Temporal status and change detection of stone quarrying and crushing activities using multi-temporal google earth images

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Abstract: Stone quarrying and crushing (SQC) activities under mining operations normally produce a destructive landscaping impression during the period from start to end. Spatio-temporal data, downloaded from Google Earth Pro s/w, coupled with remote sensing, GIS, and GPS has been used to evaluate time series (2003, 2008, 2015 and 2021) analysis of stone quarrying and crushing activities in a part of Jhansi Tehsil. Results show that the variability and pressure on land resources due to stone quarry and crushing activities were found in linear increments during the time. There was annual heavy exploitation record during 2003-2008 (30.83%) of stone from quarry sites and total increments of SQC activities were found to be 277.64% in the last 18 years. This study exhibited the prospective advantage of annual monitoring over the period and support to make the possible preparations/ management for destructive mining operations.

Keywords: Change detection, geographical information system (GIS), google earth images, mining activities, remote sensing, stone quarrying

1. Introduction

Stone quarrying is the removal process of valuable geological materials from the Earth. These materials are a form of mineral package that have economic interest to the mineworker. In a broader sense, mining refers to the extraction of any non-renewable resource such as rock, petroleum, natural gas etc. Stone mining has been a human activity since pre-historic time. The activities associated with mining frequently have a detrimental influence on the environment, both during and after the mining activity. Mining operations are related to the opening of large pits on the Earth's surface to extract land resources. The degree to which these processes are involved is largely determined by the value of the mineral resources and the quality and quantity of the output. These activities cause a notable impression on the surroundings (Valdiya 1987).

Stone quarrying and crushing activities lead to a massive change in biodiversity, this degrades the ecology and landscape. (Al-Joulani 2008; Bhadra et al. 2007; Odell et al. 2018; Zia-Khan et al. 2015). Stone dust is a by-product of stone crushing and shipping process which produces various respiratory issues as well as it directly threatens the health of mine workers and nearby people (Ahmad 2014; Chopra et al. 2012; Solanki et al. 2014; Yarahmadi et al. 2013). Soil quality and agricultural productivity are directely affect by deposition of stone dust in the surrounding region (Prajapati 2012; Zia-Khan et al. 2015). The improper handling of the massive daily amounts of stone and slurry waste produced by quarrying activities is another significant issue (Forestner 1999).

The ability to differentiate between natural changes and those imposed by human activities is essential for an effective monitoring strategy for assessing surface mining operations and their dynamics on a regional scale. Accurate and current information is required to overcome these problems. Since 1970, spatial changes in mining areas have been mapped by using analogue aerial images (Anderson et al. 1977).

This data may now be obtained by remote sensing, It has the potential to create calibrated observations with an appropriate geographic resolution with decadal time scale. The dynamics of quarries have been the subject of several local and regional studies utilising a range of remotely sensed datasets with different spatial and temporal resolutions (Bonifazi et al. 2003; Karuppasamy et al. 2016; Koruyan et al. 2012; Latifovic et al. 2005; C. C. Liu et al. 2005; Nikolakopoulos et al. 2010; Nikolakopoulos and Raptis 2014; Saroglu et al. 2005; Uça et al. 2011).

Remote sensing is an aerospace technology that uses electromagnetic energy to capture data from the Earth's surface and its surrounding atmosphere by remote sensing systems. The ERDAS Imagine, ArcGIS s/w can be used to develop the land use/ land cover changes using multi-temporal google earth images. A group of modest tools/ software such as Google Maps, Bing Maps, and Google Earth Pro can be used successfully for geo-environmental studies because of synoptic coverage and high spatial resolution satellite images. Google Earth may be utilised in a variety of fields, including transportation, urban planning, time series analysis, real-time research analysis using the Global Positioning System (GPS), environmental and climatic studies, and more, due to its simple operations and online accessibility (Singhal and Goel 2019).

The application of remote sensing and GIS in the field of comprehensive environmental issues which could be distinguishable in aerial photographs and satellite imagery (Kumar et al. 2013). Remote Sensing and GIS has developed as a major contrivance for collecting information about all features present on the Earth's surface. In recent years, very high resolution (both spatial and spectral) satellite data are available and the application has increased with respect to numerous purposes. Remote sensing and GIS have been subsidised meaningfully towards progressive activities for decades in India (Kumar et al. 2013).

The change in land cover as a result of anthropogenic activities has played a major role in global environmental change and has become a hot spot for researchers (Liu et al. 2002). Changes in land use pattern by means of remotely sensed global data is based on the evaluation of temporal data. The change in land resources over time can be determined and evaluated using digital techniques (SAC-ISRO 1990). Remote sensing techniques have been successfully applied to monitor the land use changes due to opencast strip mining, evolution of dumping of mine wastes, deforestation and erosion due to mining activities (Gupta 2005).

Remote sensing and GIS play a pivotal role in monitoring the temporal changes on the Earth's surface due to stone quarrying and crushing activities. The objective of the study is mainly focused on evaluating the temporal status of stone quarrying and crushing activities and change assessment from 2003 to 2021. This may be useful to assess the impact on land resources and control hazardous effects on the health of local workers/ villagers with proper planning.

2. Materials and Methods

This study is precisely devoted to assessing the temporal changes in stone quarrying and crushing activities using geospatial tools. The quantitative/ numerical method for identifying the temporal changes was used. To evaluate the change, stone quarrying and crushing activities were identified and stored using multi-temporal google earth images. The resulting classified area under stone quarrying and crushing activities were obtained and compared accordingly. The adopted procedure are as follows:

2.1. Software used for the study

Google Earth Pro, ERDAS Imagine and ArcGIS s/w were used to identify stone quarrying and crushing activities, data processing, thematic mapping and creation of geodatabase for temporal change assessment.

2.2. Study Area

There are 5 Tehsil under the Jhansi District of Uttar Pradesh, India *viz.*, Jhansi, Mauranipur, Moth, Garautha and Tehrauli. The north eastern part of tehsil Jhansi is primarily underlain by high rank igneous rocks of Bundelkhand cratons generally trending, these rocks consist of gneiss and granites etc. hence are quite suitable for quarry business. In this study, the cluster group of mining sites were identified for the assessment of temporal changes, that occur due to stone quarrying and crushing activities in the north eastern part of Jhansi Tehsil were determined. The study area is lies between 25° 26' 27.2616" to 25° 28' 17.5080" N and 78° 39' 5.1840" to 78° 41' 49.3008" E.

2.3. Data collection

Various data were used to assess the temporal status/ changes and the creation of thematic layers. The data included ground control points (stored from GPS), required photographs (captured from Sony camera) and high quality google earth images for the validation of the work. Total four temporal Google Earth images (Imagery Date: 31/12/2003, 29/05/2008, 14/03/2015 and 15/01/2021) with high spatial resolution have been downloaded from Google Earth Pro s/w for accurate temporal assessment.

2.4. Raster processing: Google Earth Images

Raster processing is the process that treats directly to the pixels of the image. With the help of geoprocessing tools, every pixel present on the raster image was globally positioned. The transformed coordinates are stored in georeferenced file formats like GeoTIFF and *.img. Georeferencing of temporal google earth images has been done using ERDAS imagine with the help of collected ground control points, and projected to the Geographic - WGS 1984 and re-projected into UTM44N (Universal Transverse Mercator) WGS 1984 (USGS 2018). The area of interest with reference to the study area were masked/ cliped by using the masking tool in Arc GIS.

2.5. Record the precise locations and current status of stone quarrying and crushing sites

Current field photographs and precise locations of stone quarrying and crushing sites have been recorded with the help of Sony Digital Camera and Garmin GPS for the validation of the study.

2.6.Multi-date google earth images of the study area

After the completion of the raster processing of raw data using ERDAS Imagine, the final clipped temporal google earth images for 2003, 2008, 2015 and 2021 were stored for the study (Figure 1).

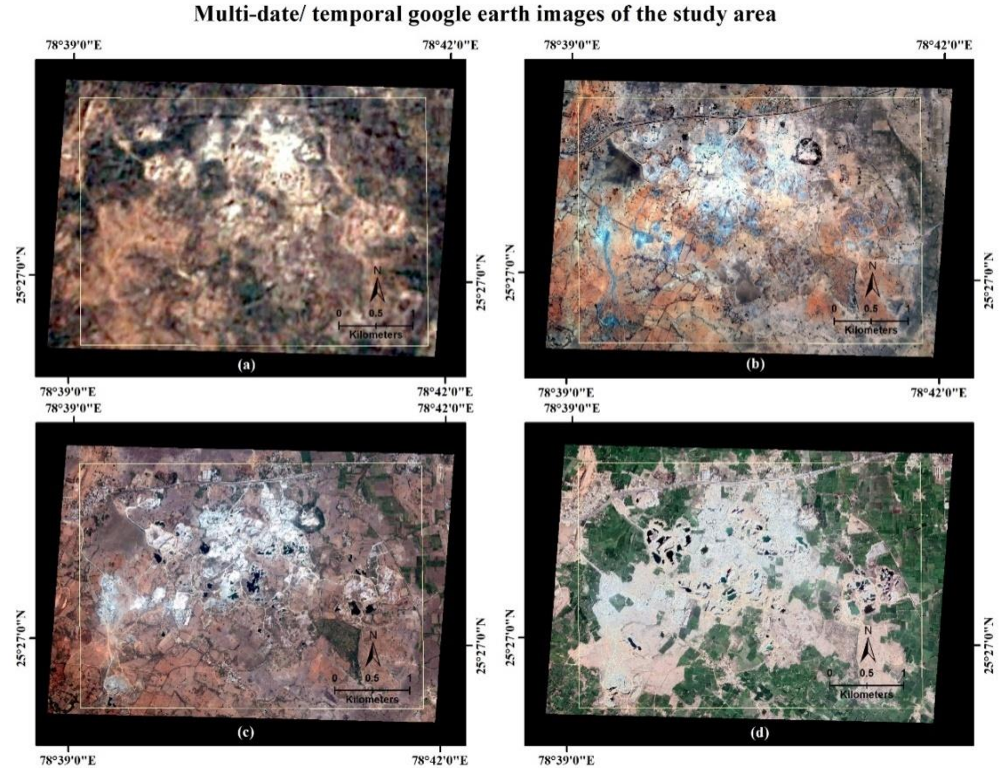


Figure 1. Multi-date google earth images of the study area: (a) acquisition date: 31/12/2003; (b) acquisition date: 29/05/2008; (c) acquisition date: 14/03/2015; (d) acquisition date: 15/01/2021

2.7. Identification of the stone quarrying and crushing activities

For the drive of identification of the stone quarrying and crushing activities, georeferenced multi-temporal google earth images were used using ArcMap. A temporal study based on the stone quarrying and crushing activities for 2003, 2008, 2015 and 2021 was done by using the manual digitization method.

2.8. Change Assessment

Temporal google earth images have been of substantial advantage in monitoring the temporal changing pattern over the year. Change detection analyses were estimated through equation 1, 2, 3 and 4 (Kashaigili and Majaliwa 2010; Kleemann et al. 2017). The magnitude of change is a degree of expansion or reduction in the LULC size. A negative value will present a decrease in LULC size while a positive value will indicate an increase in the size of LULC class (Mahmud and Achide 2012).

$$Area\ change = Area_{i\ year\ x+1} - Area_{i\ year\ x} \quad (1)$$

$$Area\ change\ (\%) = \frac{Area_{i\ year\ x+1} - Area_{i\ year\ x}}{\sum_{i=1}^{n} Area_{i\ year\ x}} X\ 100 \quad (2)$$

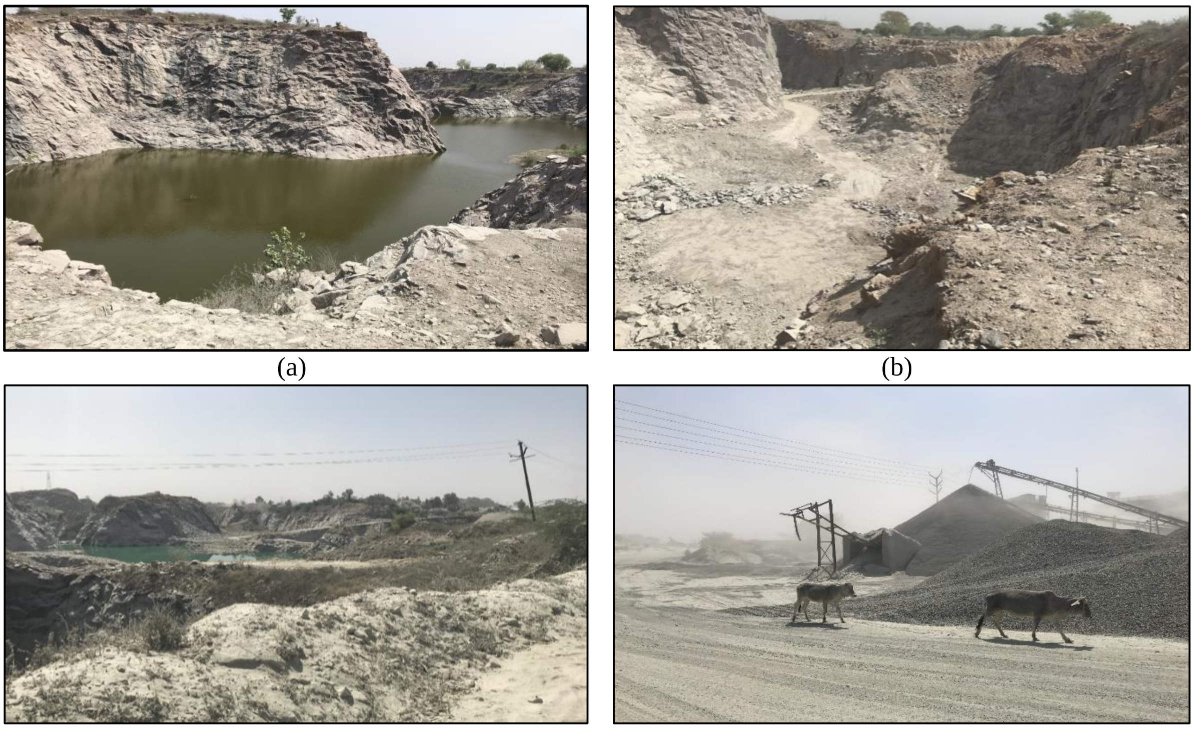
$$Annual\ rate\ of\ change = \frac{Area_{i\ year\ x+1} - Area_{i\ year\ x}}{t_{years}} \quad (3)$$

$$Annual\ rate\ of\ change\ (\%) = \frac{Area_{i\ year\ x+1} - Area_{i\ year\ x}}{\sum_{i=1}^{n} Area_{i\ year\ x}\ X\ t_{years}} X\ 100 \quad (4)$$

Where: $Area_{iyearx+1}$ = Area of land use/ land cover for the following year
$Area_{iyearx}$= Area of land use/ land cover of the current year
$\sum_{i=1}^{n} Area_{i\ year\ x}$= The total area of land use/ land cover of the current year
t_{years}= the years' difference between the first and second period

3. Results and Discussion

The total geographical area of the study area was calculated as 1532.18 ha. Assessment of temporal changes was calculated between six time series *i.e.*, 2003-08, 2003-15, 2003-21, 2008-15, 2008-21 and 2015-21. During ground trothing, the current status was categorised as active, abandoned and partially abandoned which was formed due to rigorous/ unplanned mining under the selected cluster group (Figure 2).



(a) (b) (c) (d)

Figure 2. Current status: (a) abandoned (25.463743°, 78.660621°); (b) active (25.455811°, 78.692110°); (c) partially abandoned (25.466625°, 78.671545°); (d) active crushing unit (25.455303°, 78.656038°).

3.1. Temporal status of stone quarry and crushing activities (SQCA)

Area (%) was calculated out of total geographical area (1532.18 ha) of the study area

Out of the total geographical area (1532.18 ha), stone quarry and crushing activities account 8.23% (126.14 ha) in 2003, 20.92% (320.58 ha) in 2008, 24.75% (379.25 ha) in 2015 and 31.09% (476.35 ha) in 2021 (Table 1). Figure 3 shows that there are linear increments occurring from 2003 to 2021, but the area of SQC activities was found to be maximum during 2003-2008 and found minimum between 2008-2015. The spatial distribution and temporal status of SQC activities are shown in Figure 4.

Table 1. Temporal status of stone quarry and crushing activities

	2003		2008		2015		2021	
	Hectare	%	Hectare	%	Hectare	%	Hectare	%
Area of SQCA	126.14	8.23%	320.58	20.92%	379.25	24.75%	476.35	31.09%

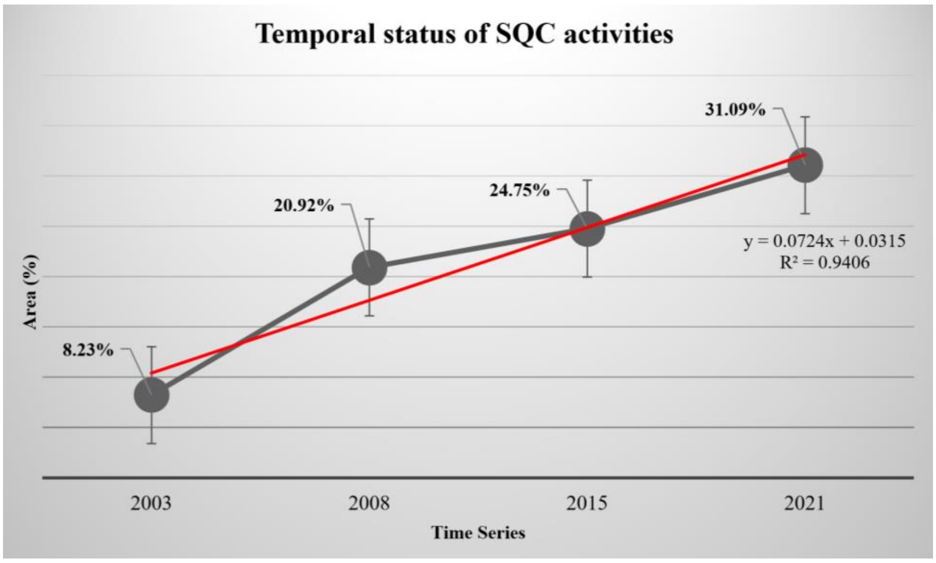


Figure 3. Temporal status of SQC activities; Red line shows a linear trend line.

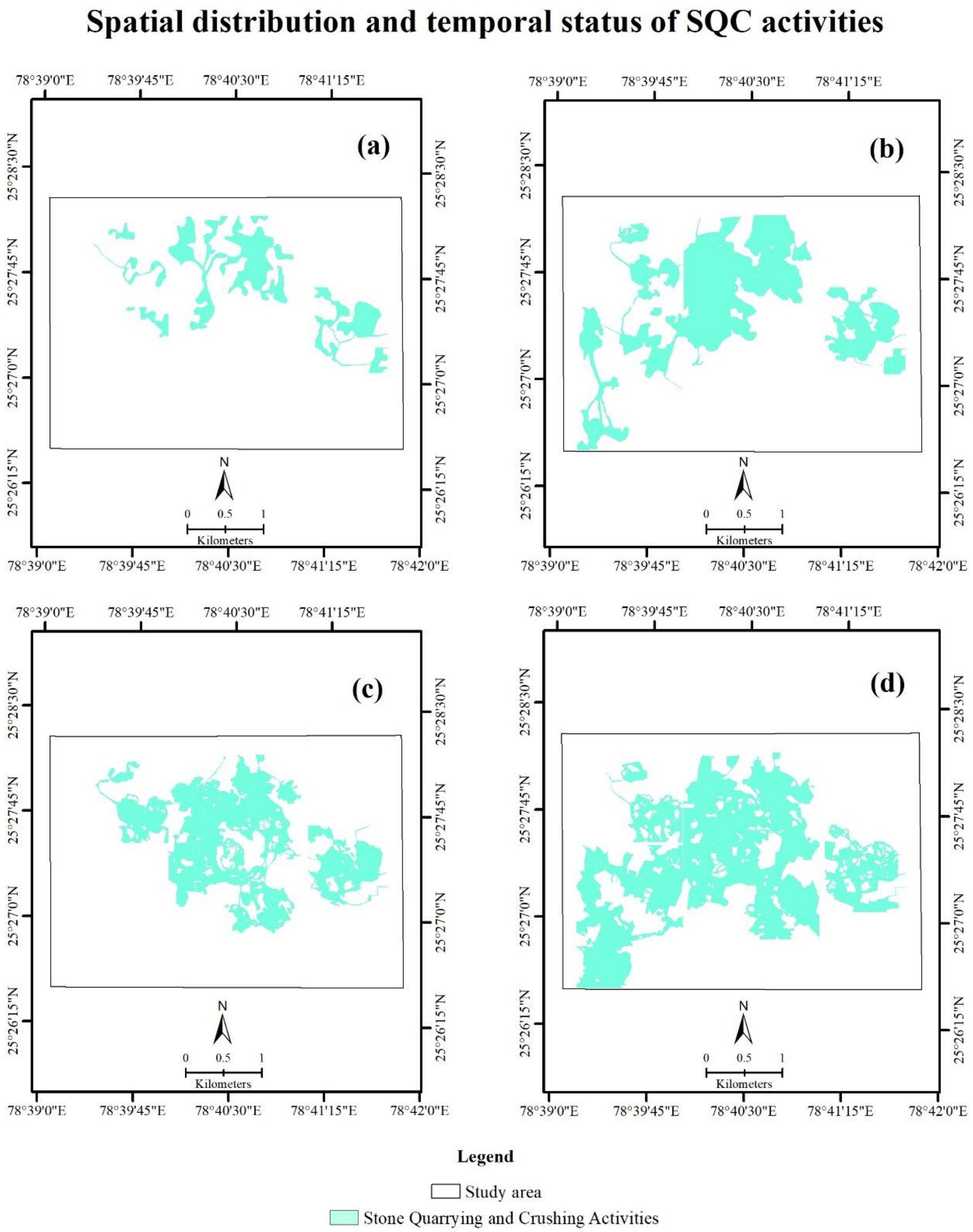


Figure 4. Spatial distribution and temporal status of SQC activities: (a) 2003; (b) 2008; (c) 2015; (d) 2021.

3.2. Temporal change assessment of stone quarry and crushing activities (SQCA)

The area change in six time series, 2003-08 (194.44 ha); 2003-15 (253.11 ha); 2003-21 (350.21 ha); 2008-15 (58.67 ha); 2008-21 (155.77 ha) and 2015-21 (97.1 ha), shows increased in every time interval due to ongoing mining activities (Table 2). The temporal change in percent was found 154.15%, 200.66%, 277.64%, 18.3%, 48.59% and 25.6% in 2003-08, 2003-15, 2003-21, 2008-15, 2008-21 and 2015-21 respectively (Figure 5). The annual rate of changes was calculated as 38.89 ha (30.83%), 21.09 ha (16.72%), 19.46 ha (15.42%), 8.38 ha (2.61%), 11.98 ha (3.74%) and 16.18 ha (4.27%) in 2003-08, 2003-15, 2003-21, 2008-15, 2008-21 and 2015-21 respectively. The annual rate of change in percent was found to be highest (38.83%) during 2003-2008 and found low (2.61%) between 2008-2015 (Figure 6). The total increments of SQC activities were found to be 277.64% in the last 18 years.

Table 2. Temporal change assessment of SQC activities

Change assessment	2003-08	2003-15	2003-21	2008-15	2008-21	2015-21
Area Change (ha)	194.44	253.11	350.21	58.67	155.77	97.1
Area Change (%)	154.15%	200.66%	277.64%	18.30%	48.59%	25.60%
Annual Rate of Change (ha)	38.89	21.09	19.46	8.38	11.98	16.18
Annual Rate of Change (%)	30.83%	16.72%	15.42%	2.61%	3.74%	4.27%

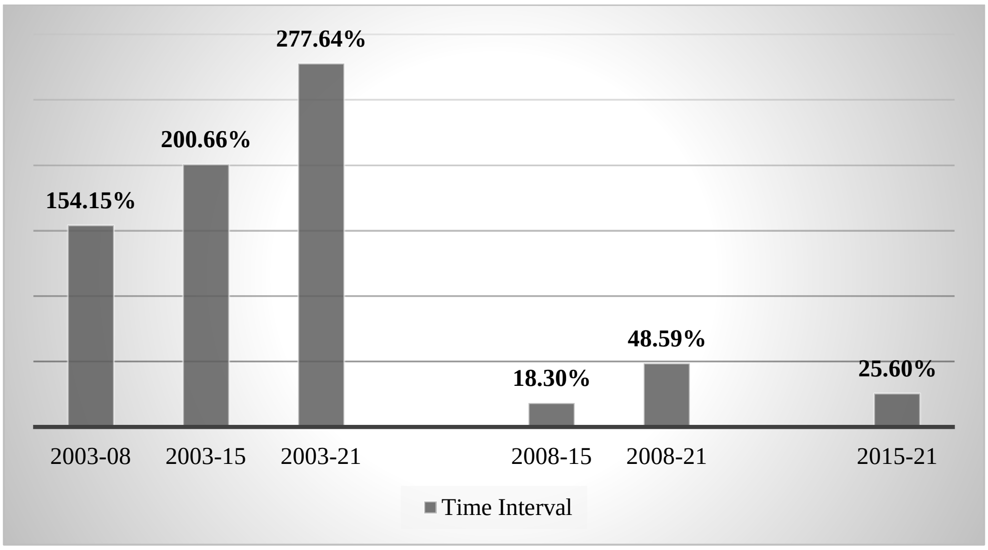


Figure 5. Temporal change in area (%) of SQC activities

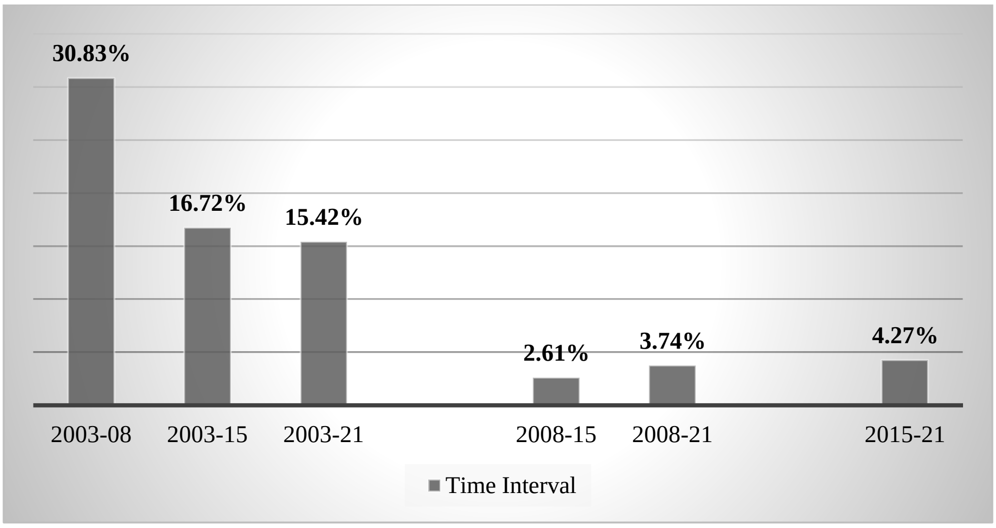


Figure 6. Annual rate of change in area (%) of SQC activities

The results show that the analysis of temporal status in and around the SQC sites after 18 years contributes to dynamic changes caused by crushing activities. In the current study, there are linear increments occur from 2003 to 2021 but in some belongings and dynamic changes occurred in the area of SQC activities was fall down due to mining pits, caused by small and large scale quarrying activities, this is because mining is predominantly undertaken in waterlogged areas (Obodai et al. 2019; Pei et al. 2017; Xiao et al. 2017). This increments has remunerated by the loss or decrease of different land use features. In 18 years time span, the overall annual rate of change in SQC activities caused the loss of important land resources. In conformity with the findings, destructive mining activities have been increased. Stone quarrying and crushing activity include the removal of earth surface features to dig out stones for building materials purpose. Therefore, the dynamic changes of the SQCA provide an excellent explanation of mining operations. In fact, the topographic changes produced by mining operations are also a result of the development of the local economy. Thus, annual monitoring of the mining area can provide information about the strategies of the economy and geo-environmental fortification (Zhao et al. 2018). Careful planning with suitable mitigation measures can be converted the local landscape of mining sites into a vegetation cover, water and wildlife century etc.

4. Conclusions

Space-born built methodology for calculating the changes in SQCA is presented and beneficial for the assessment in an area.With the help of Google Earth images, the change was found to be about 277.64% for the last 18 years (2003-2021). SQCA activities would be dangerous without proper planning/ management. The variability and pressure on land resources due to stone quarry and crushing activities has been recorded and found in linear increments during the period of time. The study showed that there was heavy exploitation of stone from quarry sites during 2003-2008. The derelict ponds form appearance as a result of rigorous quarrying and are resulting in environmental degradation which are dangerous to both human and surroundings.The prospective advantage of annual monitoring over the period and support to make the possible preparations/ management for destructive mining operations.

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