Environmental Impacts of Sandstone Quarrying and Its Waste: A Case Study of Jodhpur, India

Abhishek Singhal

Tampere University

Tampere, Finland 33720

abhisheksinghal.iitkgp@gmail.com

Sudha Goel

Indian Institute of Technology Kharagpur

Civil Engineering Department, IIT Kharagpur, West Bengal, India 721 302

sudhagoel@civil.iitkgp.ac.in

Abstract

Google Earth provides high resolution satellite images over a long period of time which can be used in various environmental and climate studies. In the present study, Google Earth was used to evaluate incremental trends in the quarrying area and associated environmental impacts. Keru region near Jodhpur city, India was selected as the study area for the present study. Time series analysis was done from 1990 to 2016 to evaluate increments in the quarrying area. After 2007, recently built stone cutting units and dumping locations were also observed. Land degradation around the quarrying zone was also quantified from 2007 to 2016 using Google Earth imagery. After time series analysis, extensive site survey was also done to check and verify different quarrying and dumping practices in the study area and their effect on the environment. The results of the time series analysis show 4.55 times increment in study area from 1990 to 2016, with a linear relationship between increment in study area along with emergence of new cutting units and waste dumping sites. Since 2007, about 71.4 hectare of agricultural land was destroyed due to quarrying activities out of which 24.3% of the land is now assimilated in sandstone quarries. Results of the site survey show that major reasons for onsite and nearby environmental degradation were use of improper machinery and vehicles; haphazard and unsystematic quarrying over a long period of time; and dumping of quarry waste.

Keywords: RS & GIS; Google Earth; Quarrying; Environment Impacts; Sandstone, Time-series-analysis.

1. Introduction

Throughout the world, quarrying and stone cutting industries are a very important part of the local economy. In this era of tremendous population growth, requirements of construction materials like stone, metals, and ceramics keep on proliferating with time. Consequently, quarrying sector has also seen a tremendous increment in terms of area coverage and intensity during past years. India has an abundance in terms of quantity and quality of minerals available throughout the country. India produces more than 27% of the total stone produced in the world, with a share of more than 11% in the world's total stone exports (CDoS). Jodhpur is one of the major sandstone quarrying and craftsmanship centres in India with the ability to extract a wide variety of sandstone in terms of its colour and texture. Due to a surge in exports during the last two decades, there has been an increase in the number of sandstone quarrying and processing units in Jodhpur and nearby areas. Currently, sandstone quarrying and processing is one of most important sectors of Jodhpur’s economy (Bhadra et al., 2007).

Although quarrying may fulfill the requirement of resources and contribute towards the local economy, the unsustainable quarrying practices are gravely affecting the nearby environment. Quarrying activities lead to an enormous change in the local environment by stripping topsoil, destroying vegetation, altering physio-chemical properties of soil and disturbing nearby ecosystems, which directly dilapidates the existing landscape and environment (Al-Joulani, 2008; Bhadra et al., 2007; Odell et al., 2017; Zia Khan et al., 2014). Waste stone dust is a major source of pollution from quarrying and transportation processes. This stone dust has a direct hazardous effect on the health of local quarrying workers by making them prone to life-threatening breathing problems like silicosis, tuberculosis, and chest pains (Ahmad, 2015; Chopra et al., 2012; Solanki et al., 2014; Yarahmadi et al., 2013). Deposition of stone dust on soil and crops due to wind and runoff leads to degradation of soil quality and crop production (Zia Khan et al., 2014; Prajapati, 2002). Another major problem associated with quarrying activities is the unsystematic management of the stone and slurry waste which is generated daily in enormous quantities (Forstner, 1999).

In order to provide possible solutions to the aforementioned problems, proper assessment of the environmental and health impacts of unsustainable quarrying practice is the first step. Remote sensing (RS) and Geographical Information Systems (GIS) are powerful tools for assessing the environmental impacts of various anthropogenic industrial activities. However, some preliminary knowledge is required to use RS and GIS tools. Learning about satellite imagery data and software like ArcGIS, Q-GIS, and ERDAS takes time, experience and effort to use them efficiently and precisely. Also, basic information technology (IT) tools are essential for applying RS and GIS and some of these tools are still out of reach for many researchers and operational users (Gorelick et al., 2017). Simple tools and software like Google Maps, Bing Maps, Google Earth, Google Earth Pro can be used effectively for environmental studies due the avalibility of high-resolution satellite images. Owing to its easy operations and online accessibility, Google Earth can be used in different areas like transportation, urban planning, time series analysis, real-time study analysis with Global Positioning System (GPS), environmental and climatical studies (Singhal and Goel, 2019a).

The aim of this study was to evaluate land-use land-cover (LU-LC) change due to sandstone quarrying activity using Google Earth. Historical images from Google Earth were used to study trends in the size of the quarrying area and to evaluate impacts of quarrying on nearby agricultural land. Sandstone quarries of Keru situated in the state of Rajasthan were considered for the study. Data collected from Google Earth and field surveys was used to identify and explain various trends in the emergence of new quarrying zones, stone cutting units and waste dumping sites. Furthermore, same data were also used to analyse the impact of increased quarrying on nearby ecosystems and agricultural lands.

1.1 Description of Study Area

Jodhpur is the second largest and second most populated city in the state of Rajasthan. It also happens to be the zonal headquarters of the mineral-related activities of Western Rajasthan. The main types of rocks that are found in the area are sandstone, granite, limestone, rhyolite, phyllite, and slate (Department of Geology, Government of Rajasthan). Jodhpur lies in the arid region of the Thar Desert where conditions can be ruthless due to extreme heat in summers (temperature varies from 28 °C to 48 °C) and cold in winters (temperature range of 8-25 °C). The wind direction is normally southwest during summers and monsoon at high speeds (20 to 30 km/h), and northeast during winters having quite low wind speeds (5 to 8 km/h).Wind speed may reach 50 to 80 km/h during severe dust storms. The southwest monsoon contributes more than 85% of the total annual rainfall, extending from July till September. Mean annual rainfall of Jodhpur city is 377.65 mm (1969 - 2014), whereas the Indian Metrological Department (IMD) Normal Annual Rainfall is 314 mm for the city.

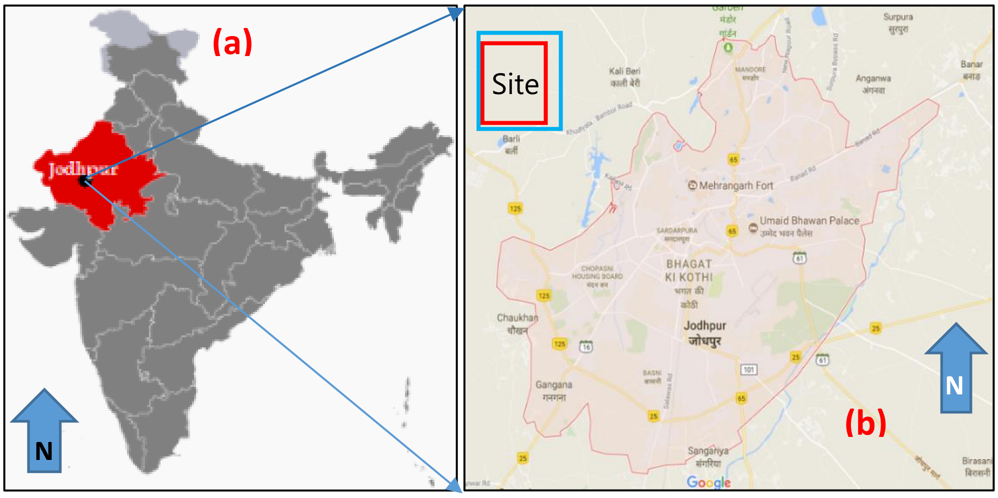


Fig 1. (a) Location of Jodhpur in India (b) Site Location with respect to Jodhpur city (Source: Google Maps)

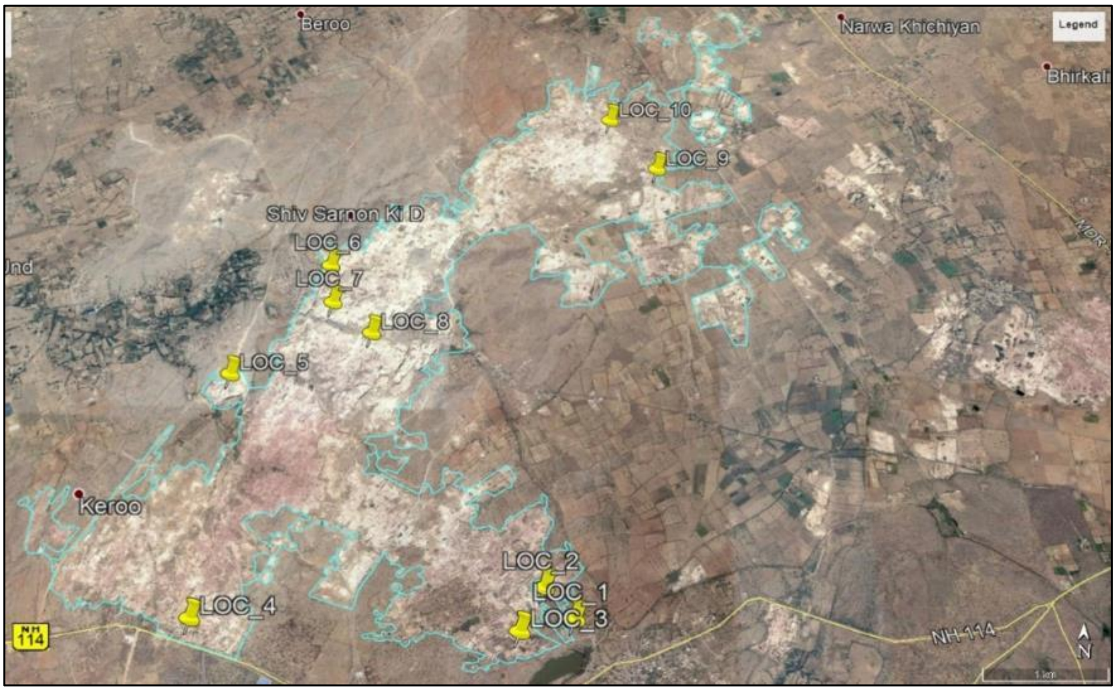


Fig 2. Satellite image of the study area and visited locations.

There are significant number of sandstone quarrying areas in between the north-west and north-eastern parts of the city. The major quarrying areas in the city are Fidusar, Keru, Bambor and areas near Mandore. The studied quarrying area (26°20'40 "N and 72°54'27 "E) is situated in the vicinity of 4 villages situated North-West to Jodhpur city - Keru, Badli, Shiv Sarnon Ki Dhani and Jakharo Ki Dhani (17.5 and 14.3 Km away from the center of the Jodhpur city) (Fig. 1b). More than 1500 metric tons of stone is sent to the city on a daily basis from Keru which makes it a vital hub for excavating sandstone in this region. In the present study, there are a huge number of quarries from where sandstone of different colours (pinkish brown, light brown, golden brown and light maroon) is extracted on a daily basis. The nature of the soil in this area varies from sandy to loamy sand which has low fertility due to the limited amount of organic matter and low nutrient concentration. Even though soil fertility is low, the quarrying area in this study is surrounded by agricultural areas in all directions (Fig. 2).

2. Materials and Methodology

In the present study, satellite images from the Google Earth pro software (version 7.3.1.4507(64-bit)) were used for time series analysis. This analysis was carried out to determine the incremental pattern in the quarrying area by comparing images of the same location from 1990 to 2016. The Historical imagery toolbar in Google Earth was used to compare historical satellite images for this time series analysis. Area and perimeter of the quarrying region were calculated by outlining the quarrying region using the ruler toolbar. Time-based comparison of the region under study was done solely only based on the calculated area. Since area and perimeter were not always directly proportionate to each other, area was found to be a better estimate of the size of any region rather than the perimeter.

Stone cutting units were visually identified and marked by a pin symbol. Using the historical imagery toolbar, number of cutting units were marked by different colour pins for different years. Identification of cutting sites and reduction in agricultural area was calculated after April-2007 because prior to it, resolution of images was not clear enough to identify cutting units, which could have led to a wrong estimate. As a result, cutting unit sites were identified in the years 2007, 2012, 2014 and 2016 due to availability of clear satellite images in these years. For calculating the area of degraded agricultural land, satellite images of the study area and its surroundings were examined from 2007 to 2016. Land which was last used for agricultural production in 2007 but observed to be non-agricultural or appeared to be barren or was now a part of stone quarry/quarry roads/waste dump yard in 2016, is termed as “destroyed/degraded agricultural land” in this study. Sample satellite images of a cutting unit, water recovery ponds at the cutting units, waste dumps and agriculture land are shown in Fig. 3 which were used for the visual identification. Waste dumping locations were also identified and their area was calculated by using the ruler toolbar (shown in Fig. 3 (c)).

To correlate satellite image data with ground truth and verify the study results, 10 locations were selected and visited (Fig. 2). Locations were selected where impacts of quarrying on agriculture and life of the local population were found to be extreme based on the results of time series analysis. Interviews and random conversations with local quarrying workers, cutting site owners, and villagers helped in collecting possible information about stone waste production, water and electricity consumption, quarrying practices and problems in the area related to quarrying.

Fig 3. (a) Satellite image of a cutting unit; (b) satellite image of water recovery ponds for slurry from cutting units; (c) satellite image of dumps used for disposing slurry and (d) satellite image of agricultural land with crops near the quarrying area.

3. Results and Discussion

3.1 Time Series analysis of quarrying area

Results of time series analysis of the quarrying area are presented in Table 1 and Fig 4. Since 1990, the area of the quarrying site has seen a continuous increment every year with an average annual incremental rate of increase of 6.73 %. On 1st December 2016, area of the quarry site in this study was 14.2 km^2 which is approximately 4.55 times the area of the same site in 1990. This increment can be directly related to a surge in stone exports in the last two decades. However, rate of increment of the site area shows less growth in last 5 years compared to increment in every 5 years from 1990 to 2012. Even though the area of this site may not have grown much in the past 5 years, there was no decrease in production of sandstone. After 2012, 94 new stone cutting units have been setup in the study area (Fig. 6(a) and Table 2). Increase in the number of stone cutting units means more production and excavation of raw sandstone. During the survey it was found that the depth of quarries has increased as opposed to the quarrying area in recent years. Currently, a significant number of quarries in the site have depths more than 10 to 12 meters. So, from the time series results it can be concluded that an accretion in the quarrying area represents an increment in stone production or excavation but the converse may not be true, i.e. increase in stone production does not necessarily result in an increase in the quarry area.

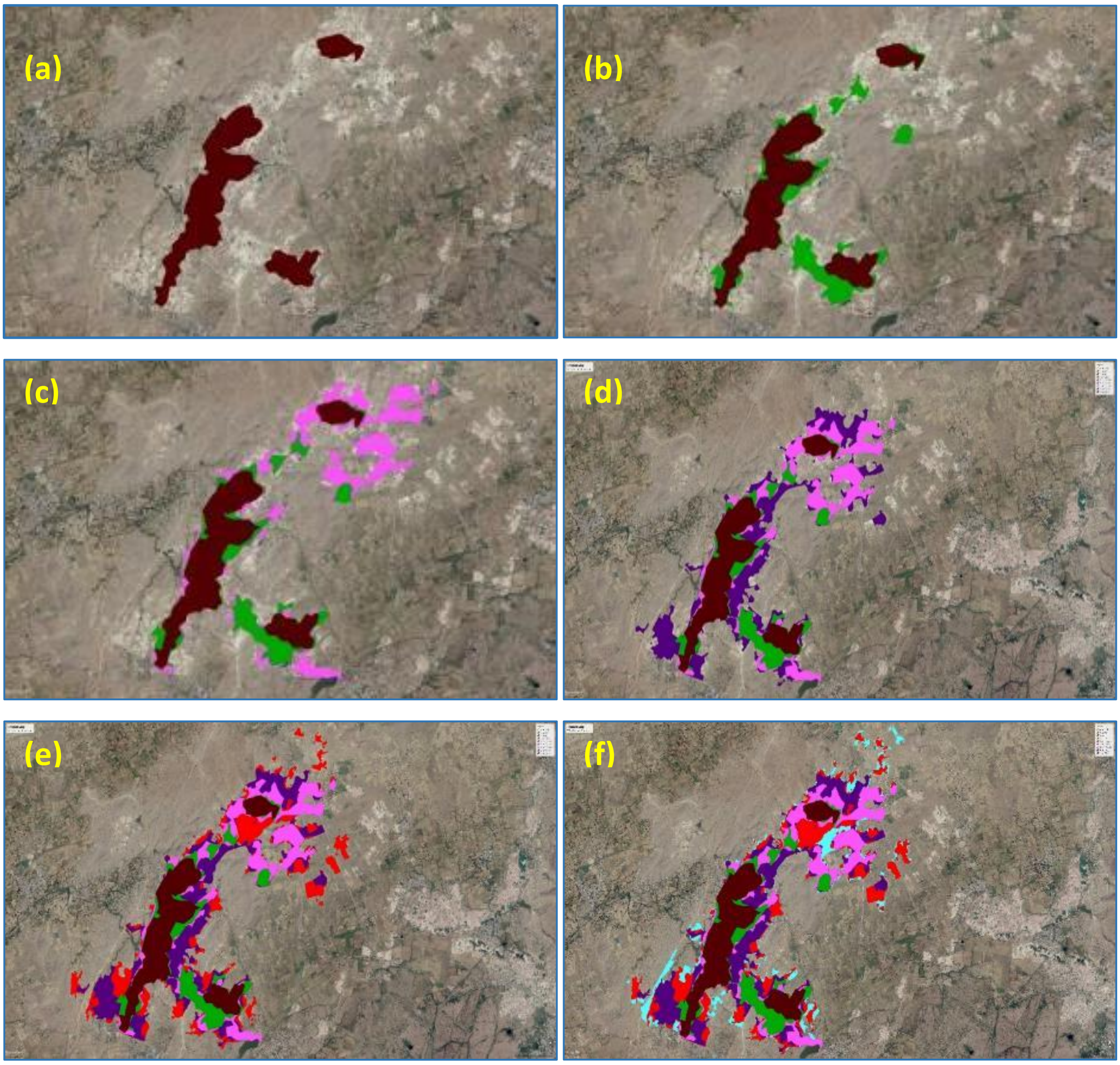


Fig 4. Increment in quarry area in consecutive years is shown with different colours (a) 1990 - dark maroon, (b) 1995 - green (c) 2000 - pink (d) 2007 - purple (e) 2012 - red (f) 2016 – aqua.

Table 1. Result of time series analysis (in order of most recent first).

Year	Area (in km^2)	Perimeter (in km)	Growth compare to last year	Annual growth
2016	14.20	82.4	1.43 %	1.43 %
2015	14.00	83	3.70 %	3.70 %
2014	13.5	88.6	6.30 %	6.30 %
2013	12.7	90	3.25 %	3.25 %
2012	12.3	89	26.80 %	6.70 % (for 2008-2012)
2008	9.7	76.2	2.32 %	2.32 %
2007	9.5	64.5	20.00 %	5.00 % (for 2003-2007)
2003	7.9	50.6	16.18 %	5.39 % (for 2000-2003)
2000	6.8	48.5	55.61 %	11.12 % (for 1995-2000)
1995	4.37	29.83	40.06 %	8.01 % (for 1990-1995)
1990	3.12	18.21	--	--

Due to the high demand for Jodhpur's sandstone in national and international markets, sandstone today is excavated in the region to a much greater extent than ever before. The main reasons behind the aforementioned increment of the site's area are: firstly, new quarrying zones and stone cutting units have been setting up at the periphery of the site and secondly, established quarrying sites are now extracting stone at a much larger scale. In December 2016, there were a total of 113 cutting units in the area out of which 94 cutting units were set up after 2007 (Fig. 6). Reason behind setting up of these cutting units was to increase the daily production and simultaneously reduce the transportation cost. Due to this uncontrollable and haphazard increment in quarrying area, nearby agricultural lands also tend to become either a part of quarries or local roads for transporting the excavated stone products. As mentioned earlier, there are 4 villages close to the quarrying site and from all sides, the site is surrounded by agricultural land. If quarrying continues to increase further in this area, it will directly affect (environmental, socio-economical and geological) the health of nearby village residents, agricultural land and people who depend on these agricultural lands.

3.2 Quarrying processes, stone cutting units and their dumping practices

3.2.1 Current quarrying practices in the area and associated problems

Extensive survey of the quarrying site and nearby areas was conducted to identify local quarrying practices and their impact on the health of local people and nearby environment. There are various processes involved in quarrying and pre-processing of sandstone. Most quarrying practices are highly unsustainable and degrade the local environment. However, some processes are environment-friendly and cost-effective. Recovery of water from the slurry waste that is generated during wet cutting and mechanical lifting of heavy slabs/stone blocks are some examples of it. Examples of unsustainable processes include open cast mining which is performed to excavate sandstone from various depths and rapid pneumatic or electric drills (Jackhammer) which are used for cutting the stone. Field survey results show that even though the extent of quarrying has increased significantly in the past two decades, quarrying practices have not shown much improvement. Improper methods like dry drilling, usage of old trucks and machinery incapable of taking heavy loads, poor slopes of the roads inside quarries, lack of use of safety equipment while working, use of diesel-based generators for running cutting units and drills and many other activities still remain the same. Operations like dry drilling by jackhammer and frequent transportation generate large amounts of dust at the site which is very dangerous to the health of anyone who is involved in these processes.

Long term exposure to dust remains the main reason for health problems related to lungs and eyes amongst the workers involved. These diseases include silicosis, asthma, tuberculosis, and irritation in eyes (Ghotkar et al., 1995; Scott and Grayson, 2013; Singh et al., 2006). A study conducted on the health of quarry workers in 2017 in present study area showed that about 65 % of them were affected by some kind of breathing problem and since 1900 there is 156% increment in the number of workers have breathing problems (Singhal and Goel, 2019b). During our survey, it was found that stone dust from the quarrying activities was very fine and was easily airborne due to the local wind velocity. These airborne dust particles end up in the nearby areas which degrade the local air and land quality. If quarrying increases further in the future, deterioration in the health of local workers and degradation of local air quality and environment is expected to further increase in the future.

3.2.2 Increment in number of cutting units during the past years and their environmental impact

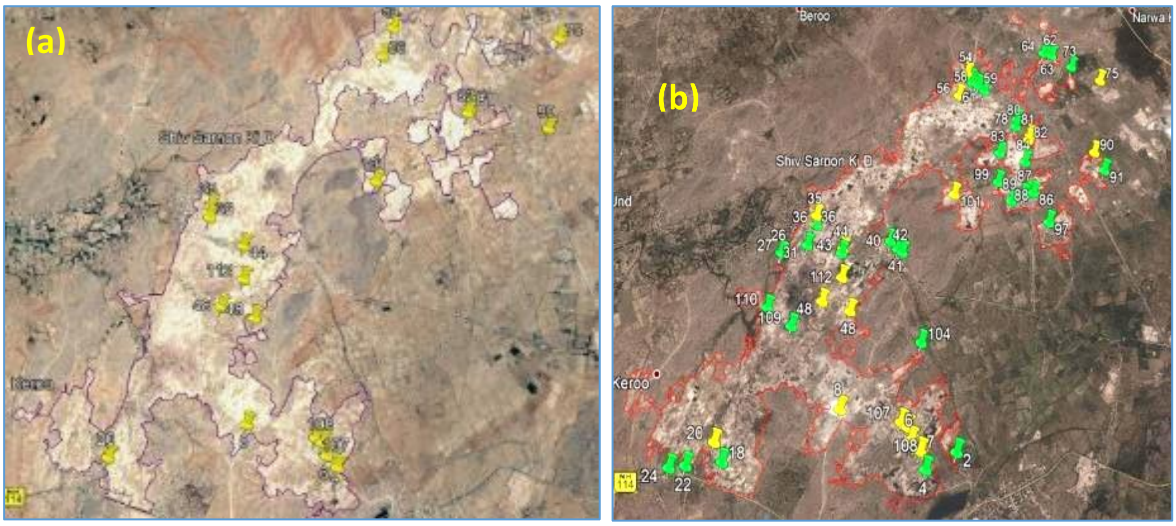
An increasing trend in the number of stone cutting units in the study area was observed from 2007 to 2016 which is clearly visible in Figure 5. In 2007, there were a total of 19 cutting units situated inside and around the site which increased to 113 in Dec-2016. The major reason behind this massive increase in cutting units is the high demand of sandstone which has led to higher production. The construction of cutting units closer to the quarrying site resulted in increased production in limited time and decrease in transportation costs.

Table 2. Number of cutting units and increment in their respective years

Date & Year	Total cutting units in the area	Increase in number of cutting units
April-2007	19	-
October-2012	55	36
November-2014	94	39
December-2016	113	19

Compared to 2012 and 2014, the increase in number of cutting units is relatively less in 2016 (Table 2). Also, the increase in area of the site is less compared to 2007-2012 and 2012-2014. This implies that very few new quarries have been excavated after 2014. By comparing the locations of the new cutting units in the satellite images, it can be seen that most of the cutting units were set up at the periphery of the study area after 2007 (Fig. 5). This shows that as a new quarrying area is excavated, more cutting units were set-up in the adjoining areas. This suggests that the number of cutting units are directly proportionate to the quarrying area.

Quality of excavation from these quarries may not have improved since the 1990s but cutting techniques have shown some improvement. Wet cutting with water is now being used for cutting stone in this study area. Mechanical lifters are available to lift heavy stone slabs and water is recovered from the slurry for reuse. The cutter is a large saw (1-3 m diameter) which can be operated using electricity or kerosene/diesel. A single cutting unit is used to shape around 12-16 tons of sandstone daily. After quarrying and cutting, around 30-50% of the total excavated stone goes to waste in the form of small scrap stone pieces and slurry. A single cutting unit consumes huge amounts of water during the cutting process (1500 to 2500 liters/day, for a cutter running for 8 to 12 hours a day - water consumption depends on the size of cutter). Used water with fine stone dust is called “slurry” and it ends up in the drain which leads to a settling tank from where water can be recovered. Due to scarcity and high cost of water, its recovery from the slurry is common practice in the area. Slurry is collected in a series of settling tanks used as sedimentation tanks to settle relatively heavy slurry (stone dust) particles. The separated slurry is then dumped on empty ground along with scrap stones from the cutting process.



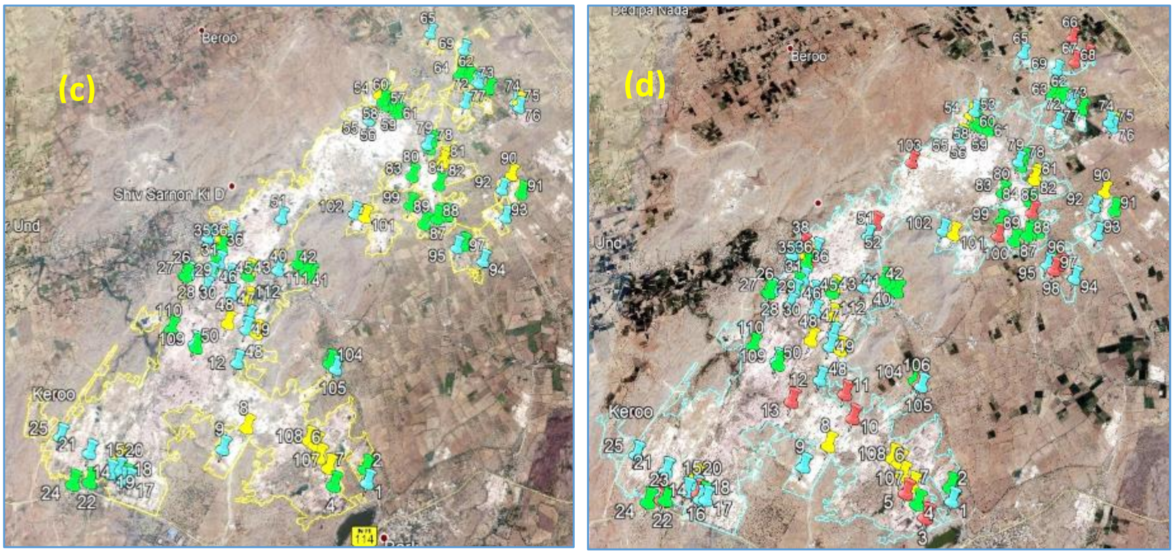


Fig 5. Cutting units around the study area in (a) 2007 [pins in yellow colour, total units: 19] (b) 2012 [pins in green colour, total 36 new units] (c) 2014 [pins in light teal colour, total 39 new units] (d) 2016 [pins in red colour, total 19 new units].

In contrast to other quarrying processes, cutting is less hazardous to the health of local workers but it has other impacts on the surroundings. From a survey of the site, it was found that on an average **8 to 10** metric tons of waste is generated daily from a single cutting unit in the form of slurry and scrap stone. Presently, there are a total of 113 cutting units in the area. Based on this, it is estimated that 904 to 1130 metric tons/day of waste is generated from the cutting units. This huge amount of waste is dumped without treatment hence leading to environmental degradation. Cutting units require electrical power thereby increasing their carbon footprint in the environment. At many places in the study area, electricity was not available and so electricity generators are used which require huge volumes of diesel as fuel (6.8 L/hour) and emit various air pollutants. Water requirements for cutting are also very high which adds an extra burden on the water scarce environment. For about 4 to 5 months of a year, the above water requirement is fulfilled from the water collected in the quarries during monsoon. For the rest of the year, they depend on either groundwater or municipality or both. This huge demand of water increases pressure on surface and groundwater resources which are already a scarce resource in the area.

3.2.3 Waste dumping practices and dumping locations

Waste generated from the quarrying and cutting process is dumped on the nearby open land without any treatment. Due to the availability of extensive empty and barren land, this practice is chronically used since the beginning of quarrying in this area. The dumping site in the study area has gigantic artificial mountains of scrap stones and stone dust which can be more than 10 meters high at some locations. There are approximately 56 major dumping sites having areas ranging from 0.12 to 4.69 hectares and heights from 3 to 11 meters. These 56 dumps cover a massive area of 0.502 km^2 which occupies 3.54 % of the total area of the site as on December 2016. Most of the dumping locations are situated close (less than 500 m) to the cutting units where the slurry and scrap stone generated from the cutting process are dumped using tractor-trolley or mini-trucks (Fig. 6). A single dumping site is generally used by 2 to 3 cutting units. As quarrying area and number of cutting units showed a massive increment in past years, the load on existing dumping sites increased and many small new dumping sites have emerged in the area. Approximately 1000 metric tons of waste is generated daily from the 113 cutting units in the study area which is crudely dumped on these nearby sites on a daily or weekly basis.

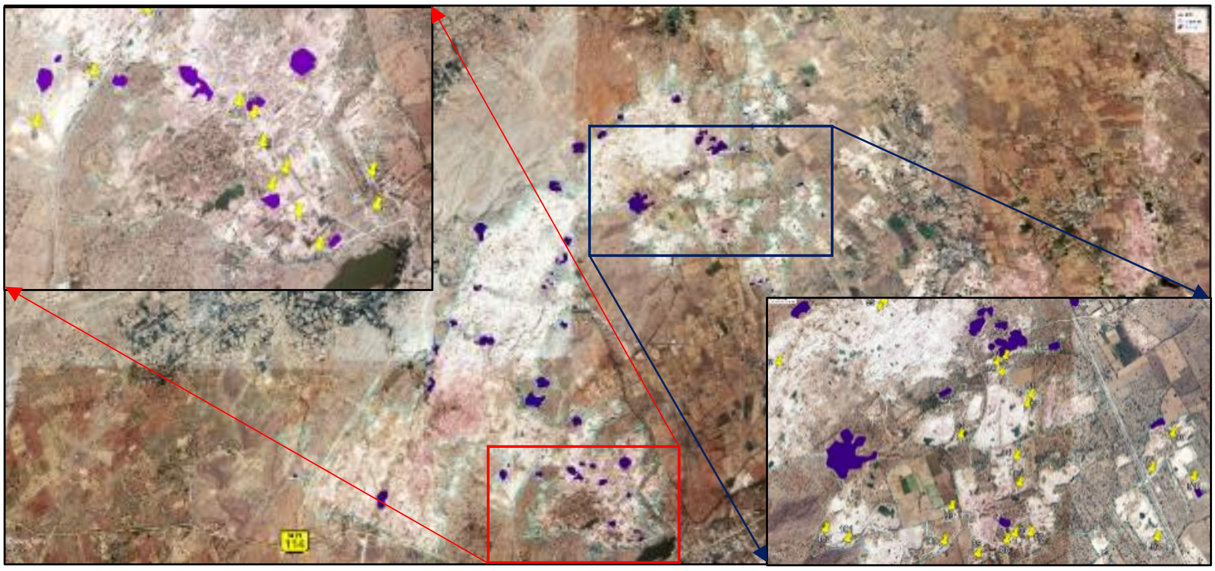


Fig 6. Slurry and scrap stone dumping grounds in the study area (Purple coloured area are dumps and yellow pins are the cutting units)

3.2.4 Impact of quarrying on agriculture

The study area is surrounded by agricultural fields in all the directions. One of the worst impacts of increase in quarrying activities during the past years can easily be seen on these agricultural lands. From 2007 to 2016, around 71.36 hectares of agricultural land has been degraded due to the heavy and unsustainable quarrying activities (Fig. 7). Out of which 17.34 hectare (24.3 % of total agricultural land destroyed) of the land is now a part of the sandstone quarries (Fig. 7). The rest of the 54.02 hectares of agricultural land is now either unpaved roads built for transportation of stone or are not suitable for agriculture due to extremely low productivity.

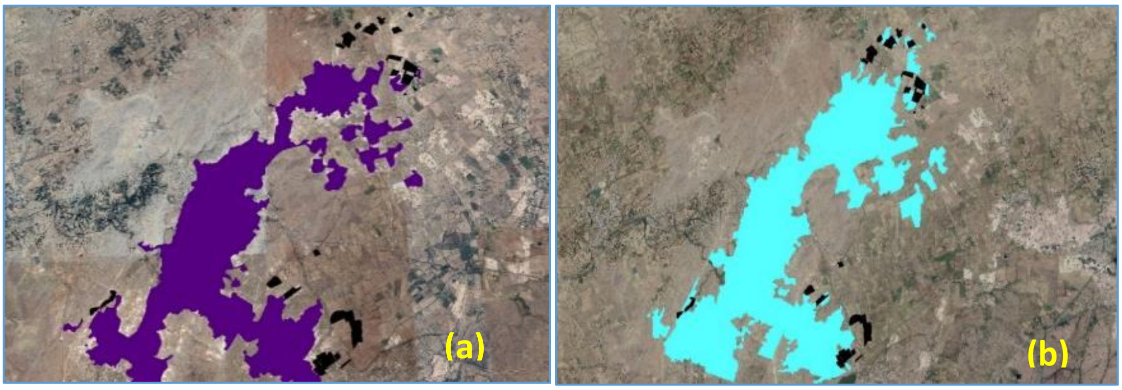


Fig 7. (a) black colour region is the land which was last used for agriculture in April 2007 and purple colour represents the study area in 2007 (b) black colour region is the land which was last used for agriculture in December 2016

A major reason behind the degradation of agricultural land is excessive quarrying without taking any proper preventive measures. After 2007, 17.34 hectares of agricultural land has been converted to stone quarries. Some of the land was used as roads for transporting finished stone or supplies in and out from the quarrying area. The remaining 54.02 hectares of land are uncultivated, primarily because of stone dust intrusion in the soil from runoff and air. But unlike the quarrying area, it can be remediated for agricultural purposes by using suitable techniques and fertilizers.

Due to stone dust intrusion, fertility and existing soil properties (like porosity, hydraulic and electrical conductivity etc.) are affected severely which leads to further decrease in crop production along with reduction in groundwater recharge (Al-Joulani, 2008). Another reason behind the decrease in productivity of these lands is deposition of dust on the crops which reduces their productivity and growth. Massive amounts of dust emerge from quarrying activities which end up in nearby residential and agricultural areas due to wind velocities that are enough to blow dust (5-18 km/hour on an average and 20-28 km/hour during summers and monsoon). The size of the stone dust varies from a few millimetres to micron size which leads to reduction in stomatal conductance of the crops and leaves by deposition over them (Zia Khan et al., 2014, Prajapati, 2002). This leads to overall reduction in growth of the crops and low crop yield which eventually leads to economic losses. Around 80% of the population in nearby villages is totally dependent on agricultural and livestock production. A decrease in crop production is a serious threat to the food and income security of the locals.

4. Conclusions

Google Earth Pro is an easily accessible online software which provides high resolution satellite images over long time periods. These images can be used in various environmental studies. In the present study, images and tools from Google Earth were used to perform time series analysis for a sandstone quarrying area from 1990 to 2016 to find incremental trends in the quarrying area, stone processing units and their associated environmental impacts. Time series analysis of study area shows that the quarrying area increased by 4.55 times from 1990 to 2016, which is a result of the surge in sandstone production during the last two decades. Time series study results shows that increment in the area can be directly related to the increment in stone production or excavation but the converse may not be true. Number of cutting units and dumping locations increased in direct proportion to the increase in quarrying area. From 2007 to 2016, around 71.36 hectares of agricultural land was destroyed of which 17.34 hectares of the land is now part of the quarrying area and the rest is unfit for any kind of agricultural activity. Major reasons for degradation of agricultural land and environment was intrusion of stone dust in the nearby environment, especially soil. This work shows that Google Earth in conjunction with ground-based information can be used to rapidly evaluate LU-LC changes and to identify spatially visible environmental impacts. The methodology used in this study can be extended to cover other mining and quarrying areas for monitoring and quantification of LU-LC change within a specific time period.

Acknowledgement

The authors wish to thank Prof. P C Pandey, Mr. Shubham Patil, Mr. Kartik Madnure, Ms. Tandra Mohanta and Dr. Kruttika Apshankar for providing useful suggestions.

References

Ahmad, A., 2014. A study of miners, demographics and health status in Jodhpur district of Rajasthan, India. Int J Develop Stud Res. 3 (1), 113-21.

Al-Joulani, N., 2008. Soil Contamination in Hebron District Due to Stone Cutting Industry. Jordan Journal of Applied Science. 10, 37-50.

Bhadra, B.K., Gupta, A.K., Sharma, J.R., Choudhary, B.R., 2007. Mining activity and its impact on the environment: Study from Makrana marble and Jodhpur sandstone mining areas of Rajasthan. Journal-Geological Society of India. 70 (4), 557.

Brimicombe, A.J., 2003, May. A variable resolution approach to cluster discovery in spatial data mining. In International Conference on Computational Science and Its Applications (pp. 1-11). Springer, Berlin, Heidelberg.

Centre for Development of Stones (CDoS). Jaipur, Rajasthan, India. https://cdos-india.com/

Chopra, K., Prakash, P., Bhansali, S., Mathur, A., Gupta, P.K., 2012. Incidence and prevalence of silicotuberculosis in western Rajasthan: A retrospective study of three years. National Journal of Community Medicine. 3(1), 161-3.

Forestner, U., 1999. Introduction to environmental impacts of mining activities. In: Jose M. Azcue, (Ed.), Environmental impacts of mining activities, Springer pp 1-3.

Ghose, M.K., Dikshit, A.K., Sharma, S.K., 2006. A GIS based transportation model for solid waste disposal–A case study on Asansol municipality. Waste management. 26 (11), 1287-1293.

Ghotkar, V.B., Maldhure, B.R., Zodpey, S.P., 1995. Involvement of lung and lung function tests in stone quarry workers. Ind J Tub. 42, 155-60.

Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., Moore, R., 2017. Google Earth Engine: Planetary-scale geospatial analysis for everyone. Remote Sensing of Environment. 202, 18-27.

Karmakar, H., Das, P., 1991. Impact of Mining on Ground and Surface Waters. 4th IMWA Congress, Ljubljana, Austria. 187-198

Odell, S.D., Bebbington, A., Frey, K.E., 2018. Mining and climate change: A review and framework for analysis. The Extractive Industries and Society. 5(1), 201-214.

Poonia, S., Rao, A.S., 2013. Climate change and its impact on Thar desert ecosystem. Journal of Agricultural Physics. 13 (1), 71-79.

Prajapati, S.K., 2012. Ecological effect of airborne particulate matter on plants. Environmental Skeptics and Critics. 1 (1), 12-22.

Scott, D.F., Grayson, R.L., 2003. Selected Health Issues in Mining. Centre for Disease Control. Available from: https://www.cdc.gov/niosh/mining/userfiles/works/pdfs/shiim.pdf

Singh, S.K., Chowdhary, G.R., Purohit, G., 2006. Assessment of impact of high particulate concentration on peak expiratory flow rate of lungs of sandstone quarry workers. Int. J. Environ. Res. Public Health. 3, 355-59.

Singhal, A., Goel, S. 2019. An Integrated Solid Waste Management (ISWM) Plan Using Google Earth and Linear programming: A Case Study of Kharagpur City, West Bengal. Treatment and disposal of solid and hazardous wastes, Springer, Cham.

Singhal, A., Goel, S. 2019. Impact of sandstone quarrying on the health of quarry workers and local residents in Keru, Jodhpur, India. Treatment and disposal of solid and hazardous wastes, Springer, Cham.

Solanki, J., Gupta, S., Chand, S., 2014. Oral health of stone mine workers of Jodhpur City, Rajasthan, India. Safety and health at work. 5 (3), 136-139.

Yarahmadi, A., Zahmatkesh, M.M., Ghaffari, M., Mohammadi, S., Labbafinejad, Y., Seyedmehdi, S.M., Nojomi, M., Attarchi, M., 2013. Correlation between silica exposure and risk of tuberculosis in Lorestan province of Iran. Tanaffos. 12 (2), 34.

Zia-Khan, S., Spreer, W., Pengnian, Y., Zhao, X., Othmanli, H., He, X., Müller, J., 2015. Effect of dust deposition on stomatal conductance and leaf temperature of cotton in northwest China. Water. 7 (1), 116-131.