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Applications of Sentinel-2 Satellite Imagery in India & Indian Mining Industry – A Scoping Review with Bibliometric Analysis

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Abstract

Use of satellite imagery for various applications is being done since last 50 years. Being able to monitor large areas, the remote sensing technology offers unmatched potential for remote monitoring of the natural resources. There is a lack of scoping reviews that consolidates the status of applications of Sentinel-2 imagery in India in general and Indian Mining Sector in particular. This scoping and bibliometric review was, therefore, conducted to map the applications of the Sentinel-2 high resolution multispectral satellite imagery in India. The evidence was synthesized using the approach called as Scoping Review with Bibliometric Analysis (ScoRBA). The study was conducted on Scopus database which identified 223 documents. The documents were processed using MS Excel and VOSviewer for bibliometric analysis. The review revealed that Sentinel-2 satellite imagery has been used in India for various diverse applications including agriculture, assessment of land use land cover, forestry, mining, assessment of water quality, flood management, urban planning, disaster risk management etc. The review further established the substantial research gap due to underutilization of the freely available high-resolution Sentinel-2 imagery by the Indian Mining Sector. The review provides the answers to the three specific research questions. This research is different from earlier research as it not only synthesizes the current status of use of Sentinel-2 imagery in Indian context but also provides clear direction for future research specifically focused on mining sector.

Keywords: sentinel-2, mining, scoping review, bibliometric analysis

1. Introduction

1.1 General

Use of satellite imagery for various applications is being done since last 50 years. The first satellite for continuous gathering of the remotely sensed data on worldwide basis was launched in the Year 1972 by National Aeronautics and Space Administration, United States of America **(Haack, 1982)**. Since then, the remote sensing technology has significantly contributed in

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monitoring of the earth's surface. The technology makes use of the spectral, spatial, temporal signatures and patterns of interaction of the light waves with features seen on the earth surfaces to discriminate the objects **(Navalgund et al., 2007)**. The continuous and fast paced developments in the field of Computer Science & Engineering and Electronics & Communication Engineering along with improvements in the sensor technology with availability of multispectral & hyperspectral sensors have greatly resulted in enhancement of the resolution of the satellite images. Further, the advancements in LIDAR & RADAR Technologies also provided the additional opportunities for collection of comprehensive and precise data pertaining to atmosphere, oceans and terrestrial surfaces **(Kemarau et al., 2025)**. These advancements along with free accessibility have resulted into use of satellite imagery for different applications. Being able to monitor large areas, the remote sensing technology offers unmatched potential for remote monitoring of the natural resources like forests, waterbodies, land use etc as well as human activities and resultant consequences like mining, agricultural expansion and urbanization **(Phiri et al., 2020)**.

The accuracy of the data analysis through satellite imagery depends on the spatial and spectral resolutions of the satellite. Higher the spatial and spectral resolution higher will be the quality of the imagery output.

Sentinel-2 Multi Spectral Imagery, which was introduced in the year 2015 by European Space Agency (ESA) and the European Union (EU), has a higher spatial resolution ranging from 10m to 60m and higher spectral resolution through thirteen bands ranging from Coastal Aerosol to Short-Wave Infra-Red. Further, the other characteristics of Sentinel-2 data like low radiometric calibration, wide swath, shorter re-visit time and free access policy aids in producing requisite information to support different applications. The Sentinel-2 Imagery has been utilized for land monitoring including forests monitoring, vegetation monitoring, agriculture crops monitoring, environmental monitoring including carbon monitoring, natural disaster monitoring like floods, wild fires, landslides and also for military purposes **[(Kocaleva et al., 2020)]**.

During literature survey it is observed that Sentinel-2 Imagery is being used in India for various applications. However, inspite of the high technological potential being offered by Sentinel-2 Imagery, its direct use in the mining sector is still underutilized. Sustainability is a buzzword today. Specifically, the mining sector is under pressure for adoption of sustainable operations in all the stages of mining life cycle.

Application of high-resolution Sentinel-2 imagery offers huge opportunities for Indian Mining Sector not only in implementation of sustainable measures but also in aspects like Safety Management.

There is a lack of scoping reviews that consolidates the status of applications of Sentinel-2 imagery in India in general and Indian Mining Sector in particular. Accordingly, this scoping review intends to evaluate the applications of Sentinel-2 Satellite Imagery in India to addresses the following three specific research questions: 1) What are the applications for which Sentinel-2 Imagery is used in India? 2) What is the extent and nature of end-use applications for Sentinel-2 Satellite Imagery in Indian Mining Sector? and 3) What is the potential of Sentinel-2 Imagery for enhancing the sustainability of Indian mining operations?

The study is needed in order to ascertain the use of remotely sensed data at higher spatial and spectral resolutions in India in general and in Indian Mining Industry in particular to facilitate decision making at various stages of the mining life cycle. Further, the study is needed to identify the research gap, if any, related to the research work on the subject topic. Identification of research gap would pave the way for further research on the topic.

This paper is well structured as per standard practice. Section 2 outlines the materials and the methods used. Section 3 summarizes the results and analysis of the scoping and bibliometric review of selected studies. Section 4 provides the conclusion and recommended further areas of research in the field. Section 5 provides the details of the limitations of the study.

1.2 Rationale behind the Scoping Review with Bibliometric Analysis

The main characteristics of the scoping reviews are, they systematically identify the range of the available evidence on a particular topic irrespective of its sources, acts as a precursor to a detailed systematic review and identify the research gap **(Munn et al., 2022)**.

We intend to explore and find out the evidence towards applications of Sentinel-2 Satellite Imagery specifically in India and in the context of Indian Mining Industry. Thus, the research is exploratory in nature. We have not encountered any scoping review with bibliometric analysis specifically on applications of Sentinel-2 Imagery in the Indian context. The objective behind the research is to gather the evidence in a systematic manner in accordance with the prescribed guidelines and identify the research gap. It is focused on key themes and not detailed synthesis of the literature. We intend to understand and present the knowledge evidence available on the research topic through quicker but rigorous methodology. This will facilitate identification of the gaps and recommend future work to be addressed on the research topic.

Further, bibliometric analysis aids in analyzing the literature available on the topic using scientific approach. Its aids in mapping the citation trends, author networks, institutional networks and author's & index keyword co-occurrence patterns using sophisticated software. However, to facilitate a comprehensive and narrative driven mapping of the literature, combination of scoping review with bibliometric analysis is advisable. This approach is called as Scoping Review with Bibliometric Analysis (ScoRBA) **(Yuniarti et al., 2025)**. It aids not only in capturing the volume of the literature but also helps in evaluating the identification, analysis and interpretation of the specific patterns associated with the research topic.

2. Materials and Methods

This section provides the details of the methodology adopted for undertaking this review. It includes details pertaining to the selected database repository, justification for selection and the research methodology used for identification of the records for methodological review.

The proposed research methodology is akin to the methodology established under Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) for Scoping Reviews (PRISMA-ScR). We have presented this review in accordance with the reporting items stipulated in the PRISMA-ScR checklist which was downloaded from https://www.prisma-statement.org/scoping on 28-09-2025. However, we have neither established nor registered any specific review protocol for this scoping review.

Further, as the objective behind this scoping review is exploratory in nature and not the rigorous evaluation of selected literature, we have not conducted any critical appraisal of the selected studies. For bibliometric analysis, we have used the open-source software viz. VOSviewer Version 1.6.20 developed by Nees Jan Van Eck and Ludo Waltman at Leiden University, The Netherlands in 2009. The VOSviewer offers the opportunity for more comprehensive analysis of large sample data with better visualization capability then other similar bibliometric software **(Ju et al., 2024)**.

A plethora of literature is available on the internet in the context of use of satellite imagery in general and also Sentinel-2 Satellite Imagery in particular. Therefore, considering the huge data available on research topic, we decided to follow a structured approach for identification, collection and review of the literature which are relevant to the selected title. Accordingly, we followed the Research Methodology as illustrated in **Figure 1**.

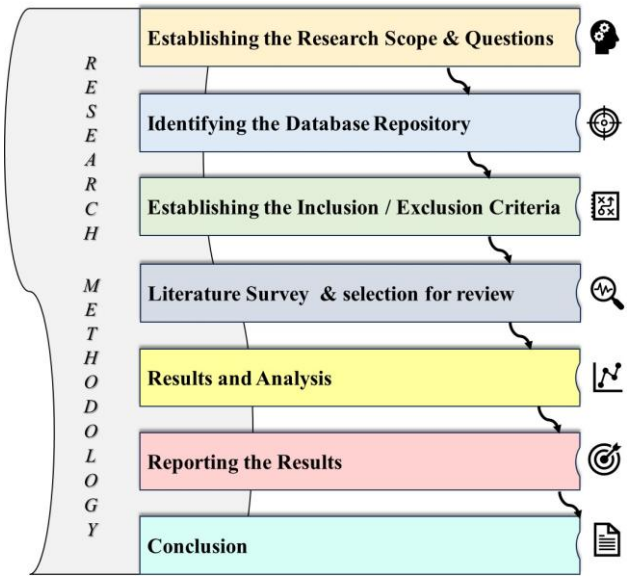


Fig. 1 Research Methodology

2.1 Establishing the Research Scope and Questions

While undertaking the literature review it is observed that the use of remote sensing data through satellite imagery is being done for monitoring, understanding and managing the earth resources since last five decades. As such thousands of the research papers based on landsat imagery and remote sensing data are available with various research depositories. The research work covers a number of applications for remote sensing data in various fields like agriculture, forestry, land use/land cover classification, urban heat land phenomenon, environmental pollution etc. In such cases, establishing the research scope and research questions is, therefore, of utmost importance to ensure practicality of the research topic. The main aim of this scoping review is to explore and find out the evidence towards use of Sentinel-2 Satellite Imagery specifically in India and in the context of Indian Mining Industry.

Accordingly, considering the specific requirement of the research topic, we have framed three research questions for answering through this review. These are 1) What are the applications for which Sentinel-2 Imagery is used in India? 2) What is the extent and nature of end-use

applications for Sentinel-2 Satellite Imagery in Indian Mining Sector? and 3) What is the potential of Sentinel-2 Imagery for enhancing the sustainability of Indian mining operations?

The answers to the research questions would throw a light on the importance of the Sentinel-2 Imagery and its contribution in India and in Indian Mining Sector. Further, the study would help in identifying the research gaps and need for future research.

2.2 Identifying Database Repository

For undertaking the review, a number of database repositories were initially searched. It was observed that the availability of the literature is heterogenous in nature consisting of books, chapters, research papers, research articles, research reports, website sources and other forms of the documents.

Further, the data exported from different database repositories have different metadata under different fields and/or tags. Also, the data structures and the file formats are different for different database repositories **(Nowakowska, 2025)**. Though manual cleaning of such data is always possible, for large datasets there are inevitable chances of occurrence of errors in the data cleaning process. Therefore, to avoid the errors resulting from analysing heterogenous data from different database repositories, we decided to undertake this review through search of a single database repository viz. Scopus.

The Scopus Database Repository, owned and maintained by Elsevier, is a multidisciplinary comprehensive database repository. It covers more than 330 disciplines, 7000+ publishers, 25.30+ million open access items, 29100+ active journals. Only the peer-reviewed, scientific articles are made available on Scopus (Source:https://www.elsevier.com/products/scopus/content?dgcid=RN_AGCM_Sourced_300005030). Further, Scopus offers advanced and user-friendly search protocol. Also, Scopus provides all the relevant metadata required to undertake bibliometric analysis in the format acceptable to VOSviewer. Therefore, considering the global database status, widely used by researchers, comprehensive coverage of scientific literature across diversified topics and importantly free accessibility, we have selected the Scopus Database for undertaking this review.

2.3 Search and Inclusion / Exclusion Criteria

Subsequent to the identification of the source for literature, the inclusion and exclusion criteria for narrowing down the literature records was undertaken. The criteria were decided considering the scope of this review article and the specific research questions framed. Considering the focus of this review on applications of Sentinel-2 Imagery in India, the search strategy is devised to capture the research articles available in the Scopus database involving advanced search for combination of following keywords as a first step: TITLE-ABS-KEY (‘Sentinel-2’ OR ‘Sentinel 2’ OR ‘Sentinel-2A’ OR ‘Sentinel 2A’ OR ‘Sentinel-2B’ OR ‘Sentinel 2B’’. As a second step, because this review is limited to applications of Sentinel-2 imaginary in the context of India, we decided to limit the literature with affiliation to India only. As a third step, we selected the language as ‘English’ and the time frame from year 2016 to 2025 as the launch of Sentinel-2 Satellite was done in the year 2015. The selected time frame

covers the last 10 years and represents relevance in applications of Sentinel-2 satellite imagery from its launch till date. Subsequently, the searched literature was subjected to multistage filtering process to select the literature most suitable for undertaking this scoping and bibliometric review.

2.4 Literature Survey and selection of literature for review

On the basis of the above methodology, we searched the Scopus database on 11-10-2025. The initial search result listed 17,743 records. Subsequently, in every next step, the we narrowed down the documents records by incorporating the limitations related to the country, language, period, document type etc. We implemented the PRISMA-ScR Methodology for entire process of selection of literature. The PRISMA Flow Chart illustrating the process indicating number of articles identified in the initial search and the number of articles selected for review is presented as **Figure 2**.

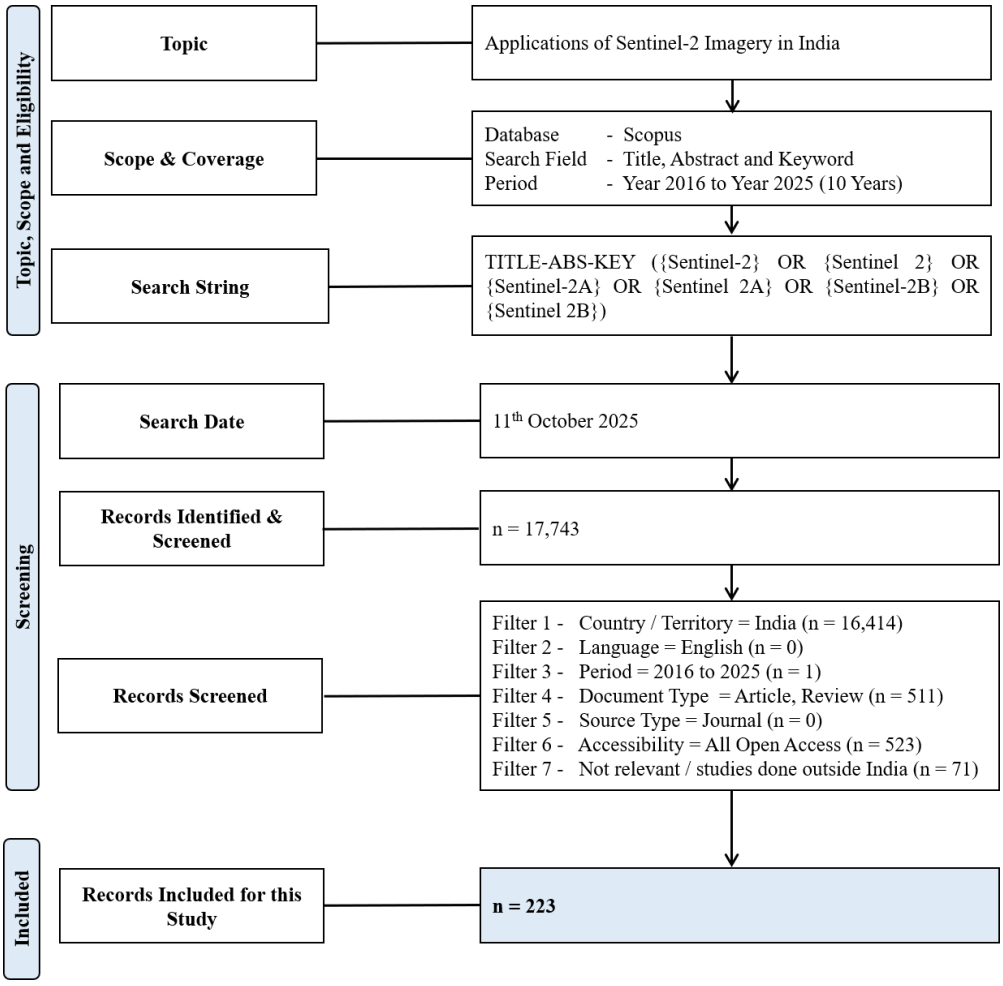


Fig. 2 PRISMA-ScR Flow Chart

Thus, document 223 records were identified for undertaking this detailed scoping review with bibliometric analysis by following a systematic structured approach to ensure presentation of the overall scenario on the topic of use of Sentinel-2 Satellite Imagery in India to facilitate the answer to the research question pertaining to its use in India in general and Indian Mining Industry in particular.

The records identified as above from the Scopus database were exported in Microsoft Excel (MS Office Home & Student 2019) in comma separated value (.csv) format for data cleaning to avoid use of erroneous data for analysis. The Scopus database provides authors data in two formats one with initials and one with full name. We used the full names as this avoids chances of mismatch and redundancy. Subsequently, the data cleaning, including for keywords, was undertaken by removing authors ids, blank spaces etc using the built-in functions of MS Excel along with the Fuzzy Lookup, a MS Excel Add-in, which identifies the similarities. Also, we prepared and used a thesaurus file for feeding the VOSviewer to avoid redundancy due to similar data like gee and Google Earth Engine, remote-sensing and remote sensing, NDVI and Normalized Difference Vegetation Index etc. This clean data was then subjected to VOSviewer for bibliometric analysis.

3. Results and Analysis

3.1 Publication Trend Analysis

Figure 3 presents the trend in publication output on the literature on Sentinel-2 Imagery in India. The polynomial fit trend line and the reasonably higher coefficient of determination (R^2) of 0.8542 establishes the increasing trend in use of Santinel-2 Satellite Imagery in India for various applications. The number of publications in the Year 2025 are less as the same are up to the date of data extraction. However, the same may increase till the completion of the year as per the trend. The decrease in number of publications in year 2025 may also be attributed to non-availability of research grants and/or the usual delays between conducting research and field studies & their eventual publication and availability in public domain.

Further, it is observed that initially for three years from the launch of Sentinel-2 Series Satellites i.e. from 2016 to 2018, the researchers with Indian affiliations have not taken the advantage of the availability of high-resolution Sentinel-2 data for various applications. However, since the year 2019 the use of Sentinel-2 imagery picked-up and is in rising trend.

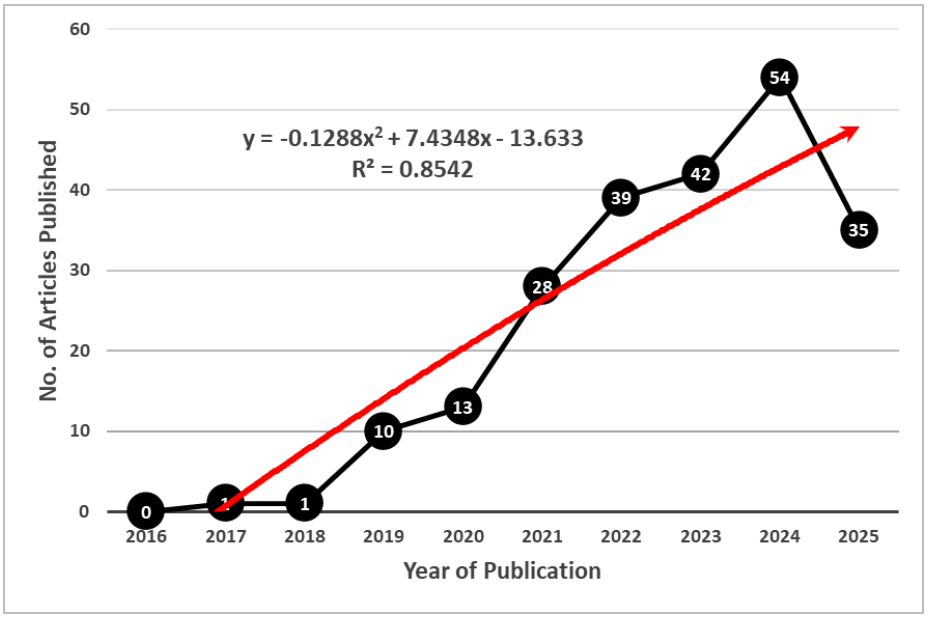


Fig. 3 Trend in publication output

The progressive increase in the research publications highlights the interest of the research community in India in the research related to use of Sentinel-2 Imagery.

3.2 Source Analysis

We found that 119 journals had published the selected 223 articles. The output of the leading eight journals which has published five or more than 5 articles were about 27.35% of the total volume of publications with Remote Sensing leading with 18 articles. The details are presented as **Figure 4**.

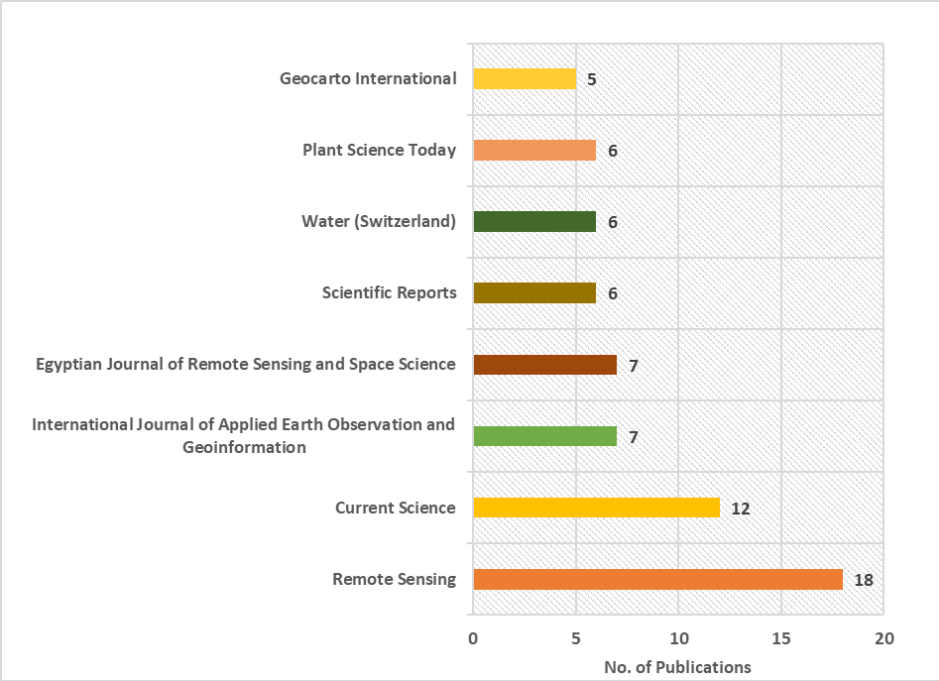


Fig. 4 Top Eight Sources for Research Articles

3.3 Co-authorship Analysis

The co-authorship analysis depicts the pattern of cooperation between or amongst the individual authors, organizations and country **(Nnedinma Umeokafor et al., 2022).** We used VOSviewer to generate the network analysis visualizations amongst the authors, organizations and countries. The parameters used for generating the maps are presented in **Table 1**.

Table 1

Parameters considered for generating Network Visualisation Maps

Type of Analysis	Co-authorship	Co-authorship	Co-authorship
Unit of Analysis	Authors	Organizations	Country
Counting Method	Full Counting	Full Counting	Full Counting
Minimum No. of Documents / Unit	1	1	1

Number of Items	853	358	42
Largest Set of connected items	58	214	42
Method of Normalization	Association Strength	Association Strength	Association Strength
Clustering Resolution	1	1	1

The network visualisation map for co-authorship by authors consisting of 58 largest set of connected authors is presented in **Figure 5.**

The authors have been indicated as nodes of the network and the link lines connects the authors to other authors. The size of the node represents the influence of the author whereas the thickness of the link lines depicts strength of the co-authorship relations. The distance between the nodes indicates the relatedness of the authors. The authors have been grouped in total eight clusters indicated with different colours in the visualisation.

The largest cluster (red) consists of 12 authors with 75 collaboration links and total link strength of 77 links. The second cluster (green) consists of 9 connected authors with 58 collaboration links and total link strength of 58 links. The other six clusters consist of balance 37 authors having collective 249 collaboration links and collective total link strength of 273 links. The visualization establishes that the authors viz. chauhan, prakash k., padalia, Hitendra, nandy, Subrata, patel, natvar r., salem, ali mohamed has a higher productivity.

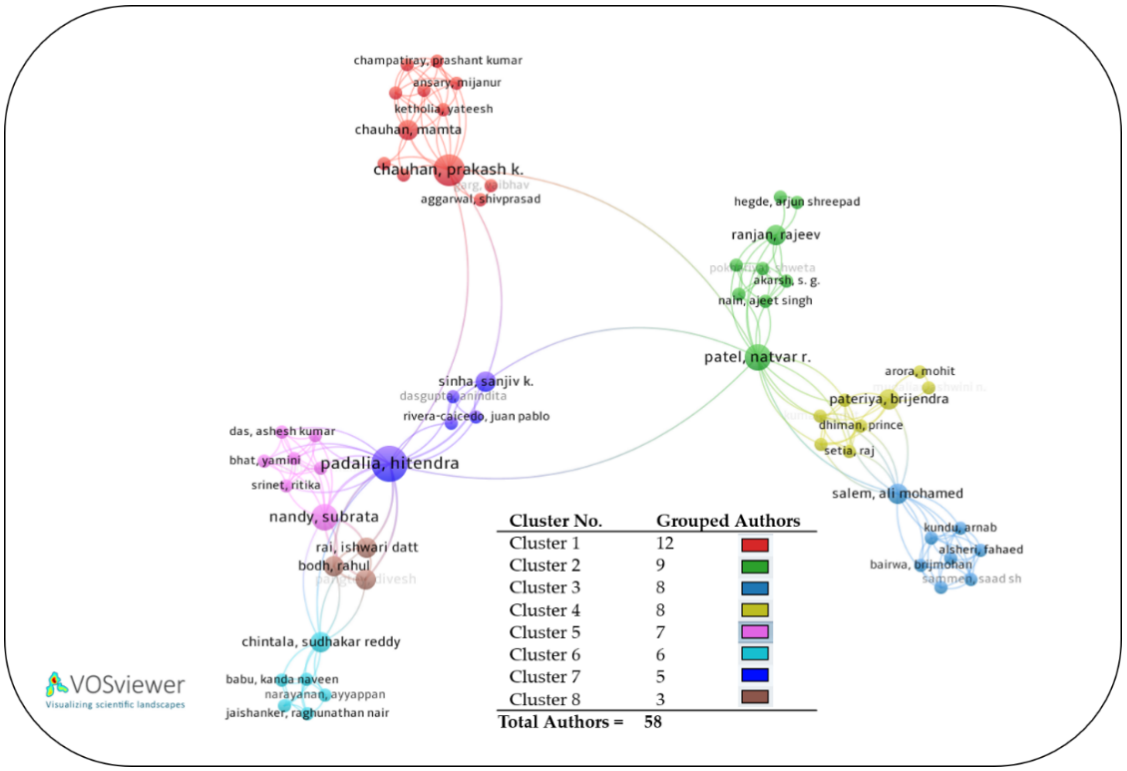


Fig. 5 Visualization of co-authorship by Authors

The quantitative summary of the impact of top eight authors is presented in **Table 2.**

Table 2

Quantitative Summary of the impact of top eight authors

Author	Links	Total link strength	Documents	Citations	Norm. Citations	Avg. Pub. Year	Avg. Citations	Avg. Norm. Citations
babu, kanda naveen	5	5	1	21	4.42	2024	21	4.42
jaishanker, raghunathan nair	5	5	1	21	4.42	2024	21	4.42
kakkara, athira	5	5	1	21	4.42	2024	21	4.42
kurian, ayushi	5	5	1	21	4.42	2024	21	4.42
narayanan, ayyappan	5	5	1	21	4.42	2024	21	4.42
aggarwal, shivprasad	2	2	1	150	2.62	2020	150	2.62
garg, vaibhav	2	2	1	150	2.62	2020	150	2.62
chintala, sudhakar reddy	10	10	2	24	4.72	2023.5	12	2.36

The average normalized citation score is the best measure of relative scientific impact. The table highlights that though the citation counts for the aggarwal, shivprasad and garg, vaibhav is higher, they are ranked 6th and 7th as other authors are more influential and have more impact on the basis of their higher average normalized citation scores.

The network visualisation map for co-authorship by organizations consisting of 214 connected organizations is presented in **Figure 6.**

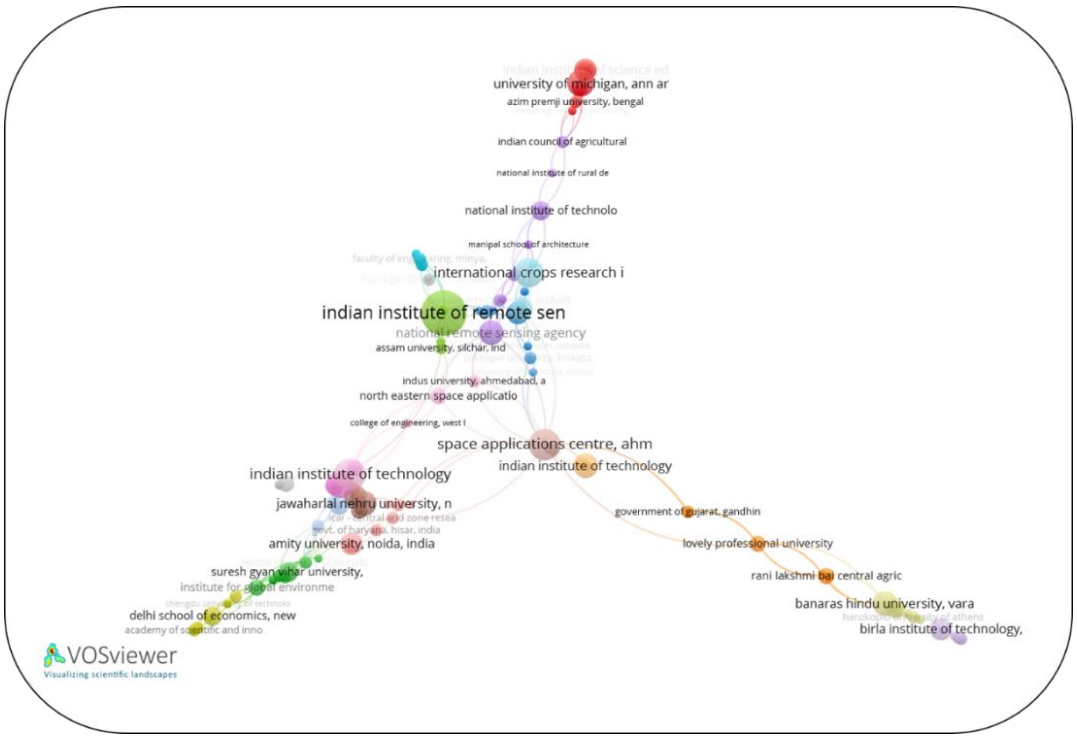


Fig. 6 Visualization of co-authorship by Organizations

We observed that the 214 connected organizations are grouped in twenty clusters. The clusters have been created on the basis of the research focus of the involved organizations like remote sensing, agriculture, environmental research etc.

Some of the prominent research organizations marking the major hub for research and collaboration & paper publications are the Indian Institute of Remote Sensing, Dehradun, Space Applications Centre, Ahmadabad, National Remote Sensing Agency, Hyderabad, Indian Agricultural Research Institute, Delhi, Banaras Hindu University, Varanasi. Also, it is observed that role of Indian Institute of Technology, Bombay and Indian Institute of Technology, Roorkee also have significant collaboration across the research domain. The Indian Institutions have strong links to international institutions like University of Michigan, United States, Institute for Global Environmental Strategies, Japan etc.

The visualisation network map for organizations reveals a robust and tight clustered collaboration network of organizations involved in diverse research fields with certain key institutions playing a major role in development of connections between them. The quantitative summary of the impact of the organizations on research related to remote sensing is provided in **Table 3**.

Table 3

Quantitative Summary of the impact of top ten organizations

Organization	Links	Total link	Documents	Citations	Norm. Citations	Avg. Pub. Year	Avg. Citations	Avg. Norm.

		strength						**Citations**
International Crops Research Institute for the Semi-Arid Tropics, Patancheru	15	18	8	70	12.53	2023.50	8.75	1.57
National Remote Sensing Agency, Hyderabad	11	11	6	103	8.63	2022.67	17.17	1.44
University of Michigan, USA	18	26	7	133	7.77	2022.43	19.00	1.11
Graphic Era University, Dehradun	8	9	7	56	7.52	2023.29	8.00	1.07
Jawaharlal Nehru University, Delhi	11	11	6	146	6.22	2021.17	24.33	1.04
IIT, Kharagpur,	9	10	6	170	6.17	2022.17	28.33	1.03
Banaras Hindu University, Varanasi	16	17	6	52	5.88	2022.67	8.67	0.98
IIT Roorkee	14	15	9	85	8.40	2023.00	9.44	0.93
Space Applications Centre, Ahmedabad	22	25	9	157	7.93	2021.89	17.44	0.88
Indian Institute of Remote	20	20	16	299	11.06	2022.44	18.69	0.69

Sensing, Dehradun								

The table highlights that though the number of documents & citations are higher in case of Indian Institute of Remote Sensing, Dehradun, it is ranked 8th as other organizations are more influential and have more impact on the basis of their higher average normalized citation scores. With total link strength of 25, the Space Applications Centre, Ahmadabad is the most central and connected organization in the Indian context. The average publication year between 2021 to 2023 highlights the recent and active landscape.

The network visualisation map for co-authorship by country consisting of 42 connected countries is presented in **Figure 7.**

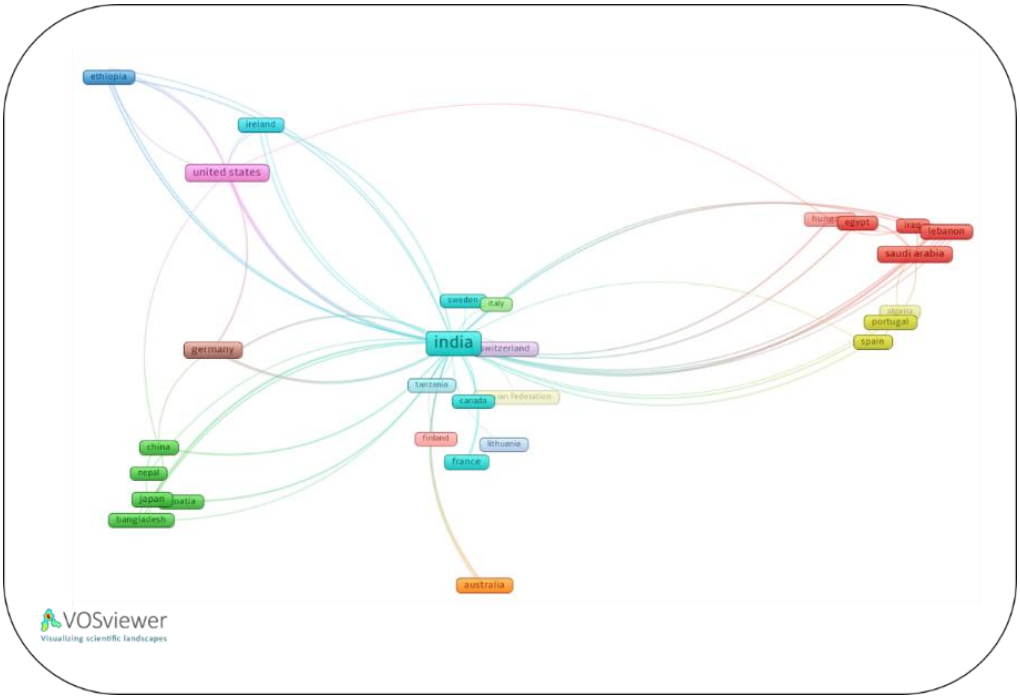


Fig. 7 Visualization of co-authorship by Country

We observed that the 42 connected countries are grouped in fifteen clusters. The clusters have been created on the basis of research interests, collaboration patterns and regional grouping within the dataset. The quantitative summary of the impact of top eight countries is presented in **Table 4.**

Table 4

Quantitative Summary of the impact of top eight countries

Country	Citations	Total Link Strength
India	3360	111
United States	551	30

Saudi Arabia	117	20
Germany	109	15
Lebanon	36	11
Japan	51	10
Iraq	1	9
Syrian Arab Republic	10	9

With total link strength of 111, the table highlights the connectivity of the Indian authors to several other authors belonging to diverse countries in the research related to use of remote sensing for various applications.

3.3 Co-occurrence Analysis for all Keywords (KW)

The study generated 1735 keywords from the selected 223 articles. We set the threshold limit of minimum five occurrences for the keywords for analysis with full counting method. The method of normalization was association strength. The set threshold resulted in generation of 58 keywords which were grouped in six clusters (indicated in different colors). The network visualisation map consisting of 58 connected keywords is presented in **Figure 8.**

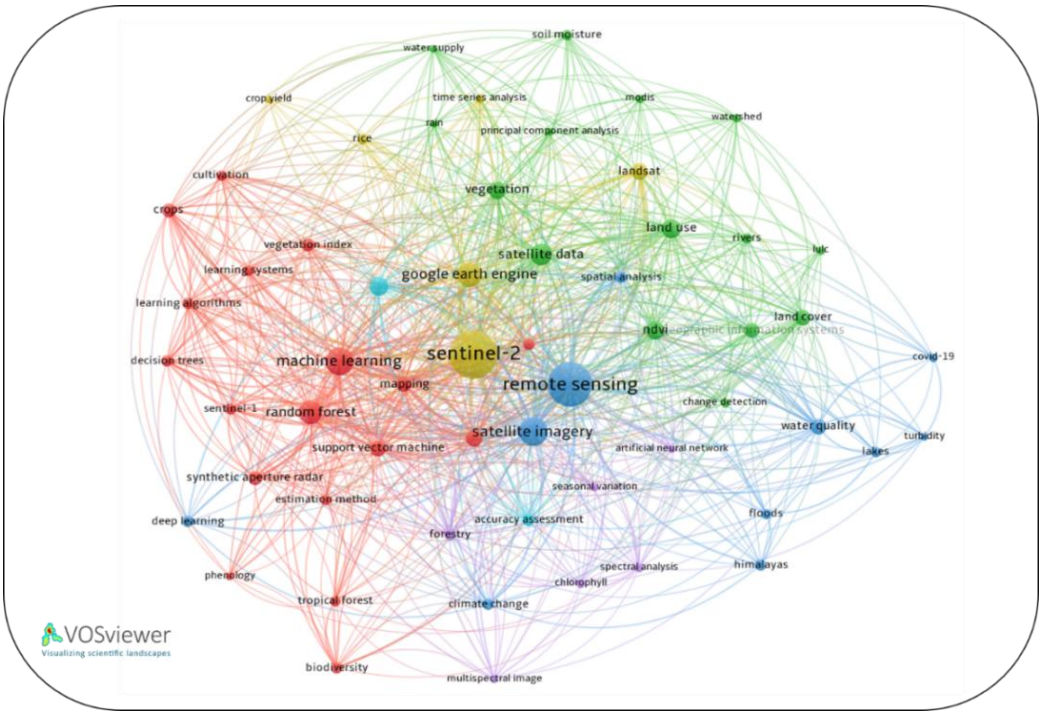
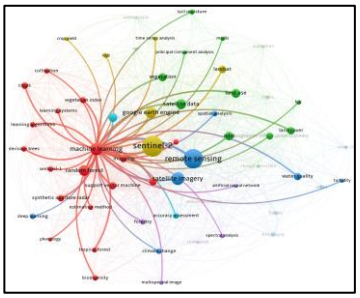
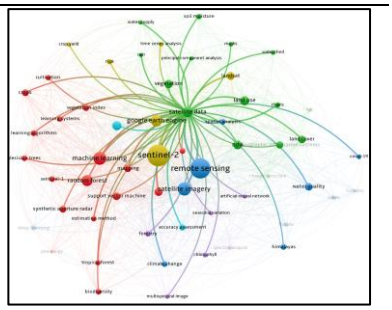
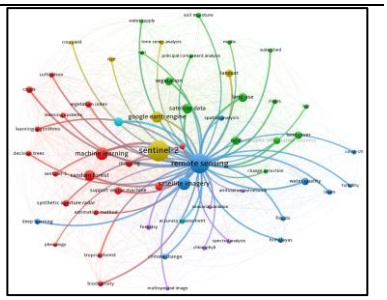
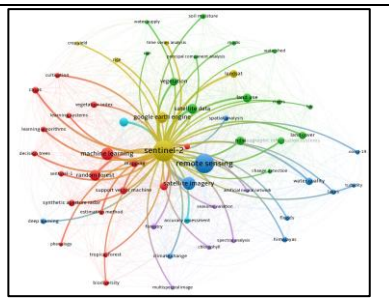


Fig. 8 Network Visualisation Map for all Keywords (KW)

Table 5 lists the cluster wise 58 keywords generated through visualisation of similarities along with corresponding maps.

Table 5

Cluster wise keywords and network maps

Cluster No.	Colour	Keywords	Keyword Network Map
1	Red	algorithm, biodiversity, crops, cultivation, decision trees, estimation method, learning algorithms, learning systems, machine learning, mapping, phenology, random forest, regression analysis, Sentinel-1, support vector machine, synthetic aperture radar, tropical forest, vegetation index	 **Fig. 5 a Cluster 1**
2	Green	change detection, geographic information systems, land cover, land use, lulc, modis, ndvi, principal component analysis, rain, rivers, satellite data, soil moisture, vegetation, water supply, watershed	 **Fig. 5 b Cluster 2**
3	Blue	climate change, covid-19, deep learning, floods, himalayas, lakes, remote sensing, satellite imagery, spatial analysis, turbidity, water quality	 **Fig. 5 c Cluster 3**
4	Yellow	crop yield, google earth engine, landsat, rice, sentinel-2, time series analysis	 **Fig. 5 d Cluster 4**

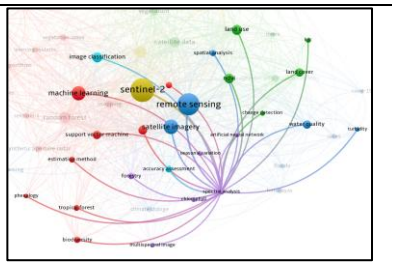
5	Purple	artificial neural network, chlorophyll, forestry, multispectral image, seasonal variation, spectral analysis	

Fig. 5 e Cluster 5

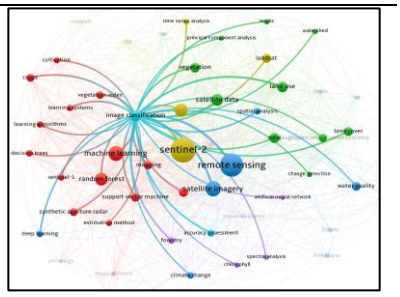
6	Cyan	accuracy assessment, image classification	

Fig. 5 f Cluster 6

Cluster 1 focuses on use of sophisticated analytical models like machine learning algorithms, random forest, support vector machine to achieve detailed and accurate spatial analysis (Mapping, Vegetation Mapping) of plant life (Crops, Forestry, Phenology). Cluster 2 keywords focus on scientific effort to use Remote Sensing and Neural Networks in a GIS environment to perform Change Detection on Land Use/Land Cover through Normalized Difference Vegetative Index (NDVI). Cluster 3 keywords grouping describes the use of advanced remote sensing and satellite imagery techniques for comprehensive, dynamic monitoring of climate change specifically assessment of risks from floods in the himalays and monitoring river water quality and environmental health along with covid-19 related applications. Cluster 4 keywords grouping indicates the use of Satellite Remote Sensing and Data Analysis techniques for agricultural monitoring and forecasting of crop yield, particularly for rice, within a specific geographical area. The input data source is predominately sentinel-2 imagery. Cluster 5 keywords grouping focuses on use of artificial neural network along with multispectral image for spectral analysis of chlorophyll, forestry for assessment of seasonal variation. Cluster 6 focuses on use of image classification techniques for accurate interpretation of the remote sensing data.

The keyword sentinel-2 is unequivocally the largest and most central node in the entire network. Its high degree centrality, indicated by the maximum number and thickness of links connecting to virtually every other term, confirms its status as the nucleus of modern high-resolution remote sensing research.

It represents the essential data stream required for the majority of adjacent scientific inquiries. The network visualisation map indicating the keywords linked to the dominant node viz. Sentinel-2 is presented in **Figure 9.**

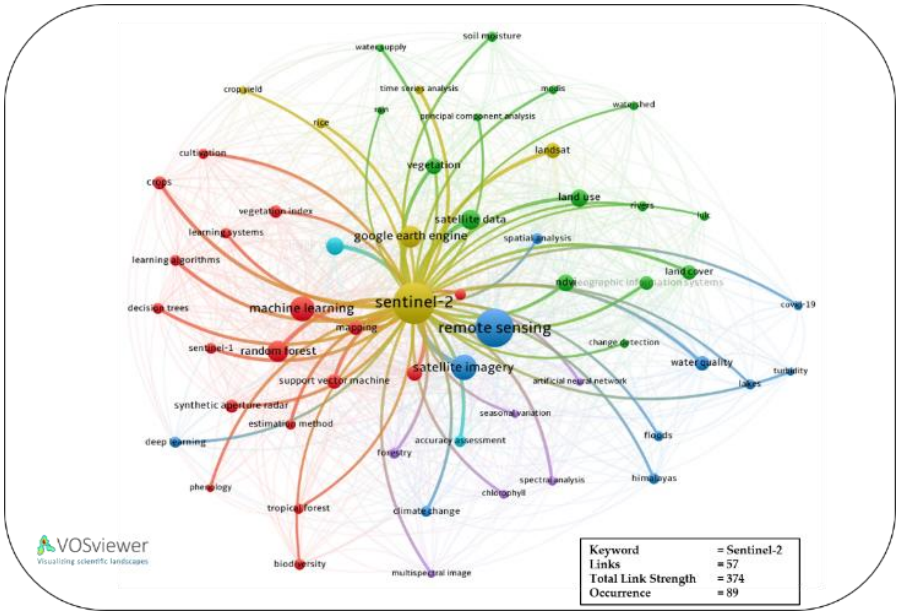


Fig. 9 Network Visualisation Map for dominant keyword

The density visualisation map for the 58 keywords is presented in **Figure 10.**

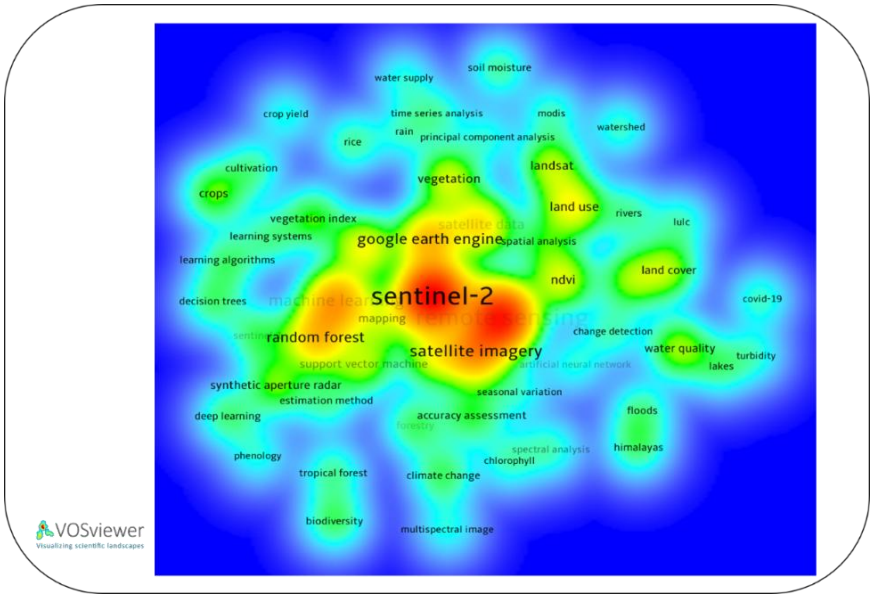


Fig. 10 Density Visualisation Map for Keywords

The density map indicates the intensity of particular keyword through colour gradient. The keywords located in the green and yellow areas shows the emerging and active research themes surrounding the central red core. It is observed that the topics related to forestry, normalized difference vegetation index (ndvi), land use, spatial analysis, image classification, machine learning etc are active in Indian context.

The keywords located in the cyan area indicates the niche topics that are yet to not explored fully. These includes artificial neural network, multispectral image, change detection, etc.

Table 6 provides the quantitative summary of the impact of top ten keywords on the basis of their occurrences.

Table 6

Quantitative Summary of the keywords

Keyword	Links	Total Link Strength	Occurrences	Avg. Pub. Year	Avg. Citations	Avg. Norm. Citations
Sentinel-2	57	374	89	2022.56	15.08	0.88
Remote sensing	57	317	78	2022.60	20.59	1.12
Satellite imagery	47	197	38	2023.18	6.68	0.70
Machine learning	46	187	37	2023.30	18.11	1.39
Google earth engine	41	131	30	2022.60	18.27	1.36
Random forest	44	163	28	2022.96	20.11	1.27
Satellite data	49	125	24	2022.88	12.46	1.13
Image classification	39	115	20	2022.55	16.70	1.08
Land use	40	126	20	2022.95	33.65	1.55
Ndvi	35	63	18	2022.72	15.00	1.12

The table highlights that though the keyword ‘Sentinel-2’ has appeared more frequently in the research papers, the influence of the keyword ‘Land use’ was the highest with Average Normalized Citation score of 1.55.

This indicated extensive use of Sentinel-2 Imagery specifically for research related to land use. Also, the Sentinel-2 applications are closely associated with use of machine learning and google earth engine.

3.4 Systematic Literature Review

For further synthesizing the evidence regarding the scope and nature of the application of Sentinel-2 Imagery in India to facilitate answering the research questions set for this scoping review, we mapped the use of the Sentinel-2 Imagery with its applications. For this we used the abstracts of the selected research articles. We synthesized the nature of studies undertaken in India within different geographical regions to understand the applications of Sentinel-2 imagery. On the basis of the abstracts of the 223 research articles selected for this review, we categorized studies under various application areas. We found that the research related to applications of Sentinel-2 imagery is usually multidisciplinary i.e. involving inputs from multiple disciplines like environmental science, artificial intelligence & machine learning, urban planning, ecology & environment, forestry, agriculture, Disaster Risk Management etc. However, based on the abstracts, we marked the primary application area for the use of Sentinel-2 imagery in various fields. **Figure 11** provides the details of the identified application area, number of studies linked to this area and the percentage of the same.

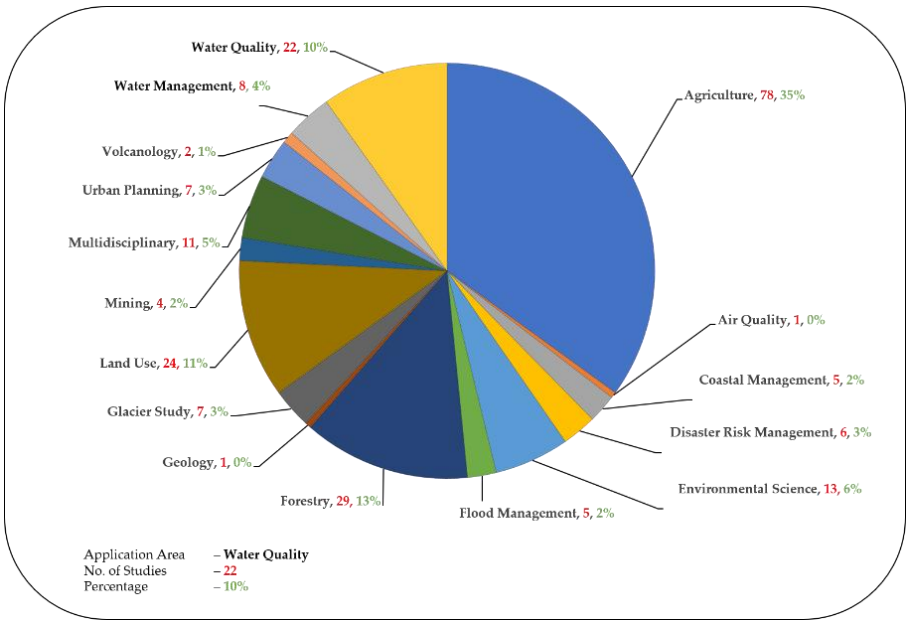


Fig. 11 Application Area, Number of Studies and Percentage

With 78 studies related to diverse applications like crop yield estimation, mapping of residue burn areas, identification of moisture deficit areas, estimation of Soil Organic Carbon etc, the agriculture sector leads in use of Sentinel-2 Imagery. This is followed by forestry (29 studies involving tracking mangroves forests, wildlife habitat classification, biomass & carbon stock estimation, forest health monitoring etc), land use (24 studies mostly involving Land Use & Land Cover Mapping) and water quality (22 studies involving monitoring of Total Suspended Solids, predicting surface water quality, monitoring of water bodies, eutrophication in lakes etc).

Figure 12 provides the geographical distribution of the studies undertaken in India using Sentinel-2 Imagery.

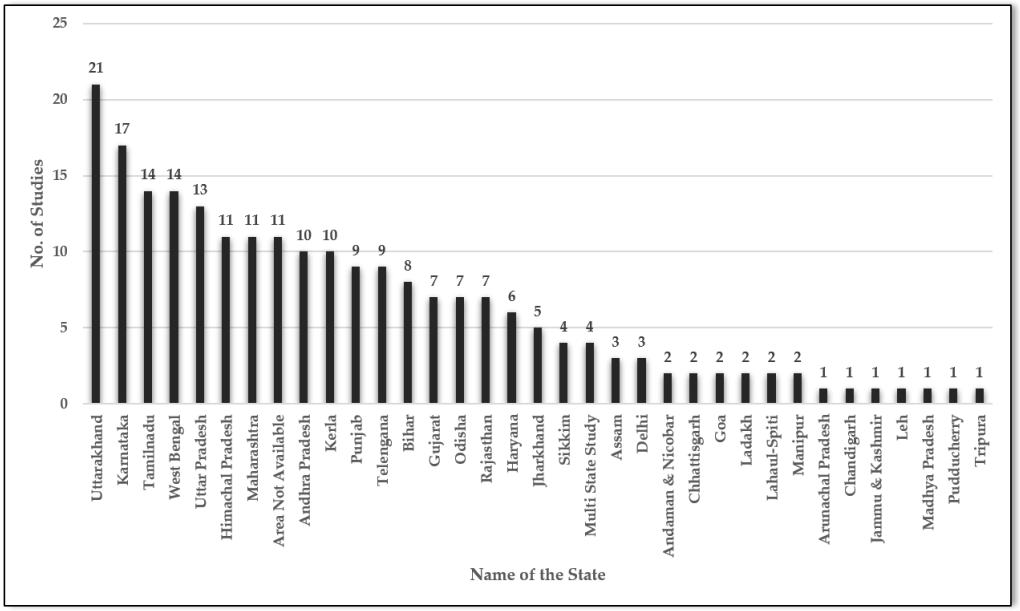


Fig. 12 Application Area, Number of Studies and Percentage

With 21 studies, Uttarakhand leads the research work involving applications of Sentinel-2 imagery.

3.5 Application of Sentinel-2 Imagery in Mining Context

We observed that only four studies (2%) have been done in the context of mining sector. Ojha, Abhishek Kumar et al. used the Sentinel-2 Imagery for detection and classification of the lead-zinc mining areas using machine learning algorithms (Ojha, Abhishek Kumar et al., 2025). Pandey, Mayank et al. examined the reforestation done on coal mine overburden utilizing various machine learning algorithms like Support Vector Machine, Random Forest and Maximum Likelihood Classifier (Pandey, Mayank et al., 2025). Chowdam, Venkata Sudhakar et al. used the Sentinel-2A Imagery for demarcating the active limestone mining areas for transformation assessment (Chowdam, Venkata Sudhakar et al., 2022). It is observed that these three studies done in the mining context are nothing but assessment of land use land cover. The fourth study done by Tripathi, Mahesh Kumar; Govil, H. was undertaken for automatic lineament extraction to facilitate lineament analysis which aids in identification of mineralized zones (Tripathi, Mahesh Kumar; Govil, H., 2021).

4. Conclusions

This study applied the Scoping Review with Bibliometric Analysis (ScoRBA) methodology to map the applications of the Sentinel-2 high resolution multispectral satellite imagery in India. From the study it emerged that the Sentinel-2 imagery has been used for various diverse applications including agriculture, assessment of land use land cover, forestry, mining, assessment of water quality, flood management, urban planning, disaster risk management etc. The study establishes the potential of Sentinel-2 Imagery in governance process in the matters related to urban planning and disaster risk management.

The review underscored the use of advanced artificial intelligence and machine learning techniques in processing of the Sentinel-2 imagery which has enhanced the accuracy in interpretation of the remotely sensed data. The review also highlighted the underutilization of the freely available high-resolution Sentinel-2 imagery by the Indian Mining Sector. This review advocates the need for exploring the use of Sentinel-2 imagery by the Indian Mining Sector for addressing the various issues related to sustainable operations, social obligations, operational safety etc. The multispectral Sentinel-2 imagery can be used for identification of slope instability, monitoring rock trap geometry, monitoring of mine disasters, monitoring of vegetation and land dynamics.

The precise Digital Elevation Model prepared through remote sensing methodology would help the mine planners in identification of the locations for waste dumps, infrastructure etc with focus on sustainable operations. Through regular remote monitoring of the water bodies located in the vicinity of mining areas for assessment of water quality, Sentinel-2 imagery aids in sustainable mining operations. Future research may also be directed towards use of Sentinel-2 imagery for assessment of air pollution (PM_{10} and $PM_{2.5}$) on remote basis. This would aid in replacement of costly Ground Air Quality Monitoring Stations. We specifically recommend use of Sentinel-2 imagery assisted by advanced Geological Information System Software like

QGIS in combination with Artificial Intelligence & Machine Learning for regular monitoring of the mine reclamation areas and vegetation health in both coal and non-coal mines.

This review provides the answers to the three research questions delineated at the beginning. This research is different from earlier research as it not only synthesizes the current status of use of Sentinel-2 imagery in Indian context but also provides clear direction for future research specifically focused on mining sector.

5. Limitations

Despite the structured approach and robust methodology applied for this review, the study has certain inherent limitations. It is based solely on the basis of the articles retrieved from a single database viz. Scopus. This may have resulted in exclusion of some of the works related to applications of Sentinel-2 in India. Further, the literature available in regional languages is not captured in this review. This review is entirely focused on use of Sentinel-2 imagery and as such the literature related to use of other landsat imagery like Landsat 8, Sentinel-1 have not been captured in the identified articles. Subject to above limitations, we are of the opinion that the review incorporates all the relevant research articles available in the Scopus database and are representative in nature.

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Conflict of Interest

The author(s) declare no conflict of interest.

Author Contributions

Conceptualization – Harshad Pophali, Data Curation – Harshad Pophali, Formal Analysis – Harshad Pophali, Dr. Anupam Kher, Funding Acquisition – Not Applicable, Investigation – Harshad Pophali, Dr. Anupam Kher, Methodology – Harshad Pophali, Project Administration – Not Applicable, Resources – Harshad Pophali, Dr. Anupam Kher, Software – Not Applicable, Supervision – Dr. Anupam Kher, Validation – Harshad Pophali, Dr. Anupam Kher, Visualization - Harshad Pophali, Dr. Anupam Kher, Writing (Original Draft) – Harshad Pophali, Writing (Review & Editing) – Dr. Anupam Kher

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