximum possible efficiency in the use of energy resources.[9,10]



(a)

(b)

Figure 6: (a) Crude oil and fuel oil consumption for electricity production thousand tons/ year), (b) electricity generation natural gas consumption (TJ/year)

The most priority area of energy conservation in gas production is the development and implementation of technologies for field gas treatment, which reduces material costs and energy consumption while meeting regulatory requirements for the quality of commercial products

6.2 Emissions to Air

Operational losses of gas and condensate during production and treatment, leading to environmental pollution, are associated with a number of reasons:[11]

- Imperfect systems for collecting and transporting gas and condensate;
- A low degree of sealing of raw materials and commodity tanks;
- Imperfect separation equipment and separation process;
- Breakthroughs of gas pipelines and product pipelines due to accidents and violations of the rules of their technical operation;
- Burning part of the gas in flares, including at compressor stations due to their insufficient capacity.

The greatest damage to the environment is caused by the combustion of gases containing hydrogen sulfide. The main amount of emissions enters the atmosphere during the blowing of wells leaving drilling, after workover and various studies.

The main sources of emissions of pollutants into the air from gas production facilities are shown in Table (1) and Figure (7).

Table 1: Emissions of pollutants from hydrocarbon production facilities.[12]

Naime-Considerations	Units	Weight of pollutants in waste gases before cleaning per ton of manufactured products		Sources of emission mations	Purification method, re The use	Weight of pollutants in waste gases after cleaning per ton of	
					Manufactured products		
		Range	Average			Range	Average
Gas, gas condensate, oil and gas condensate fields							
Nitrogen oxides	kg / t. AD products (year)	0.69-0.71	0.7	Chimneys, torch	-	0.69-0.71	0.7
Carbon monoxide	kg / t. AD products (year)	1.99-2.01	2	Chimneys, torch	-	1.99-2.01	2
Methane	kg / t. AD products (year)	1.40-1.60	1.5	Torch, candle	-	1.40-1.60	1.5
Gas, gas condensate, oil and gas condensate fields containing hydrogen sulfide							
Nitrogen oxides	kg / t. AD products (year)	0.40-0.60	0.5	Chimneys, torch	-	0.40-0.60	0.5
Carbon monoxide	kg / t. AD products (year)	2.40-2.60	2.5	Chimneys, torch	-	2.40-2.60	2.5
Methane	kg / t. AD products (year)	0.40-0.60	0.5	Chimneys	-	0.40-0.60	0.5
sulphur dioxide	kg / t. AD products (year)	25.9-26.1	26	torch	-	25.9-26.1	26

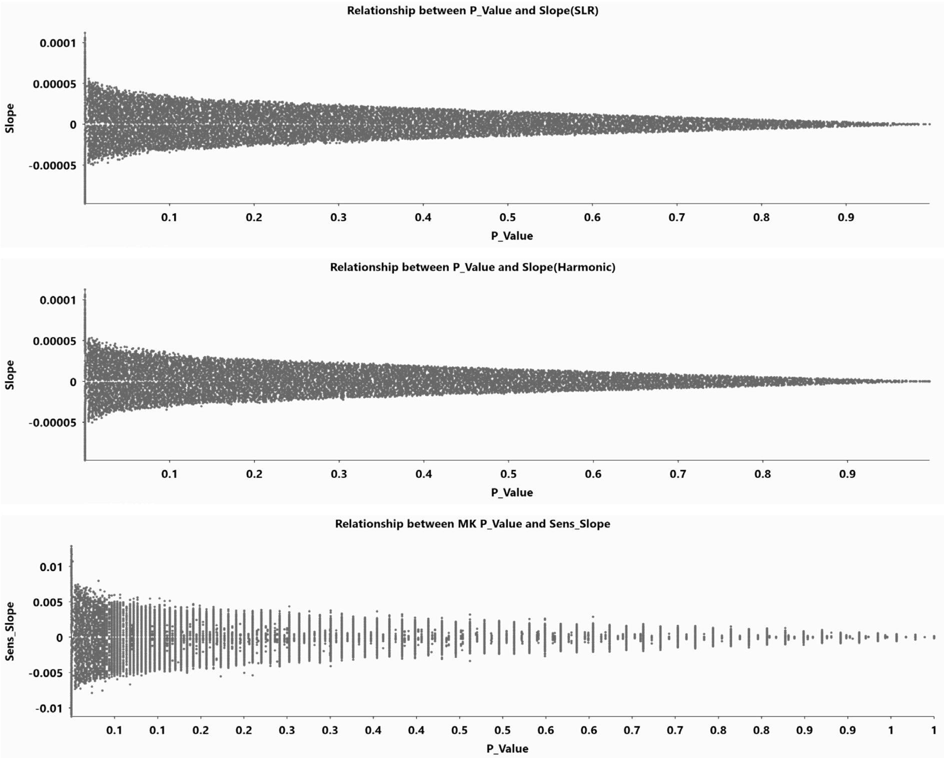


Figure 7: Relationship between P value and Emissions

7. Remote sensing

For the production of crude oil and gas, it is important to introduce the gas flaring activity (GF) at the oil processing plant, which is a regular procedure used either as a disposal or as a protection measure in order to alleviate pressure through the combustion of the gas generated during various industrial activities. [13, 14]. Since the 1990's the regulations on calculating flare gas for the measurement of carbon dioxide (CO2) tax on oil activities in Norway have been enforced, the environmental, social, and economic implications associated with GF are evident[15, 16]. GF is an industry activity which spans almost 300 million tons of CO2 equivalent emissions annually and makes a significant contribution towards climate change and constitutes significant waste from a valuable non-renouvelable energy resource. Nevertheless, a number of technological, regulatory and/or economical constraints and in some geographic areas are still in place today [17,18].

8. Satellite imagery for identification of fires

The capabilities of sensors to detect fire signals from the earth orbit is focused on fire detection. Both primary signal types are direct (heat and flames) and indirect for this function (burned and smoke surfaces). Direct signals are most often used in the identification of fire while indirect signals are used for post-fire evaluation and management. Most satellite fire detection research studies on forest/biomass fires, because their effects attract significant attention from the research community and the availability of validated fire- hotspot algorithms helps research. The research community

9. Satellite Imager Identification of Gas Flares

Due to its relatively high spatial resolution Landsat data have been chosen for the present study as a suitable sensor. Current fire detection strategies are developed for larger, ephemeral fires that are typically based on near-real time fire monitoring. developed in order to show how the distribution of CO_2 Emission Doses and Refinery Locations are distributed in the Iraq as shown in Figure (8). For detection of gas flares, Landsat data can outline its possible benefits as:

(i) Landsat has a good spatial resolution that is tailored to the accurate detection of high temperature yet low spatial flares;

(ii) the location and almost continuous existence of the flares means the unlikely detriment of the detection process is the relatively low temporal resolution of Landsat images;

(iii) the long Landsat database and the time span of the newly deployed Landsat 8 helps this device to detect shifts of spatiotemporal flaring on a long- term basis.

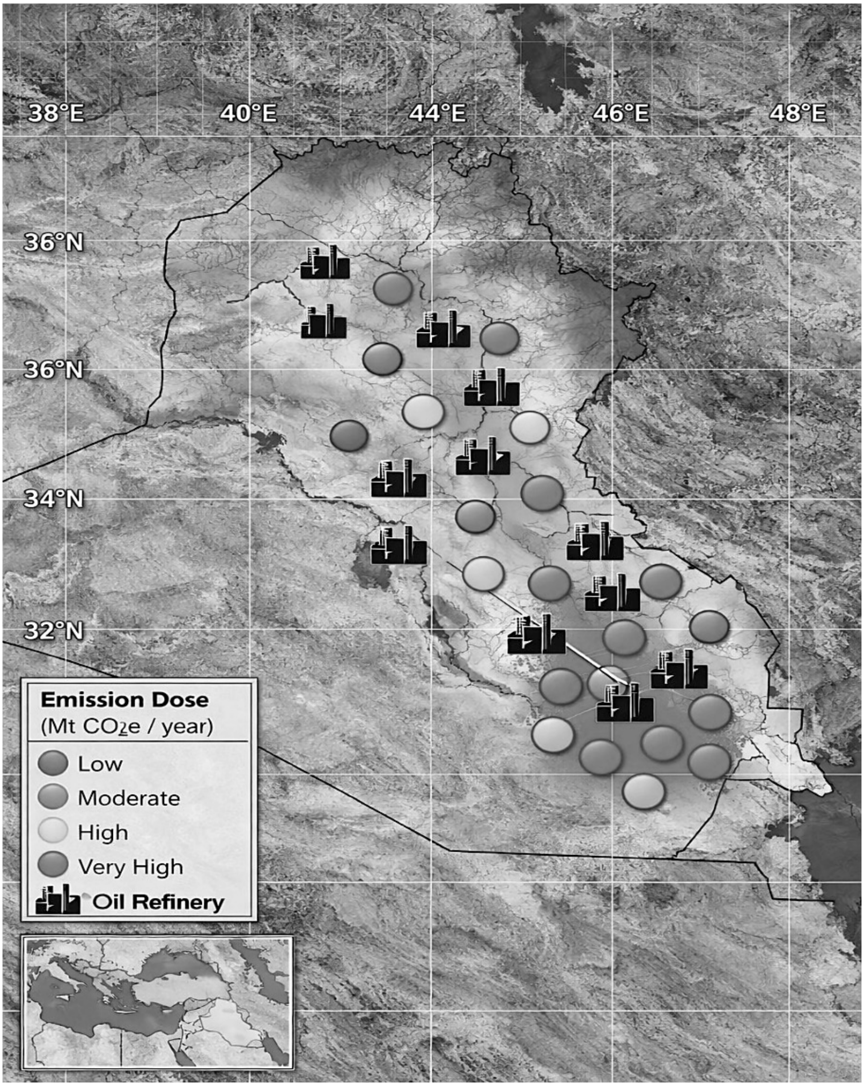


Figure 8: A spatial distribution of CO_2 Emission Doses and Refinery Locations

10. Conclusion

Iraq's natural gas reserves were the twelfth highest in the world at the end of 2017, according to OGJ, at almost 135 billion cubic feet (Tcf). Some three-quarters of Iraq's natural gas reserves are related to oil, the bulk of which are situated in the South's supergiant fields.

Iraq has produced 357 billion cubic feet of dry natural gas (BCF), while a further 18 Bcf have been re-injected in the course of the year.

In 2017, Iraq was ranked as the world's second largest source of flared gas behind the Russian government by 629 Bcf of natural gas. Inadequate pipelines and other midstream facilities have made natural gas flared. In 2017, Iraq consumed dry gas 422 Bcf, some used in the electricity industry.

In June 2017, Rq commenced importing gas from Iran into the power stations near Baghdad, including the stations of Al–Besmaya, Al–Quds, Al– Mansuriyah, and Al–Sadr. Annual imports of natural gas averaged 132 million cubic feet per day in 2017, although this amount may increase as new generation capacity for natural gas is online in Iraq. In 2017, these volumes were increased. Iraq imported an average of 265 MMcf/d between January and May 2018, this doses increase to hort-term (2026–2027): Imports likely to hover around 6–7 billion m³ per year until new gas-processing plants reach full capacity. Medium-term (2028–2030): Expected decline to < 4 billion m³ as domestic capture projects expand in Rumaila, West Qurna, and Majnoon. Long-term goal: Transition from net importer to balanced producer, leveraging GIS-based monitoring of flaring reduction and pipeline optimization. The integration of remote sensing and GIS techniques has provided a comprehensive spatial understanding of Iraq's gas flaring patterns and their environmental implications. The satellite-based analysis revealed that flaring intensity and emission doses are highly concentrated in the southern oil fields, particularly near Basra, Rumaila, and West Qurna, where refinery density and pipeline networks are most extensive. The interpolation of emission doses indicates a clear correlation between refinery proximity and elevated CO_2-equivalent emissions, emphasizing the need for improved gas capture and utilization infrastructure.

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