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Remote sensing and GIS based approach to evaluate the impact of stone quarrying and crushing activities on land resources

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Abstract

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Keywords

GIS, Google Earth images, impact assessment, land resources, remote sensing, stone quarrying

Erratum

Author affiliation corrected: from "School of Study in Earth Science" to "School of Studies in Earth Science".

RESEARCH ARTICLE

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Abstract

The land is one of the most treasures to support life, like food, fibre, medicine, and minerals, etc. Stone quarrying is one of the key elements which supports socio-economic development and industrial expansion. RS and GIS play an important role in environmental assessment to monitor the stone quarries and related activities for time to time. The present study was carried out to evaluate the impact of stone quarrying and crushing activities (SQCA) on land resources. Therefore, matrix change analysis of 2021, 2015, 2008 and 2003 were used for change detection. High-resolution Google Earth Pro images were used for the assessment of spatial as well as temporal changes caused by stone quarries and associated activities, which result in land use/land cover changes. The results show that the temporal changes in and around the quarrying sites over 18 years have contributed to dynamic changes in land use/land cover. According to the study, damaging mining operations have grown in the area. SQCA are mostly carried out on agricultural land as well as wasteland, which decreases about 18.44% and 59.89% during the study period. Abandoned pits left without reclamation converted to derelict ponds degrading the landscape and becoming dangerous for humans and the ecosystem.

Keywords: GIS, Google earth images, impact assessment, land resources, remote sensing, stone quarrying

1. Introduction

Rocks play a crucial role in a country's industrial development, social progress, and economic prosperity. Rocks are finite and non-renewable in nature. Once a mineral was extracted from the soil, it was lost incessantly, not just for present generations but also for all future generations [1]. Mineral resource mining and exploitation have a significant influence on water, biological resources, air, and land, as well as the socio-economic condition of the surrounding population. It primary focus is the environmental challenges, like these the surface mining industries of Jhansi are facing nowadays. The extent of the impact depends on the type and intensity of mining operations, as well as the geological and geomorphological context. It causes significant damage to the earth's landscape and ecological ecosystems [2].

Quarrying is necessary to obtain stones not provided through agricultural or artificial sources from land. Since prehistoric times, stone mining and crushing have been a social activity. To remove required materials, modern stone quarrying and crushing procedures include excavating or blasting for rock formations. Mining activities of any kind typically have a negative influence on land resources and the topography of mining sites. Unscientific quarrying and crushing endangers the ecosystem, reducing natural resources and biodiversity. The environment in and surrounding quarrying operations is being obliterated by the problems of abandoned material dumps [3]. Quarrying and open-cast mining entail the excavation of massive pits on the ground surface to recover surficial and superficial deposits, as well as the blasting of surface rocks and inorganic deposits to remove the material. The degree to which these processes are mechanised is largely determined by the value of the mineral resources and the output quality and quantity. These actions leave a lasting imprint on the environment

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[4]. The effects of quarrying can eventually result in larger-scale topographical changes, environmental changes, and biodiversity loss. As a result, it is critical to put in place a solid exploration, exploitation, and development strategy to get the most out of minerals and rocks. From prehistoric times, humanity has exploited rocks as the primary construction material from the earth's crust.

Land Resources refer to a clearly defined region of the earth's surface that encompasses all components of the biosphere closely overhead or underneath the surface, such as climate, landforms, surface hydrology/sedimentary layers, groundwater and geo-hydrological reserve, built-up, vegetation and livestock [5]. Every human settlement requires land as a basic natural resource. It is the foundation of key financial activity and serves as a valuable resource for farmers. The land is mankind's most precious resource; it supplies minerals, medicine, fibre, food, etc. It is made up of a combination of inorganic and organic components and serves as a landfill for much of the trash produced by modern society. The availability of land resources has a long-term impact on socioeconomic growth. Land resources are crucial in affecting economic, social, and cultural advancement. Land resource definition is based on the interpretation of connected physical qualities as a basis for human activity, and dynamic factors of both the natural environment and the occupying civilization are taken into account in each given case. Because of the differences in both situations, particularly man's action in time and space, land has different purposes and/or values [6].

Remote sensing and GPS data integrated with geographic information systems (GIS) may help with a synoptic examination/analysis of how the earth's systems are changing at local, regional, and global stages. As a result, there was an opportunity for quick and precise access to data needed to examine such changes [7]. Remote sensing is the process of extracting statistics about the features presented on earth's surface from space, utilising electromagnetic radiation reflected or emitted from the earth's surface in one or more areas of the electromagnetic spectrum [8]. In order to capture reactions depending on diverse features existing on the earth's surface, remote sensing equipment's are utilised. The captured notes are then transported to a station for additional processing, interpretation, and analysing of data. To comprehend the recorded interpretations, produce information on the different land-use/land-cover aspects based on size, tone, shape, texture, and pattern, among other factors [8,9].

Because of its multispectral mode, synoptic perspective, and repeated coverage, the employment of remote sensing/GIS in stone quarrying and crushing activities as part of mining environmental research offers distinct benefits. Thanks to the advancement of high-resolution multispectral satellite data, imaging spectrometry is a viable approach for investigating the environmental impacts of stone quarrying and crushing activities. Remote sensing techniques have been effectively employed to monitor land use changes owing to opencast strip mining, the influence of underground mining and subsidence, the development of mine waste dumping, deforestation, and erosion related to mining operations [10]. Remote sensing with space-borne sensors was the gold standard for getting repeatable and synoptic measurements of spectral behaviour in a variety of situations. i.e., changes in land resources, soil, atmosphere and water, etc. Integrated GIS and remote sensing have previously been used to map the distribution of a variety of living, as well as their landscapes, ecosystems, bio-climatic conditions, etc. [11–16]. Remote sensing and GIS tools are also very much effective in evaluating the temporal changes in land resources.

2. Materials and methods

The materials and methods are the actions used to identify or analyse the problem/information about the study and preparation of datasets to help in deriving the appropriate solution to the problem. The quantitative method was used to assess the impact of stone quarrying and crushing activities on land resources. In this study, different land resource features were classified using multi-temporal google earth images. The resulting classified land resource features were compared accordingly. The following methodology was adopted to evaluate the impact of stone quarrying and crushing on land resources.

2.1. Study area

Jhansi district lies in the south-west portion of Uttar Pradesh, India. There are five tehsils under Jhansi District *viz.*, Jhansi, Mauranipur, Moth, Garautha, and Tehrauli. The northeastern part of tehsil Jhansi is primarily underlain by igneous rocks of Bundelkhand cratons consisting of gneiss and granites, which is quite suitable for quarry business. In this study, the impact of stone quarrying and crushing activities on land resources have been evaluated in a part of Jhansi tehsil (latitude: 25.440906N–25.471530N and longitude: 78.651440E to 78.697028E) and were determined using google earth images (Fig. 1).

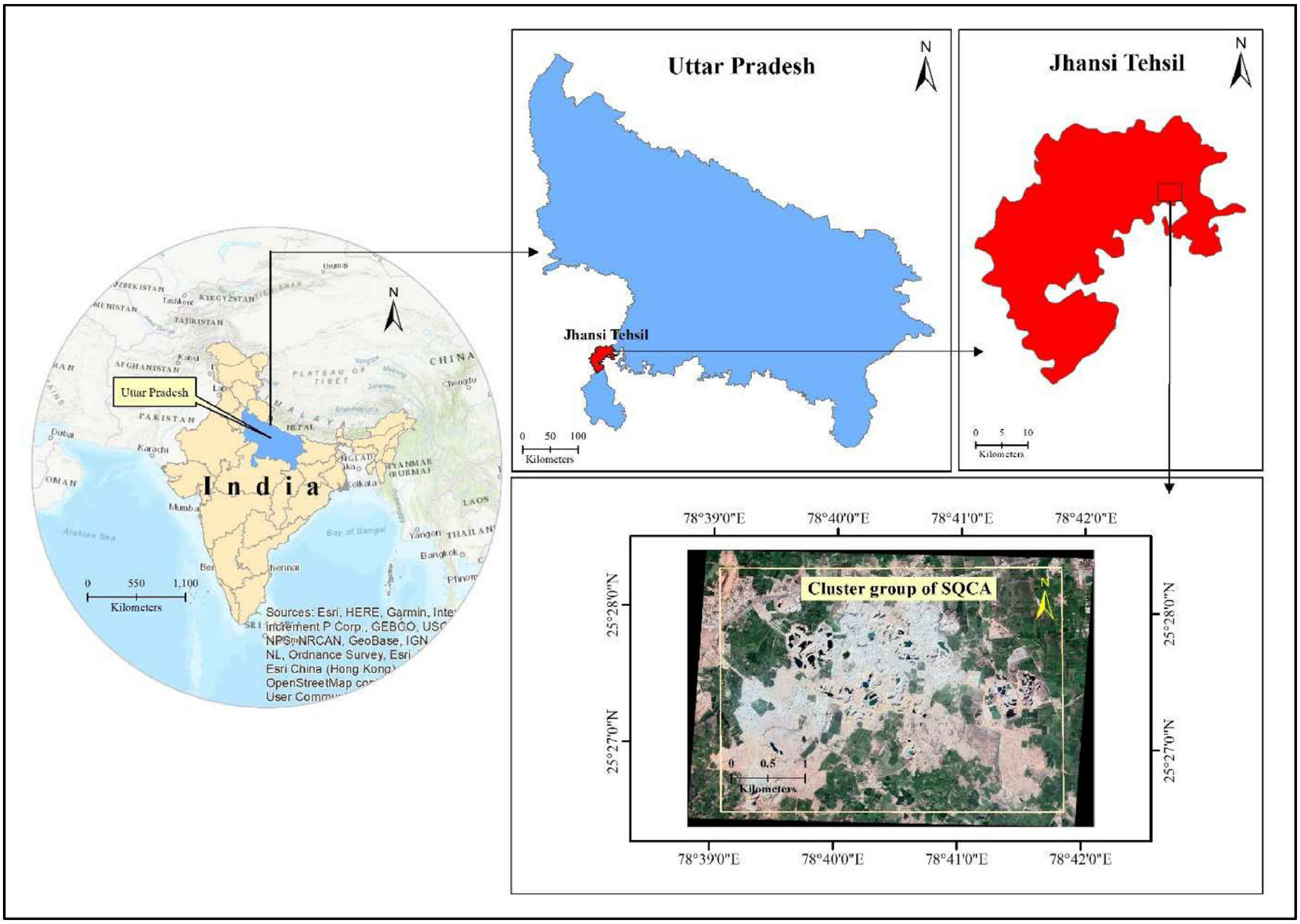

Fig. 1. Map showing study area (North-Eastern part of tehsil Jhansi, Uttar Pradesh, India).

2.2. Software used for the study

Google Earth Pro, ERDAS Imagine, ArcGIS, and MS Office software were used for data processing, thematic mapping, and the creation of geodatabase to evaluate the impact of stone quarrying and crushing activities on land resources.

2.3. Data collection

Due to the availability of high-resolution satellite images, modest tools and software such as Google Maps, Bing Maps, and Google Earth may be utilised efficiently for environmental research. Google Earth may be utilised in a variety of fields, including transportation, urban planning, time series analysis, and real-time research analysis using the Global Positioning System (GPS), environmental, climatic studies, and more [17]. Four temporal google earth images (Imagery Date: 31/12/2003, 29/05/2008, 14/03/2015, and 15/01/2021) in total have been downloaded using Google Earth Pro software for the identification of different land resource features.

2.4. Raster processing: google earth images

The process involves turning over the real-world position to each pixel of the raster file. Every point on the raster image can be determined as per the position on the Earth's surface. The transformed coordinates are stored in georeferenced file formats like GeoTIFF and *.img, etc. Georeferencing of temporal google earth images (for 2003, 2008, 2015, and 2021) have been done using ERDAS imagine software with well-disseminated Ground Control Points (GCP), collected from Google Earth Pro s/w and projected to the Geographic (Lat./Long.) WGS 1984 datum and re-projected to the Universal Transverse Mercator (UTM) WGS 1984 datum [18]. The study area was clipped by using the masking tool in ArcMap s/w.

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

The completion of the raster processing of raw data is followed by clipping of the study area for the different years. The final clipped temporal google earth images for 2003, 2008, 2015, and 2021 were stored for the study (Fig. 2).

2.6. Classification of land resources

Land use/land cover Level – II classification scheme developed by NRSC/ISRO [19] has been used for the classification of land resource features in a predefined cluster group of stone quarrying and crushing sites. As per this classification scheme for land resource features, built-up (urban), built-up (rural), mining/quarrying activities, agriculture plantation, cropland, forest/tree outside forest, waterbodies and wastelands including scrub and stony waste were mapped, for last 18 year (2003–2021), from geo-referenced multi-temporal google earth images with manual digitization method/technique using ArcMap software.

2.7. Change matrix analysis

The impact of SQCA on land resources was evaluated based on change matrix analysis. The change matrix analysis was performed on different land resource features present inside the polygon of SQCA from the current year, i.e., 2021, to past years 2015, 2008, and 2003; 2015 to 2008 and 2003; and 2008 to 2003. It is very much important to have a temporal dataset for the identification/classification of changing patterns in land use and land cover (LULC) over the specified years. The change matrix was done using the confusion matrix tool in ArcMap software. The amount of change refers to the extent to which the LULC size has grown or shrunk. A negative score indicates a reduction in LULC size, whereas a positive value indicates an increase in LULC size [20].

3. Results and discussion

This effort may assess the impact of stone quarrying and crushing activities (SQCA) on different land resources in the surroundings of quarry and crushing sites under selected cluster groups in a part of Jhansi Tehsil. Out of the total geographical area (1532.18 ha), stone quarry and crushing activities account for 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 and Fig. 3). The spatial distribution of temporal status of SQCA are shown in Fig. 4.

For the betterment of the result under the evaluation of the impact on land resources of 2003, 2008, and 2015 due to SQCA in 2021, 2015, and 2008, the study was classified into three measures accordingly:

3.1 Impact of SQCA in 2021 on land resources of 2015, 2008 and 2003.

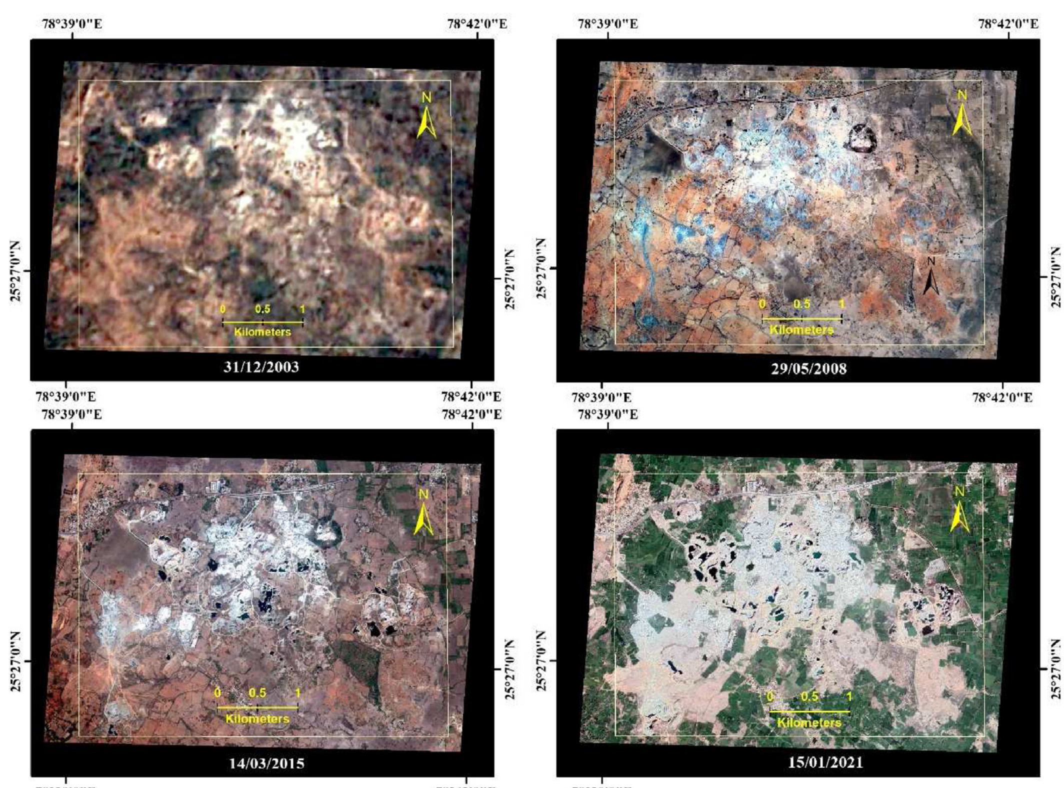

Fig. 2. Multi-date Google Earth images of the study area.

Table 1. Temporal status of stone quarrying and crushing activities.

Class Name	2003		2008		2015		2021	
	Hectare	%	Hectare	%	Hectare	%	Hectare	%
SQC activities	126.14	8.23	320.58	20.92	379.25	24.75	476.35	31.09

Area (%) was calculated out of total geographical area (1532.18 ha) of cluster group of stone quarrying and crushing sites.

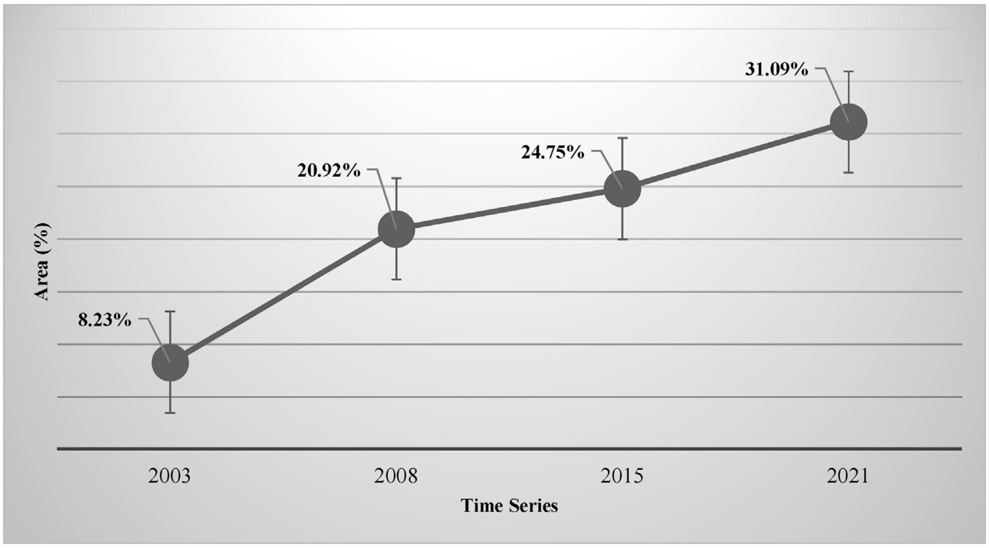

Fig. 3. Graphical representation: temporal status of stone quarrying and crushing activities.

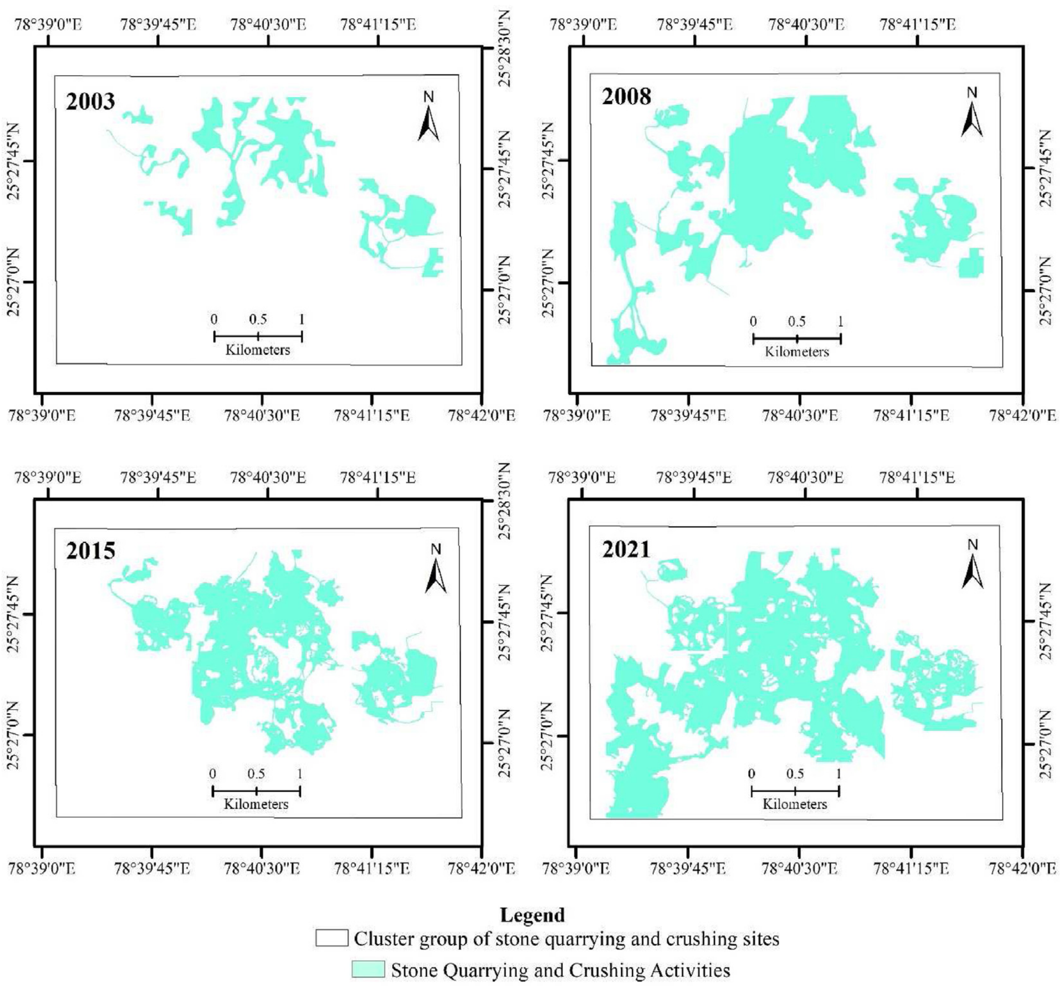

Fig. 4. Spatial distribution: temporal status of stone quarrying and crushing activities.

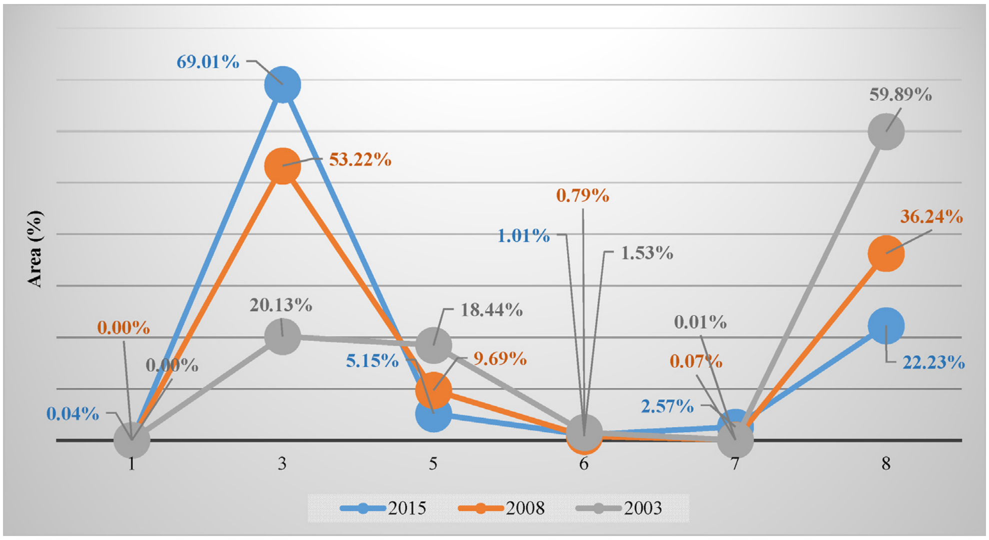

Fig. 5. Graphical representation: Impact of SQCA in 2021 on land resources of 2015, 2008, and 2003; 1 = Built-up (Urban); 3 = SQC activities; 5 = Cropland; 6 = Forest/Tree outside forest; 7 = Waterbodies; 8 = Wastelands; absent categories have zero value.

3.2 Impact of SQCA in 2015 on land resources of 2008 and 2003.

3.3 Impact of SQCA in 2008 on land resources of 2003.

3.1. Impact of SQCA in 2021 on land resources of 2015, 2008 and 2003

During the period from 2003 to 2021, the immovable area under SQC activities in respect of 2021 was found to be 328.74 ha (69.01%), 253.49 ha (53.22%), and 95.87 ha (20.13%) in 2015, 2008, and 2003, respectively. The area under SQC activities of 2021 has been converted from different land resources in 2015, 2008, and 2003 (Fig. 5). Built-up urban (0.18 ha; 0.04%), cropland (24.52 ha; 5.15%), forest/trees outside forest (4.8 ha; 1.01%), waterbodies (12.22 ha; 2.57%) and wastelands (105.89 ha; 22.23%) have been converted into SQCA in 2021 from 2015. In 2008, most of the area that was transformed to SQCA of 2021 is from cropland (46.16 ha; 9.69%), forest/trees outside forest (3.75 ha; 0.79%), waterbodies (0.32 ha; 0.07%) and wastelands (172.62 ha; 36.24%). It is observed that the same pattern was followed for 2003 as most of the area was transformed from cropland (87.83 ha; 18.44%), forest/trees outside forest (7.31 ha; 1.53%), waterbodies (0.06 ha; 0.01%) and wastelands (285.27 ha; 59.89%) into SQCA in 2021. The major conversion was found from the area of wastelands and cropland in each respective year to SQC activities in 2021 (Table 2). Figure 6 shows the thematic map of spatial distribution.

3.2. Impact of SQCA in 2015 on land resources of 2008 and 2003

During the period from 2003 to 2015, the fixed area under SQC activities in respect of SQCA in 2015 was found to be about 239.81 ha (63.24%) in 2008 and 94.90 ha (25.02%) in 2003. The area under SQCA in 2015 has been converted from mainly two categories of land resource of 2008, and 2003 (Fig. 7). Maximum area of about 55.54% (210.65 ha) and 28.61% (108.49 ha) were converted from wastelands of 2003 and 2008 respectively. The area under cropland, about 18% (68.26 ha) in 2003 and about 7.41% (28.11 ha) in 2008, has also been replaced by SQCA in 2015 (Table 3). Figure 8 shows the thematic map of spatial distribution.

Table 2. Impact of SQCA in 2021 on land resources of 2015, 2008, and 2003.

Year	Area	1	2	3	4	5	6	7	8	9
2015	Hectare	0.18	0.00	328.74	0.00	24.52	4.80	12.22	105.89	476.35
	%	0.04	0.00	69.01	0.00	5.15	1.01	2.57	22.23	100.00
2008	Hectare	0.01	0.00	253.49	0.00	46.16	3.75	0.32	172.62	476.35
	%	0.00	0.00	53.22	0.00	9.69	0.79	0.07	36.24	100.00
2003	Hectare	0.01	0.00	95.87	0.00	87.83	7.31	0.06	285.27	476.35
	%	0.00	0.00	20.13	0.00	18.44	1.53	0.01	59.89	100.00

1 = Built-up (Urban); 2 = Built-up (Rural); 3 = SQC activities; 4 = Agriculture plantation; 5 = Cropland; 6 = Forest/Tree outside forest; 7 = Waterbodies; 8 = Wastelands; 9 = Total area under SQCA in 2021.

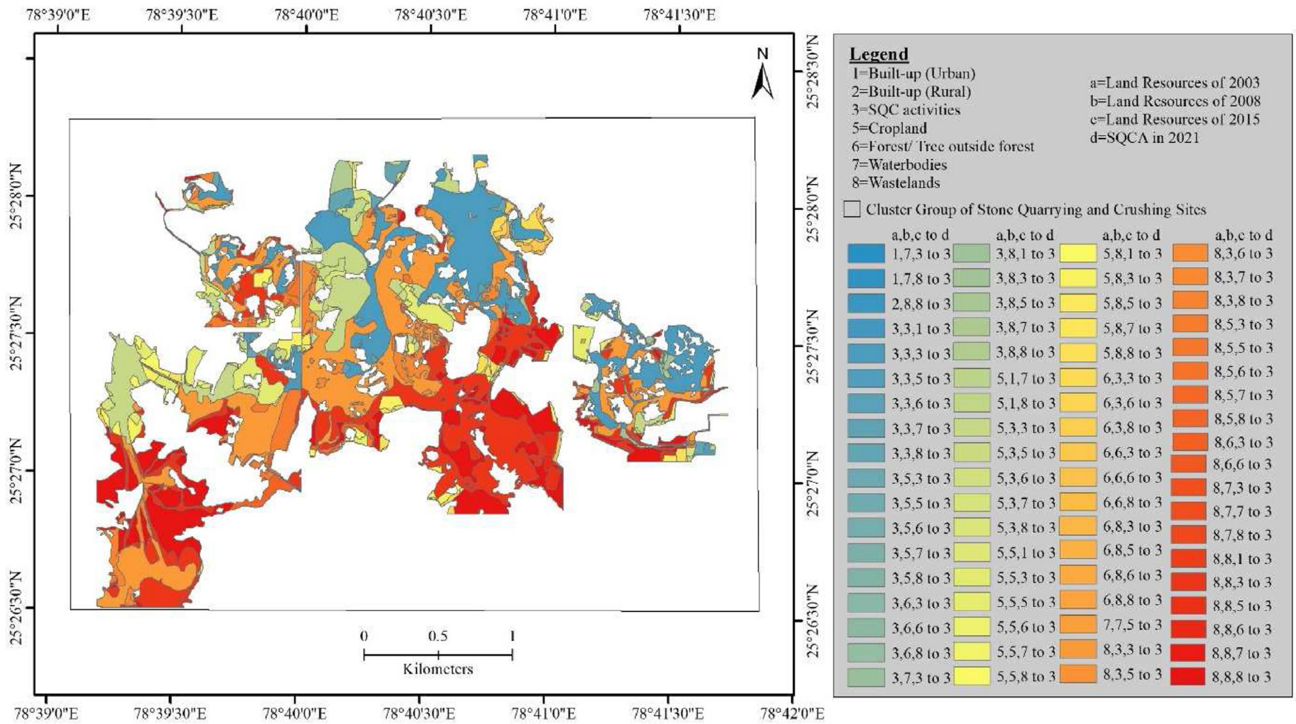

Fig. 6. Spatial distribution: impact of SQCA in 2021 on land resources of 2015, 2008, and 2003.

3.3. Impact of SQCA in 2008 on land resources of 2003

During the period, the secure area under SQCA was delineated about 110.76 ha (34.55%) from 2003 to 2008 (Fig. 9). The area under SQC activities in 2008 has been converted from built-up rural (0.1 ha; 0.03%), cropland (64.66 ha; 20.17%), forest/trees outside forest (4.71 ha; 1.47%), and wastelands (140.34 ha; 43.78%) of land resource of 2003. The maximum area (about 43.78%) of the wasteland of 2003 has been replaced by SQC activities in 2008 (Table 4). Figure 10 shows the thematic map of spatial distribution.

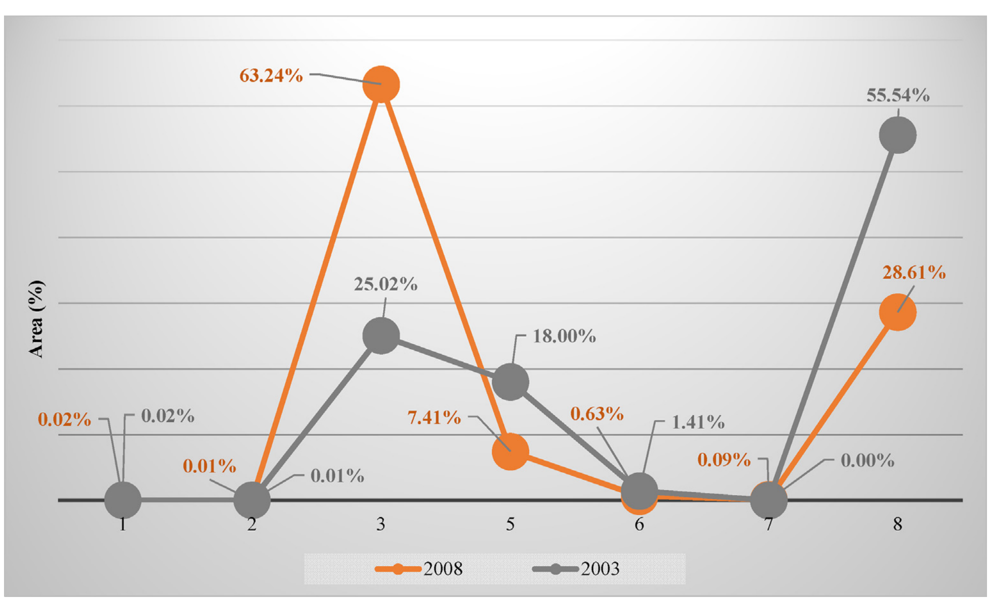

Fig. 7. Graphical representation: impact of SQCA in 2015 on land resources of 2008 and 2003; 1 = Built-up (Urban); 2 = Built-up (Rural); 3 = SQC activities; 5 = Cropland; 6 = Forest/Tree outside forest; 7 = Waterbodies; 8 = Wastelands; absent categories have zero value.

Table 3. Impact of SQCA in 2015 on land resources of 2008 and 2003.

Year	Area	1	2	3	4	5	6	7	8	9
2008	Hectare	0.06	0.02	239.81	0.00	28.11	2.38	0.35	108.49	379.22
	%	0.02	0.01	63.24	0.00	7.41	0.63	0.09	28.61	100.00
2003	Hectare	0.07	0.02	94.90	0.00	68.26	5.36	0.00	210.65	379.26
	%	0.02	0.01	25.02	0.00	18.00	1.41	0.00	55.54	100.00

1 = Built-up (Urban); 2 = Built-up (Rural); 3 = SQC activities; 4 = Agriculture plantation; 5 = Cropland; 6 = Forest/Tree outside forest; 7 = Waterbodies; 8 = Wastelands; 9 = Total area under SQCA in 2015.

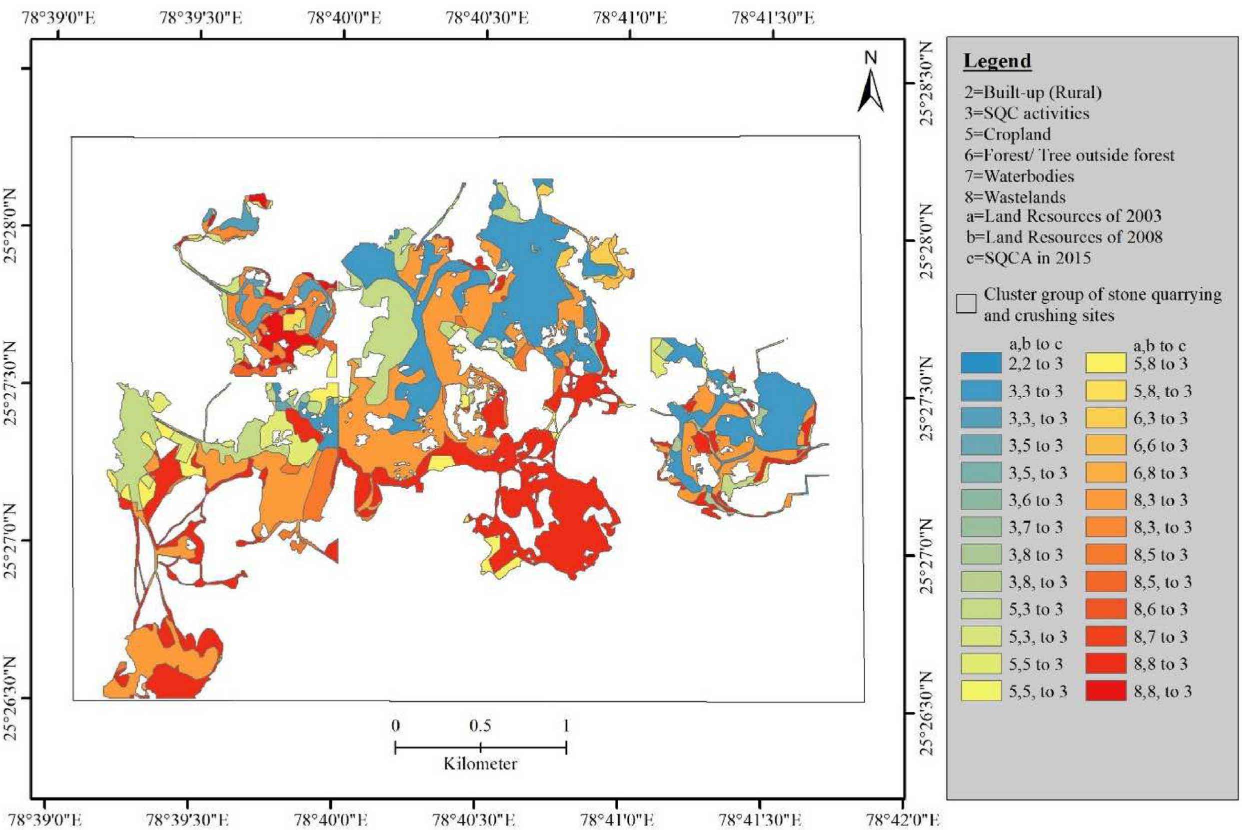

Fig. 8. Spatial distribution: impact of SQCA in 2015 on land resources of 2008 and 2003.

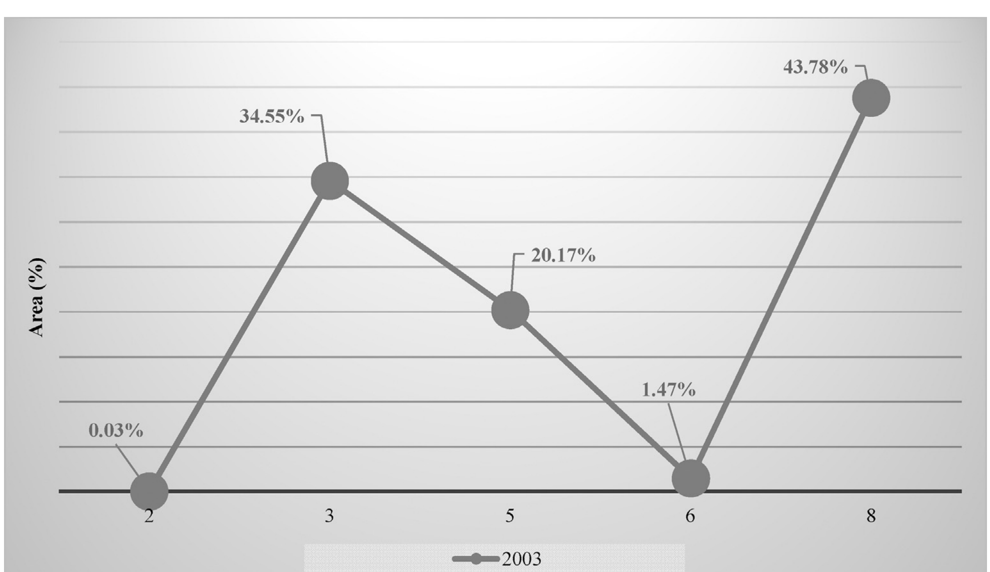

Fig. 9. Graphical representation: Impact of SQCA in 2008 on land resources of 2003; 2 = Built-up (Rural); 3 = SQC activities; 5 = Cropland; 6 = Forest/Tree outside forest; 8 = Wastelands; absent categories have zero value.

Table 4. Impact of SQCA in 2008 on land resources of 2003.

Year	Area	1	2	3	4	5	6	7	8	9
2003	Hectare	0.00	0.10	110.76	0.00	64.66	4.71	0.00	140.34	320.57
	%	0.00	0.03	34.55	0.00	20.17	1.47	0.00	43.78	100.00

1 = Built-up (Urban); 2 = Built-up (Rural); 3 = SQC activities; 4 = Agriculture plantation; 5 = Cropland; 6 = Forest/Tree outside forest; 7 = Waterbodies; 8 = Wastelands; 9 = Total area under SQCA in 2008.

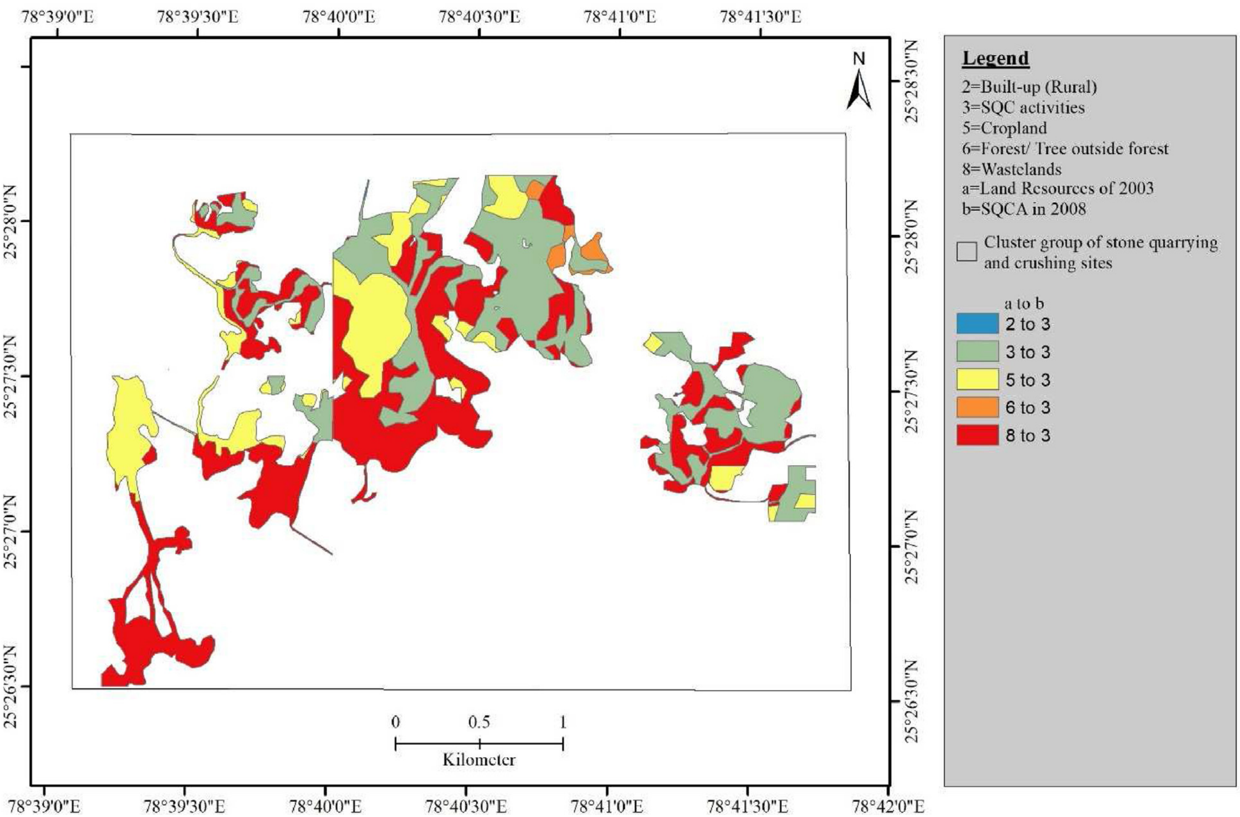

Fig. 10. Spatial distribution: impact of SQCA in 2008 on land resources of 2003.

The results show that the major conversion of land resources was from wastelands (59.89% in 2003, 36.24% in 2008, and 22.23% in 2015) and cropland (18.44% in 2003, 9.69% in 2008, and 5.15% in 2015) to SQC activities in 2021. In conformity with the findings, destructive quarrying activities have been increased. These increments has remunerated by the loss or decrease of different land use features. Quarrying operations, as well as the development of storage facilities, office facilities and the opening of access roads to the quarries, all contribute to the loss of land resources [21–24]. As the quarry grows, terraces form, leaving visible scars of great colour contrast, diminishing the landscape's aesthetic appeal and degrading the scenic quality of places [25–28]. Dust and noise from crushing stone and quarrying activities alter existing ecosystems, causing local hydrological and geological regimes to be disrupted [29]. In addition, these activities alter the substratum, and landscape patterns, destroy natural habitat, disturb natural succession, and alter genetic resources [30]. Increased SQC activities have resulted in a variety of social challenges and conflicts in many parts of the world, including issues of land use, socio-cultural survival and community displacement, cultural site damage, self-determination, resource control, and the formation of ghost towns [31]. 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

Remote sensing and GIS, with the help of google earth images, are very useful to evaluate the impact

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of SQCA on land resources. The study concludes that most of the area of agricultural land and wastelands takes has been converted into SQCA for the past 18 years (2003–2021). Most of the wastelands have been transformed into derelict ponds like appearance as a result of rigorous quarrying. These will result in environmental degradation, which can be dangerous to both humans and the surrounding ecosystem.

Ethical statement

The authors stated that the study was accompanied according to ethical standards.

Funding body

None.

Conflicts of interest

The authors asserted no conflict of interest.

Acknowledgments

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Appendix

Appendix — A. LULC Change matrix analysis 2003-21.

2003–2021		SQCA in 2021	Grand Total
2003	Built-up (Urban)	0.01	0.01
	Built-up (Rural)	0.00	0.00
	SQCA	95.87	95.87
	Agriculture plantation	0.00	0.00
	Cropland	87.83	87.83
	Forest/Tree outside forest	7.31	7.31
	Waterbodies	0.06	0.06
	Wastelands	285.28	285.28
	Grand Total	476.36	476.36

Appendix — B. Change matrix analysis 2008-21.

2008–2021		SQCA in 2021	Grand Total
2008	Built-up (Urban)	0.01	0.01
	Built-up (Rural)	0.00	0.00
	SQCA	253.49	253.49
	Agriculture plantation	0.00	0.00
	Cropland	46.16	46.16
	Forest/Tree outside forest	3.75	3.75
	Waterbodies	0.32	0.32
	Wastelands	172.62	172.62
	Grand Total	476.35	476.35

Appendix — C. Change matrix analysis 2015-21.

2015–2021		SQCA in 2021	Grand Total
2015	Built-up (Urban)	0.18	0.18
	Built-up (Rural)	0.00	0.00
	SQCA	328.74	328.74
	Agriculture plantation	0.00	0.00
	Cropland	24.52	24.52
	Forest/Tree outside forest	4.80	4.80
	Waterbodies	12.22	12.22
	Wastelands	105.90	105.90
	Grand Total	476.36	476.36

Appendix — D. Change matrix analysis 2003-15.

2003–2015		SQCA in 2015	Grand Total
2003	Built-up (Urban)	0.07	0.07
	Built-up (Rural)	0.02	0.02
	SQCA	94.90	94.90
	Agriculture plantation	0.00	0.00
	Cropland	68.26	68.26
	Forest/Tree outside forest	5.36	5.36
	Waterbodies	0.00	0.00
	Wastelands	210.65	210.65
	Grand Total	379.26	379.26

Appendix — E. Change matrix analysis 2008-15.

2008–2015		SQCA in 2015	Grand Total
2008	Built-up (Urban)	0.06	0.06
	Built-up (Rural)	0.02	0.02
	SQCA	239.81	239.81
	Agriculture plantation	0.00	0.00
	Cropland	28.11	28.11
	Forest/Tree outside forest	2.38	2.38
	Waterbodies	0.35	0.35
	Wastelands	108.49	108.49
	Grand Total	379.22	379.22

Appendix — F. Change matrix analysis 2003-08

2003–2008		SQCA in 2008	Grand Total
2003	Built-up (Urban)	0.00	0.00
	Built-up (Rural)	0.10	0.10
	SQCA	110.76	110.76
	Agriculture plantation	0.00	0.00
	Cropland	64.66	64.66
	Forest/Tree outside forest	4.71	4.71
	Waterbodies	0.00	0.00
	Wastelands	140.34	140.34
	Grand Total	320.57	320.57

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