Review

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Anuva Chowdhury , Surajit Ghosh * , Bunyod Holmatov

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Review

EO-Based Rice Mapping Studies in Vietnamese Mekong Delta Compared to Global Context: A Bibliometric Analysis

Anuva Chowdhury [1], Surajit Ghosh [2] and Bunyod Holmatov [2]

[1] Department of Remote Sensing, Birla Institute of Technology Mesra, Ranchi Jharkhand; anuvachowdhury11@gmail.com
[2] International Water Management Institute, Colombo, Sri Lanka; s.ghosh@cgiar.org
[2] International Water Management Institute, Colombo, Sri Lanka; b.holmatov@cgiar.org
* Correspondence: Dr Surajit Ghosh International Water Management Institute, 127 Sunil Mawatha, Battaramulla, Colombo, Sri Lanka Email: s.ghosh@cgiar.org

Abstract: The present article summarises Earth Observation (EO)-based rice mapping strategies since 1979, with a focus on data, methodologies, and methods based on 3,700 research publications across global literature and its comparison with the Vietnamese Mekong Delta (VMD). Various quantitative analyses were conducted through bibliometric analysis using the VOS viewer and Scopus database. Optical images, particularly MODIS and Landsat time series datasets, were found to be the most commonly utilized. Landsat data had the highest share in the global context, while MODIS data research dominated in the VMD, while Sentinel series data and the Google Earth Engine (GEE) platform became more popular in recent years. The research on rice mapping using UAVs has been gradually creeping into global rice mapping research but is a loophole yet to be implemented in the VMD. The most widely used approaches for rice mapping globally were Random Forest, Support Vector Machine, and Principal Component Analysis. Indices like EVI, NDVI, and RVI were commonly used for rice mapping and monitoring. The findings underscore the critical role of EO-based rice mapping studies in the VMD in addressing sustainability and food security challenges.

Keywords: earth observation; rice mapping; SCOPUS; Vietnamese Mekong delta; bibliometric analysis; google earth engine; MODIS; Landsat

1. Introduction

The global population is anticipated to surge by nearly 9.8 billion by 2050 (UN-DESA 2017), with 54.34% of Asia's contribution to the world's share by 2050 (UN World Population Prospects 2019), demanding additional food production. Rice, a staple crop for more than half the world's population (Mosleh et al., 2015), is cultivated in over 100 countries. However, there are more than 110,000 cultivated kinds of rice, each with a unique quality and nutritional makeup (Fukagawa et al., 2019). In 2012, 11.5% of the world's cultivable land was covered by paddy fields. About 19% of the world's daily calories come from rice, which was consumed an average of 65 kg annually per person between 2010 and 2011 (IRRI, AfricaRice and CIAT 2010). Despite a sizable worldwide rice cultivation area and rising rice production in many nations, overall demand frequently exceeds the supply (Mosleh et al., 2015). Additionally, it is anticipated that the world will consume 873 million tonnes of rice in 2030 (Prasetyo et al., 2018). In the global context, rice must be given the utmost consideration due to its significance as a staple food for more than 90% of the population in underprivileged and developing nations, its contribution to Sustainable Goal target 2 - Zero Hunger, and its significance in international trade (Fukagawa et al., 2019).

Mapping the rice cropping systems is crucial and has been increasingly explored using earth observation (EO) data to estimate the area under cultivation, yield, seasonality and many more (Zhang et al., 2017; Asilo et al., 2014; Kwak et al., 2015; Peprah et al., 2021). The widespread geographical coverage and freely available Earth Observation (EO) data with increased spatial and temporal resolution play a boon in studying the different perspectives of rice cultivation, from phenology to yield assessment. Depending upon the availability of the data sources, paddy mapping strategies are classified into three parts. Optical satellite-based methods based on from local to global scales, rice cultivating areas can be mapped using the Finer Resolution Observation and Monitoring of Global Land Cover (FROM-GLC), Medium Resolution Imaging Spectrometer (MERIS), Moderate Resolution Imaging Spectroradiometer (MODIS), Landsat Series comprising of TM, ETM and OLI, hyperspectral datasets, AHVRR and Sentinel-2 dataset time series; secondly, microwave or radar-based satellite data using Sentinel-1, RADARSAT, Envisat etc. and thirdly, a fusion or combination of both optical and microwave datasets, for rice mapping (Zhao et al., 2021). A number of the published studies have had difficulties identifying and classifying paddy rice pixels in varied environments due to commonly employed coarse spatial (MODIS, 500 m) and low temporal resolution (Landsat, 16-days) data (Gallego 2004; Zhen et al., 2013; Zhou et al., 2013). Since paddy rice fields in south and southeast Asia are small due to land fragmentation, applying MODIS leads to low classification accuracy attributed to mixed pixels incorporating several crops (Teluguntla et al., 2015). However, employing Sentinel-2 data, which has higher revisit frequency and greater spectral and radiometric resolutions, could increase the precision of classification by capturing spatial variety in agricultural management practices (Liu et al., 2020). The ability to estimate phenological events is further enhanced by data derived from time-series analysis of EO data (Shew and Ghosh, 2019; Yin et al., 2019), such as Normalized Difference Vegetation Index (NDVI) (Guan et al., 2016), Enhanced Vegetation Index (EVI) (Li et al., 2018), Normalized Difference Land Surface Water Index (LSWI) (Chandrasekar et al., 2010), Normalized Difference Water Index (NDWI) (McFeeters, 2013), Normalized Difference Flood Index (Boschetti et al., 2014) and others indices. Recently, machine learning and deep learning techniques in EO-based rice mapping have significantly increased (Clauss et al., 2016; Yin et al., 2019; Chen et al., 2020). Google Earth Engine (GEE), a cloud-based repository for satellite imagery and processing tools, has grown in current times due to its potential for handling sizable volumes of datasets and its capability to visualize, process, and analyze big data. Recently, these indices-based studies have been approached using the GEE platform for mapping and monitoring rice using time series and phenology-based algorithms of vegetation indices (Waleed et al., 2022) due to its advantage of cloud computing and rapid monitoring are being widely explored (Dinesh Kumar et al., 2019; Clauss et al., 2018). An effective literature analysis technique would be beneficial to support upcoming studies, summarise historical evolution, and uncover hotspots. The bibliometric analysis incorporates an interdisciplinary combination of computing, facts and data, has robust quantitative functions, offers a thorough and systematic statistical appraisal of literature widely applied in many domains, and effectively describes the general trajectory of a subject's or field's development (Hou et al., 2021). l. The bibliometric analysis tool has been used in studies related to rice physiology and management (Morooka et al., 2014; Liu et al., 2017; Peng, 2017), and perennial staple crops (Kane et al., 2016), studies on the application of fertilizers in rice farming (Sun and Yuan 2019); rice cultivation and irrigation exposure (Sun and Yuan 2020a); review on top-cited papers in global rice research (Sun and Yuan 2020b); rice cultivation and the impacts of climate change (Yuan and Sun 2022), trends and research features on greenhouse gas emissions from rice production (Sossa et al., 2022) and research of rice cultivation and its interconnection between greenhouse gases (Yuan and Sun 2023). The application of bibliometric analysis on EO-based rice mapping focusing on the Vietnamese Mekong Delta (VMD) has not been attempted. Mekong Delta is Vietnam's most significant agricultural and aquaculture production zone, producing 50% of the nation's rice, 80% of the nation's fruit, and 60% of the country's fish production (International Centre for Environmental Management 2012). In 2019, the VMD contributed 54.46% of the country's rice cultivation area, making it the primary rice-producing region (General Statistics Office - GSO 2018). Thus, the investigation tried to dig deep into rice mapping and excavate the annual trend of literature propagation in applying EO data in rice research through the Scopus enlisted keyword co-occurrence analysis using the bibliometric method. The VMD stands out as a critical area among the regions where rice is vital to the economy and food security. This article presents a comprehensive bibliometric analysis that aims to unravel the role of EO-based rice mapping studies in the VMD compared to global studies. The analysis seeks to shed light on the contributions of these studies to sustainability and food security in the region.

2. Materials and Methods

2.1. Study Area

Vietnam heavily relies on rice production in the Mekong River deltas for its food supply and national economy. Considered one of the most fertile agricultural regions globally, Vietnam is the world's second-largest rice exporter and the seventh-largest rice consumer. Rice cultivation in Vietnam follows three distinct cropping seasons: winter-spring (December to March), summer-autumn (April to August), and autumn-winter (September to November). Farmers typically sow either irrigated or non-irrigated fields in the autumn-winter season, from mid-July to the end of August (Minh et al., 2019). These different seasons allow for continuous rice production throughout the year. Three ecosystems within the country's geographic regions influence Vietnam's rice-growing culture. The northern delta, characterized by a tropical monsoon climate, experiences cold winters and relies on rainfed and flood-prone rice varieties. On the other hand, the highlands of the north cultivate upland rice varieties due to their specific conditions. Finally, the southern delta, i.e., VMD, dominates rice cultivation in Vietnam and benefits from a warm and humid climate year-round, accompanied by abundant sunshine. (Figure 1)

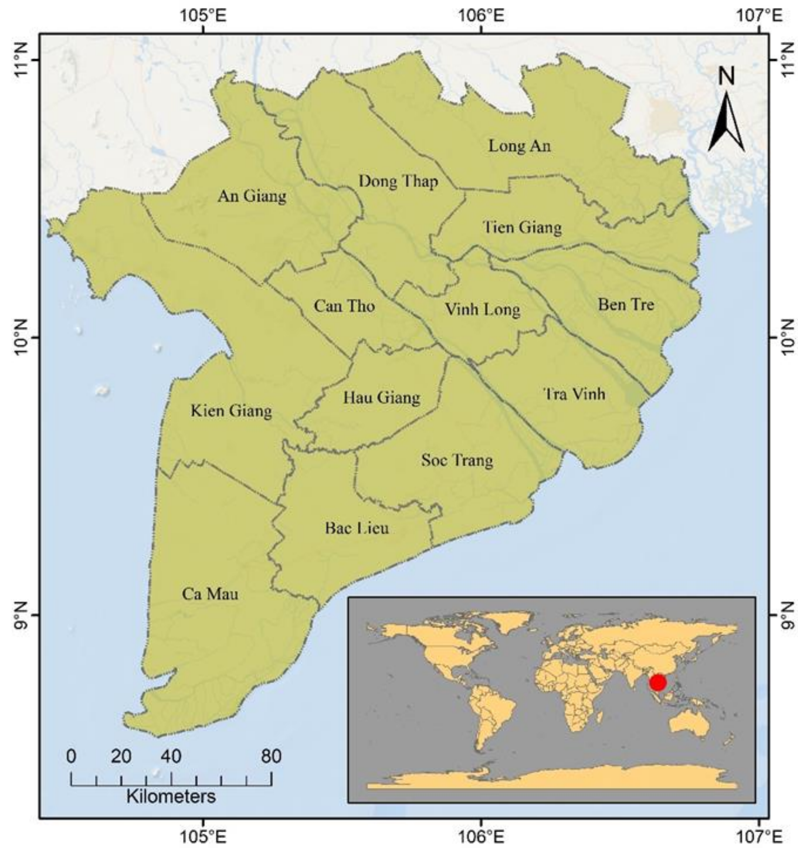

Figure 1: Study Area.

2.2. Data

SCOPUS (https://www.scopus.com), a repository for scientific publications, is one of the most extensive global collections of abstracts and citations from peer-reviewed literature from Elsevier Group. SCOPUS preview database is exclusively selected primarily for two reasons, i.e., it has a sizable collection of top-notch quality scientific research publications and a widespread reputation in academia for conserving high-quality, peer-reviewed investigations and articles, and the catalogue

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of bibliometric output produced by the directory makes text mining and bibliometric analyses convenient (Deng and Romainoor, 2022). The information search is carried out considering a few criteria set by the author based on the perception and the requirement of the analysis. The filtered data can then be exported from the web repository of SCOPUS (1979 to 2022) in CSV format for analysis.

2.3. Method

A keyword plays a vital role in capturing the core idea of literature, and a cluster of keywords together conveys the essence and outline of the study (Badaluddin et al., 2021). Thus, keywords are used to depict research boundaries and forecast upcoming trends since keywords are a viable way to describe research hotspots. The domain or subject matter that is most intimately correlated to the issue covered in the author's study is typically listed along with several keywords. It is also typical for reviewers, and editors in particular, to augment such material with additional keywords gleaned from databases in accordance with the publication's topic content. In the theme, the unified keywords used for text mining are Rice, Paddy, Remote Sensing, Geospatial, Mapping, Earth Observation and GEE to study the various remote sensing applications in the rice mapping and monitoring preview. These particular keywords were used in the search engine so that all the literature in the form of Articles, Reviews, Conference papers, Letter, Conference reviews, Book chapters, Editorial, Data papers, Erratum, Notes, Short surveys, Books and Reports, having the specific words or in various combinations within the title, abstracts and keywords can be extracted to for the study domain. Using these aforementioned keywords in the search tab of the SCOPUS database, 3700 papers on the themes were extracted. By specifying the export type "complete records and cited references", the data was downloaded and saved in CSV format. It was then imported into the VOS viewer for additional citation analysis. Utilizing the SCOPUS preview database data ((Bibliometric data), network and overlay visualizations have been made using the programme in VOS viewer to spot co-occurrence and concentrations of articles with many options. The VOS viewer (version 1.6.18, 2022, Leiden University, Leiden, Netherlands) is used to build and display bibliometric networks. These networks can be created using citations, co-authorship or bibliographic coupling. (Figure 2)

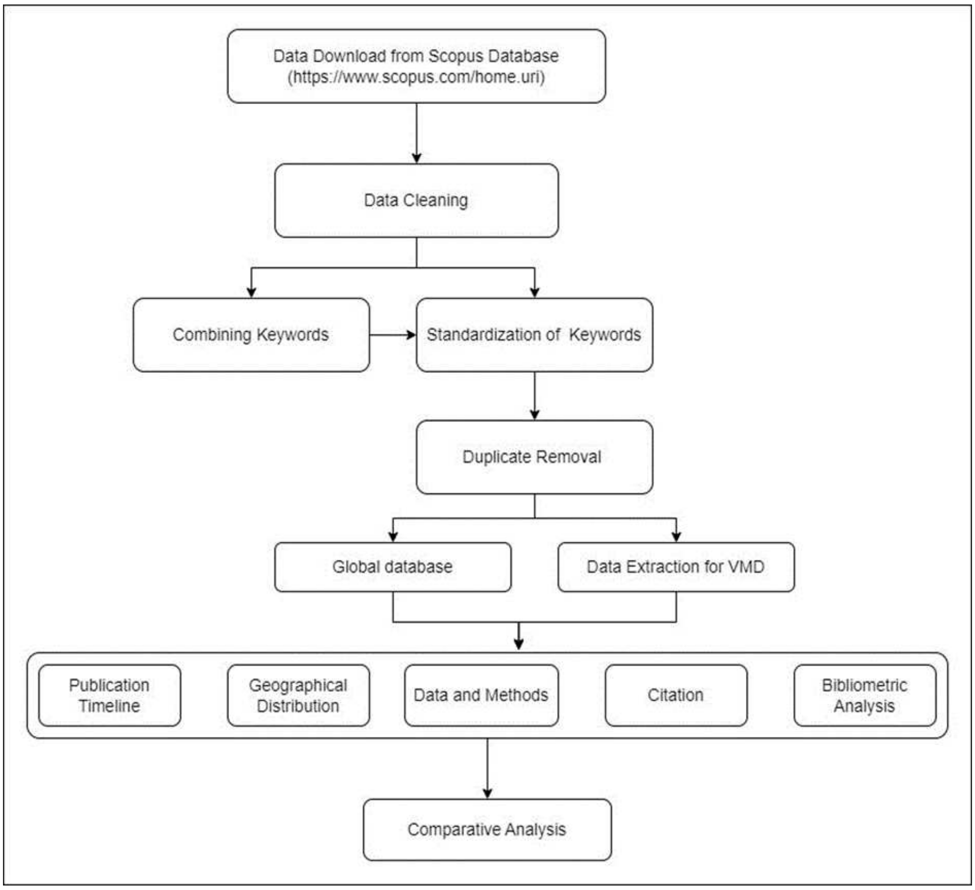

Figure 2. Methodology flowchart.

3. Results and discussion

3.1. Publication history

Rice cultivation is extensively practiced in Southeast Asia, with India, China, Bangladesh, Thailand, Indonesia, and Vietnam being the top producers. These countries are also the major contributors to scientific research on rice mapping using remote sensing techniques. The Vietnamese Mekong Delta has shown a significant increase in research on rice mapping using EO data in recent years. The application of EO data for rice mapping gained momentum in the 1980s and has since seen substantial growth.

The scientific and academic research on rice mapping across the globe started in 1974 (4) and gradually showed an increasing trend. The breakthrough in the number of publications occurred in 2005(77), with the highest number of articles published in 2020 (350). (**Figure 3**)

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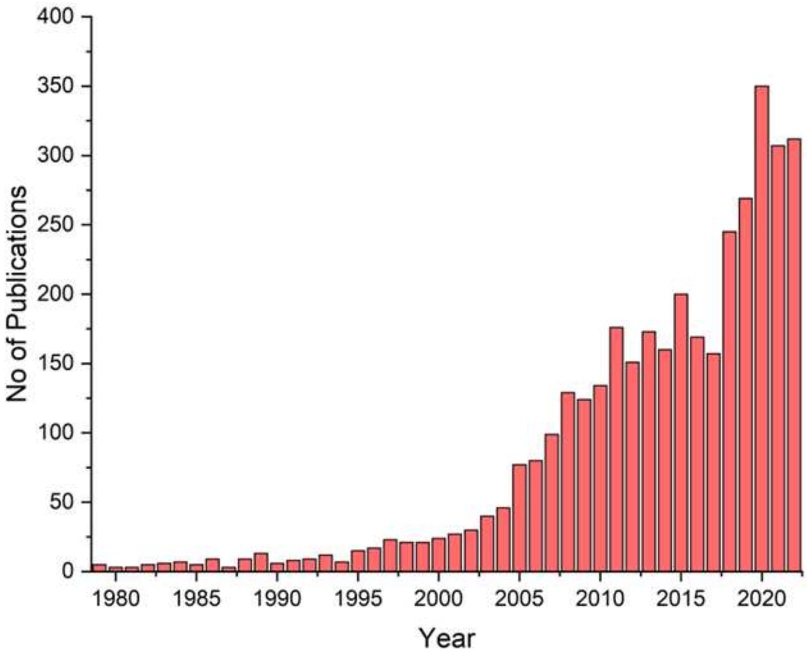

Figure 3: Year-wise publication Globally.

The scientific investigation on rice mapping in the VMD started in 1997 and gradually showed an increasing trend. The peak number of publications per year stands in 2018 and 2021 (10), followed by 2020 (8), 2012, 2013 and 2022 (7). (**Figure 4**) Japan was the first country to bring in rice research, 'On the seasonal winds in autumn over Kawagishi village, the valley of tenryū' in the Journal of Agricultural Meteorology in 1953. The first paper based on the direct implication of rice mapping using EO data was 'Temporal Study on Paddy (Rice) Using X-Band Scatterometer' in a conference proceeding in the Proceedings of the International Symposium on Remote Sensing of Environment published in 1979 from India. The first few papers on rice cultivation in the VMD, 'Landcover classification over the Mekong River Delta using ERS and RADARSAT SAR images' and 'Application of multitemporal ERS SAR in delineating rice cropping systems in the Mekong River Delta' were published in the conference proceeding of International Geoscience and Remote Sensing Symposium (IGARSS). The first paper to be published in China based on rice monitoring using EO data, named 'Regional paddy monitoring system using NOAA HRPT data', was published in 1989 in the Digest - International Geoscience and Remote Sensing Symposium (IGARSS). The first publication in Bangladesh was published in 1990 in the conference proceeding Proceedings of the International Symposium on Remote Sensing of Environment. The dominant leap in the research of rice mapping using remote sensing techniques started in 1980 and has taken a hike in the last decade. Before these years, the number of publications was limited to one per year, with most of the year without any and lacking direct implication of EO data analysis.

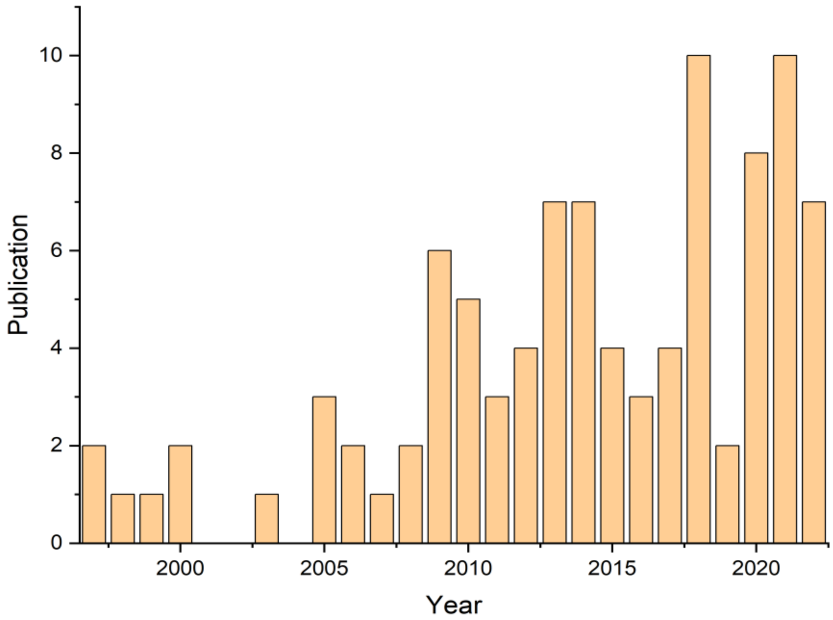

Figure 4. Year-wise publication in the Vietnamese Mekong Delta.

3.2. Country-wise publication

Rice cultivation is extensively practiced in Southeast Asia due to its favourable climate. Bangladesh, Cambodia, China, India, Indonesia, Iran, Japan, Laos, Malaysia, Myanmar, Nepal, North Korea, Pakistan, Philippines, South Korea, Sri Lanka, Taiwan, Thailand, and Vietnam are the leading rice farming areas. India, China, Bangladesh, Thailand, Indonesia, and Vietnam fall under the top six rice-producing countries (FAO 202, https://www.fao.org/faostat/en/#home). The global rice mapping research using EO data is spread over the southeastern and eastern zones where the area under cultivation and harvesting is high. Consequently, China, India, Japan, Indonesia, Vietnam (Mekong Delta Region), and Bangladesh are the major rice research countries using remote sensing techniques (Figure 5). It is indistinct from the SCOPUS database that the chief rice-producing nations are the major contributors to scientific investigation in rice mapping using remote sensing techniques. There are several exceptions, such as Japan, which ranks 12th in rice production yet third in the number of scientific research. However, Bangladesh, the third-largest rice producer, only provides 4% of the EO-based rice mapping repository. These areas are predominated by two or three cropping seasons. Vietnam, being an exception, has five cropping seasons for rice cultivation. China, Bangladesh, and Indonesia have three rice cropping seasons, whereas India, Thailand, Philippines, Myanmar (Burma), and others have only two dominant rice cropping seasons. (Source: https://ipad.fas.usda.gov/cropexplorer/cropview/commodityView.aspx?cropid=0422110). India is one of the largest producers of rice, followed by China and Bangladesh. The leading exporters are Japan, China, Myanmar, and Vietnam. China, being the second producer and exporter of rice, ranks first in scientific investigations of rice mapping through remote sensing techniques. India, the largest producer and ranks as the ninth largest exporter, does not lag behind in research and development as it has the second-highest number of scientific publications in this domain. Vietnam holds the sixth position in scientific research for rice mapping using remote sensing techniques and is the fifth largest producer globally. Consequently, Bangladesh, the third-largest producer and fifth-largest exporter, has around 1.8% of research articles on rice mapping using EO data.

Thus, research on rice mapping using EO data is prominent in major rice-producing countries like China, India, and Vietnam. These countries also have multiple cropping seasons for rice cultivation. Other significant rice producers like Bangladesh also contribute to research but to a lesser extent. Remote sensing techniques play a vital role in monitoring and managing rice cultivation, supporting sustainable agriculture in these regions.

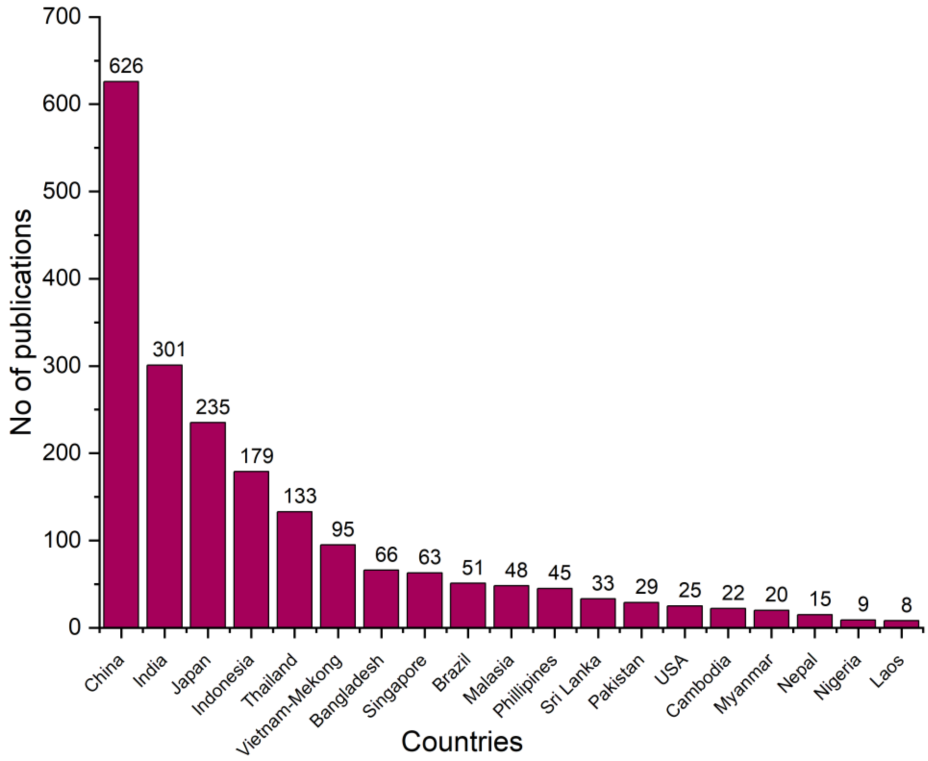

Figure 5. Country-wise publication.

3.3. EO data and methods used in the publications

Different sensors and satellites mounted on airborne and space-borne platforms can constantly capture and monitor the Earth's surface to gather a wide range of data. These images are used in agricultural studies to monitor the transplanting, growth, and harvesting phases, detect anomalies, estimate yield, and map the extent of cultivation. Several approaches, such as Machine learning Algorithms, Support Vector Machine (SVM), Random Forest (RF), Time series analysis, and phenological indices, have been developed to map rice-producing regions worldwide (**Table 1**).

Table 1. Approach/method used in the publications.

Approaches/Platform	No of Literatures	
	Global	Mekong
Random Forest	168	24
Linear Mixture Model	7	2
Empirical Mode Decomposition	13	6
Semiautomatic Hierarchical Clustering Algorithm	17	1
Isodata	18	2
Time Series Analysis	33	22
Principal Component Analysis	50	3
Support Vector Machine	165	4
GEE	89	3

The highest application of MODIS satellite is seen in the VMD region, followed by the Landsat Time series satellite data (**Table 2**). Contrarily, from a global perspective, Landsat Time series data takes a larger share than MODIS data. Thus, it is understood that the Optical Dataset predominates

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in rice mapping using EO datasets. The advancement in geospatial domains with liberated and open data policies from the United States Geological Survey (USGS) providing Sentinel 2 MSI datasets and Copernicus Open Access Hub of the European Union, providing Sentinel -1 datasets, Radar images are capturing a significant position in the study of rice mapping using EO data. Sentinel -1 sensor, with its' cloud-penetrating property, is more famous for mapping and monitoring rice cultivation. The application of HJ-1A/B (CCD1/2) is limited globally, but no application is found in the VMD. AVHRR hyperspectral images are used for only two publications that focused on the study of VMD, whereas there is no application in the global domain. Commercial satellite data such as SPOT, Terrasar-X and Radarsat have also occupied a place in studying rice mapping using remote sensing techniques.

Table 2. Earth observation (EO) satellite sensors' characteristics and related publications.

Satellite	Spatial Resolution (m)	Temporal resolution (days)	No of Literatures		Availability
			Global	*Mekong*	
Landsat (OLI/ ETM/TM)	30 m	16	578	18	Open
Sentinel-1	5–40	12	323	12	Open
Sentinel-2 (MSI)	10–20	5	164	3	Open
Modis (Terra/ Aqua)	250–1000	1–2	448	29	Open
UAV			191	0	Commercial
HJ-1A/B (CCD1/2)	30	2–4	10	0	Open
SPOT (HRV (SPOT1~3) VGT (SPOT-4) HRG/HRS/VGT(SPOT-5))	1000	1	181	7	Commercial
COSMO-SkyMed (SAR)	3–15 m	16	12	1	Commercial
TerraSAR-X (SAR)	3–10 m	11	31	5	Commercial
ENVISAT (ASAR)			53	6	Open
RADARSAT-1 (SAR)	10–100 m	24	18	1	Commercial
RADARSAT-2 (SAR)	3–100 m	24	62	2	Commercial
ALOS-2 (PALSAR-2)	25 m	14	12	2	Commercial
AVHRR			0	2	Open
Total			3700	94	

Note: ASAR—Advanced Synthetic Aperture Radar; CCD—Charge Coupled Device; ETM+—Enhanced Thematic Mapper Plus; HRG—High-Resolution Geometric Imaging Instrument; HRS—High-Resolution Stereoscopic Imaging Instrument; HRV—High-Resolution Visible; MODIS- Moderate Resolution Imaging Spectroradiometer; MSI—Multispectral Instrument; MSS—Multispectral Scanner; OLI—Operational Land Imager; SAR—Synthetic Aperture Radar; SPOT-Satellite pour l'Observation de la Terre; TM—Thematic Mapper; UAV- Unmanned Aerial Vehicle; VGT—VEGETATION.

Landsat and MODIS are the most frequently used optical remote-sensing satellites for rice mapping. Radar data, namely Sentinel-1 and TerrasAR-X, are frequently employed in recent studies

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(Kuang et al., 2022; Xiao et al., 2022). Some of the literature using satellite-based remote sensing techniques in rice mapping, such as Liew (1998), used Synthetic aperture radar (SAR) imagery from the multitemporal ERS-2 satellite to map and delineate regions in the VMD that were cultivated with various types of rice crops. Sakamoto et al. (2009) provide a strategy for assessing spatiotemporal changes in the farming systems of the VMD based on MODIS time-series imagery. In the context of the VMD, rice mapping using Landsat data contributes to approximately 19%, whereas MODIS data contributes 31%, giving it the lion's share of the available research in this area. A total of 89 scientific publications have used GEE for rice mapping across the globe, whereas a mere share of only 3 publications using GEE have focused on the VMD. The top three approaches or methods used for global rice mapping are random forest, support vector machine, and time series analysis. In the VMD region, Random Forest is also the top-applied approach, followed by Time Series Analysis and Empirical Mode Decomposition. In recent years, unmanned aerial vehicles (UAVs) have emerged as a low-cost alternative in sensing technology mapping and monitoring natural resources. The first application of UAV in vigour mapping based on Normalized Differentiated Vegetation Indices (NDVI), studied in Italy, proved highly appropriate for precision agriculture in medium-sized farms. (Norasma et al 2019). The use of UAVs in rice is critical for classification, phenological behaviour, yield estimation, and activating many researchers to create a rice database at the global, national, and regional levels (Shim et al. 2009).

Traditional machine learning techniques such as RF, SVM, and Timeseries analysis have been widely used. Newer approaches with the application of these methods and the GEE platform have given a new dimension to the study of EO-based rice mapping. The application of UAVs in rice mapping, used for crop health detection, yield estimation and vegetation vigour mapping, is gradually gaining relevance globally. However, UAV research in rice mapping in the VMD is yet to be started, giving further avenues for research exploration.

The phenological indices-based assessment for rice mapping using time series EO data is widely practised worldwide for scientific investigations. Among the various vegetation indices, EVI holds the lion's share in studying rice mapping using EO data globally and in the VMD. NDVI is the second-highest method applied in the phenological indices for global rice mapping, but contrarily, it is the third-highest method for VMD after the RVI. NSWI and LSWI are two indices comparatively more used for rice mapping in VMD than the Global perspective (**Figure 6**). Thus, EVI, NDVI and RVI are the top three applied indices for monitoring and mapping rice cultivation.

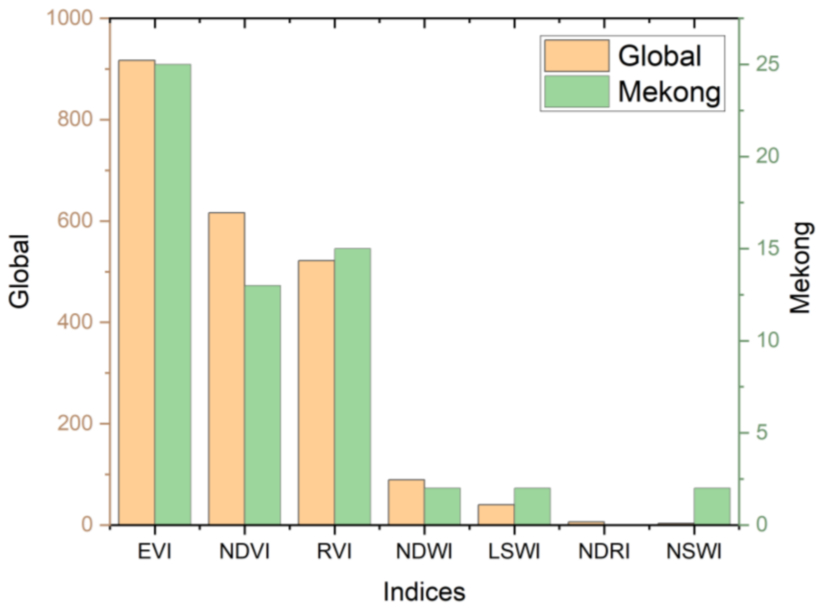

Figure 6. Comparison of Phenological Indices.

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Therefore, Remote sensing plays a crucial role in rice mapping globally, with prominent use in major rice-producing countries like China, India, and Vietnam. Different sensors and satellites, including MODIS, Landsat, and Sentinel-1, are widely employed for capturing Earth's surface data. Optical datasets are predominant in rice mapping using EO data, but radar data from sensors like Sentinel-1 and TerraSAR-X are gaining relevance. Traditional machine learning techniques like Random Forest and Support Vector Machine are commonly used, while newer approaches with the application of these methods on the GEE platform are opening new possibilities. UAVs are also emerging as a low-cost alternative for monitoring rice crops. Phenological indices-based assessment, particularly EVI, NDVI, and RVI, are extensively used for rice mapping globally. The VMD region has shown significant research interest in this field, and there is further potential for exploration, especially in UAV research.

3.4. Publication outlets and citation

The top four highest-cited papers in the study of rice mapping over the VMD are "Remote sensing of rice crop areas" (Kuenzer & Knauer 2013), "Mapping rice paddy extent and intensification in the Vietnamese Mekong River Delta with dense time stacks of Landsat data" (Kontgis et al., 2015); "Mapping the irrigated rice cropping patterns of the Mekong Delta, Vietnam, through hyper-temporal spot NDVI image analysis" (Nguyen et al., 2012) and "Mapping rice cropping systems in Vietnam using an NDVI-based time-series similarity measurement based on DTW distance" (Guan et al., 2016). The highest citation, above 100, is in the Journals Proceedings of the National Academy of Sciences of the United States of America, International Journal of Remote Sensing and Remote Sensing of Environment. Five articles have citations between 80 to 100 in the journals of Remote Sensing, Science of the Total Environment, Environment, Development and Sustainability, Landscape and Urban Planning and IEEE Transactions on Geoscience and Remote Sensing. On the other hand, there are 34 articles pertinent to rice mapping using EO data without any citation. Those papers mainly belong to the conference proceeding articles. The top five highest articles globally are "Spatiotemporal characteristics, patterns, and causes of land-use changes in China since the late 1980s" (Liu et al., 2014), with a cite score of over 1000. "Spatial and temporal patterns of China's cropland during 1990-2000: An analysis based on Landsat TM data" (Liu et al. 2005), "A crop phenology detection method using time-series MODIS data" (Sakamoto et al. 2005), "Mapping paddy rice agriculture in southern China using multi-temporal MODIS images" (Xiao et al. 2005), and "Mapping paddy rice agriculture in South and Southeast Asia using multi-temporal MODIS images" (Xiao et al. 2006) which has a citation of above 600. The highest cited paper was published in the Journal of Geographical Sciences and Remote Sensing of Environment. Out of the total list of publications globally, only 83 articles show a cite score of above 100, followed by 46, between the score of 80-100. There are around 600 articles ranging between a cite score of 10 and 30. More than 1100 articles without citations contribute to symposiums, conference proceedings and journal articles. (**Figure 7**)

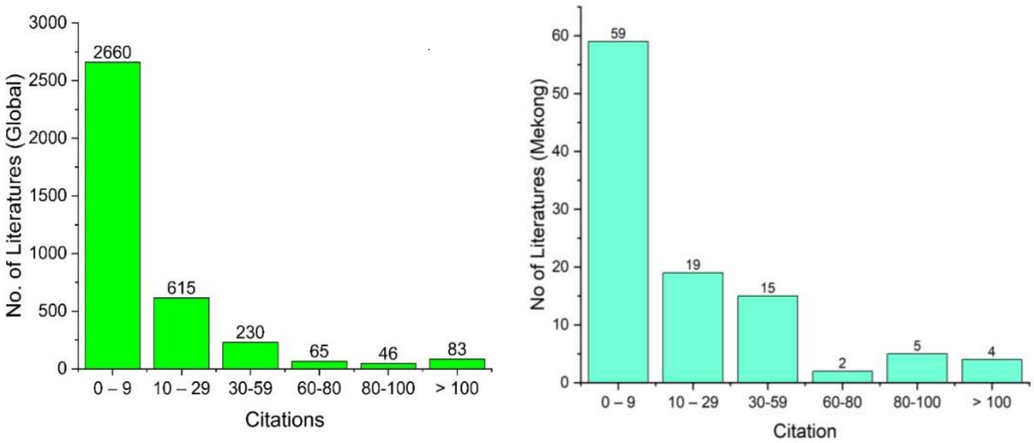

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Figure 7: Citation Comparison a) Global literature b) VMD Literature.

Rice mapping research in the Vietnamese Mekong Delta (VMD) has resulted in highly cited papers, with four prominent ones garnering over 100 citations. However, there are also 34 articles without any citations, mostly from conference proceedings. Globally, rice mapping research has produced top-cited papers from various research areas, with "Spatiotemporal characteristics, patterns, and causes of land-use changes in China since the late 1980s" being the highest-cited paper. While some articles have received high citation scores, a significant number have not received any citations, showcasing the diverse nature of research in this field.

3.5. Co-occurrence and connectivity analysis

Using the full counting approach, 837 unique keywords were used for the co-occurrence analysis. The keywords were divided into clusters based on the colour scheme, ranging from dark blue to yellow.

A bibliometric network is constructed adopting the full counting technique, where each link that results from an interaction has a full weight of 1, suggesting that the total weight of a choice is equivalent to the number of linkages emanating from it. (Rodriguez et al 2016). In cases where full counting is used, the occurrences variable reflects the aggregate number of times an expression appears across all the research articles. The interconnected web and the circles describe the periodic arrangements of research publications. The dark blue colour symbolizes paper before 2010, and the yellow colour variation describes the publication of recent years. The clusters were formed based on the co-occurrence of keywords for the year-wise publication on rice mapping using EO data. The connectivity network of all keywords examined by the VOSviewer programme is displayed in the figure (**Figure 8**). The analysis and connectivity diagrams were made using default parameters. The co-occurrence Only 18, 53, and 117 of the comprehensive 837 keywords have been utilized at least ten, five, and thrice, respectively.

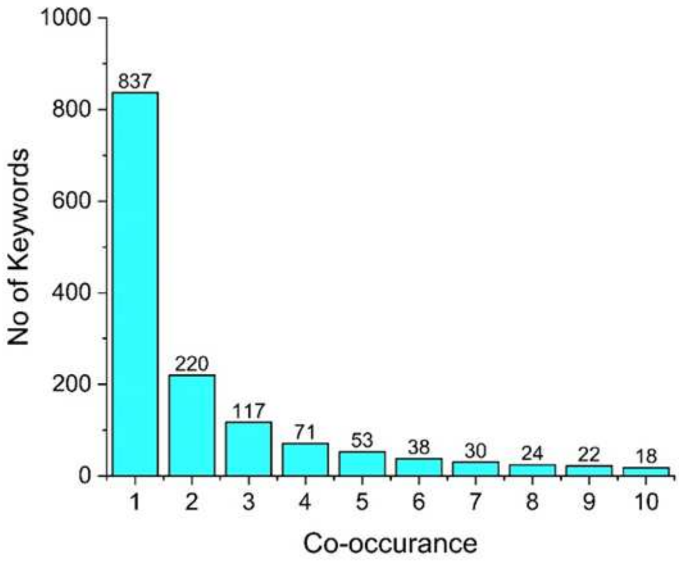


Figure 8: Number of Co-occurrence Keywords.

The interconnects between the clusters include the keywords based on the number of co-occurrences, and the radius of the circles symbolizes the number of publications in which each term appears. In general, the keyword repeats relatively frequently in circles of larger sizes. Consequently, if two words co-occurred more commonly in the analyzed list of publications, they appeared closer to one another. There are seven major clusters, which stand for seven different subfields of rice study. Different colours are associated with various groups of keywords, indicating the yearly significance of keywords, such as the gradient from blue to yellow denotes the publication year associated. Yellow colour connectivity suggests significant keywords in recent years; the dark blue link indicates keywords used in older literature. **Figure 9** shows the network visualization having four clusters, which are colour-coded using red, blue, green, and yellow. The red network denotes cluster 1 comprising 18 keywords like Aquaculture, Asia, Drought, Eurasia, Farming system, Flood, GIS, Irrigation, Landsat, Lulc, Modis, Paddy Field, Rivers, Satellite Data, Southeast Asia, Thailand, Timeseries and Vietnam. The second cluster is coded in green with 16 keywords, which are Backscattering, Biology, Classification, Decision Tree, Forestry, Image Classification, Mapping, NDVI, Polarization, Radar Remote Sensing, Sar, Sentinel -1, Space Optics, Space-Based Radar, Vegetation and Vegetation Index. Climate Change, Crops, Enhanced Vegetation Index, Food Supply, Mean Square Error, Mekong Delta, Mekong River, Remote Sensing, Rice, Rice Monitoring, Rice Production, Rice Systems, and Rice Yield are the 14 keywords that come under the third cluster that is coded using blue. Lastly, agricultural production, agricultural robots, agriculture, cultivation, and image processing are categorized in cluster 4, demarcated using the yellow colour.

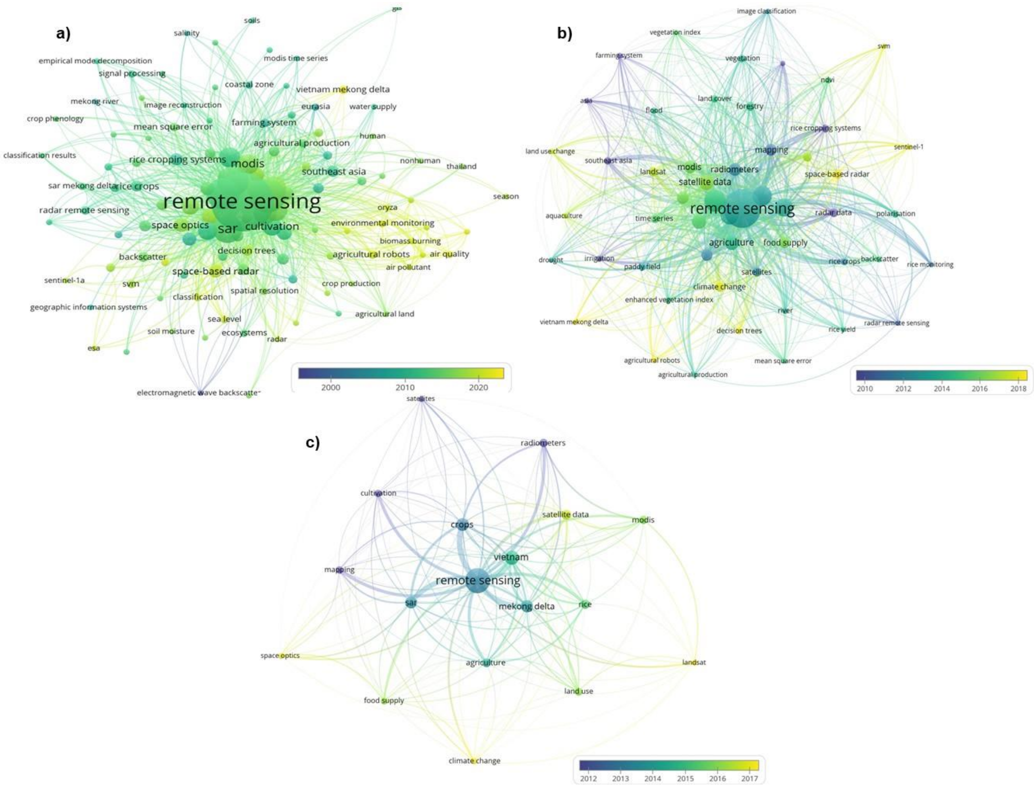


Figure 9A: **Publication Year** a) 3 co-occurrence b) 5 co-occurrence and c) 10 co-occurrence .

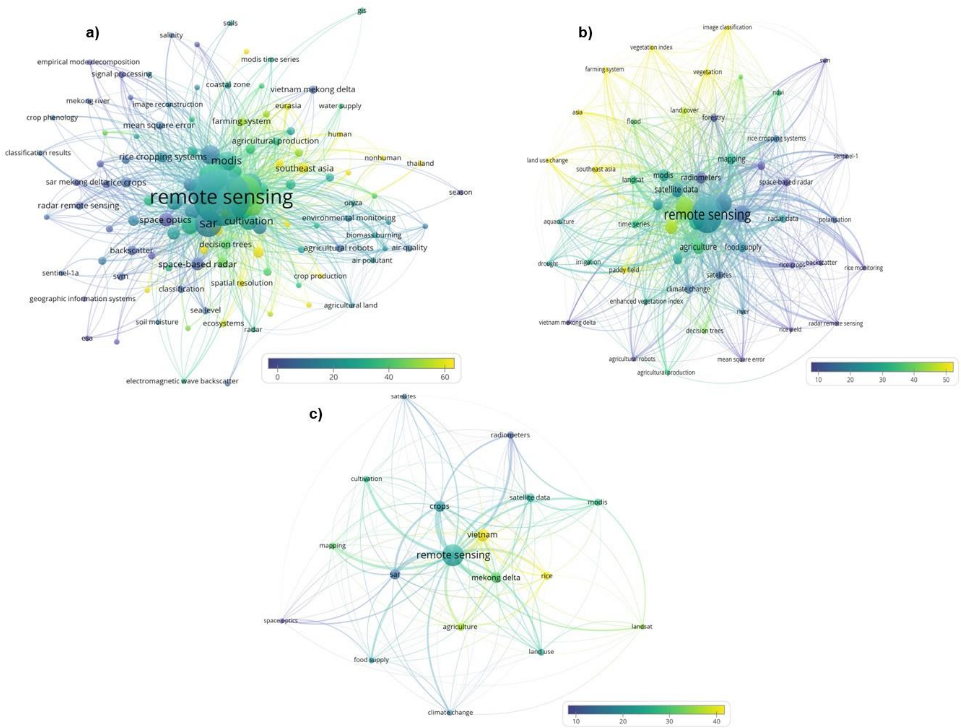
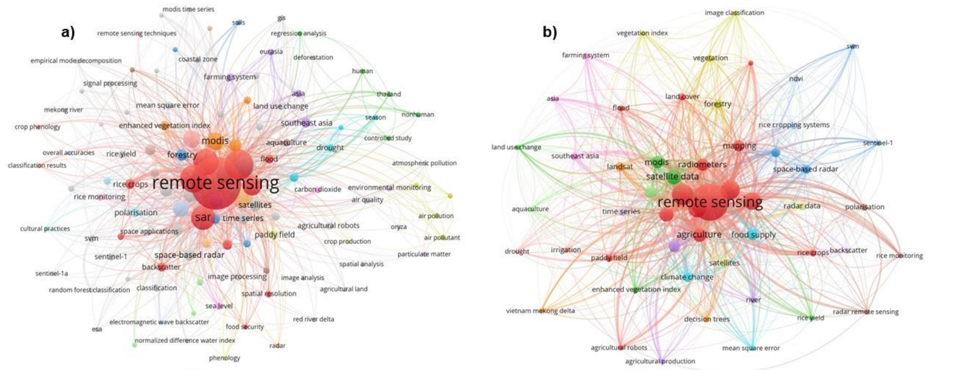
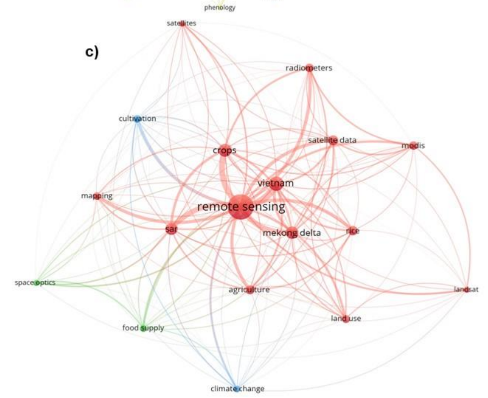


Figure 9B: **Citation** a) 3 co-occurrence b) 5 co-occurrence and c) 10 co-occurrence.





	Cluster		Cluster		Cluster
	1		8		14
	2		9		15
	3		10		16
	4		11		17
	5		12		18
	6		13		< 19
	7				

Figure 9C: Clustering a) 3 co-occurrence b) 5 co-occurrence and c) 10 co-occurrence .

The analysis revealed a notable increase in publications on EO-based rice mapping in the VMD and the global context over the past decades. However, it became evident that the VMD is an area of particular interest, accounting for a significant portion of the research outputs. This emphasis can be attributed to the region's importance in rice production and the increasing demand for sustainable agricultural practices. The citation analysis highlighted seminal studies that have significantly influenced the field and served as a foundation for subsequent research. Thematic analysis of the selected publications revealed common research themes, including mapping rice cropping patterns,

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monitoring yield variability, assessing water management practices, and studying the impacts of climate change on rice production. These studies have contributed to a better understanding of the dynamics of rice cultivation in the VMD and provided valuable insights into improving sustainability and food security. The research output in this region reflects the pressing need for accurate and up-to-date information to support effective land management decisions, water resource allocation, and climate change adaptation strategies.

EO-based rice mapping studies directly align with SDG 2 (Zero Hunger) by providing accurate information on rice cropping patterns, yield variability, and water management practices. These studies support efforts to enhance food security and promote sustainable agricultural practices in the VMD. The insights gained from such studies can inform decision-making processes related to crop management, resource allocation, and adaptation strategies, ultimately contributing to the goal of ending Hunger and achieving food security. Secondly, EO-based rice mapping studies contribute to SDG 15 (Life on Land) by monitoring and assessing the impacts of climate change on rice production. These studies provide valuable information for land management and conservation efforts. Understanding the dynamics of rice cultivation and its relationship with land use can support sustainable land management practices and help protect ecosystems in the VMD, contributing to preserving biodiversity and promoting sustainable land use.

Furthermore, EO-based rice mapping studies indirectly contribute to other SDGs, such as SDG 13 (Climate Action), by providing insights into the vulnerability of rice production to climate change and facilitating the development of climate-resilient agricultural practices. Additionally, these studies can contribute to SDG 6 (Clean Water and Sanitation) by assessing water management practices in the context of rice cultivation and supporting the sustainable use of water resources in the region. Thus, EO-based rice mapping studies provide valuable insights and information that can support sustainable agricultural practices, enhance food security, promote climate resilience, and contribute to conserving ecosystems in the VMD. By addressing these sustainability challenges, EO-based rice mapping studies play a crucial role in advancing progress towards the broader agenda of the UN SDGs.

4. Conclusions

A comprehensive analysis of rice mapping through EO data from 1979 to 2022 has been conducted using the SCOPUS database, employing bibliometric techniques. A total of 3,700 pieces of literature were evaluated globally, with 95 articles explicitly focusing on the VMD. Vietnam ranks sixth based on the number of scientific research on the aspects of rice mapping with the use of remote sensing techniques and is the fifth largest rice producer worldwide.

The analysis reveals that optical datasets are predominantly used in rice mapping through EO data. The study also highlights the significant contribution of geospatial advancements and freely available datasets. Machine learning algorithms, random forest (RF), support vector machines (SVM), time series analysis, phenological indices, and other spectral indices have been developed to map rice-producing regions worldwide. However, only two pieces of literature focused on studying the VMD using AVHRR hyperspectral images, with no global application reported among the 3700 literature analyzed for the study. Commercial satellite data from sources like SPOT, Terrasar-X, and Radarsat are also utilized in studying rice mapping. Several highly cited articles have been identified, such as "Spatiotemporal characteristics, patterns, and causes of land-use changes in China since the late 1980s" (Liu et al., 2004) and "Mapping paddy rice agriculture in southern China using multi-temporal MODIS images" (Xiao et al., 2005). The top-cited articles specific to the VMD area include works by Sakamoto et al. (2006), Kuenzer and Knauer (2013), Kontgis et al. (2015), and Nguyen et al. (2012). The journals "Remote Sensing of Environment" and the "International Journal of Remote Sensing" have the highest citations in this research field. The co-occurrence analysis of keywords revealed eight, four, and two clusters for the top three, five, and ten co-occurrences, respectively, indicating the critical research fronts in rice mapping using EO data. Over time, the number of publications in the VMD has increased, with the highest number observed in 2020 and 2021. Similarly, the uppermost number of journal publications specific to the VMD was recorded in 2018 and 2020, spanning from 1997 to 2022. In conclusion, the bibliometric analysis carried out in the present study provides a quantitative and comprehensive overview of rice mapping using EO data. Compared to global studies, the bibliometric analysis presented here provides valuable insights into the role of EO-based rice mapping studies in the VMD. These studies have significantly contributed to understanding rice cultivation dynamics, monitoring agricultural practices, and improving sustainability and food security in the region. The findings highlight the importance of continued research efforts and collaboration to address the evolving challenges faced by the VMD and similar agricultural regions worldwide.

The use of bibliometric analysis may give a further scope of studies in the application perspective of rice mapping using the EO datasets, such as the amount of methane emission and its impact on climate change. EO-based rice mapping has a scope for aiding in coping with natural calamities like floods and drought, where rice mapping can provide information on crop growth, yield estimation and thus provide a rapid assessment for estimating food production, a way towards food security and crop insurance.

Supplementary Materials: The downloaded datasets were first filtered to extract the list of literature on rice research using remote sensing techniques available for the VMD using the conditional formatting and filter tool in Excel. The selected datasets were exported for further use. The SCOPUS list provides in-depth information based on the category Authors, Author full names, Author(s) ID, Title, Year, Source title, Volume Issue Art. No., Page start, Page end, Page count, DOI, Cited by, Link, Abstract, Author Keywords, Indexed Keywords, Document Type, Publication Stage, Open Access, Source, EID (Scopus ID). The list of Indexed Keywords and Author's Keywords provided in the SCOPUS database was amalgamated into a single list of keywords using the Excel function. There were instances when duplicate values in the combined keywords list were removed using a code in Excel (Supplementary Table S1). The cleaned data had variation in many places, such as in some literature, it was reported to be land use; in some, it was reported as land-use; other instances were normalized difference vegetation index, NDVI etc. These variations were standardized to a single form for further analysis.

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References

Asilo, S., De Bie, K., Skidmore, A., Nelson, A., Barbieri, M., & Maunahan, A. (2014). Complementarity of two rice mapping approaches: Characterizing strata mapped by hypertemporal MODIS and rice paddy identification using multitemporal SAR. Remote Sensing, 6(12), 12789-12814.

Badaluddin, N. A., Lion, M., Razali, S. M., & Khalit, S. I. (2021). Bibliometric analysis of global trends on soil moisture assessment using the remote sensing research study from 2000 to 2020. Water, Air, & Soil Pollution, 232(7), 271.

Boschetti, M., Nutini, F., Manfron, G., Brivio, P. A., & Nelson, A. (2014). Comparative analysis of normalized normalized difference spectral indices derived from MODIS for detecting surface water in flooded rice cropping systems. *PloS one*, *9*(2), e88741.

Chandrasekar, K., Sesha Sai, M. V. R., Roy, P. S., & Dwevedi, R. S. (2010). Land Surface Water Index (LSWI) response to rainfall and NDVI using the MODIS Vegetation Index product. *International Journal of Remote Sensing*, *31*(15), 3987-4005.

Chen, J., Lian, Y., & Li, Y. (2020). Real-time grain impurity sensing for rice combine harvesters using image processing and decision-tree algorithm. *Computers and Electronics in Agriculture*, *175*, 105591.

Clauss, K., Ottinger, M., Leinenkugel, P., & Kuenzer, C. (2018). Estimating rice production in the Mekong Delta, Vietnam, utilizing time series of Sentinel-1 SAR data. International journal of applied earth observation and geoinformation, 73, 574-585.

Clauss, K.; Yan, H.; Kuenzer, C. (2016) Mapping rice in China in 2002, 2005, 2010 and 2014 with MODIS time series. Remote Sens. 2016, 8, 434.

Deng, L., & Romainoor, N. H. (2022). A bibliometric analysis of published literature on healthcare facilities' facilities' wayfinding research from 1974 to 2020. *Heliyon*, e10723.

Dinesh Kumar, C., & Satishkumar, J. (2019). Rice Crop Monitoring Using SENTINEL-1 C-Band Data. The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 42, 73-77.

Fukagawa, N. K., & Ziska, L. H. (2019). Rice: Importance for global nutrition. Journal of nutritional science and vitaminology, 65(Supplement), S2-S3.

Guan, X., Huang, C., Liu, G., Meng, X., & Liu, Q. (2016). Mapping rice cropping systems in Vietnam using an NDVI-based time-series similarity measurement based on DTW distance. Remote Sensing, 8(1), 19.

Hou, L. X., Mao, L. X., Liu, H. C., & Zhang, L. (2021). Decades on emergency decision-making: A bibliometric analysis and literature review. *Complex & Intelligent Systems*, *7*, 2819-2832.

IRRI, A. (2010). CIAT (2010) Global Rice Science Partnership (GRiSP). *CGIAR Thematic Area*, *3*.

Kane, D. A., Roge, P., & Snapp, S. S. (2016). A systematic review of perennial staple crops literature using topic modeling and bibliometric analysis. PloS one, 11(5), e0155788.

Kontgis, C., Schneider, A., & Ozdogan, M. (2015). Mapping rice paddy extent and intensification in the Vietnamese Mekong River Delta with dense time stacks of Landsat data. *Remote Sensing of Environment*, *169*, 255-269.

Kuang, W., Zhang, S., Du, G., Yan, C., Wu, S., Li, R., ... & Liu, J. (2022). Monitoring periodically national land use changes and analyzing their spatiotemporal patterns in China during 2015–2020. Journal of Geographical Sciences, 32(9), 1705-1723.

Kuenzer, C., & Knauer, K. (2013). Remote sensing of rice crop areas. *International Journal of Remote Sensing*, *34*(6), 2101-2139.

Kwak, Y., Shrestha, B. B., Yorozuya, A., & Sawano, H. (2015). Rapid damage assessment of rice crop after large-scale flood in the cambodian floodplain using temporal spatial data. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, *8*(7), 3700-3709.

Liu, J., Kuang, W., Zhang, Z., Xu, X., Qin, Y., Ning, J., ... & Chi, W. (2014). Spatiotemporal characteristics, patterns, and causes of land-use changes in China since the late 1980s. *Journal of Geographical sciences*, *24*, 195-210.

Liu, J., Liu, M., Tian, H., Zhuang, D., Zhang, Z., Zhang, W., ... & Deng, X. (2005). Spatial and temporal patterns of China's cropland during 1990–2000: an analysis based on Landsat TM data. *Remote sensing of environment*, *98*(4), 442-456.

Liew, S. C., Kam, S. P., Tuong, T. P., Chen, P., Minh, V. Q., & Lim, H. (1998). Application of multitemporal ERS-2 synthetic aperture radar in delineating rice cropping systems in the Mekong River Delta, Vietnam. *IEEE Transactions on Geoscience and Remote Sensing*, *36*(5), 1412-1420.

Liu, B., Zhang, L., & Wang, X. (2017). Scientometric profile of global rice research during 1985–2014. Current science, 1003-1011.

McFeeters, S. K. (2013). Using the normalized difference water index (NDWI) within a geographic information system to detect swimming pools for mosquito abatement: a practical approach. Remote Sensing, 5(7), 3544-3561.

Minh, H. V. T., Avtar, R., Mohan, G., Misra, P., & Kurasaki, M. (2019). Monitoring and mapping of rice cropping pattern in flooding area in the Vietnamese Mekong delta using Sentinel-1A data: A case of an Giang province. ISPRS International Journal of Geo-Information, 8(5), 211.

Morooka, K., Ramos, M. M., & Nathaniel, F. N. (2014). A bibliometric approach to interdisciplinarity in Japanese rice research and technology development. Scientometrics, 98(1), 73-98.

Mosleh, M. K., Hassan, Q. K., & Chowdhury, E. H. (2015). Application of remote sensors in mapping rice area and forecasting its production: A review. Sensors, 15(1), 769-791.

Murthy, C. S., Poddar, M. K., Choudhary, K. K., Pandey, V., Srikanth, P., Ramasubramanian, S., & Senthil Kumar, G. (2022). Paddy crop insurance using satellite-based composite index of crop performance. *Geomatics, Natural Hazards and Risk*, *13*(1), 310-336.

Nguyen, T. T. H., De Bie, C. A. J. M., Ali, A., Smaling, E. M. A., & Chu, T. H. (2012). Mapping the irrigated rice cropping patterns of the Mekong delta, Vietnam, through hyper-temporal SPOT NDVI image analysis. International journal of remote sensing, 33(2), 415-434.

Nguyen, T. T. H., De Bie, C. A. J. M., Ali, A., Smaling, E. M. A., & Chu, T. H. (2012). Mapping the irrigated rice cropping patterns of the Mekong delta, Vietnam, through hyper-temporal SPOT NDVI image analysis. *International journal of remote sensing*, *33*(2), 415-434.3

Norasma, C. Y. N., Fadzilah, M. A., Roslin, N. A., Zanariah, Z. W. N., Tarmidi, Z., & Candra, F. S. (2019, April). Unmanned aerial vehicle applications in agriculture. In *IOP Conference Series: Materials Science and Engineering* (Vol. 506, No. 1, p. 012063). IOP Publishing.

Peng, S. B. (2017). Booming research on rice physiology and management in China: A bibliometric analysis based on three major agronomic journals. Journal of Integrative Agriculture, 16(12), 2726-2735.
Peprah, C. O., Yamashita, M., Yamaguchi, T., Sekino, R., Takano, K., & Katsura, K. (2021). Spatio-temporal estimation of biomass growth in rice using canopy surface model from unmanned aerial vehicle images. *Remote Sensing*, *13*(12), 2388.
Perianes-Rodriguez, A., Waltman, L., & Van Eck, N. J. (2016). Constructing bibliometric networks: A comparison between full and fractional counting. *Journal of informetrics*, *10*(4), 1178-1195.
Prasetyo, Y., Sukmono, A., Aziz, K. W., & Aji, B. J. P. S. (2018, June). Rice productivity prediction model design based on linear regression of spectral value using NDVI and LSWI combination on landsat-8 imagery. In *IOP Conference Series: Earth and Environmental Science* (Vol. 165, No. 1, p. 012002). IOP Publishing.
Primicerio J, Gennaro S, Fiorillo E, Genesio L, Lugato E, Matese A, and Vaccari F (2012). A flexible unmanned aerial vehicle for precision agriculture. Precision Agriculture, 517-523.
Sakamoto, T., Yokozawa, M., Toritani, H., Shibayama, M., Ishitsuka, N., & Ohno, H. (2005). A crop phenology detection method using time-series MODIS data. Remote sensing of environment, 96(3-4), 366-374.
Sakamoto, T., Morinaka, Y., Ohnishi, T., Sunohara, H., Fujioka, S., Ueguchi-Tanaka, M., ... & Matsuoka, M. (2006). Erect leaves caused by brassinosteroid deficiency increase biomass production and grain yield in rice. *Nature biotechnology*, *24*(1), 105-109.
Sakamoto, T., Van Cao, P., Van Nguyen, N., Kotera, A., & Yokozawa, M. (2009). Agro-ecological interpretation of rice cropping systems in flood-prone areas using MODIS imagery. Photogrammetric Engineering & Remote Sensing, 75(4), 413-424.
Shew, A. M., & Ghosh, A. (2019). Identifying dry-season rice-planting patterns in bangladesh using the landsat archive. Remote Sensing, 11(10), 1235.
Shim D, Han J S, and Yeo H T (2009). A Development of Unmanned Helicopters for Industrial Applications. Journal of Intelligent and Robotic Systems, 407-421.
Sossa, C. L. G., Sanogo, S., Naab, J. B., & Sintondji, L. O. (2022). Trends and research features on greenhouse gas emissions from rice production: review based on bibliometric analysis. *Environmental Science and Pollution Research*, *29*(49), 73828-73841.
Sun J, Yuan BZ (2019) Visualization analysis of research on rice with fertilizer from the 'agronomy' category based on CiteSpace. Curr Sci 117(9):1449–1458. https:// doi. org/ 10. 18520/ cs/ v117/ i9/ 1449- 1458
Sun J, Yuan BZ (2020) A bibliometric analysis of research on rice and irrigation from the 'Agronomy' category based on the Web of Science. Curr Sci 119(3):438–446. https:// doi. org/ 10. 18520/ cs/v119/ i3/ 438- 446
Sun J, Yuan BZ (2020) Mapping of the world rice research: a bibliometric analysis of top papers during 2008–2018. Ann Libr Inf Stud 67(1):56–66
Sun, J., & Yuan, B. Z. (2020). Mapping of the world rice research: A bibliometric analysis of top papers during 2008–2018.
Teluguntla, P., Thenkabail, P. S., Xiong, J., Gumma, M. K., Giri, C., Milesi, C., ... & Yadav, K. (2015). Global Cropland Area Database (GCAD) derived from remote sensing in support of food security in the twenty-first century: current achievements and future possibilities.
Waleed, M., Mubeen, M., Ahmad, A., Habib-ur-Rahman, M., Amin, A., Farid, H. U., ... & El Sabagh, A. (2022). Evaluating the efficiency of coarser to finer resolution multispectral satellites in mapping paddy rice fields using GEE implementation. Scientific Reports, 12(1), 13210.
Wu, B., Zhang, M., Zeng, H., Tian, F., Potgieter, A. B., Qin, X., ... & Loupian, E. (2023). Challenges and opportunities in remote sensing-based crop monitoring: a review. *National Science Review*, *10*(4), nwac290.
Xiao, X., Boles, S., Frolking, S., Li, C., Babu, J. Y., Salas, W., & Moore III, B. (2006). Mapping paddy rice agriculture in South and Southeast Asia using multi-temporal MODIS images. Remote sensing of environment, 100(1), 95-113.
Xiao, X., Boles, S., Liu, J., Zhuang, D., Frolking, S., Li, C., ... & Moore III, B. (2005). Mapping paddy rice agriculture in southern China using multi-temporal MODIS images. Remote sensing of environment, 95(4), 480-492.
Xiao, D., Niu, H., Guo, F., Zhao, S., & Fan, L. (2022). Monitoring irrigation dynamics in paddy fields using spatiotemporal fusion of Sentinel-2 and MODIS. Agricultural Water Management, 263, 107409.
Xiao, M., Luo, Y., Zhang, H., Yu, Y., Yao, H., Zhu, Z., & Ge, T. (2022). Microplastics shape microbial communities affecting soil organic matter decomposition in paddy soil. Journal of Hazardous Materials, 431, 128589.
Yin, Q.; Liu, M.; Cheng, J.; Ke, Y.; Chen, X. (2019) Mapping rice planting area in Northeastern China using spatiotemporal data fusion and phenology-based method. Remote Sens. 2019, 11, 1699.
Yuan, B. Z., & Sun, J. (2022). Bibliometric analysis of rice and climate change publications based on Web of Science. Theoretical and Applied Climatology, 150(1-2), 347-362.
Zhang, Y., B. Yang, X. Liu, and C. Wang. 2017. "Estimation of Rice Grain Yield from Dual-Polarization Radarsat-2 SAR Data by Integrating a Rice Canopy Scattering Model and a Genetic Algorithm." *International Journal of Applied Earth Observation and Geoinformation* 57: 75–85.
Zhao, R., Li, Y., & Ma, M. (2021). Mapping paddy rice with satellite remote sensing: a review. *Sustainability*, *13*(2), 503.

 doi:10.20944/preprints202310.0892.v1

Zhou, G., Xu, D., Xu, D., & Zhang, M. (2013). Southern rice black-streaked dwarf virus: a white-backed planthopper-transmitted fijivirus threatening rice production in Asia. *Frontiers in Microbiology*, *4*, 270.