Applications Of Modeling By Artificial Intelligence Of A Forecast System For The Production Of Alternative Energies

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Abstract:

The present investigation consists of a bibliometric review related to the prediction systems for the production of renewable energies through artificial intelligence. In this regard, a systematic bibliographic search of the topic was carried out in the Scopus database in November 2022 using the search equation: (TITLE-ABS-KEY ("artificial intelligence") OR TITLE-ABS-KEY (" machine learning") OR TITLE-ABS-KEY ("Deep learning") AND TITLE-ABS-KEY ("renewable energies ") OR TITLE-ABS-KEY ("alternative energies") OR TITLE-ABS-KEY ("clean energies" ") AND TITLE-ABS-KEY ("predictive model*") OR TITLE-ABS-KEY ("forecast* systems") OR TITLE-ABS-KEY ("predictive method") OR TITLE-ABS-KEY ("predictive analytics ")). The results obtained show that between the years 2021 and 2022, 58% of all the investigations carried out are concentrated. In the geographical section, China (36) turned out to be the country that contributed the most papers to the subject studied, closely followed by the United States (34). In turn, the four journals that publish the most on the subject were ENERGIES (14), IEEE ACCESS (11), JOURNAL OF CLEANER PRODUCTION (6) and APPLIED ENERGY (5), while the 3 authors with the most published articles were Deo RC (12), Ghimire S (6) and Raj N (4). Finally, the three publications with the highest

number of citations were Hu Q, 2016, Renew Energy (301), Ahmad MW, 2018, J Clean Prod (151) and Ahmad T, 2020, Sustainable Cities SOC (149).

Keywords: prediction systems, renewable energies, artificial intelligence, machine learning, alternative energies.

1. Introduction

In recent years, the range of energy sources made up of solar photovoltaic, hydraulic and wind generation have come to the fore as guarantors of the future continuity of energy supply globally, and for this reason, it has become a strategic almost mandatory for countries to be guarantors of the sustained and sustainable development of renewable energies (García-Samper et al., 2022; Hernández Palma et al., 2022), and in the same way, promote the use of inexhaustible energy sources, implement multiple energy strategies, achieve greener energy production and protect the integrity of energy production and distribution methods, ensuring the overall reliability of the system (Hernández Palma, 2020).

It should be noted that renewable energy production is subject to very dynamic changes in environmental parameters and operating conditions. This is a very important consideration when conducting reliability studies, simulating asset degradation, and forecasting renewable energy production (Ferrero et al., 2019). As renewable energy becomes more popular on the global grid, improving the accuracy of renewable energy production forecasts is critical to the planning, management, and operation of power systems. However, this is a difficult task as the available data on renewable energy is patchy and confusing. Various methods, including physical models, statistical methods, artificial intelligence methods, and their hybrid methods, have been shown to improve the accuracy of renewable energy forecasts (Wang et al., 2019).

As is well known, sustainability and minimal environmental pollution are the main benefits offered by renewable energy sources, but the increase in load requirements, global warming and the world energy crisis force them to accelerate their development. a speed for which the necessary structures do not yet exist in most countries, and for this reason the techniques of monitoring and prediction of generation systems from renewable energy sources constitute one of the bastions of this need for development to greater efficiency and performance of energy networks (Ahmad, Zhang & Yan, 2020).

It is for all of the above described, that in the present work a documentary review and bibliometric analysis of all the available literature in the scientific context for prediction systems for the production of renewable energies through artificial intelligence is

proposed, with the purpose of serving as a diagnostic basis for the situation of the topic developed within the scientific community, so that future research has at hand precise information on which are the areas with the greatest lack of scientific production and who produces, for whom they produce, from where they produce and when the most significant contributions are produced in this regard.

2. Methodology

The main objective of this work was to carry out a bibliometric analysis, which is the standardized method for the purposes of this research (Samper, Florez, Borre y Ramírez, 2022). As a first step, a systematic literature search of the topic was conducted in the Scopus database in November 2022 with the keywords "artificial intelligence", "renewable energies" and "predictive models". Below, Table 1 shows the standardization of keywords.

Table 1. Keyword standardization.

Keywords	Descriptors
Artificial intelligence	*Machine learning * Deep learning
Renewable energies	* alternative energies * clean energies
Predictive models	*predictive model* * forecast* systems * predictive method * predictive analytics

Source: author (2022).

The search equation posed on the basis of Scopus was: (TITLE-ABS-KEY ("artificial intelligence") OR TITLE-ABS-KEY ("machine learning") OR TITLE-ABS-KEY ("Deep learning") AND TITLE-ABS-KEY ("renewable energies ") OR TITLE-ABS-KEY ("alternative energies") OR TITLE-ABS-KEY ("clean energies") AND TITLE-ABS-KEY ("predictive model*") OR TITLE-ABS-KEY ("forecast* systems") OR TITLE-ABS-KEY ("predictive method") OR TITLE-ABS-KEY ("predictive analytics")); yielded 202 results related to prediction systems for the production of renewable energies through artificial intelligence and cover a period of time between 2010 and 2023.

The results obtained were exported from Scopus in CSV format; Excel software, the Bibliometrix suite of the R statistical software and the VOSviewer software were used to analyze this information. From this, a variety of indicators were generated allowing the analysis of the number of documents that are published in a selected period of time, types of documents, authors with the largest number of publications,

the dynamics of the sources, as well as the institutions and countries with greater trends in the area and the behavior of the citations. General information on the studies consulted is presented in Table 2.

Table 2. Main information of the data obtained from Scopus.

MAIN INFORMATION ABOUT DATA	
Timespan	2010:2023
Sources (Journals, Books, etc)	130
Documents	202
Annual Growth Rate %	0
Document Average Age	1,82
Average citations per doc	13,74
References	8361
DOCUMENT CONTENTS	
Keywords Plus (ID)	1616
Author's Keywords (DE)	686
AUTHORS	
Authors	710
Authors of single-authored docs	9
AUTHORS COLLABORATION	
Single-authored docs	11
Co-Authors per Doc	4
International co-authorships %	27,72
DOCUMENT TYPES	
article	138
book chapter	6
conference paper	50
conference review	3
retracted	1
review	4

Source: author using the R software based on information from Scopus (2022).

Table 2 shows the main information of the documents consulted, you can see the time period from 2010 to 2023; In total 202 documents were analyzed, of which it can be ruled out that they are mostly articles with 138, followed by 50 conference documents.

3. Results and discussion

The results of the Scopus database search were organized into three sections; first the laws of bibliometric productivity, second the different bibliometric indicators and finally the analysis of relationships and co-occurrences.

3.1. Laws of bibliometric productivity

It will begin by showing the estimate of the coefficient of Lotka's law, explaining that there is a quantitative relationship between authors and contributions produced in a given field over a period of time, a few authors produce most of the scientific output, and a larger group of authors produces fewer articles (Alves, 2019).

Table 3 shows that Lotka's law is complied with, the largest number of authors, being 646 and equivalent to 91%, are those who have the least contributions with a single article, 6.2% have made 2 contributions, 2.4% have made 3 contributions and 0.1% have made between 4 and 12 contributions. From these it can be concluded that most of the contributions made are by researchers who carry out temporary or transitory research in the subject of study.

Table 3. Lotka's Law.

Documents	N. Authors	Proportion by authors
1	646	0,91
2	44	0,062
3	17	0,024
4	1	0,001
6	1	0,001
12	1	0,001

Source: author using R software based on information from Scopus (2022).

On the other hand, when applying Bradford's law in Table 4, it is observed that 33.8% of the published articles are concentrated in the first 19 journals and that these belong to zone 1 of Bradford's law, where a relatively small number of periodicals are concentrated and are the most productive (Alves, 2019).

Of these we can highlight the first 5 journals: Energies, IEEE Access, Journal of Cleaner Production, Applied Energy and IEEE Systems journal.

Table 4. Bradford's Law.

Zone	No. Journals	No. Titles	Percentages
Zone 1	11	67	33,17%
Zone 2	53	69	34,16%
Zone 3	66	66	32,67%

Source: author using R software based on information from Scopus (2022).

3.2. Bibliometric index

Figure 1 shows that the annual scientific production related to the research topic has been growing since 2018, especially in 2021 and 2022 where 58% of all research carried out is concentrated; indicating a growing interest in the research topic.

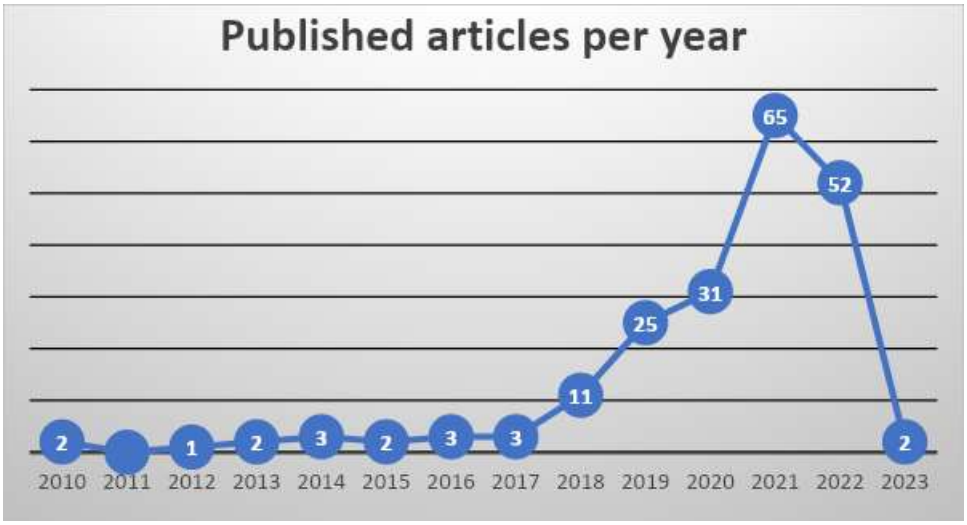

Figure 1. Annual scientific production. Source: author based on information from Scopus (2022).

A geographical analysis was carried out in order to know the countries in which more research is being carried out on the subject. In figure 2 it can be seen on the map that the dark green countries are the ones that have the most research in this field, we can highlight China (36), the United States (34), India (23), South Korea (17), Australia (16), United Kingdom (12) and Turkey (8).

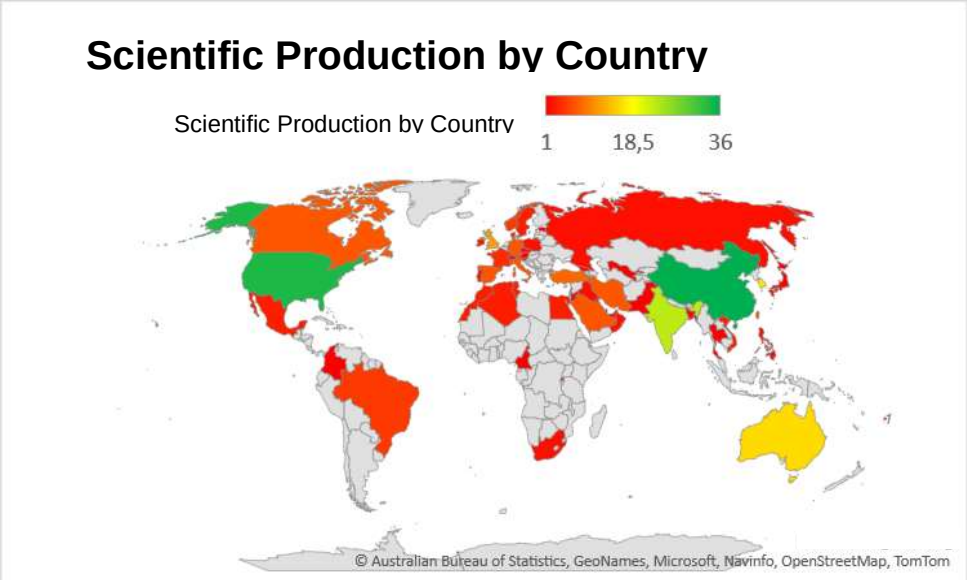

Figure 2. Scientific production by country. Source: author based on information from Scopus (2022).

China, which is one of the countries that conducts more research in the field, there are studies related to predictive models assisted by machine learning for the production of clean electrodes in lithium and zinc batteries that are considered as a promising alternative energy storage technology (Zhou et al., 2021; Liu et al., 2021).

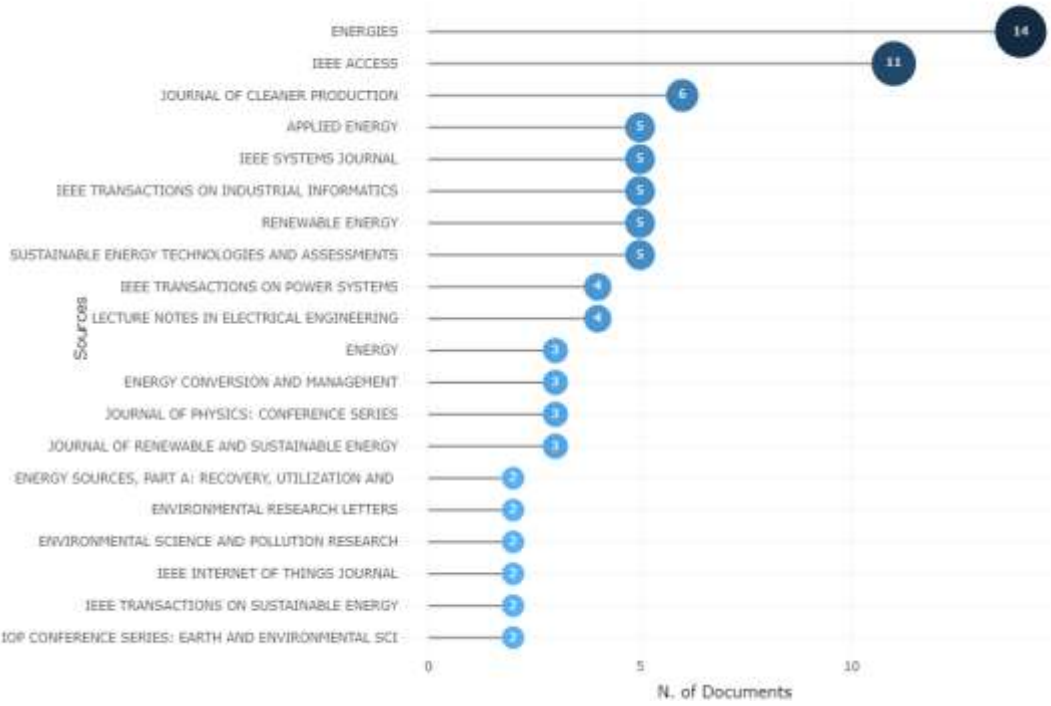

Figure 3. Most relevant sources. Source: author using R software based on information from Scopus (2022).

On the other hand, an analysis of the most relevant sources in the research topic was carried out; In Figure 3 it can be seen that the four journals that publish the most on the subject are ENERGIES (14), IEEE ACCESS (11), JOURNAL OF CLEANER PRODUCTION (6) and APPLIED ENERGY (5).

In the journal Energies there are several publications related to predictive models for photovoltaic electricity generation (Yousif et al., 2017; Yu et al., 2020; Koti Reddy & Singh, 2021; De Freitas Viscondi & Alves-Souza, 2021).

In the second journal with more publications, there are researches related to wind energy, from the use of Deep learning and machine learning to create predictive models for wind speed based on wind turbines (Dolatabadi et al., 2020; Chatterjee & Dethlefs, 2022; Fahim et al., 2022).

The production per author is moderate compared to the number of articles published from 2010 to 2023. As can be seen in figure 4, the 3 authors with the most published articles are Deo RC (12), Ghimire S (6) and Raj N (4).

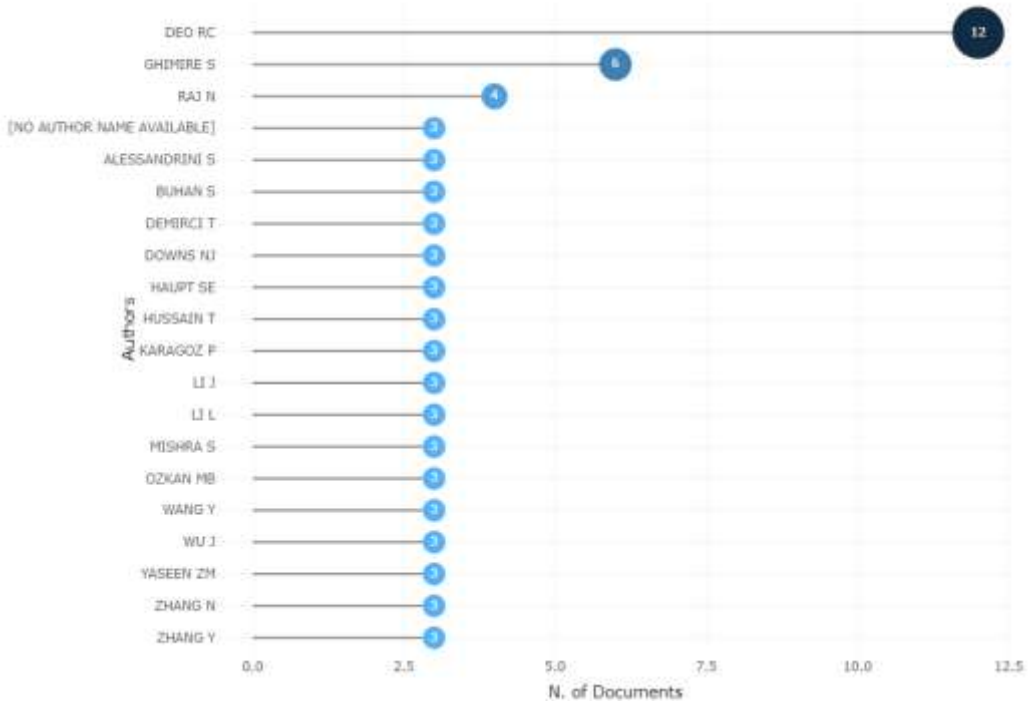

Figure 4. Most relevant authors. Source: author using the R software based on information from Scopus (2022).

The three authors with the most publications have several publications in co-authorship that deal with predictive models based on neural networks and machine learning to predict solar radiation as an approach to the viability of renewable energies, the installation and management of solar energy production systems in remote and inaccessible places (Ghimire et al., 2018; Ghimire et al., 2019a; Ghimire et al., 2019b).

Table 5. Most cited articles.

Articles	DOI	Total Citations
HU Q, 2016, RENEW ENERGY	10.1016/j.renene.2015.06.034	301
AHMAD MW, 2018, J CLEAN PROD	10.1016/j.jclepro.2018.08.207	151
AHMAD T, 2020, SUSTAINABLE CITIES SOC	10.1016/j.scs.2020.102052	149
MAGAZZINO C, 2021, RENEW ENERGY	10.1016/j.renene.2020.11.050	113
LIU H, 2019, ENERGY CONVERS MANAGE	10.1016/j.enconman.2019.05.020	108
SHARIFZADEH M, 2019, RENEWABLE SUSTAINABLE ENERGY REV	10.1016/j.rser.2019.03.040	97
GHIMIRE S, 2019, J CLEAN PROD	10.1016/j.jclepro.2019.01.158	97
DEO RC, 2018, RENEW ENERGY	10.1016/j.renene.2017.09.078	95
LEE W, 2018, IEEE ACCESS	10.1109/ACCESS.2018.2883330	77
LIU K, 2021, J CLEAN PROD	10.1016/j.jclepro.2020.125159	63
ELMAZ F, 2020, ENERGY	10.1016/j.energy.2019.116541	61
WANG Y, 2019, IEEE INTERNET THINGS J	10.1109/JIOT.2018.2877510	61

QUAN DM, 2013, IEEE INT CONF FUZZY SYST	10.1109/FUZZ-IEEE.2013.6622453	57
GHIMIRE S, 2018, REMOTE SENS ENVIRON	10.1016/j.rse.2018.05.003	55
BASSAM A, 2010, COMPUT GEOSCI	10.1016/j.cageo.2010.01.006	52
GHIMIRE S, 2019, ENERGIES	10.3390/en12122407	49
LI J, 2021, J CLEAN PROD	10.1016/j.jclepro.2020.123928	44
LI DHW, 2019, ENERGY	10.1016/j.energy.2019.115857	43
HAI T, 2020, IEEE ACCESS	10.1109/ACCESS.2020.2965303	41
ZHANG N, 2012, IEEE PES INNOV SMART GRID TECHNOL, ISGT	10.1109/ISGT.2012.6175757	41

Source: author applying R software based on information from Scopus (2022).

Table 5 shows the 20 publications that have the most citations, the three most representative are Hu Q, 2016, Renew Energy (301), Ahmad MW, 2018, J Clean Prod (151), Ahmad T, 2020, Sustainable Cities SOC (149), Magazzino C, 2021, Renew Energy (113) and Liu H, 2019, Energy Convers Manage (108); in turn, Table 6 contains a description of the ten most cited articles in relation to the research topic.

Table 6. Ten most cited articles.

Highlight	**Year**	**Source**	**Cite**
Wind speed prediction from transfer learning for large-scale wind power generation as renewable energy	2016	RENEW ENERGY	(Hu et al., 2016)
Predictive model for solar thermal systems and informed decision making and for fault detection and diagnosis	2018	J CLEAN PROD	(Ahmad et al., 2018)
Analysis of predictive models of renewable energy needs applied as an energy planning tool	2020	SUSTAINABLE CITIES SOC	(Ahmad et al., 2020)
Use of machine learning in the relationship between solar and wind energy production and carbon consumption	2021	RENEW ENERGY	(Magazzino et al., 2021)
Study of smart predictors in the field of wind energy forecasting.	2019	ENERGY CONVERS MANAGE	(Liu et al., 2019)
Machine learning methods for renewable energy generation	2019	RENEWABLE SUSTAINABLE ENERGY REV	(Sharifzadeh et al., 2019)
Prediction of global incident solar radiation to establish the efficiency of solar energy resources as clean and free energy, and identify and evaluate solar-powered sites	2019	J CLEAN PROD	(Ghimire et al., 2019)

AI-based model for wind speed prediction to establish the viability of wind energy as a clean energy option	2018	RENEW ENERGY	(Deo et al., 2018)
Use of neural networks for the forecasting of photovoltaic solar energy	2018	IEEE ACCESS	(Lee et al., 2018)
Using machine learning to predict the massive charge of renewable energy in lithium batteries	2021	J CLEAN PROD	(Liu et al., 2021)

Source: author using information from Scopus (2022).

3.3. Analysis of relationships and Co-occurrences

The analysis of relationships and co-occurrences was carried out using the VOSviewer software, taking as a parameter that the author has a minimum of one document and a minimum of two citations.

The co-authorship analysis shows that of 706 authors, 493 meet the parameters of which only 41 are connected to other authors; this can be seen in figure 5, in which 5 clusters can be identified. From this it can be said that there are very few authors who are connected working with other authors on the research topic of 493 only 41 do so which is equivalent to 12%.

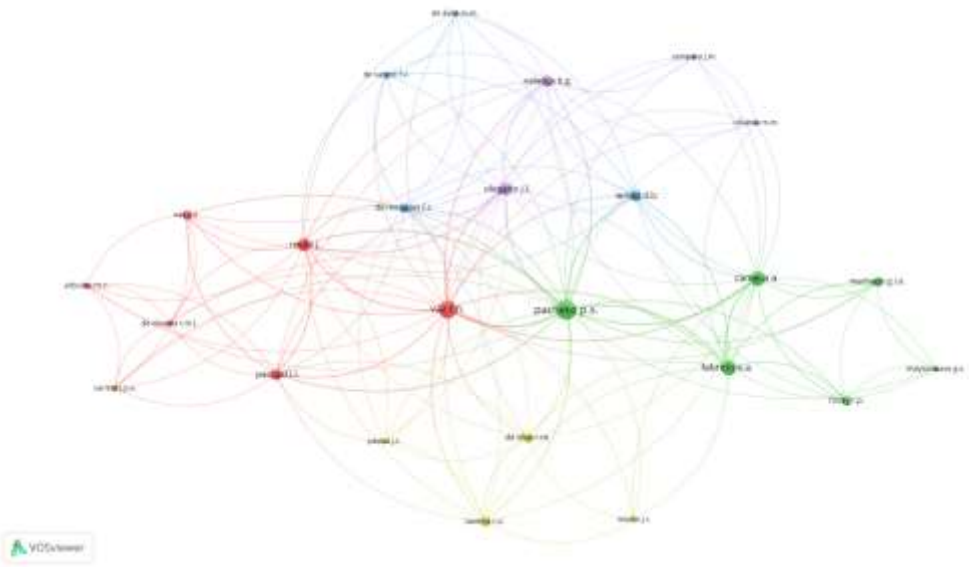

Figure 5. Co-authorship relationship, source: own elaboration using VOSviewer software based on Scopus information (2022).

Then, an analysis of co-occurrence of keywords was performed, the parameter was that the minimum number of occurrences of a keyword is 5, of 1995 words only 132 meet the parameter, this can be evidenced in figure 5 where 6 clusters are identified; it can be highlighted the following words: forecasting, predictive analytics,

machine learning, learning systems, deep learning and renewable energies.

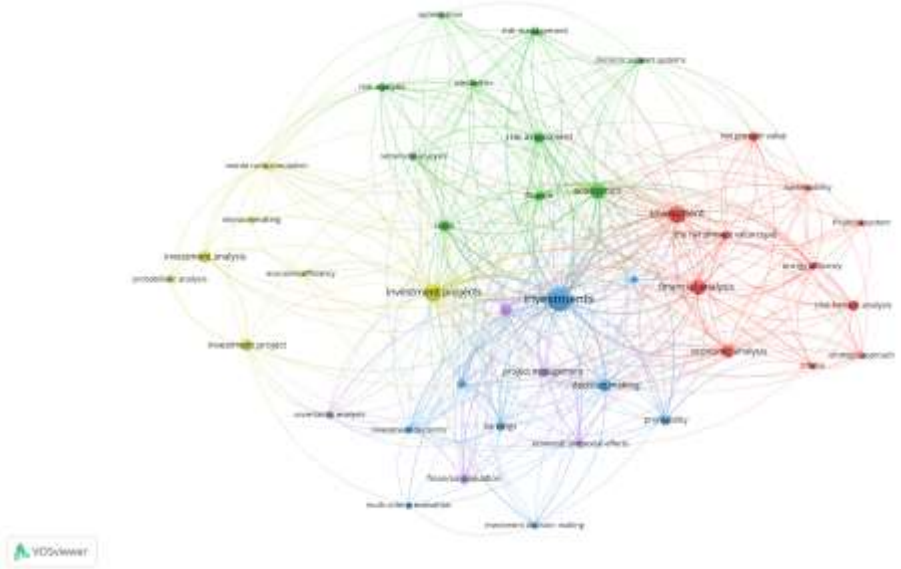

Figure 6. Keywords relationship, source: own elaboration using VOSviewer software based on Scopus information (2022).

5. Conclusions

From the 202 documents analyzed in this bibliometric study carried out based on information from the Scopus database on the subject of prediction systems for the production of renewable energies through artificial intelligence, the following can be concluded:

68% of the documents consulted are articles, 25% are conference documents and the remaining 7% are other formats. The scientific production analyzed in the period from 2010 to 2023 shows a growing trend, there is interest in this research topic especially in the years 2021 and 2022 where 58% of all publications are concentrated.

China, the United States, India, South Korea, Australia, the United Kingdom and Turkey represent 72% of the twenty countries that generated the most publications in the field of research. On the other hand, the journals that publish the most on the subject are Energies, IEEE Access, Journal of Cleaner Production and Applied Energy concentrate 18% of the publications, the rest of the publications are disseminated among different journals. In turn, the most productive authors are Deo RC, Ghimire S and Raj N, each with four or more items; This taking into account that 91% of researchers in this field are transient.

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