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Agriculture waste management: a bibliometric analysis

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Abstract: This study presents a detailed bibliometric analysis of agricultural waste management and its related policies. Literature on agricultural waste management has been reviewed for a time period of ten years (2011 to 2020) from Scopus database. Quantitative analysis and network visualisation has been conducted to highlight the core research constituents like authors, countries, journals, institutions, etc. RStudio and VOSviewer applications have been used for data analysis and visualisation. The scientific interests and most active and cited authors in the field have been identified along with their relationships. Most relevant publications and the most occurring keywords in the research field have also been highlighted. This approach helps in unpacking the evolutionary nuances of the agricultural waste management, identifying the emerging trends and areas and developing reference for future research.

Keywords: agriculture; agriculture waste management; waste management policy; bibliometric analysis.

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1 Introduction

Agriculture is the employment of farming practices for generating food (Nagendran, 2011). Agricultural practices always give rise to additional by-products that are less valuable than useful and desirable crop end products. "Agricultural wastes are unwanted or unsalable materials generated completely or partially from agricultural activities that are concerned with crop growing, animal rearing for an initial purpose of living". These are the leftover materials after crop harvesting and includes stems, leaves, peels, etc. (Prasad et al., 2020). It includes animal waste, crop waste, food processing waste and hazardous chemicals. Agricultural waste is a general term for organic matter that has been discarded during production of various major crops (Dai et al., 2018). The crops like rice, wheat, sugarcane, maize, millets, etc. generate approximately 3.7 Pg dry organic matter (Medina et al., 2021). Hence, agricultural waste can be considered as primary residues that can be converted into sustainable and useful products with the help of conversion techniques. The waste is majorly produced by cultivation activities, animal rearing on farm by the families of farmers and aquaculture (Mettu et al., 2020).

Agricultural sector is facing great challenges in terms of disposal and management (Esparza et al., 2020). This is a major problem for developing countries specially but affects developed countries also (Das et al., 2019). Developing countries lack efficient infrastructure for waste management and disposal and developed countries however, have high standards of living and per capita income that results in elevated waste generation due to refusal of products and services (Mmereki et al., 2016; Gupta, 2020a). Recently, agricultural waste has become a major source of pollution and is degrading the environment to a great extent globally (Wang et al., 2016). Annually approximately 140 billion tons of waste is generated by agricultural sector (Dutta and Subhashini, 2021). Agricultural waste demands adequate disposal and management so that it is utilised or recycled in an efficient manner. Improper disposal of such waste openly can change the chemistry of atmosphere and initiate adverse climatic changes (Medina et al., 2021).

Crop residue burning has various adverse effects. Open stubble burning has contributed majorly in environmental pollution. It is a potent hazard to animals, plants, aquatic life as well as humans. Direct burning of such waste releases green house gases (GHGs) and particulate matter into the atmosphere that leads to air pollution and ultimately to global warming (Almomani, 2020). It can cause various heart, respiratory

and neurological diseases or can be a cause of cancer (Singh et al., 2021). It is a threat to mankind and its well-being that leads to rise in mortality rates. Agro-waste contaminates soil and nearby water source as well. Adverse effects are not just limited to humans, rather agro-waste affects flora also. Loss of biodiversity is also a major drawback of poor agricultural waste management. This is caused due to decrease in fertility of soil by excessive use of chemicals like pesticides, herbicides, insecticides etc. As most cultivation activities are favoured by hot and humid weather, so is the proliferation of weeds and insects. This condition leads to usage of huge amounts of herbicides, pesticides and weedicides that ultimately results in chemical build-up in the climate and increases temperature. This increasing temperature is the cause of global warming. These chemicals not only degrades soil quality and impair its fertility, permeability and crop growth (Komnitsas and Zaharaki, 2014), but pollutes water sources also. As fertilisers contain huge amounts of nitrogen, phosphorus and potassium, these chemicals after run off from agricultural lands into nearby water bodies results in nutrient overload called eutrophication which in return leads to oxygen depletion and death of fishes (Ramírez-García et al., 2018). Crop producing lands mainly get deprive of essential nutrients that ultimately results in global nutrient imbalance (Gontard et al., 2018). Moreover, manure and organic material from poultry farms is a home to various harmful bacteria, parasites and heavy metals that not only pollutes surface water but contaminates ground water also (Zhang et al., 2016). Air pollution not only affects humans and environment, it also alters the development of a country by decreasing tourist's inflow and increasing people sickness (Zhang et al., 2020a). Collectively, these factors lead to degradation of human and environmental health.

During the last 50 years, production of agricultural waste has increased three folds (FAO, 2017). The reason behind this is the accelerated population growth, technological enhancement in agricultural sector and soil expansion for cultivation purposes (Gupta, 2020b). Approximately 23.7 million tons of food is produced every day at global level that has imposed a negative effect on environment and has compromised sustainability (Kumar and Vidhyalakshmi, 2012). Agriculture sector solely contributes 21% of the greenhouse gases that are being emitted into the atmosphere (Duque-Acevedo et al., 2020a). By 2050, world population is estimated to increase up to 10 billion and waste production is supposed to exceed 4 billion mark which stands for double of the current amount, hence indicates urgency to address and mitigate climatic changes (Tankha et al., 2020). According to statistics provided by Indian Agricultural Research Institute (IARI), India burns 22 Mt of rice stubble every year (Abdurrahman et al., 2020). These figures are supposed to increase with time and increasing population. This need for agro-waste management is heightened by climatic change impacts on agricultural sector and precipitation patterns, increasing global temperature and pests and weeds (Toop et al., 2017).

There are a lot of factors that influence adequate utilisation and recycling of waste. Due to inter-disciplinary nature of the field, it is difficult to identify main challenges confronted in waste management (Bernal, 2017). One of the major problem in utilisation of agricultural waste is the huge and unknown amounts of waste that is generated every year (Wang et al., 2016). There is also another major challenge in front of the policy makers and stake holders, that is the transformation of complicated, heterogeneous and biodegradable substances into some valuable products that can reduce the dependence on fossil fuels (De Corato et al., 2018; Gupta, 2022). Furthermore, a potential constraint in

the management of agro-waste is the lack of data regarding various geographical regions about quantity and characteristics of the waste produced. Promotion of recycling of waste is not highlighted enough (Bourguignon et al., 2015). There is lack of cost-effective technologies needed for the conversion of agro-waste into useful commodities and also discontinuous supply chain of waste stands as an opposition against efficient management of waste (Kapoor et al., 2020). Lack of knowledge and understanding of the alternative methods and concept of sustainability, in addition to resistant behaviour of the farmers towards new technologies is also a challenge against efficient agricultural waste management (Laurett et al., 2021; Gupta and Kumar, 2008). Other few challenges in waste management are funding problems in waste management projects; lack of coordination between state and central government bodies responsible for managing agro-waste; lack of public awareness, their participation towards management and research work in the field (Chand Malav et al., 2020).

Global warming is a serious and alarming problem, hence utilising and recycling the waste generated is the best and efficient way to control it (Gupta and Kumar, 2012). Rapid industrialisation, increasing population, enhancement in standard of living and over-use of natural resources has resulted in environmental pollution that is affecting human kind. It has become a serious threat to ecological balance and needs to be addressed. Recently, enormous amount of agricultural waste is being generated year after year. It is increasing rapidly. Present methods of disposal are lagging behind to manage the current amounts of agro-waste and utilising it as a resource. As fertilisers alter the quality of soil and its buffer capacity, reusing agricultural waste can help in improving soil quality (Dai et al., 2018). Agricultural waste can be served as a raw material for production of various bio-products like enzymes, antibiotics, bio-fuels etc. and utilised as a resource. If this huge pool of trapped biomass is utilised wisely, it will definitely support global economy. Owing to such adverse effects of agricultural waste on humans and environment, underlying problems and issues should be examined, policies and their functionalities need to be reframed so that problems can be overcome that are preventing farmers from being sustainable. Potential alternatives should be introduced.

Agricultural waste management is a complicated process and demands individual as well as collective attention. A multi-disciplinary approach is needed towards adequate understanding of the problem and its possible solutions. Effective management of waste involves certain steps including collecting waste, treatment, its disposal, storage and recycling (Okoro et al., 2020). For policymakers, agricultural waste management has recently become a matter of utmost priority in the fields of ecological agriculture and sustainable development (Dutta and Subhashini, 2021). Policies regarding the same should be encouraged to utilise the waste as a biomass resource. The extent of the problem can be estimated by figuring out the quantity of agro-waste generated and its characteristics (Loehr, 1978). Adopting circular economy can be a good plan towards this problem. Interest in utilising the agricultural waste rather than just disposal should be encouraged for extracting the maximum benefit out of the waste (Gupta et al., 2012). This can be attained by motivation and innovation, change in thinking regarding waste and better alternatives to handle it. Conversion of this huge amounts of agro-waste into some useful commodity is a necessity for human well-being and global economic growth (Gontard et al., 2018), as agro-waste has a high potential of generating sustainable energy from renewable resources. This global issue requires adequate and practical reforms in the structure of the world economy (Gupta, 2016).

Rest of the paper includes literature review of the agricultural waste management followed by bibliometric analysis that is the aim of this study. The results and findings are presented along with discussion in the later sections.

2 Literature review

Agricultural sector play a significant role in the global economy and its development (Kumar and Gupta, 2021). But there has been limited research and discussion regarding management of agricultural waste in the available literature. The possible reason could be the handling of ago-waste by farmers or the persons owing the land themselves rather than public sector involvement (Bhuvaneshwari et al., 2019). Agricultural sector however, sponsors a great opportunity for development and business in developing as well as developed countries because there is tremendous increase in demand for food for growing population. Intensification of agricultural activities has resulted in elevated environmental pollution and difficulties in agro-waste disposal.

The concept of bibliometric analysis and its method was first proposed by Alan Pritchard in 1969 (Fernández-González et al., 2020). It represents relationship between authors, articles, disciplines, organisations and countries examining bibliometric data quantitatively and objectively (Albort-Morant and Ribeiro-Soriano, 2016). These methods of analysis have gained recognition to a greater extent in recent times. Factors like information flow between various disciplines, easy access to bibliometric software and enhanced communication can be attributed to this immense popularity (Khan et al., 2021). Bibliometrics can be used for a variety of purposes, like unveiling recent research trends in a field, identifying collaboration patterns and intellectual structure of a particular domain (Verma and Gustafsson, 2020). Bibliometric analysis can be an effective tool in decoding and mapping the large volume of unstructured scientific data and evolutionary path of various disciplines (Donthu et al., 2021). Relationship among a research field and a paper is represented graphically by bibliometric maps that utilises visualisation techniques (Ahmed et al., 2018). Hence, it can help research scholars in advancing the knowledge of the field, contributing ideas and identifying gaps in research.

Various techniques used in the analysis of bibliometric data are co-authorship analysis, co-word analysis, bibliographic coupling and co-word analysis. In this study, co-authorship, co-citation and co-word analysis has been deployed. Co-authorship indicated the collaboration among authors of different disciplines, organisations and countries in a field of research (Acedo et al., 2006). It's a formal way of collaborating intellectually. Co-citation analysis signifies the similarity in themes of publications cited together (Hjørland, 2013). It indicates the co-occurrence of two publications in the reference list of third one. These relationships give insights of concerned research field. Similarly, co-word analysis uses 'words' as its unit of analysis (Emich et al., 2020). Unlike other two methods of analysis, this method examines the actual content of an article. It gives the number of occurrence of a word in a document and can be plotted in the form of a map that signifies strength of correlation (Su and Lee, 2010). Hence, bibliometric analysis objectively evaluates the research work carried out in a field (Noyons et al., 1999) and provides a macroscopic view of scientific literature available (Van Nunen et al., 2018). This method has also been used in analysing scientific research

literature of various disciplines like business (Kumar et al., 2021), management (Ellegaard and Wallin, 2015), human resource (Andersen, 2021), marketing, etc.

A lot of efforts have been made overtime to investigate agriculture waste management. Medina et al. (2015) reviewed the management and stabilisation of crop residues. The process of composting was taken into account to enhance suitable environmental conditions. Nguyen et al. (2019) reviewed agriculture waste as a source of sustainable and renewable energy source for the production of bio-based and value added products. Optimal usage of waste and application of techniques was disclosed in the study. Moreover, Martinho (2019) used the bibliometric technique to analyse the core areas related to agriculture and highlighted the best waste management techniques prevailing and utilised in the agriculture sector all around the globe. A scientometric study was conducted by He et al. (2019) for a time period of 1970–2016 that offered insights of evolutionary trends and topics of the waste management in the agriculture sector. The study revealed the reliance of agriculture waste management on regional and global policies that are specific to each social, economic and cultural background. Duque-Acevedo et al. (2020b) analysed the agricultural biomass management strategies with the help of circular economy. Their evolution over the period was studied and the bibliometric analysis of the keywords of circular economy models was done. By analysing the overview of the paper, sustainability was emphasised and policies regarding the same were approached. These studies pointed out the problem of growing agriculture waste management and also revealed questions for further researches. With increasing participation of research scholars in this research area and the development of topic will provide easy approach for future scholars. Bibliometric method can be used to bridge information between past and future researches to resolve the prevalent issues.

In this paper, literature regarding the agriculture waste and its management has been reviewed for a time period from 2011–2020. It was analysed that management of agro-waste is limited and at its initial stages. Each sector is aware of the importance of the agriculture waste management, still there are a few publications of bibliometric study in the field. Hence, based on this literature review, this paper aims to conduct bibliometric analysis of the existing research in this field and develop a systematic structure of the concept. A result of the study provides information about current research trends and topics to develop links for scientific references in future. These results can be utilised by government to articulate and modify their development plans and programs. These aspects are also related to farmers and stakeholders in agriculture sector, hence can be utilised for transitioning to new and better economic models. The work will also serve the purpose of identifying terms related to agriculture waste, their recovery techniques and the gained relevance of topic during recent years.

3 Methodology

Bibliometric analysis is interdisciplinary in nature and integrates various components like statistics, mathematics, philology and other knowledge carriers (Raghuram et al., 2010). It helps in exploring distribution patterns and identifying characteristics of the available literature systematically and objectively, hence helps in evaluating recent status of research and development in the research field (Zhang et al., 2020b). Bibliometrics analyses information and provides relationships among authors, citations, keywords, journals etc. (Feng et al., 2017). This analysis processes data and produces output as

'quantity'. This paper utilises the method of bibliometric analysis for performing literature review and quantitatively assessing the literature regarding agricultural waste management and its related policies.

3.1 Data collection

Scopus database has been used for collecting data because of its comprehensive nature (http://www.scopus.com). Data was extracted from Scopus databased on 1 November 2021. The coverage of the database is vast. In order to extract the data, following queries were run on the Scopus database.

- Query 1:

  ('Agricultural waste' AND 'management') OR ('agro waste' AND 'management') OR ('agri waste' AND 'management') OR ('agriculture waste' AND 'management') OR 'agricultural waste management'.

- Query 2:

  ('Agricultural waste' AND 'management') OR ('agro waste' AND 'management') OR ('agri waste' AND 'management') OR ('agriculture waste' AND 'management') OR 'agricultural waste management' AND ('bibliometric' OR 'bibliometry' OR 'bibliography' OR 'bibliographic').

Query 1 resulted in a total of 1,648 documents. 'Agricultural waste management' is the main keyword and focus of the query. Query 2 was run in the database that resulted in eight documents. This query is regarding 'bibliometric analysis' of agricultural waste management.

3.2 Data analysis

For ensuring consistency, a data cleaning process was conducted. Errors were manually checked, corrected and a coding standard was set. Descriptive analysis was done and network plots of co-authorship, co-citation and co-word analysis was plotted. Information like most influential authors, most cited journals, documents and keywords was obtained. Network maps were plotted with the help of VOSviewer. Research trends were conceptualised and the field of agriculture waste management was explored.

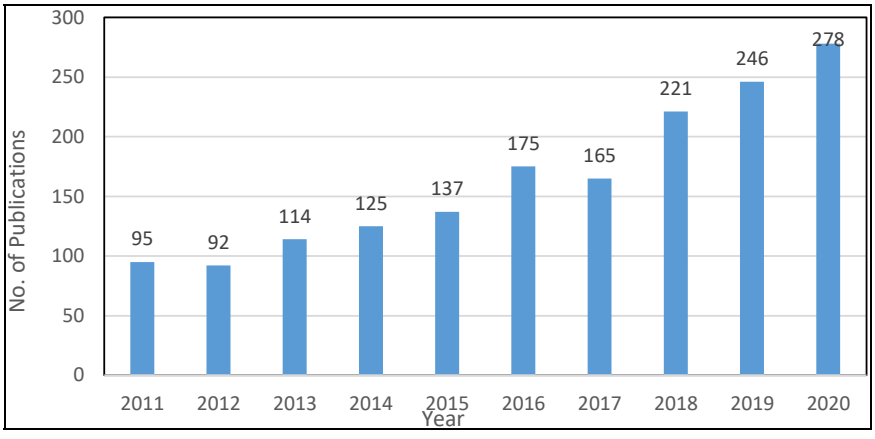
4 Bibliometric analysis

In modern times, bibliometric or scientific analysis can help oriented individuals and researchers in thoroughly understanding the research direction and patterns of a particular research field, hence resulting in better understanding and tracking of current research trend. Due to advancement in technology, various tools and software has been available to perform bibliometric analysis. Some of these software includes VOSviewer, Bibexcel, Histcite, Gephi and Citespace. Bibliometric tools used in this paper are R Studio and VOSviewer. R Studio is easy to operate and a powerful software that analyses vast range of data and fulfils research demands. VOSviewer is used to analyse networks and create scientific maps as it helps in understanding the relationship between knowledge units in an efficient manner.

4.1 Descriptive analysis

Figure 1 represents the number of research articles published in this field from 2011 to 2020. It can be seen from the figure that there has been an increased participation and paper publication in this field. In 2011 and 2012, there were less than 100 papers published in this field that immensely increased up to 278 in 2020. The annual growth rate of paper published in this field is 12.67%. These statistics showed the growing interest and concern of people and research scholars in this particular field.

Figure 1 Annual scientific production (see online version for colours)



4.2 Journal analysis

In addition to the number of articles published every year, the sources of published articles are also ranked in this paper. Table 1 lists down top ten journals in the field of agriculture waste management. These journals are mostly related to environment and ecology. *Science of the Total Environment* is a scientific journal in the field of environmental science that ranked first among all the sources by publishing 114 articles in the related field. *Waste Management* and *Soil and Tillage Research* ranked second and third with 106 and 92 articles respectively. These ranking of journals indicate the increased attention of various disciplines including technological attributes towards the issue of agriculture waste.

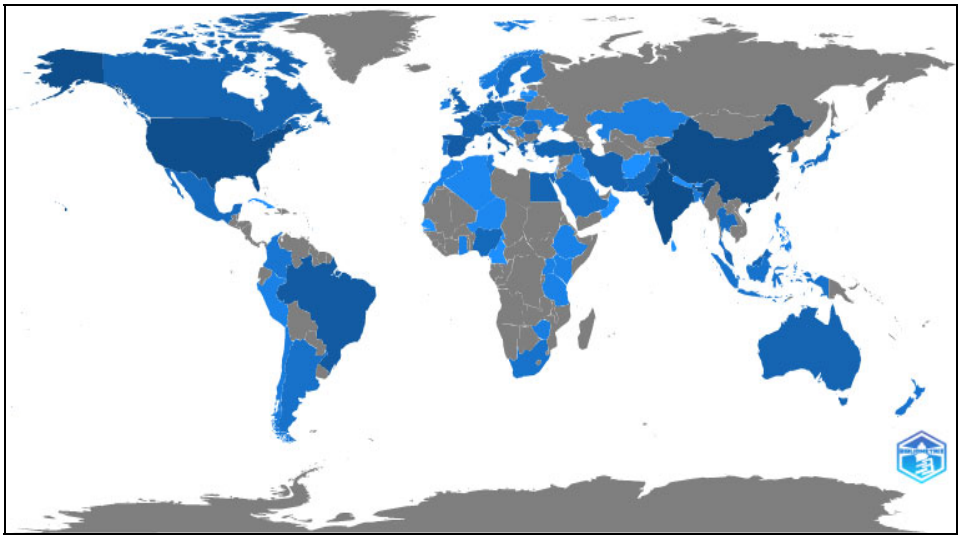
Geographical distribution of documents published in the field has been shown in Figure 2. Total numbers of articles are marked on the map with the help of colours. The grey part on Figure 2 represents absence of any contribution towards the field by the respective country or region and blue part represents articles published by that certain country. The deeper the blue colour, the more articles have been published by that country or region. On the map, China has the deepest blue colour that indicates the highest number of articles published in this field, with 282 articles. India stands second in the list with a massive contribution of 254 articles. After China and India, USA ranked third in its contribution with 248 articles. These three countries have contributed maximum number of articles towards agriculture waste management. More countries like Brazil, Italy, Spain and Greece have also occupied significant position. However, there

are certain countries like Russia, in which this field saw no articles during the studied period of time.

Table 1 List of top 10 publication sources

Rank	*Sources*	*Articles*
1	*Science of the Total Environment*	114
2	*Waste Management*	106
3	*Soil and Tillage Research*	92
4	*Bioresource Technology*	81
5	*Journal of Environmental Management*	42
6	*Journal of Cleaner Production*	31
7	*Water Science and Technology*	28
8	*Geoderma*	26
9	*Environmental Technology (United Kingdom)*	24
10	*Chemosphere*	23

Figure 2 Geographical distribution of articles published during 2011–2020 (see online version for colours)



4.3 Keyword analysis

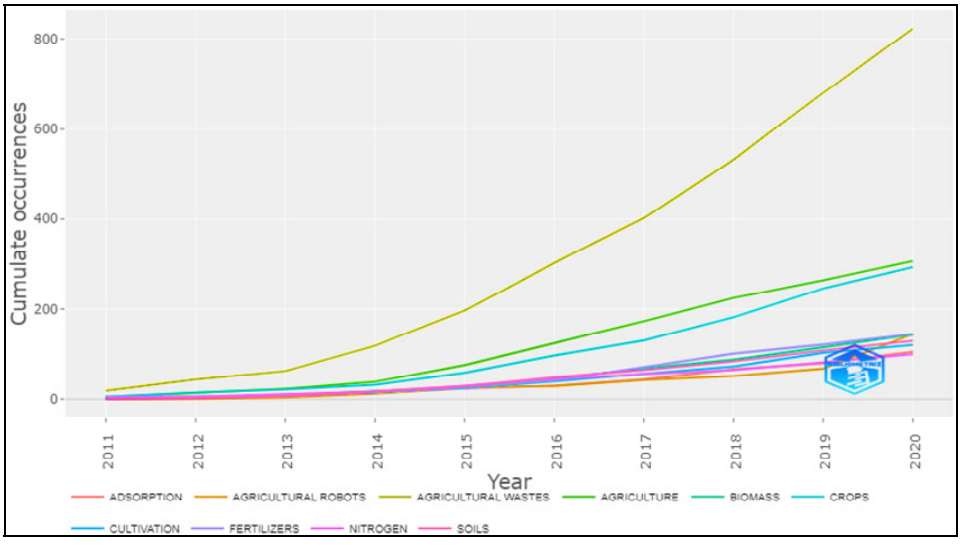
Out of 1,648 documents, 4,826 author's keywords were analysed with R, a table listing top 15 keywords with maximum occurrence was obtained (Table 2). Table 2 represents that 'adsorption', 'biochar', 'agricultural waste', 'anaerobic digestion' and 'biogas' are the top five keywords with maximum frequency of occurrence among all the articles. In addition, biomass, bioenergy and sustainability have also occurred considerably. The term, agriculture waste has occurred synonymously by the name of 'agriculture wastes', 'crop residues' and 'agricultural wastes' and their occurrence as keywords are

considerable in number. These keywords represent the orientation of research scholars and scientists towards adequate management of agriculture waste. The keyword sustainability emphasises its requirement and growing attention towards the same, but its frequency suggests that there is still some scope of exploration in this field.

Table 2 Top 15 keywords

S. no.	*Author's keywords*	*Frequency*
1	Adsorption	88
2	Biochar	74
3	Agricultural waste	65
4	Anaerobic digestion	63
5	Biogas	56
6	Biomass	52
7	Waste management	49
8	Bioenergy	48
9	Crop residue	47
10	Agricultural wastes	36
11	Sustainability	32
12	Agricultural residues	30
13	Crop residues	29
14	Activated carbon	26
15	Soil organic carbon	25

Figure 3 Time sequence analysis diagram of keyword plus (see online version for colours)



In addition, a total of 5,137 keyword plus were also analysed for the time period of ten years (2011–2020) and time sequence analysis diagram (Figure 3) of keyword plus was obtained from 1,648 articles. Keyword plus are different kind of keywords. They are

independent of author's keywords and title of the articles and represents more detailed search result by evaluating the article content. Keyword plus are the phrases or words that are extracted from titles of references by some computer algorithms (Liao et al., 2019). Figure 3 indicates that 'agricultural wastes', 'agriculture' and 'crops' are the top 3 occurring words. Surprisingly, adsorption occurred less frequently as a keyword plus as compared to author keyword. Several other words like agricultural robots and fertilisers have also occurred significantly as keyword plus that indicates the direction of research towards wise management of agriculture waste and its conversion into some useful commodity.

Table 3 Top 10 papers with highest number of citations

S. no.	*Papers*	*TC*	*TC per year*
1	Libra, J.A. (2011) *Biofuels*	998	83.1667
2	Pittman, J.K. (2011) *Bioresour. Technol.*	996	83.0000
3	Shen, H. (2013) *Environ. Sci. Technol.*	478	47.8000
4	Yao, Y. (2011) *J. Hazard Mater.*	398	33.1667
5	Ali, R.M. (2016) *Ecol. Eng.*	397	56.7143
6	Bilal, M. (2013) *J. Hazard Mater.*	351	35.1000
7	Christofoletti, C.A. (2013) *Waste Manage*	293	29.3000
8	Silva, V. (2019) *Sci. Total Environ.*	276	69.0000
9	Abdolali, A. (2014) *Bioresour. Technol.*	271	30.1111
10	Xu, R-K. (2011) *Bioresour. Technol.*	249	20.7500

4.4 Citation analysis

Top ten most cited articles out of 1,648 articles have been listed in Table 3. The table also lists first author, year of publication, source, total number of citations and total citations per year. The most cited paper is the one by Judy A. Libra et al. published in *Biofuels* in 2011. This paper focused on carbonisation of agricultural waste to char for producing a variety of other environment friendly products. This paper has total citation of 998 and has the highest total citations per year which makes it an extensive influential paper. The number of citations indicate that more research work is carried out in the discipline and there is growing attention towards it.

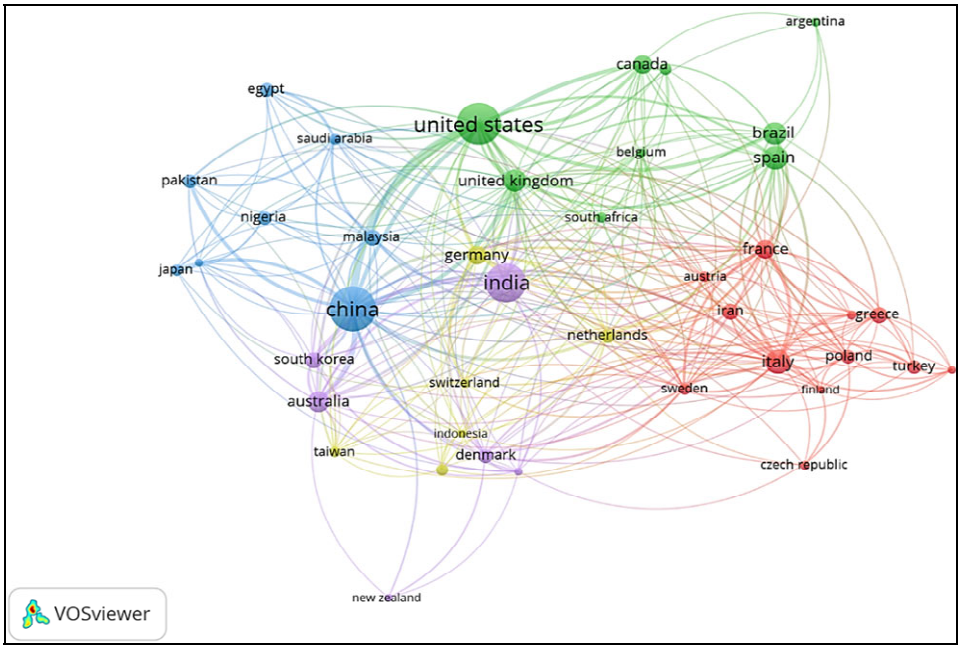
5 Network analysis

5.1 Co-authorship analysis

Figure 4 shows the analysis of cooperation among various nations. The network has been plotted using VOSviewer. In the diagram, each country is represented by a node and different colours represents clusters. Components of a single cluster have high similarity index and different clusters shows high differences. Lines between the nodes of two countries represents co-authorship relationship among authors of those respective countries. When two countries collaboratively publish more frequently, line between those two countries would be thicker as compared to others. As shown in Figure 4, China,

USA, India, Italy, Spain and Britain are highly active among all countries towards academic cooperation in this field. China has a huge cooperation index with many other countries like USA, Britain, Australia, Germany, Italy and Spain. Academic cooperation between China and USA is quite massive and significant. Cooperation of Italy and Spain with other countries along the globe is also very close which signifies that geography plays a vital role in academic cooperation. Due to technological advancements, there has been an increased communication internationally among authors of different countries that enrich the field with varied contributions and collaborations.

Figure 4 Co-authorship network of countries (see online version for colours)



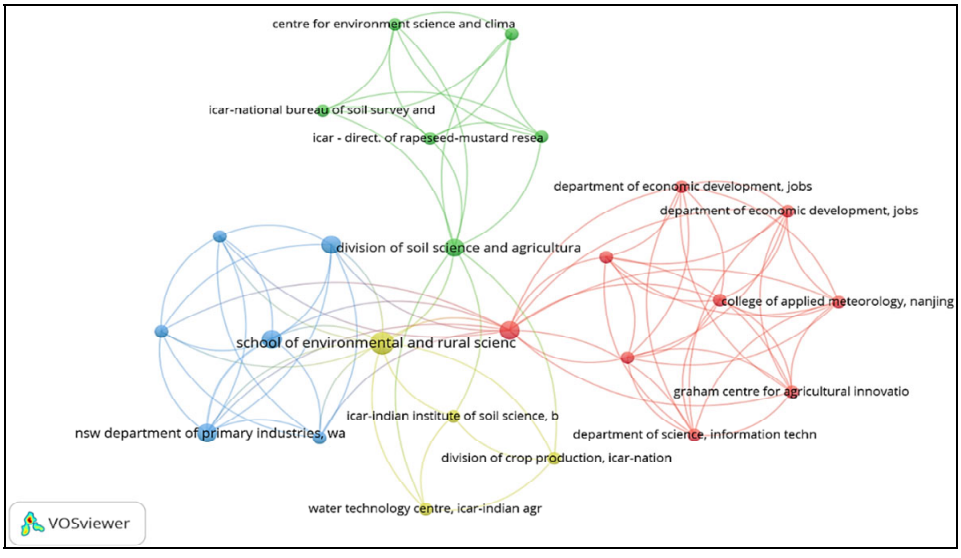
Cooperation among various institutes of these countries was also analysed as shown in Figure 5. For this purpose, a total of 4,256 organisations were screened on the basis of published articles. Out of all, 25 institutes with 89 links were selected and divided into four clusters. Among these institutes, School of Environmental and Rural Science (Australia), School of Environmental and Resource Sciences (China) and ICAR-IARI are the largest nodes. These results confirm the trends that are depicted in Figure 4.

5.2 Co-citation analysis

Co-citation analysis concept was first proposed by an American scientist Henry Small in 1973. He gave the concept in his article 'Co-citation in the scientific literature: a new measure of the relationship between publications'. This analysis measures the degree of correlation between two different documents. It describes the occurrence of two articles in the reference list of the third article together, hence forms the knowledge base of any particular field or topic and emerging research trends (González-Alcaide et al., 2016). It can also explore author's relationship with each other and identify those who do not

actively collaborate. Citation of two different articles together indicates that the authors are studying and researching on the same topic. Furthermore, it also helps in analysing and mining the developments and relations between articles. Co-citation frequency can aid in quantifying the academic influence of references.

Figure 5 Co-authorship network of organisations (see online version for colours)



Co-citation network of cited authors has been shown in Figure 6. On account of threshold setting and huge number of articles, number of citations per author was set to 30 that resulted in 692 authors from 116,197 authors. Authors were divided into five different clusters represented by different colours. A cluster represents inter-connected nodes containing similar information. Size of the nodes represents the impact of citations of author's documents. Article citation depends on the number of published articles and their impact. Figure shows that Rattan Lal has the highest number of citations and his impact cannot be underestimated in this field.

Figure 6 Co-citation network of cited authors (see online version for colours)

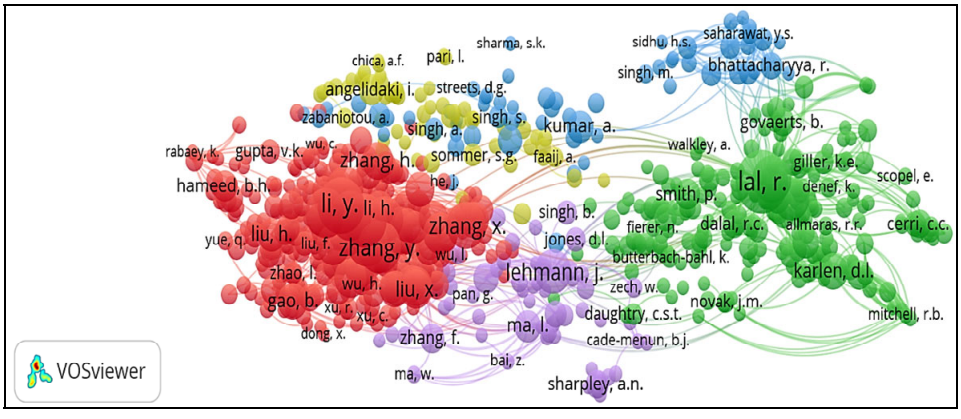


Figure 7 Co-citation network of cited sources (see online version for colours)

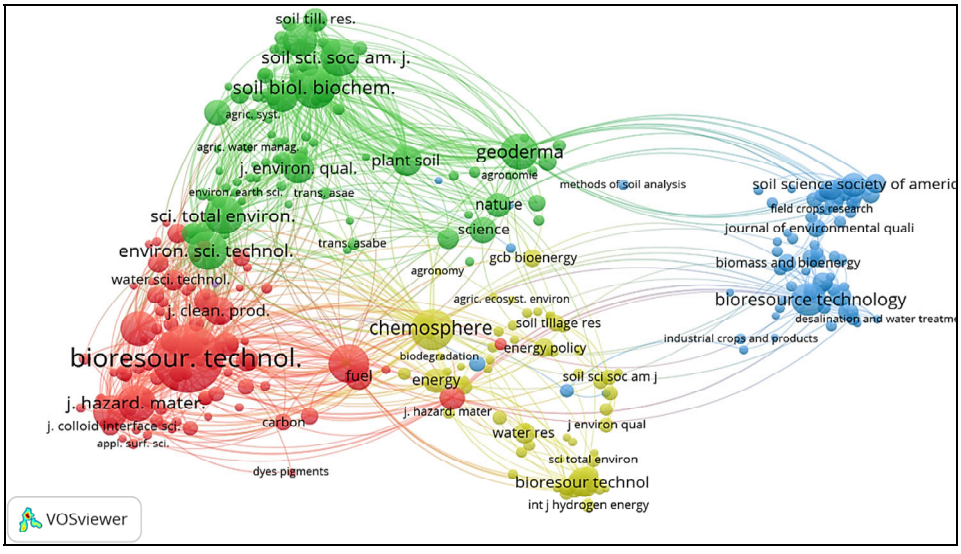
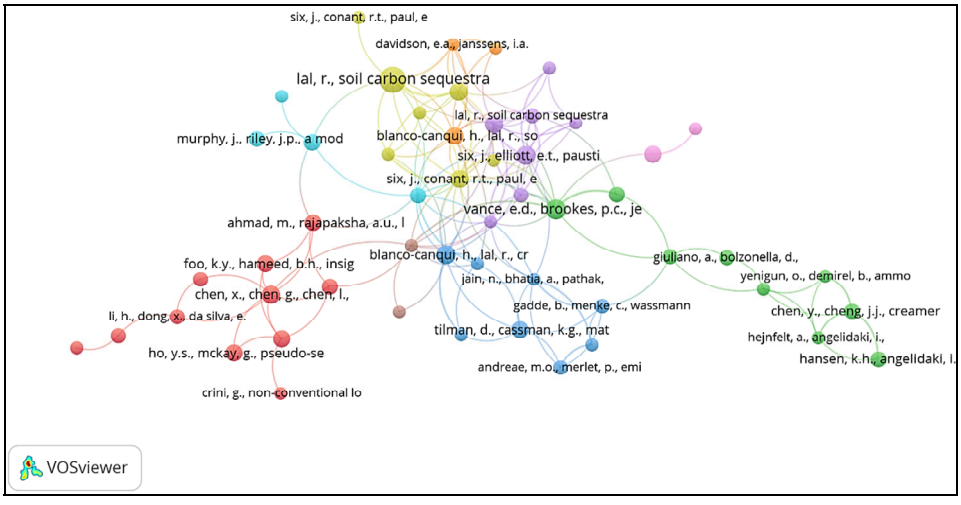


Figure 8 Co-citation network of cited references (see online version for colours)



Documents of a similar cluster are mostly cited together representing a close relationship in topics or research area of all articles. A keen evaluation of the research areas and topics was done and the clusters were divided into four different subjects. Cluster 1 (red colour) of documents is the largest one containing 301 nodes and topics are related to agricultural waste products and their management techniques aimed at improving environmental quality. Cluster 2 (green) contains 208 items that focuses on production of bio-based products. Sustainability is the main focus of the cluster. Cluster 3 (blue) and cluster 4 (yellow) containing 62 items both focus on the impacts of these bio-based products in improving the existing soil, water and environment quality.

Cluster 5 (purple) having 59 items majorly focuses on the mitigation measures prevailing in several developed as well as developing countries during certain periods of time.

Co-citation network analysis of cited sources was also done as shown in Figure 7. Minimum citation number was set to 30, and total number of sources fulfilling the criteria was 328. It can be seen from the figure that *Bioresource Technology* is the most cited source with total citation number of 2,159. However, the influence of *Chemosphere*, *Soil Biology and Biochemistry* and *Biomass Bioenergy* should not be underestimated.

Figure 8 shows the co-citation analysis network of cited references. The value of cited articles was set to 5 and 57 documents were retrieved, out of which, 53 documents form co-citation network. There were a total of nine clusters among which the largest ones contained 11 articles in red cluster and nine articles in green. Yellow cluster contains the largest node that represents an article published by Rattan Lal in 2004.

5.3 Co-word analysis

Co-word analysis is a method of content analysis that utilises keywords in articles for plotting scientific maps related to that particular field (Callon et al., 1983). Keywords can be conceptualised based on the frequency of their occurrence that aids researchers in analysing the actual content of article. Just like co-citation analysis, it helps in generating relationships among various keywords. Density map is an effective way of analysing the influence and strength of keywords (An and Wu, 2011). VOSviewer is an easy and user friendly tool of constructing network. Different colours like red, yellow, blue and green indicates different values of density as shown in Figure 9. More the warmer colour, higher is the density. This high density reflects more frequent occurrence of the concept in that field. According to the figure, ‘agriculture waste’ is the hottest keyword which is highly accompanied by ‘waste management’. Three major parts can be figured out of the density map. First part is about agricultural waste, second part examines soil, its components and nutrients, and the third part is related to effects and utilisation of agriculture waste.

Keyword is the building block of co-word analysis and a threshold should be set to examine their frequency of occurrence (Zupic and Čater, 2015). A total of 4,887 keywords were identified from all papers, but it is quite difficult to plot network of such huge data. Minimum occurrence of keywords was kept to 10 and a total of 69 keywords was obtained. Figure 10 shows the network map of co-word analysis of author’s keywords in which different colours represent different clusters. Each keyword is represented by a node and size of the node emphasises the occurrence frequency of that keyword. These five clusters are evaluated and labelled according to the focus of the research area and keywords included.

Cluster 1 is represented by red colour with a total of 19 keywords. Documents of this cluster focuses on the ‘utilisation’ of the agriculture waste for the fabrication of useful products like biogas, compost, methane, etc. Main keywords of the cluster are ‘agricultural waste’, ‘anaerobic digestion’ and ‘biogas’. These products can be utilised for the benefit of mankind as well as environment.

Cluster 2 contained articles that are related to ‘waste management’ and its techniques. Bio-based products are then utilised in treating water and soil. Some of the most occurring keywords are ‘adsorption’, ‘biochar’, ‘waste management’ and ‘activated carbon’. Pyrolysis and gasification are some of the techniques used to treat waste.

Figure 9 Co-word analysis network of all keywords (see online version for colours)

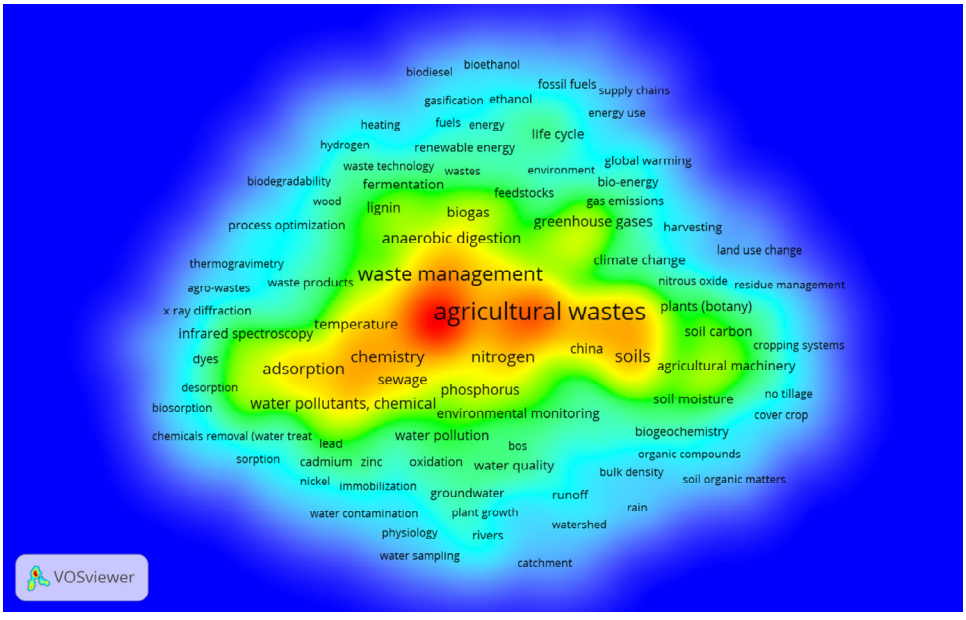
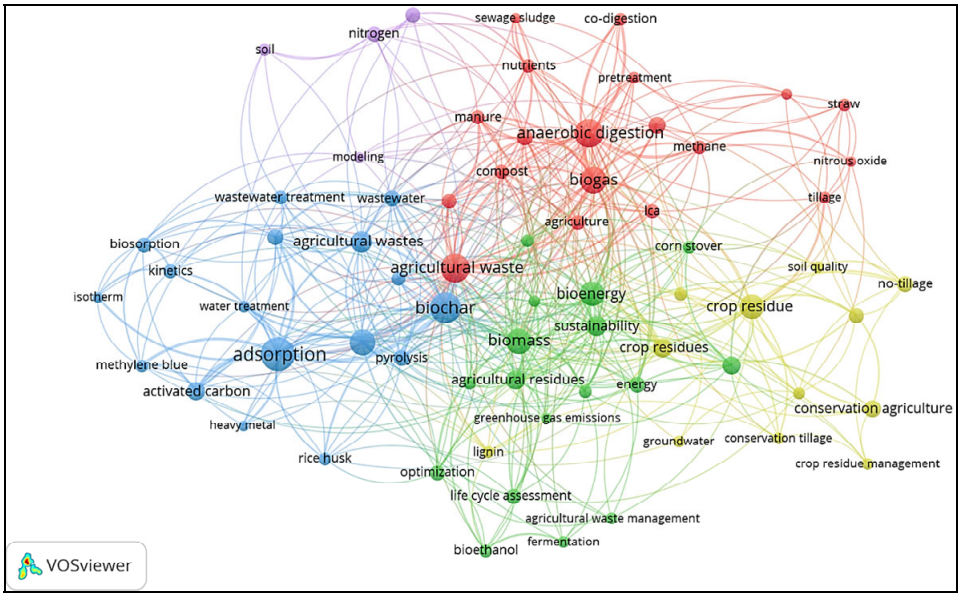


Figure 10 Co-word analysis network of author keywords (see online version for colours)



Cluster 3 emphasised ‘sustainability’ in managing waste and energy production. Keywords included in this cluster are ‘bioenergy’, ‘biomass’ and ‘sustainability’. In this cluster, life cycle assessment was also emphasised. Sustainability was elevated by managing green house emissions while utilising the agricultural waste. Energy production and conservation was the main focus of the cluster.

Lastly, clusters 4 and 5 emphasised ‘crop management’ and its components. Soil and water quality was given immense importance. Some of the keywords included ‘crop residue’, ‘conservation agriculture’, ‘soil quality’ and ‘water quality’. Soil management was highly emphasised in these clusters.

6 Discussion

Agriculture waste and its management turns out to be a matter of global attention that needs adequate steps. Increasing population has intensified the generation of waste in an attempt of fulfilling the needs of food and shelter that has resulted in severe environmental degradation. In this paper, bibliometric analysis on Scopus database is done during the time period of 2011–2020. A total of 1,648 articles were obtained regarding agriculture waste management. According to statistics, maximum numbers of research articles are published during the year 2018–2020, that indicates the increased attention of researchers towards the field recently. The analysis also highlighted the top authors, journals, countries, papers and institutes that are actively engaging in this domain. Network maps of co-authorship analysis, co-citation analysis and co-word analysis were also plotted. Through analytics, various clusters were also formed related to agriculture waste and its management. These clusters provide information about various considerations required for the proper management of agriculture waste.

Co-authorship analysis revealed that China, India and USA are the top contributors of articles in the field and also showed high co-operation among USA, Britain, Australia, Germany, Italy and Spain. In addition to countries, four clusters of institutes were also formed among which School of environmental and rural science (Australia), School of Environmental and Resource Sciences (China) and ICAR-IARI formed the largest nodes.

Co-citation analysis also resulted in clusters that represented different themes. Themes included ‘waste management techniques’, ‘waste derived products’, ‘sustainability’ and ‘management plans’. The focus of researchers should be towards adequate management of waste with efficient techniques. Alternative use of waste to develop variety of useful products should be the aim of research. Scholars can also assess the effectiveness of agro-waste derived products in different fields that can provide a framework for future developments.

Co-word analysis of author’s keywords was also conducted. Four themes identified were ‘waste utilisation’, ‘waste management’, ‘sustainability’ and ‘crop management’. This theme indicates the main areas of improvement in the research field. Researchers should emphasise their work towards better utilisation of waste and their conversion techniques. There has been an increasing attention towards the concept of sustainability and efforts are being made to develop new models of waste management. Researchers need to focus their efforts to developing a holistic management approach based on the insights of data.

7 Conclusions

As agriculture sector is quite vast and rich in terms of organic matter and availability, more researchers are engaging towards this interdisciplinary sector. Researches are

developed as well as developing countries are needed to elevate its management. This study has illustrated research flow of work in this field with the help of bibliometric analysis. This analysis of the data suggests new research directions towards improvement in an attempt to implement them in future researches.

Regardless of all the implications of this method that can provide a literature review of the work done during the past and generalising the content to assist researchers, there are still certain limitations to the method. Only Scopus is used as a database and there might be results that are not comprehensive. To make the study more reliable, another database can be used in conjugation to extract the data. In addition, the search results may have covered an irrelevant as well as redundant article that alters the quality of study. Moreover, the selections of keywords, naming the clusters are the potential parts of biasness due to author's subjective analysis. To reduce these factors, other analytic methods can be used in addition to the bibliometric method. In this era of science and technology, quantitative and qualitative research is crucial in this field to preserve environment and elevate social and economic development.

References

Abdurrahman, M.I., Chaki, S. and Saini, G. (2020) 'Stubble burning: effects on health & environment, regulations and management practices', *Environmental Advances*, October, Vol. 2, p.100011, https://doi.org/10.1016/j.envadv.2020.100011.

Acedo, F.J., Barroso, C., Casanueva, C. and Galán, J.L. (2006) 'Co-authorship in management and organizational studies: an empirical and network analysis', *Journal of Management Studies*, Vol. 43, No. 5, pp.957–983, https://doi.org/10.1111/j.1467-6486.2006.00625.x.

Ahmed, A.S.F., Vanga, S. and Raghavan, V. (2018) 'Global bibliometric analysis of the research in biochar', *Journal of Agricultural and Food Information*, Vol. 19, No. 3, pp.228–236, https://doi.org/10.1080/10496505.2017.1403328.

Albort-Morant, G. and Ribeiro-Soriano, D. (2016) 'A bibliometric analysis of international impact of business incubators', *Journal of Business Research*, Vol. 69, No. 5, pp.1775–1779, https://doi.org/10.1016/j.jbusres.2015.10.054.

Almomani, F. (2020) 'Prediction of biogas production from chemically treated co-digested agricultural waste using artificial neural network', *Fuel*, April, Vol. 280, p.118573, https://doi.org/10.1016/j.fuel.2020.118573.

An, X.Y. and Wu, Q.Q. (2011) 'Co-word analysis of the trends in stem cells field based on subject heading weighting', *Scientometrics*, Vol. 88, No. 1, pp.133–144, https://doi.org/10.1007/s11192-011-0374-1.

Andersen, N. (2021) 'Mapping the expatriate literature: a bibliometric review of the field from 1998 to 2017 and identification of current research fronts', *International Journal of Human Resource Management*, Vol. 32, No. 22, pp.4687–4724, https://doi.org/10.1080/09585192.2019.1661267.

Bernal, M.P. (2017) 'Grand challenges in waste management in agroecosystems', *Frontiers in Sustainable Food Systems*, September, Vol. 1, pp.1–4, https://doi.org/10.3389/fsufs.2017.00001.

Bhuvaneshwari, S., Hettiarachchi, H. and Meegoda, J.N. (2019) 'Crop residue burning in India: policy challenges and potential solutions', *International Journal of Environmental Research and Public Health*, Vol. 16, No. 5, https://doi.org/10.3390/ijerph16050832.

Bourguignon, D., EPRS and Bourguignon, D. (2015) *Briefing Understanding Waste Management Policy Challenges and Opportunities*, EPRS | European Parliamentary Research Service, June [online] http://www.europarl.europa.eu/RegData/etudes/BRIE/2015/559493/EPRS_BRI%282015%29559493_EN.pdf (accessed 15 January 2024).

Callon, M., Courtial, J.P., Turner, W.A. and Bauin, S. (1983) 'From translations to problematic networks: an introduction to co-word analysis', *Social Science Information*, Vol. 22, No. 2, pp.191–235, https://doi.org/10.1177/053901883022002003.

Chand Malav, L., Yadav, K.K., Gupta, N., Kumar, S., Sharma, G.K., Krishnan, S., Rezania, S., Kamyab, H., Pham, Q.B., Yadav, S., Bhattacharyya, S., Yadav, V.K. and Bach, Q.V. (2020) 'A review on municipal solid waste as a renewable source for waste-to-energy project in India: current practices, challenges, and future opportunities', *Journal of Cleaner Production*, Vol. 277, p.123227, https://doi.org/10.1016/j.jclepro.2020.123227

Dai, Y., Sun, Q., Wang, W., Lu, L., Liu, M., Li, J., Yang, S., Sun, Y., Zhang, K., Xu, J., Zheng, W., Hu, Z., Yang, Y., Gao, Y., Chen, Y., Zhang, X., Gao, F. and Zhang, Y. (2018) 'Utilizations of agricultural waste as adsorbent for the removal of contaminants: a review', *Chemosphere*, Vol. 211, pp.235–253, https://doi.org/10.1016/j.chemosphere.2018.06.179.

Das, S., Lee, S.H., Kumar, P., Kim, K.H., Lee, S.S. and Bhattacharya, S.S. (2019) 'Solid waste management: scope and the challenge of sustainability', *Journal of Cleaner Production*, Vol. 228, pp.658–678, https://doi.org/10.1016/j.jclepro.2019.04.323.

De Corato, U., De Bari, I., Viola, E. and Pugliese, M. (2018) 'Assessing the main opportunities of integrated biorefining from agro-bioenergy co/by-products and agroindustrial residues into high-value added products associated to some emerging markets: a review', *Renewable and Sustainable Energy Reviews*, November, Vol. 88, pp.326–346, https://doi.org/10.1016/j.rser.2018.02.041.

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N. and Lim, W.M. (2021) 'How to conduct a bibliometric analysis: an overview and guidelines', *Journal of Business Research*, May, Vol. 133, pp.285–296, https://doi.org/10.1016/j.jbusres.2021.04.070.

Duque-Acevedo, M., Belmonte-Ureña, L.J., Cortés-García, F.J. and Camacho-Ferre, F. (2020a) 'Agricultural waste: review of the evolution, approaches and perspectives on alternative uses', *Global Ecology and Conservation*, Vol. 22, https://doi.org/10.1016/j.gecco.2020.e00902.

Duque-Acevedo, M., Belmonte-Ureña, L.J., Yakovleva, N. and Camacho-Ferre, F. (2020b) 'Analysis of the circular economic production models and their approach in agriculture and agricultural waste biomass management', *International Journal of Environmental Research and Public Health*, Vol. 17, No. 24, pp.1–34, https://doi.org/10.3390/ijerph17249549.

Dutta, N. and Subhashini, S. (2021) 'Organic farming: a vision for a sustainable nation', *International Journal of Modern Agriculture*, Vol. 10, No. 2, pp.2948–2957 ISSN: 2305-7246, ISSN: 2305-7246.

Ellegaard, O. and Wallin, J.A. (2015) 'The bibliometric analysis of scholarly production: how great is the impact?', *Scientometrics*, Vol. 105, No. 3, pp.1809–1831, https://doi.org/10.1007/s11192-015-1645-z.

Emich, K.J., Kumar, S., Lu, L., Norder, K. and Pandey, N. (2020) 'Mapping 50 years of small group research through small group research', *Small Group Research*, Vol. 51, No. 6, pp.659–699, https://doi.org/10.1177/1046496420934541.

Esparza, I., Jiménez-Moreno, N., Bimbela, F., Ancín-Azpilicueta, C. and Gandía, L.M. (2020) 'Fruit and vegetable waste management: conventional and emerging approaches', *Journal of Environmental Management*, July, Vol. 265, https://doi.org/10.1016/j.jenvman.2020.110510.

FAO (2017) *Strategic work of FAO for Sustainable Food and Agriculture 2 for More Information on the Strategic Work of FAO for Sustainable Food and Agriculture A Vortex of Pressures Calls for a New Paradigm* [online] http://moodle2.gla.ac.uk/pluginfile.php/1307030/mod_resource/content/1/FAO 2017%281%29.pdf (accessed 20 February 2024).

Feng, Y., Zhu, Q. and Lai, K.H. (2017) 'Corporate social responsibility for supply chain management: a literature review and bibliometric analysis', *Journal of Cleaner Production*, Vol. 158, pp.296–307, https://doi.org/10.1016/j.jclepro.2017.05.018.

Fernández-González, J.M., Díaz-López, C., Martín-Pascual, J. and Zamorano, M. (2020) 'Recycling organic fraction of municipal solid waste: systematic literature review and bibliometric analysis of research trends', *Sustainability*, Vol. 12, No. 11, Switzerland, https://doi.org/10.3390/su12114798.

Gontard, N., Sonesson, U., Birkved, M., Majone, M., Bolzonella, D., Celli, A., Angellier-Coussy, H., Jang, G.W., Verniquet, A., Broeze, J., Schaer, B., Batista, A.P. and Sebok, A. (2018) 'A research challenge vision regarding management of agricultural waste in a circular bio-based economy', *Critical Reviews in Environmental Science and Technology*, Vol. 48, No. 6, pp.614–654, https://doi.org/10.1080/10643389.2018.1471957.

González-Alcaide, G., Calafat, A., Becoña, E., Thijs, B. and Glänzel, W. (2016) 'Co-citation analysis of articles published in substance abuse journals: Intellectual structure and research fields (2001–2012)', *Journal of Studies on Alcohol and Drugs*, Vol. 77, No. 5, pp.710–722, https://doi.org/10.15288/jsad.2016.77.710.

Gupta, A. (2016) 'Synthesis, chemical resistance, and water absorption of bamboo fiber reinforced epoxy composites', *Polymer Composites*, Vol. 37, No. 1, pp.141–145.

Gupta, A. (2020a) 'Improvement of physiochemical properties of short bamboo fiber-reinforced composites using ceramic fillers', *Journal of Natural Fibers*, Vol. 17, No. 11, pp.1582–1593.

Gupta, A. (2020b) 'Effect of industrial waste on chemical and water absorption of bamboo fiber reinforced composites', *Silicon*, Vol. 12, No. 1, pp.139–146.

Gupta, A. (2022) 'Influence of filler content on tribological behavior of cenopshere flyash filled bamboo fiber reinforced composites', *Journal of Natural Fibers*, Vol. 19, No. 15, pp.12051–12067

Gupta, A. and Kumar, A. (2008) 'Potential of bamboo in sustainable development', *Asia Pacific Business Review*, Vol. 4, No. 3, pp.100–107, Sage Publication.

Gupta, A. and Kumar, A. (2012) 'Chemical properties of natural fiber composites and mechanisms of chemical modifications', *Asian Journal of Chemistry*, Vol. 24, No. 4, pp.1831–1836.

Gupta, A., Kumar, A., Patnaik, A. and Sandhyarani, B. (2012) 'Effect of filler content and alkalization on mechanical and erosion wear behavior of CBPD filled bamboo fiber composites', *Journal of Surface Engineered Materials and Advanced Technology*, Vol. 2, No. 3, pp.149–157.

He, K., Zhang, J. and Zeng, Y. (2019) 'Science of the total environment knowledge domain and emerging trends of agricultural waste management in the field of social science', *A Scientometric Review*, Vol. 670, pp.236–244, https://doi.org/10.1016/j.scitotenv.2019.03.184.

Hjørland, B. (2013) 'Facet analysis: the logical approach to knowledge organization', *Information Processing and Management*, Vol. 49, No. 2, pp.545–557, https://doi.org/10.1016/j.ipm.2012.10.001.

Kapoor, R., Ghosh, P., Kumar, M., Sengupta, S., Gupta, A., Kumar, S.S., Vijay, V., Kumar, V., Kumar Vijay, V. and Pant, D. (2020) 'Valorization of agricultural waste for biogas based circular economy in India: a research outlook', *Bioresource Technology*, February, Vol. 304, p.123036, https://doi.org/10.1016/j.biortech.2020.123036.

Khan, M.A., Pattnaik, D., Ashraf, R., Ali, I., Kumar, S. and Donthu, N. (2021) 'Value of special issues in the journal of business research: a bibliometric analysis', *Journal of Business Research*, November, Vol. 125, pp.295–313, https://doi.org/10.1016/j.jbusres.2020.12.015.

Komnitsas, K. and Zaharaki, D. (2014) 'Assessment of human and ecosystem risk due to agricultural waste compost application on soils: a review', *Environmental Forensics*, Vol. 15, No. 4, pp.312–328, https://doi.org/10.1080/15275922.2014.950775.

Kumar, S., Sureka, R., Lim, W.M., Kumar Mangla, S. and Goyal, N. (2021) 'What do we know about business strategy and environmental research? Insights from business strategy and the environment', *Business Strategy and the Environment*, Vol. 30, No. 8, pp.3454–3469, https://doi.org/10.1002/bse.2813.

Kumar, V. and Gupta G. (2021) *Strategic Management During a Pandemic*, Routledge, Taylor & Francis Group, USA.

Kumar, V. and Vidhyalakshmi, P. (2012) 'Cloud computing for business sustainability', *Asia-Pacific Journal of Management Research and Innovation*, Vol. 8, No. 4, pp.461–474.

Laurett, R., Paço, A. and Mainardes, E.W. (2021) 'Sustainable development in agriculture and its antecedents, barriers and consequences – an exploratory study', *Sustainable Production and Consumption*, Vol. 27, pp.298–311, https://doi.org/10.1016/j.spc.2020.10.032.

Liao, H., Tang, M., Li, Z. and Lev, B. (2019) 'Bibliometric analysis for highly cited papers in operations research and management science from 2008 to 2017 based on essential science indicators', *Omega*, Vol. 88, pp.223–236, UK, https://doi.org/10.1016/j.omega.2018.11.005.

Loehr, R.C. (1978) 'Hazardous solid waste from agriculture', *Environmental Health Perspectives*, December, Vol. 27, pp.261–273, https://doi.org/10.1289/ehp.7827261.

Martinho, V.J.P.D. (2019) 'Best management practices from agricultural economics: mitigating air, soil and water pollution', *Science of the Total Environment*, Vol. 688, pp.346–360, https://doi.org/10.1016/j.scitotenv.2019.06.199.

Medina, J., Calabi-Floody, M., Aponte, H., Santander, C., Paneque, M., Meier, S., Panettieri, M., Cornejo, P., Borie, F. and Knicker, H. (2021) 'Utilization of inorganic nanoparticles and biochar as additives of agricultural waste composting: effects of end-products on plant growth, C and nutrient stock in soils from a Mediterranean region', *Agronomy*, Vol. 11, No. 4, p.767, https://doi.org/10.3390/agronomy11040767.

Medina, J., Monreal, C., Barea, J.M., Arriagada, C., Borie, F. and Cornejo, P. (2015) 'Crop residue stabilization and application to agricultural and degraded soils: a review', *Waste Management*, Vol. 42, pp.41–54, https://doi.org/10.1016/j.wasman.2015.04.002.

Mettu, S., Halder, P., Patel, S., Kundu, S., Shah, K., Yao, S., Hathi, Z., Ong, K.L., Athukoralalage, S., Choudhury, N.R., Dutta, N.K. and Lin, C.S.K. (2020) 'Valorisation of agricultural waste residues', *Waste Valorisation*, pp.51–85, https://doi.org/10.1002/9781119502753.ch4.

Mmereki, D., Baldwin, A. and Li, B. (2016) 'A comparative analysis of solid waste management in developed, developing and lesser developed countries', *Environmental Technology Reviews*, Vol. 5, No. 1, pp.120–141, https://doi.org/10.1080/21622515.2016.1259357.

Nagendran, R. (2011) 'Agricultural waste and pollution', in *Waste*, Elsevier Inc., https://doi.org/10.1016/B978-0-12-381475-3.10024-5.

Nguyen, H., Jamali, M. and Hossein, M. (2019) 'Agricultural wastes preparation, management, and applications in civil engineering: a review', *Journal of Material Cycles and Waste Management*, p.0123456789, https://doi.org/10.1007/s10163-019-00872-y.

Noyons, E.C.M., Moed, H.F. and Luwel, M. (1999) 'Combining mapping and citation analysis for evaluative bibliometric purposes: a bibliometric study', *Journal of the American Society for Information Science*, Vol. 50, No. 2, pp.115–131, https://doi.org/10.1002/(sici)1097-4571(1999)50:2<115::aid-asi3>3.3.co;2-a.

Okoro, E.E., Okafor, I.S., Igwilo, K.C., Orodu, K.B. and Mamudu, A.O. (2020) 'Sustainable biogas production from waste in potential states in Nigeria – alternative source of energy', *Journal of Contemporary African Studies*, Vol. 38, No. 4, pp.627–643, https://doi.org/10.1080/02589001.2020.1825650.

Prasad, M., Ranjan, R., Ali, A., Goyal, D., Yadav, A., Singh, T.B., Shrivastav, P. and Dantu, P.K. (2020) 'Efficient transformation of agricultural waste in India', *Contaminants in Agriculture: Sources, Impacts and Management*, pp.271–287, https://doi.org/10.1007/978-3-030-41552-5_13.

Raghuram, S., Tuertscher, P. and Garud, R. (2010) 'Mapping the field of virtual work: a cocitation analysis', *Information Systems Research*, Vol. 21, No. 4, pp.983–999, https://doi.org/10.1287/isre.1080.0227.

Ramírez-García, R., Gohil, N. and Singh, V. (2018) 'Recent advances, challenges, and opportunities in bioremediation of hazardous materials', in *Phytomanagement of Polluted Sites: Market Opportunities in Sustainable Phytoremediation*, https://doi.org/10.1016/B978-0-12-813912-7.00021-1.

Singh, G., Kaur, K. and Meetei, T.T. (2021) 'Effect of in stubble burning on physico chemical properties of soil, yield and environmental qualities', *The Pharma Innovation*, Vol. 10, No. 5, pp.298–305.

Su, H.N. and Lee, P.C. (2010) 'Mapping knowledge structure by keyword co-occurrence: a first look at journal papers in technology foresight', *Scientometrics*, Vol. 85, No. 1, pp.65–79, https://doi.org/10.1007/s11192-010-0259-8.

Tankha, S., Fernandes, D. and Narayanan, N.C. (2020) 'Overcoming barriers to climate smart agriculture in India', *International Journal of Climate Change Strategies and Management*, Vol. 12, No. 1, pp.108–127, https://doi.org/10.1108/IJCCSM-10-2018-0072.

Toop, T.A., Ward, S., Oldfield, T., Hull, M., Kirby, M.E. and Theodorou, M.K. (2017) 'AgroCycle – developing a circular economy in agriculture', *Energy Procedia*, Vol. 123, pp.76–80, https://doi.org/10.1016/j.egypro.2017.07.269.

Van Nunen, K., Li, J., Reniers, G. and Ponnet, K. (2018) 'Bibliometric analysis of safety culture research', *Safety Science*, August, Vol. 108, pp.248–258, https://doi.org/10.1016/j.ssci.2017.08.011.

Verma, S. and Gustafsson, A. (2020) 'Investigating the emerging COVID-19 research trends in the field of business and management: a bibliometric analysis approach', *Journal of Business Research*, Vol. 118, pp.253–261, https://doi.org/10.1016/j.jbusres.2020.06.057.

Wang, B., Dong, F., Chen, M., Zhu, J., Tan, J., Fu, X., Wang, Y. and Chen, S. (2016) 'Advances in recycling and utilization of agricultural wastes in China: based on environmental risk, crucial pathways, influencing factors, policy mechanism', *Procedia Environmental Sciences*, Vol. 31, pp.12–17, https://doi.org/10.1016/j.proenv.2016.02.002.

Zhang, X., Wu, J., Yang, H., Shao, J., Wang, X., Chen, Y., Zhang, S. and Chen, H. (2016) 'Preparation of nitrogen-doped microporous modified biochar by high temperature CO_2-NH_3 treatment for CO_2 adsorption: effects of temperature', *RSC Advances*, Vol. 6, No. 100, pp.98157–98166, https://doi.org/10.1039/c6ra23748g.

Zhang, N., Ren, R., Zhang, Q. and Zhang, T. (2020a) 'Air pollution and tourism development: an interplay', *Annals of Tourism Research*, August, Vol. 85, https://doi.org/10.1016/j.annals.2020.103032.

Zhang, X., Yu, Y. and Zhang, N. (2020b) 'Sustainable supply chain management under big data: a bibliometric analysis', *Journal of Enterprise Information Management*, Vol. 34, No. 1, pp.427–445, https://doi.org/10.1108/JEIM-12-2019-0381.

Zupic, I. and Čater, T. (2015) 'Bibliometric methods in management and organization', *Organizational Research Methods*, Vol. 18, No. 3, pp.429–472, https://doi.org/10.1177/1094428114562629.