Detection of Illegal Kiln Activity During SMOG Period

Usman Nazir[1,2], Muhammad Awais Ather[1] and Murtaza Taj[1]
[1] Department of Computer Science, Syed Babar Ali School of Science and Engineering
Lahore University of Management Sciences (LUMS), Lahore, Pakistan
{17030059, 18030044, murtaza.taj}@lums.edu.pk
[2] Planetary Health Informatics Lab, University of Oxford, UK
usman.nazir@ndorms.ox.ac.uk

***Abstract*—Brick Kilns are known to be a leading cause of air pollution. The toxins and gaseous emissions from brick kilns leads to SMOG. It is a mixture of invisible toxic gases such as carbon monoxide (CO), ozone (O_3), sulphur dioxide (SO_2) and particulate matter like soot and carcinogens. We propose how low spatial resolution remote sensing data can be used to identify illegal industrial activity i.e. kiln operation particularly during winter SMOG period through heat signature values and the concentration of gases like CO, NO_2, SO_2 and O_3 in the atmosphere.**

***Index Terms*—Google Earth Engine, Spectral properties, Brick Kiln, Sustainable Development Goals**

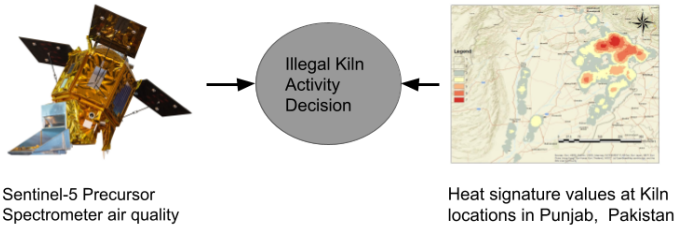


Fig. 1: Proposed architecture to identify illegal kiln operation using gaseous emissions data from Sentinel-5P satellite and heat signature values.

I. Introduction

Brick Kilns are the primary cause of ambient air pollution in underdeveloped countries [1], [2]. Most of the brick kilns in Asia burn coal as a fuel source, resulting in SMOG and poor air quality [3]. Coal combustion, industrial and vehicular emissions, fires and reactions of these photochemical emissions are the cause of man-made SMOG [4]. It is mainly present in lower part of atmosphere. SMOG is a mixture of invisible toxic gases such as carbon monoxide (CO), ozone (O_3), sulphur dioxide (SO_2) and particulate matter like soot and carcinogens [5].

The emission from brick kilns mainly consists of dust particles, fine particles of coal, organic matters and low amount of gases such as SO_2, NO_2, H_2S and CO [6]. The emission factors per 1,000 bricks were averaged up to 6.35–12.3 kg of CO, 0.52–5.9 kg of SO_2 and 0.64–1.4 kg of particulate matter (PM) [7]. Few of these gases are emitted directly and some are formed from the emission of air pollutants like O_3 from NO_2. That is why reduction in SMOG often involves mitigation of NO_2 emissions [8]. Nonetheless, because of human activity such as burning of fossil fuels; greenhouse gases are increasing at exponential rate in atmosphere which causes the average temperature to rise and eventually leading to disastrous effects on earth's climate [see Fig. 2]. Traditionally, production of bricks is a procedure in which hand-made bricks are baked in Bull's Trench Kilns which is about two centuries old procedure. Different other kinds of brick making plants are also introduced such as Hoffman kiln, tunnel kiln, modified FCBTK and the VSBKs. But in Pakistan, Mostly Bull's Trench Kilns with fixed chimney (FCBTK) are used. International Centre for Integrated Mountain Development (ICIMOD) introduced a new technology while working in Nepal which is based on significant improvement on Bull's Trench Kilns by modifying the flow of hot air used to progressively bake brick. This technology is known as Induced Draught Zig Zag Brick Kiln. The environment protection department (EPD) of Punjab, Pakistan in collaboration with All Pakistan Brick Kiln Owners Association is introducing this Zig Zag technology which is environment friendly and cost effective for the production of bricks. Zig Zag Kilns are said to improve fuel efficiency by 40% and reduce 70% gaseous emissions as compared to the conventional Bull's Trench Kilns.

In this study, we identify illegal kiln activities in different tehsils of Pakistan using gaseous emissions data from Sentinel-5P satellite and heat signature values [see Fig. 1]. The effects of air contamination have become one of the most significant test for public specialists. The measurement of emissions and their spatial appropriation are fundamental for any air quality program. We performed regional examination by utilizing a Geographic Information System (GIS). This advanced step gives land use maps which can be inferred with a few characterization methods on satellite images or computerized aerial imagery. This combination of land use maps along with concentration maps of contaminants, permits acknowledgment of regions presented to high contamination levels and the relative subjection during time. The progressive step of this regional analysis permits recognizable proof of

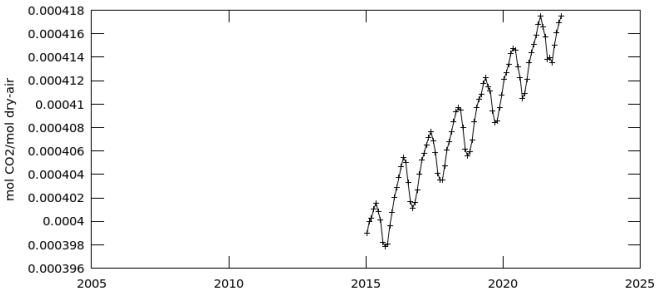


Fig. 2: Greenhouse gas CO_2 is increasing at an exponential rate in Pakistan [Image courtesy: GIOVANNI Application].

destinations ideal for the establishment of monitoring stations adhering to the standards given by the mandates in force. This methodology can further support planning of monitoring network systems concentrated on air quality.

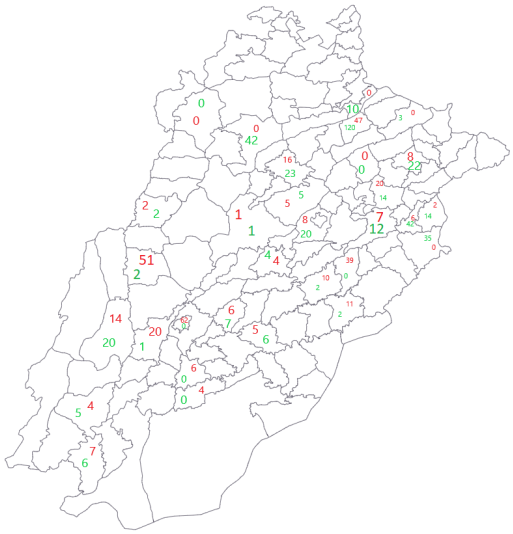


Fig. 3: Ground Truth: illegal kiln activity cases by Environmental Protection Authority (EPA) in different tehsils of Punjab, Pakistan (Red number shows the No. of FIR lodged against brick kilns and green number shows the number of brick kilns sealed by EPA).

II. Related Work

Satellite information have been utilized for the tracing of chemical plumes, assist air quality projections, give indication during extraordinary air contamination occasions, gauge model executions, evaluate toxin emissions and study long haul air contamination patterns [9]–[12]. However significant difficulties have been faced in order to overcome this problem. In [13], it was exhibited how Malaysian administrations has already proposed the establishment of a network called Malaysian Remote Sensing Agency (MRSA) for this purpose which is a huge step taken. However, the study area of this research was taken in Penang Island which is the second small-scaled state of Malaysia. Explaining the causes and effects of Aerosol

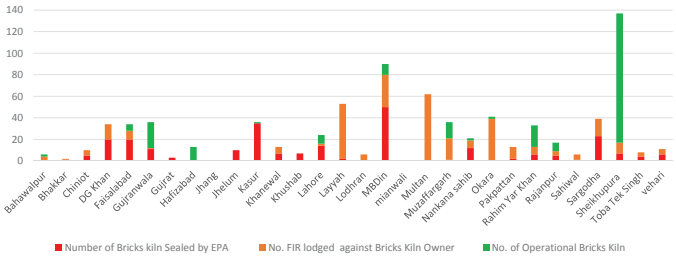
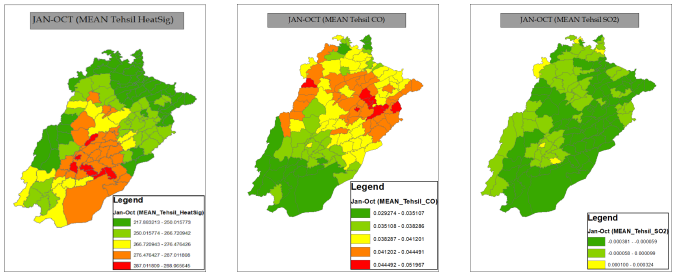


Fig. 4: Mean Heat Signature value is directly proportional to no. of illegal kilns operating in SMOG period.



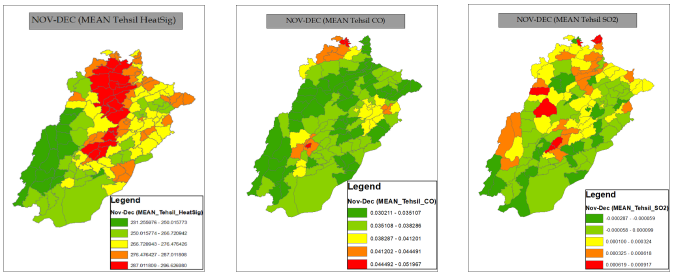
(a) Heat signature (b) CO (c) SO_2

Fig. 5: In January-October mean values of Heat Signature, CO and SO_2 at Tehsils of Punjab, Pakistan.

which is a suspension of fine solid and liquid droplets in air which can be natural or anthropogenic. Moreover, the centre of this research was to examine the presentation of their advanced algorithm for delineate PM10 using Landsat 5 having a Thematic Mapper (TM) along with a Multispectral Scanner System (MSS) contrivance. The proposed algorithm models in this study area was demonstrated to be authentic and reliable for corresponding environmental study.

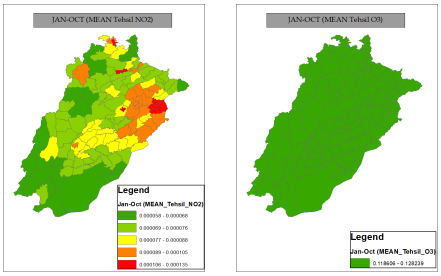
For acquiring preventative measures it is necessary to have information from time to time about the changes that take place in air pollution degrees. Reflecting this view, there has been an attempt made in [14] for developing a model that will be helpful in analyzing the quality of air using a remotely sensed data which will be easy and quick in process. This study includes vegetation indices, pixel values as well as some urbanization indexes which were used with the help of Landsat ETM+ for evolving regression dependent models with API (Air Pollution Index), this information was further calculated with in-situ air pollutants. This model of multi-variate regression amid Landsat along with the most corresponded variables that gave precise and accurate air pollution image. Almost 90.5% of exactness was acquired through the comparison that was made between Air Pollution Index Interpolated Images and API modelled.

Brick Kilns have been identified as a major source of pollution, mainly because of poor technology and extremely poor quality of fuel that is used. After China, India is reported to be the second largest producer of bricks. [15] shows how over 24 million tons of coal is used in the process per year. In 2017, India's CPC board ordered all brick kilns to switch to a



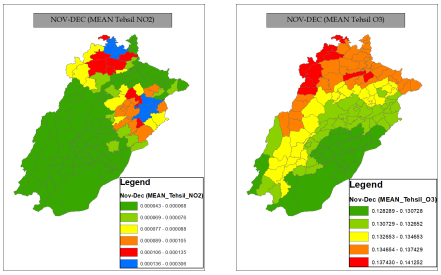
(a) Heat signature (b) CO (c) SO_2

Fig. 6: In November-December mean values of Heat Signature, CO and SO_2 at Tehsils of Punjab, Pakistan.



(a) NO_2 (b) O_3

Fig. 7: In January-October mean values of NO_2 and O_3 at Tehsils of Punjab, Pakistan.



(a) NO_2 (b) O_3

Fig. 8: In November-December mean values of NO_2 and O_3 at Tehsils of Punjab, Pakistan.

new method for the production of bricks which is a Zig-Zag kiln. It is shown in [16], how Zig-Zag kiln used less coal and its structure helps in reducing the fine particulate matter emissions by 51%. Thus, [16] also outlays how the tunnel kiln strings better in connection with environmental aspects and quality of brick manufactured. However the drawback is the low investment in this manufacture method and because the process has a requirement of electricity for operating it is a downside as in many parts of India consistent electricity supply is not available.

While the rapid increase in urbanization and development, the demand of brick production is also rising. There have been clear and unfavorable wellbeing results in population living in the prompt region of brick kilns. With regards to [7], which is introducing checking results of every day block furnace stack discharges and inferred variables of it. The study area of this study is the province of Vietnam. Air pollution checking were made on an hourly premise which demonstrated surrounding centralization of CO, SO_2, $PM2.5$ and $PM10$. Whereas SO_2 was observed and resulted of having a high frequency level in comparison with others.

Air contamination keeps on pulling in increasingly more open consideration. Space-based infrared sensors give a measure to screen air quality in enormous regions. In [17], a band choice technique of space based infrared sensors is suggested for urban air contamination discovery, in which perception geometry, ground and climate radiant qualities, and sensor system framework commotions are coordinated. This proposed system is executed to investigate an ideal band for identifying four unique sorts of vaporous poisons and segregating aerosol particle contamination to demonstrate its value. This material science based investigation strategy can be utilized in space-based infrared sensor structure, particularly for obtaining accessible information in districts with generally low pollutant fixations. This methodology can likewise be utilized to recover pollutant concentrations.

III. Proposed Method

To detect the environmental impact caused by operation of brick kilns during SMOG period is a challenging problem for which theoretical background of remote sensing data such as, heat signature and gaseous emissions for the detection of heat emission and air pollution. RGB bands does not give us the information about heat signature and gaseous emissions. RGB bands only tells us about the kilns locations, we can see whether the kiln is present on the specified image or not. What we need is the heat signature and data on gaseous emissions to know if the kiln is working or not which can be calculated using Landsat-8 satellite's Thermal Infrared 1 Band (band 10) and Sentinel-5 satellite's TROPOMI (TROPOspheric Monitoring Instrument).

The image resolution for which we are getting data from Landsat-8 satellite's Thermal Infrared 1 Band (band 10) is accurate for heat signature values i.e. 30 meters. The data we are getting from Sentinel-5 satellite for gaseos emissions: CO, NO_2, SO_2 and O_3 uses the patch of 7×7 km^2 which is not much accurate for kilns because a brick kiln is usually 30 meters wide. So we are fusing two different types of data to get close to our result which is detecting illegal operation of kilns [see Fig. 1]. Current data and state of the art techniques cannot accurately find the kiln heat signature and concentration of gases emitted by kilns. This is why we are looking at tehsils level to measure these parameters before and during SMOG period, so the Environment Protection Department (EPD) can be notified that these tehsils are violating the protocols set by government.

The heat signature and gaseos emissions dataset, we generated in this paper, provides the basis for the detection of illegal operation of kilns during SMOG period (see Fig. 4). The proposed architecture we aim to implement is shown in

Fig. 1.

A. Dataset

The main source of data set is Punjab Brick Kiln Census[1] and Kiln-Net paper [18]. The data was retrieved for 9348 brick kiln locations. The location coordinates were separated from the data. We used those coordinates to generate the data of heat signature, CO, NO_2, SO_2 and O_3 using Google Earth Engine (GEE) which is a remote sensing tool. We calculated mean, median and max of all these parameters along two time periods. The time periods are: January- October, 2019 and November- December, 2019. The reason for selection of these time period is the ground truth data: No. of FIR lodged against brick kilns and the number of brick kilns sealed in SMOG period in year 2019 (see Fig. 3).

As the area of interest is Punjab, Pakistan. We extracted shape files of tehsils of Punjab using ArcGIS Online to gather the data on tehsil level using GEE.

B. Heat signature and gaseous emissions

Landsat-8 satellite images have additional bands with different wavelengths. These bands represent different type of information which cannot be perceived by human eye. The satellite senses energy (light from the sun) reflecting from the earth's surface back to the sensor at different wavelengths depending on the composition of the object the light struck. For example, if we take bands 5, 6, 7 and stack those in the RGB color space so that our screens can display infrared and near-infrared light. Similarly, Thermal Infrared 1 Band (band 10) is used in proposed methodology to determine temperature or heat signature values of earth's surface. We can use different combination of these bands to find different properties of earth such as vegetation index, moisture index, built-up index etc. The data we get from these bands uses image resolution of 15-30 meters per pixel.

Satellite imagery also provide information about the gaseous emission in the atmosphere. We used Sentinel-5 satellite to get information about concentration of different gases such as CO, NO_2, SO_2, O_3, $HCHO$, CH_4 and aerosol optical depth. The spectrometer covers the spectral range from the ultraviolet to the shortwave infrared (270-2385 nm) with a spatial resolution of 7 x 7 km^2.

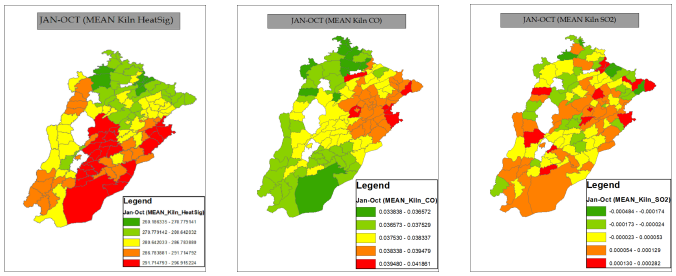
IV. Experimental Results

In this section we discussed the comparison of different illustrations on data set and the results we obtained from our proposed method. Discussion on obtained results and its comparison is also mentioned in this section.

A. Tehsil Level Analysis

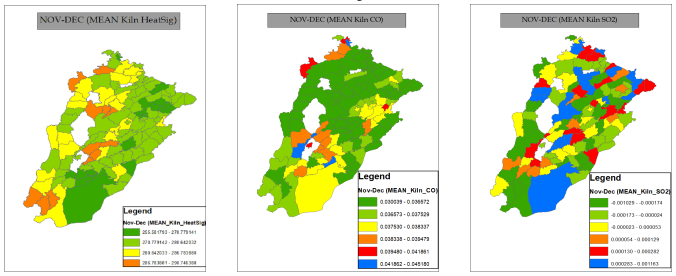
In this section we discuss the illustrations of tehsils, for which we get the results of mean values on heat signature, CO, SO_2, NO_2 and O_3 during January-October and November-December 2019.

[1]http://dashboards.urbanunit.gov.pk/brick_kiln_dashboard/



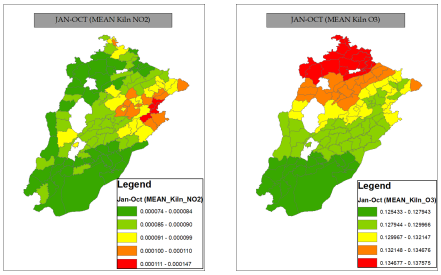
(a) Heat signature (b) CO (c) SO_2

Fig. 9: In January-October mean values of Heat Signature, CO and SO_2 at Kiln locations of Punjab, Pakistan.



(a) Heat signature (b) CO (c) SO_2

Fig. 10: In November-December mean values of Heat Signature, CO and SO_2 at Kiln locations of Punjab, Pakistan.

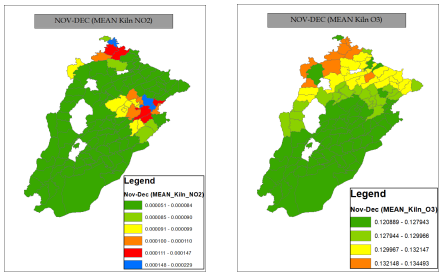


(a) NO_2 (b) O_3

Fig. 11: In January-October mean values of NO_2 and O_3 at Kiln locations of Punjab, Pakistan.

The heat signature for Jan-Oct period (Fig. 5a) in northern Punjab is comparatively lower than heat signature for Nov-Dec period (Fig. 6a). This does not necessarily mean that kilns activity has increased in later period. Similarly, heat signature for Jan-Oct period (Fig. 5a) in southern Punjab is comparatively higher than heat signature for Nov-Dec period (Fig. 6a). Heat Signature on tehsil level depends on other factors too e.g. industrial activities. So we cannot say anything for sure about kilns activity by looking only at heat signature on tehsil level.

The CO emission for Jan-Oct period (Fig. 5b) in northern Punjab is comparatively higher than CO emission for Nov-Dec period (Fig. 6b). This does not definitely mean if the kilns activity has decreased in later period. Similarly, CO emission for Jan-Oct period (Fig. 5b) in southern Punjab is almost same as CO emission for Nov-Dec period (Fig. 6b). CO emission



(a) NO_2 (b) O_3

Fig. 12: In November-December mean values of NO_2 and O_3 at Kiln locations of Punjab, Pakistan.

on tehsil level depends on other factors too e.g. burning of oils, gases, coal, wood and fires. We cannot say anything about kilns activity by looking only at CO emission on tehsil level.

The SO_2 emission for Jan-Oct period (Fig. 5c) in Punjab is comparatively lower than SO_2 emission for Nov-Dec period (Fig. 6c). This does not mean that kilns activity has increased in later period because these results show us the overall activity of that tehsil. Burning of fossils fuels such as coal, oil, diesel etc. are the main cause behind emission of SO_2. Kiln activity cannot be determined by looking at SO_2 emission on tehsil level.

The NO_2 emission for Jan-Oct period (Fig. 7a) in southern Punjab is comparatively higher than NO_2 emission for Nov-Dec period (Fig. 8a). This does not certainly mean that kilns activity has decreased in later period. Similarly, NO_2 emission for Nov-Dec period (Fig. 8a) in northern Punjab has somewhat increased as compared to Jan-Oct period (Fig. 7a). NO_2 emission on tehsil level depends on other factors such as burning of fuels from cars, trucks, buses, power plants, brick kilns etc.

The O_3 emission for Jan-Oct period (Fig. 7b) in all tehsils of Punjab is lower than O_3 emission for Nov-Dec period (Fig. 8b). This does not depicts that kilns activity has increased in later period. Some chemicals that react to form ozone O_3 are oil refining, aviation, petrochemicals, motor vehicle exhaust, bushfires and burning off. 70% of the nitrogen oxides and 50% of the organic chemicals that form ozone O_3 are produced by motor vehicle exhaust. Organic chemicals emission because of vegetation can also help form ozone O_3.

B. Kiln Level Analysis

In this section we discuss the illustrations of kilns, for which we get the results of mean values on heat signature, CO, SO_2, NO_2 and O_3 during Jan-Oct and Nov-Dec 2019.

The heat signature for Jan-Oct period (Fig. 9a) in Punjab is comparatively higher than heat signature for Nov-Dec period (Fig. 10a). This means that kilns activity has significantly decreased in later period. Out of 128 tehsils, we found that heat signature of 27 tehsils was higher in Nov-Dec period than Jan-Oct period. This means that the operation of kilns has increased in those tehsils during SMOG period.

The CO emission for Jan-Oct period (Fig. 9b) in Punjab is comparatively higher than CO emission for Nov-Dec period (Fig. 10b). This shows that kilns activity has notably decreased during the SMOG period due to which CO emissions are less because of the kilns activity. For the areas in which CO emission is higher during Nov-Dec can be because of illegal kiln activity.

The SO_2 emission for Jan-Oct period (Fig. 9c) in Punjab is comparatively lower than SO_2 emission for Nov-Dec period (Fig. 10c). This can be because of the kilns activity has increased in later period or it can be due to burning of fossils fuels such as coal, oil, diesel etc. are the main cause behind emission of SO_2.

The NO_2 emission for Jan-Oct period (Fig. 11a) in Punjab is higher than NO_2 emission for Nov-Dec period (Fig. 12a). The diagram show us that kilns activity has significantly decreased in Nov-Dec period. In some tehsils, we see the increase in NO_2 emission but that can be because of kiln activity or burning of fuels from cars, trucks, buses, power plants etc.

The O_3 emission for Jan-Oct period (Fig. 11b) in all tehsils of Punjab is higher than O_3 emission for Nov-Dec period (Fig. 12b). The data depicts in diagram that kilns activity has decreased during SMOG period which is Nov-Dec. We can see the red and orange spikes in Jan-Oct period (Fig. 11b) are turning to orange and yellow spikes showing us that emissions of O_3 are highly decreasing in Nov-Dec period.

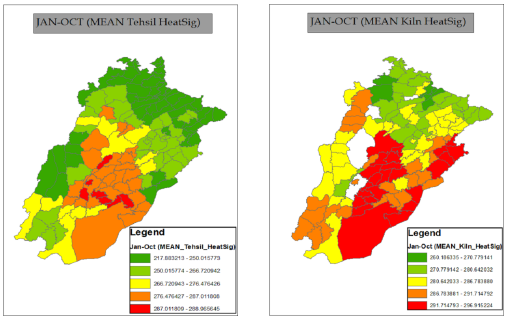
C. Qualitative Evaluation

All the factors discussed above in both sections are directly related to kiln activity and SMOG. What we need to understand is brick kiln activity has an immediate connection to SMOG. The smoke coming out of brick kilns produce several toxic gases such as CO, SO_2, NO_2 and O_3.

The diagrams of tehsils portray compelling results but those diagrams indicate the results of whole tehsil instead of just the brick kilns, due to which we do not have absolute results for brick kilns activity by examining results of only tehsils. Owing to this reason we decided to go deeper and calculated the data of heat signature, CO, SO_2, NO_2 and O_3 on kilns level.

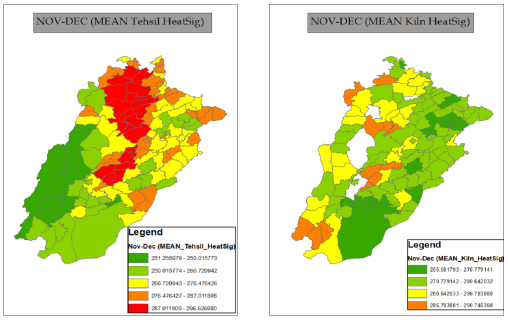
The new data represented more accurate results and we can illustrate from those new diagrams that brick kilns activity is tremendously decreasing during the SMOG period because of Punjab government's restriction but there are still some tehsils in which authorities are not monitoring the situation and not working properly. We can see from the heat signature, CO, NO_2 and O_3 emission of kilns that operations of kilns are decreased during Nov-Dec period. However, we get conflicting result from SO_2 diagrams which tells us that SO_2 emissions are increasing during SMOG period but that can be because of other factors such as burning of fossil fuels.

Looking at Fig. 13a and 13b, we can clearly see from the diagram, mean heat signature of kilns are higher as compared to tehsils because data of tehsils incorporate the mean data of the whole tehsils whereas kiln data is only specific to the kilns of those tehsils. Similarly, from Fig. 14a and 14b, we



(a) Teshils (b) Kilns

Fig. 13: In January-October mean values of heat signature at Tehsils and Kiln locations of Punjab, Pakistan.



(a) Teshils (b) Kilns

Fig. 14: In November-December mean values of heat signature at Tehsils and Kiln locations of Punjab, Pakistan.

see that mean heat signature of kilns are getting lower as compare to tehsils as kiln data is only focusing on kilns of tehsils as compared to whole activity of the tehsils. From Fig. 13b and 14b, we can extract that kiln activity is decreasing during winter SMOG period and there are some tehsils in which activity is increasing and are violating the government's restrictions.

V. Conclusion

For detection of illegal kiln activity, our proposed method found from the remote sensing data that around 27 tehsils (in Punjab, Pakistan) out of 128 were causing the increase in SMOG. Most of the brick kilns burn coal as a fuel source, resulting in SO2 and particulate matter (PM) emissions, causing poor air quality and associated health problems. For future work, we can calculate the concentration of greenhouse gases emitted or absorbed by trees to identify better results on tehsil level. To increase the impact of the overall work we can work together with International Labor Organization (ILO) and National Institute of Health (NIH) to come up with actionable items and policy briefs to improve the human rights condition of the labor workforce. We can also work with Environment Protection Department (EPD), Pakistan to enforce the preventive measures on tehsil level regarding illegal kiln operation.

VI. Acknowledgement

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