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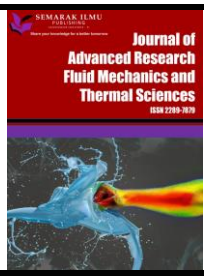

Mathematical Modeling of Groundwater Surface Water Interaction Represented using Boussinesq Equation – A Bibliometric Study

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ABSTRACT

Water is a significant, a must-needed natural resource for mankind and all living species on earth. Apart from for drinking and domestic needs, water is being used for other purposes like farming and industry. Groundwater is a natural, easily available water source. It is predicted that, by 2025, two-thirds of the world's population may face water shortage. Due to anthropogenic activities, quality of groundwater is hampered. The study of groundwater with the help of mathematical modeling gives a thorough idea of all the parameters which affect groundwater. Bibliometric studies aids researchers and funding agencies to focus on the research area in which more attention is required. It helps the new researchers to identify the varied areas pertaining to the research field in which one needs to focus more to get fruitful results. The use of Boussinesq equations is one of the leading methods in modeling the problem in groundwater analysis. This paper provides an overall picture of research carried out in groundwater analysis in the current century. This analysis is based on the publications available in Scopus database using some graphical tools. Figures and facts are interpreted in the form of plots, charts, and tables. This survey revealed that the maximum publications are from journals and conferences and USA lead the publications in this area. A lot of publications in this area are from journals of Fluid mechanics followed by journals of Civil engineering. The number of papers and papers published in journals of different areas shows the importance of this research topic and also the thrust.

1. Introduction

The fresh water which is 3 % of the water available on earth plays an important role in human life. This 3% constitutes water in rivers, lakes, springs, and in ground. Among these, the valuable natural resource for the living species is the groundwater, which is readily available for day-to-day needs. The existence and occurrence of groundwater is neglected by water resource managers for many decades. Due to technological advancement, one can detect the deterioration of water resources. This necessary element for all living beings is directly or indirectly affecting public health and national economy. Many researchers are working to find the solution to increase water table level. In this case, the biggest misconception is that surface water and groundwater are separate

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entities. They are not only connected but affect each other quantitatively and qualitatively. Hence it is very important to understand the geological situations, movement of groundwater, relation between groundwater and surface water, and aquifer's nature before planning any water resource development activity.

The relation between surface water and groundwater is an emerging area for hydrological research. Proper management of natural resources is an important duty of human beings in today's world. Knowledge of water table fluctuation in the aquifer during recharge or withdrawal is the key point for water resource managers to understand the flow processes. There are many methods to understand these key processes. One of the widely used methods is fieldwork which involves collation of the actual data on site and analyse the same. This is time consuming and expensive task.

Method of mathematical modelling is a widely used tool to analyse different practical phenomenon and to understand the process and changes in the flow mechanism [1]. Researchers like Jalasabri *et al.,* [2] have used computational fluid dynamics (CFD) to study effect of fineness, altitude and velocity on an airship design for aerodynamical characteristics. Ji [3] have also used CFD modelling to discuss natural convection in air cavities. Bryant and Ng [4] have done numerical modelling by applying mesh based CFD method of hydraulic jump using RNG k-ϵ and SST k-ω turbulence models. Abobaker *et al.,* [5] have conducted numerical analysis of wind tunnel wall effect on two dimensional subsonic flow over a NACA 0012 air foil by considering different parameters like height, angle of attack, etc. Bahambary and Fleck [6] have conducted CFD simulation of isolated wind turbine. Models involving flow mechanism can predict the fluctuation in water level under certain conditions. Generally, the flow is interpreted in the form of set of linear and / or non-linear partial differential equations. Based on the approach of continuity equation, mass balance equation and Dupuit assumptions of neglecting the vertical flow, the 3-D flow equation is given by

$$\frac{\partial}{\partial x}\left(K_x \frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_y \frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_z \frac{\partial h}{\partial z}\right)=S\frac{\partial h}{\partial t} \tag{1}$$

where *S* is a specific yield, *h* is water table height and K_x, K_y and K_z are the hydraulic conductivity of the aquifer in *X, Y* and *Z* direction respectively. Above equation is redeveloped by Chapman [7] for the isotropic aquifers resting on sloping base in 2-D rectangular aquifer by assuming; (i) for small inclination of free surface stream lines are nearly horizontal, (ii) hydraulic gradient is equal to slope of free surface and does not vary with the depth.

The equation is as follows:

$$\frac{\partial}{\partial x}\left(h\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(h\frac{\partial h}{\partial y}\right)-\tan\theta_x\frac{\partial h}{\partial x}-\tan\theta_y\frac{\partial h}{\partial y}+\frac{Q}{K}=\frac{S}{K}\frac{\partial h}{\partial t} \tag{2}$$

Eq. (2) is called Boussinesq equation which is a second order non-linear partial differential equation, parabolic in nature. This equation is used when the subsurface drainage is over moderately sloping beds. Here tan θ_x and tan θ_y are the downward bed slopes along the positive directions of *X* and *Y* axis respectively. By considering the hypothetical data, one can simulate the model and check the variations in important characteristics under various hydrological conditions [8]. The parameters involved can be tested using the closed form of solution [9-11]. The solution of PDE is usually obtained either by using suitable numerical technique and / or analytical method. In the beginning, it is Theis [12] who started researching in this area and then followed by Hantush [13]. The research continued thereafter, and many mathematical models are developed. A simple approach of Darcy law which

states that the velocity is directly proportional to stream stage difference is used by many researchers. The boundary variability is interpreted in the form of Robin boundary conditions [14]. Essential modelling using many different techniques in confined as well as the unconfined aquifer is the area in which researchers have concentrated for decades. Zlotnik and Tartakovsky [15] has studied unconfined aquifer system for water table fluctuation. For the basic flow model, two approximations of an unconfined aquifer are presented, in the first case, the streamlines are almost horizontal (Dupuit assumptions) and in the other case, streamlines are parallel to the Baseline (Dupuit–Forchheimer assumption) [16,17]. Many researchers' have used the Dupuit Forchheimer assumption to approximate the flow [18]. In the period 1980 to 2000, researchers mostly focused on analytical study of transient water exchange when the stream is fully penetrating the aquifer [19,20]. Moreover, the study is carried out further to observe the fluctuation of the water table in presence of clogging layer for various configurations like confined, unconfined, and leaky aquifers [21].

The flow mechanism in this process is often approximated in the form of nonlinear partial differential equation called as Boussinesq equation. Mathematical models based on the stream stage variations due to recharge/discharge are studied using Boussinesq equation by many researchers like Bansal and Das [22], Bansal *et al.,* [23], Lande *et al.,* [24], Bansal [25], Rai and Manglik [26], and Childs [27]. Many more researchers contributed from 1941 to till date and developed the models using mathematical tools. The differential or difference equations arising in hydrological models gives us significant results in finding the role of key characteristics. These equations can be analytically solved by employing Laplace transforms and Finite Fourier transforms. Researchers also use semi analytical methods like Adomian's [28] decomposition method, Laplace decomposition method, perturbation method, etc. to solve well hydraulic problems are presented [29,30].

The main aim of this paper is to study bibliometric analysis of the literature in the area of groundwater seepage and water table variation in an aquifer. The Bibliometric analysis of different databases can help in finding the research gap and limitations. Bibliometric analysis of groundwater life cycles is done by Bryant and Ng [4], Herraro-Franco *et al.,* [31], Pande and Mulay [32], Cascajares *et al.,* [33], Priyono *et al.,* [34], Shaikh *et al.,* [35], Marino [36], and Tang *et al.,* [37], which triggered many authors to study the hydrological mathematical modelling. The focus of this bibliometric study is to carry out the detailed analysis of scientific publications available in different research databases [38,39].

This analysis provides detailed information regarding the specific field, specific journals, number of papers, types of publications, etc.

2. Data Collection

For this bibliometric review, the data source is Scopus database, and it is analysed using various bibliometric tools. Nonlinear partial differential equations like "Boussinesq Equation" are widely used in mathematical modelling of water table variations under recharge /withdrawal. The main key word used in this paper to fetch the data from Scopus database is "Boussinesq Equation". Preliminary search gives 5179 papers. Since the mathematical modelling is the focus of this study, the secondary keywords used here are "numerical methods", "analytical methods", "Laplace transforms" and "Fourier transforms" by keeping in mind that Laplace transforms and Fourier transforms techniques are the most widely used techniques in this area of research. The set of keywords used to search the data are "Boussinesq Equation" and ("numerical methods" or "analytical methods" or "Laplace transforms" or "Fourier transforms". Each of the keywords selected here gives strong mathematical correlation and clearly indicate the mathematics used to develop hydrological models. The secondary search reduces to 1518 publications for which the analysis is carried out.

3. Methodology

The methodology proposed here involves the following stages and the same is depicted in Figure 1.

(i) Selection of topic
(ii) Keyword selection
(iii) Collection of data
(iv) Analysis of data
(v) Scientific structure

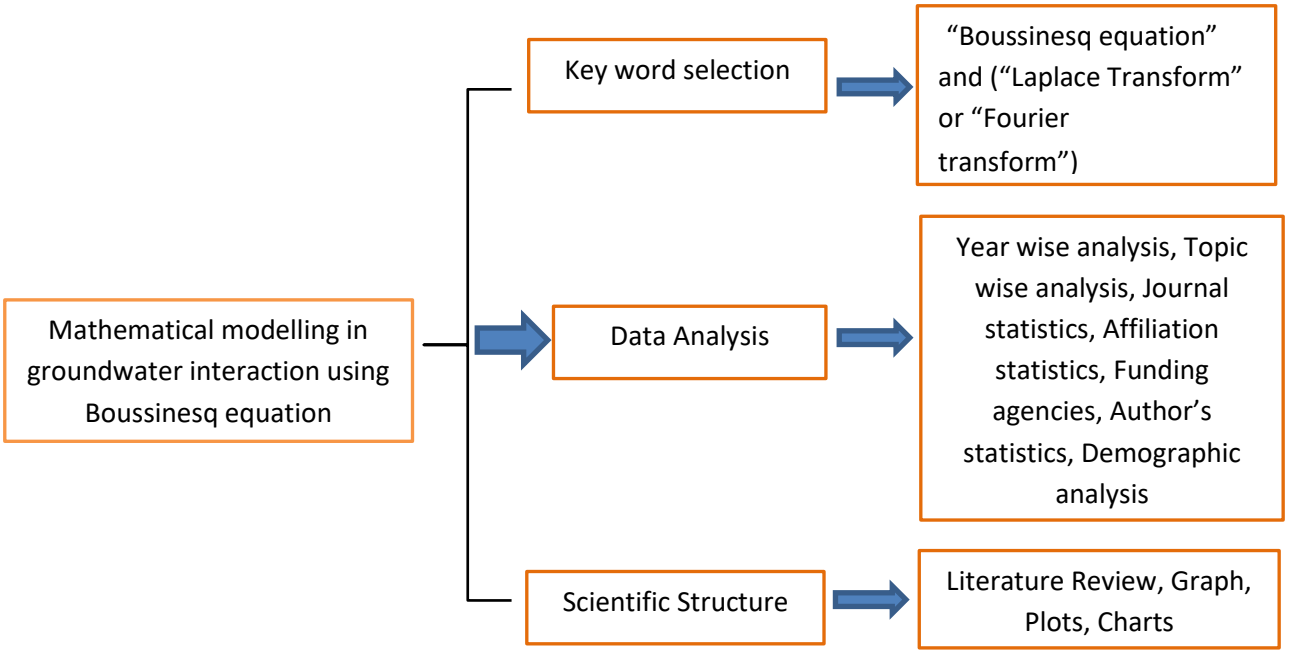

Fig. 1. Process of data analysis

3.1 Publication Trend Per Year

One can understand the importance of the topic from the fact that first paper in Scopus is published in the year 1968. The data from 1968 to till data has been taken for the current analysis (Table 1). It is observed that till 1990, not much research was carried out but after 1990, the number of publications increased significantly. The reason behind this may be the availability of the advanced software/technology which is used to solve highly difficult mathematical problems. The level of accuracy of the result is also increased and error has been reduced with the modern tools used in solving problems. Moreover, basic awareness among people related to water is increased and hence this area is getting more attractive for researchers. The maximum number of publications is in the year 2018 (87). Evolution of the research in the last five years can be clearly seen form the data as more than 75 papers on an average per year are published in this period. The trend line is drawn by considering the data of last 22 years in Figure 2.

Table 1
Publication per year

Year	No. of papers	Year	No. of papers	Year	No. of papers	Year	No. of papers	Year	No. of papers
1968	2	1979	1	1990	6	2001	15	2012	61
1969	0	1980	3	1991	11	2002	29	2013	68
1970	1	1981	3	1992	13	2003	39	2014	61
1971	0	1982	2	1993	8	2004	45	2015	61
1972	0	1983	2	1994	10	2005	35	2016	68
1973	1	1984	9	1995	18	2006	48	2017	75
1974	3	1985	4	1996	17	2007	54	2018	87
1975	5	1986	9	1997	21	2008	59	2019	82
1976	5	1987	6	1998	21	2009	60	2020	86
1977	0	1988	5	1999	17	2010	56	2021	84
1978	4	1989	6	2000	23	2011	65	2022 (till August)	45

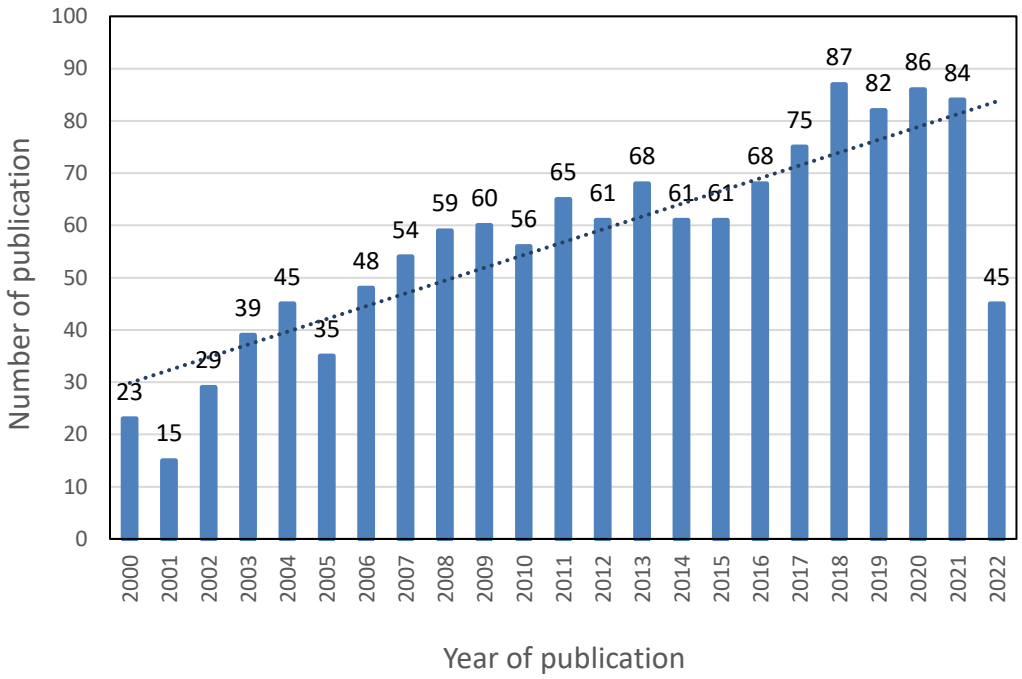

Fig. 2. Year wise publication trend

4. Bibliometric Analysis

The data collected from Scopus data base is analysed in terms of many parameters like type of research papers, geographic region, and citation, etc. Statistical analysis is carried out to complete the analysis about affiliation, authors, source, funding agencies and journal, etc. to name a few.

4.1 Nature of Publication

It is observed that different types of publications are available in the literature. The publications include journal papers, conference papers, book chapters, etc. Approximately, 90% of the research output is through peer reviewed journal articles and remaining from other types of publications. The detailed statistics is as shown in Figure 3.

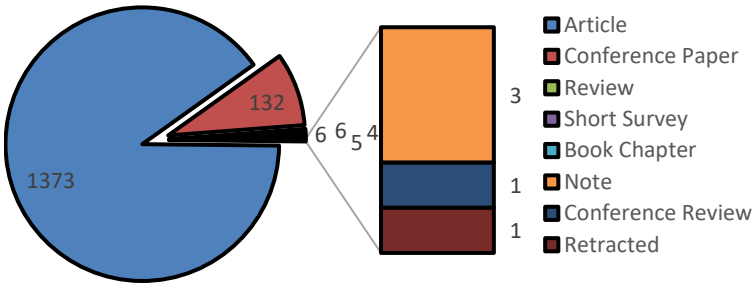

Fig. 3. Nature of publication

4.2 Country-Wise Contribution

It is observed that the researchers of more than 78 countries are involved in the research of mathematical modelling of groundwater modelling using Boussinesq equation. Figure 4 gives the details of countries which have published more than 50 papers. This gives the idea of widespread coverage of the topics in different parts of the world. The United States showed remarkable participation followed by China with 24% and 21% of the total number of publications respectively. From this analysis, it is guaranteed that the citizens of several countries are now aware about the importance of water and its management which will help the world in managing the important resources in a better way. Though it starts in a progressive country like United States of America, many developing countries are also now promoting the research for proper management of water resources. Figure 5 represents the geographic locations of top 10 publishing countries in the area of ground water modelling using Boussinesq equations.

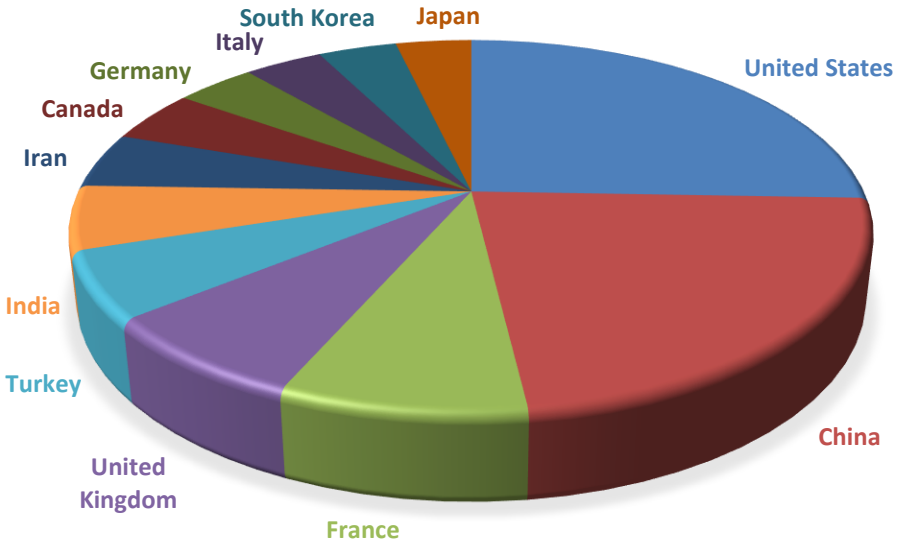

Fig. 4. Country-wise contribution

Fig. 5. Geographical location of top 10 publishing countries

4.3 Major Research Topics

Though this bibliometric study is on mathematical hydrological modelling, the related papers are published in journal with diverse areas like medicine, neuroscience, social science, material science, and biological science. Maximum publications are in Engineering and Mathematical sciences. The contribution of the research in various topics shows the relevance to the real-time application.

The observation in the analysis is addressed through the pie chart shown in Figure 6. From the Chart one can easily trace out that the maximum contribution is from the engineering field followed by Mathematics, Environment, Physics, etc.

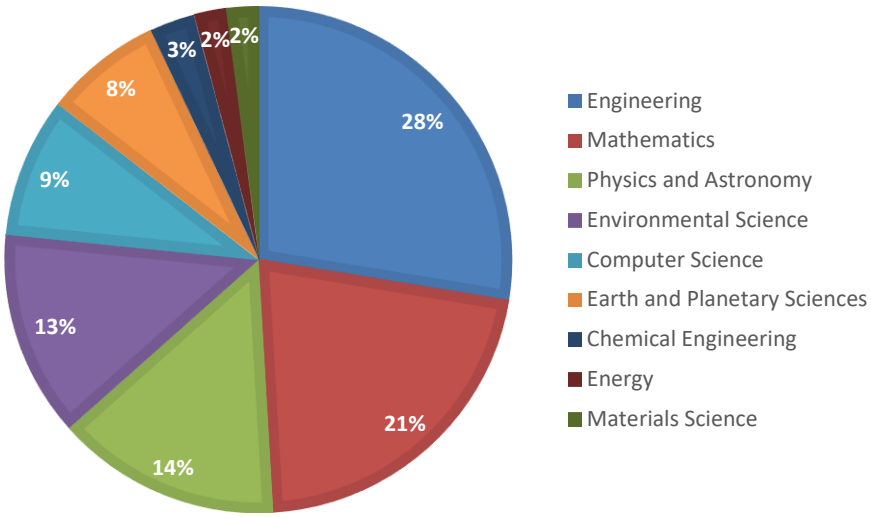

Fig. 6. Contribution in different areas

4.4 Top Authors

More than 250 researchers are working in this area. There are almost 159 researchers who published more than 4 papers. Figure 7 shows the contribution made by the top 10 authors in the research. Many Authors are from the background of Civil, Environmental Sciences, Geology, Geo-informatics, etc. Mathematicians contributed remarkably by developing mathematical models for the problems in this field.

A notable contribution is by Wazwaz A.M. with 18 papers. Among these top 10 publishing authors Madsen, P.A. has got maximum citation (630) from his 17 published articles. Figure 7 gives the details of author wise publications. The authors who published minimum of 10 papers are included in the table.

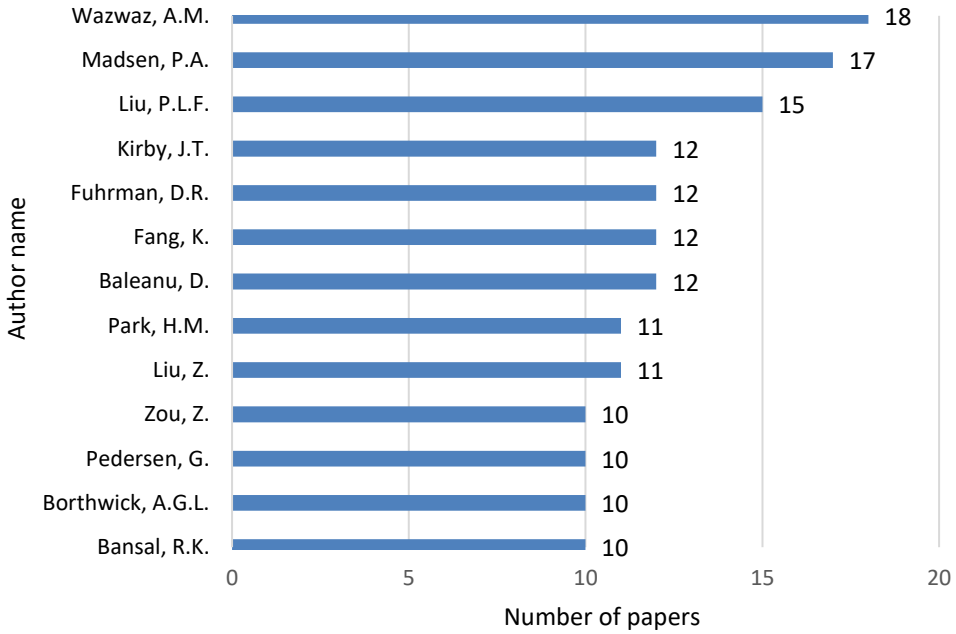

Fig. 7. Contribution of top authors

4.5 Network Analysis

The network of authors is visualized in Figure 8. It is depicting the data of co-author network. It is observed from the figure that almost all main researchers working on this field have connection among themselves, either directly or indirectly which shows that there is a collective effort among researchers to take the research in this area to a newer height.

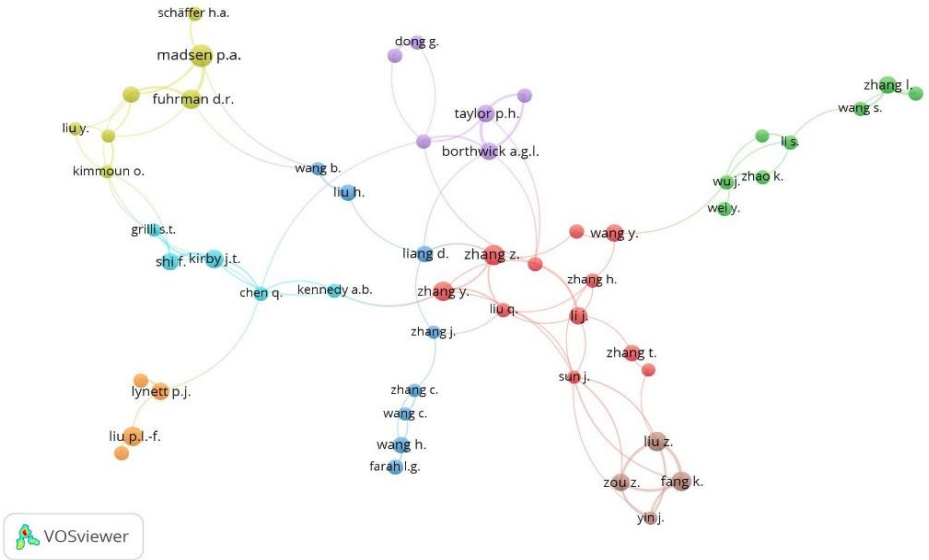

Fig. 8. Network analysis of authors

Figure 9 indicates the cluster of keywords related to Boussinesq equation. This shows the wide variety of research happening in ground water modelling using Boussinesq equation.

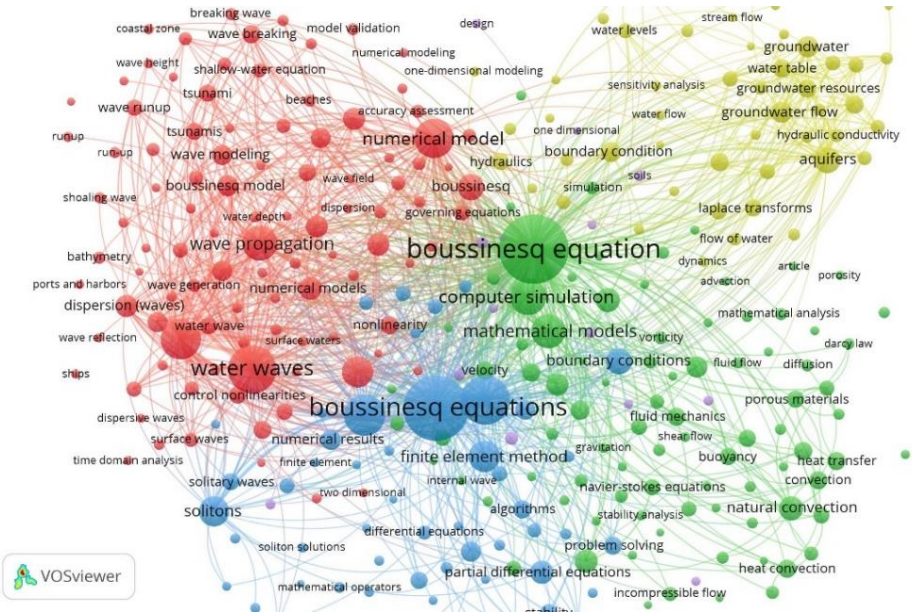

Fig. 9. Network analysis of key words

4.6 Affiliation Statistics

The data of affiliation gives us an idea about top universities working in this area. According to the Scopus database the Dalian University of Technology, Liaoning, China stands number one in terms of affiliation. The second topmost affiliation is of State key laboratory of coastal and offshore Engineering which is again a part of Dalian university. Researcher from almost 160 universities all over the world are working in this area. Along with these two, CNRS centre of national defence has also contributed remarkably to this area. The statistics of university affiliation is presented as a bar graph in Figure 10. It is observed from the data that the contribution of other top universities is mostly between 10 and 20. Table 2 shows the list of universities (left to right) along with number which is depicted in Figure 10.

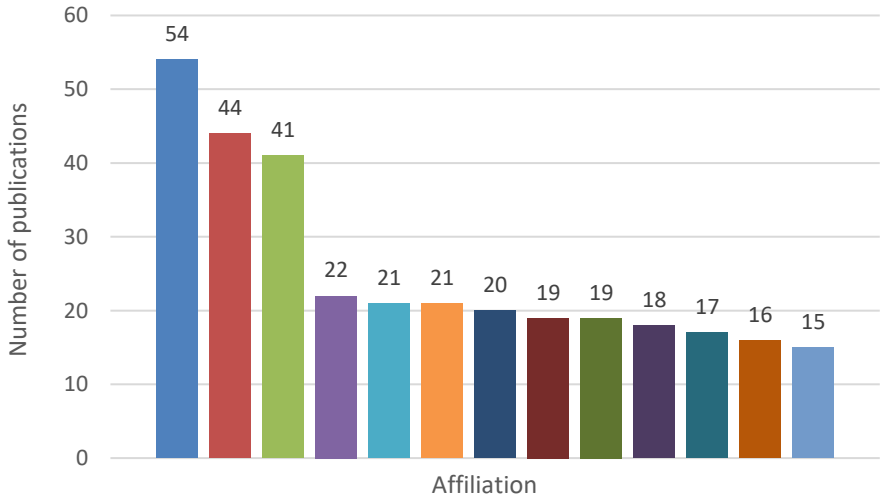

Fig. 10. Affiliations details

Table 2
Affiliation details

Dalian University of Technology	54
State Key Laboratory of Coastal and Offshore Engineering	44
CNRS Centre National de la Recherche Scientifique	42
Hohai University	22
Chinese Academy of Sciences	21
Texas A&M University	21
Technical University of Denmark	20
Cornell University	19
Universitetet i Oslo	19
Shanghai Jiao Tong University	18
Saint Xavier University	17
University of Delaware	16
Ministry of Education China	15
Firat Üniversitesi	14
University of Leeds	14
Nanjing Normal University	14

4.7 Journal Statistics

The articles published in almost 157 journals from different parts of the world shows the widespread scope of the topic. Below is the representation which shows the contribution of top journals which published 15 or more than 15 papers. One of the journals of fluid mechanics published the highest number of papers (80) and next is the Coastal Engineering journal which published 67 papers.

Some of the good journals that contributed significantly are International Journal for Numerical Methods in Fluids, Water Resources Research, Journal of Hydrology, Applied Mathematics and Computation, etc. Figure 11 gives more details of the journal statistics.

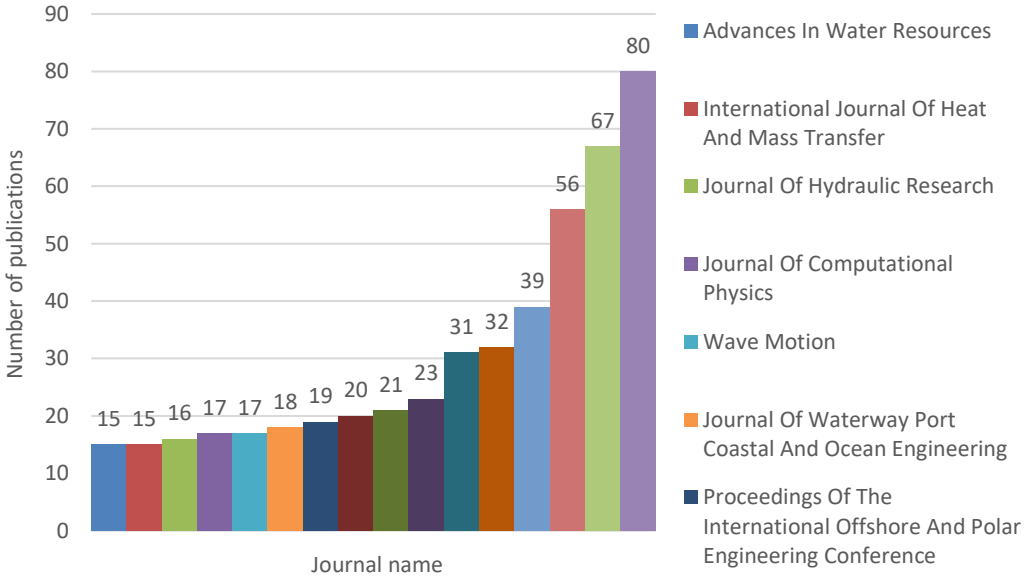

Fig. 11. Journal statistics

4.8 Funding Agencies

To increase the research activity and the related research output, adequate funding plays an important role. Many funding agencies sponsored projects in this area that are related to environmental sustainability. Almost 17% of the total contribution of funding is given by National Natural Science Foundation of China. Institutes like National Science Foundation and Office of Naval Research also extended funding to research in this field. Detailed statistics of funding agencies is depicted in the form of a pie graph in Figure 12.

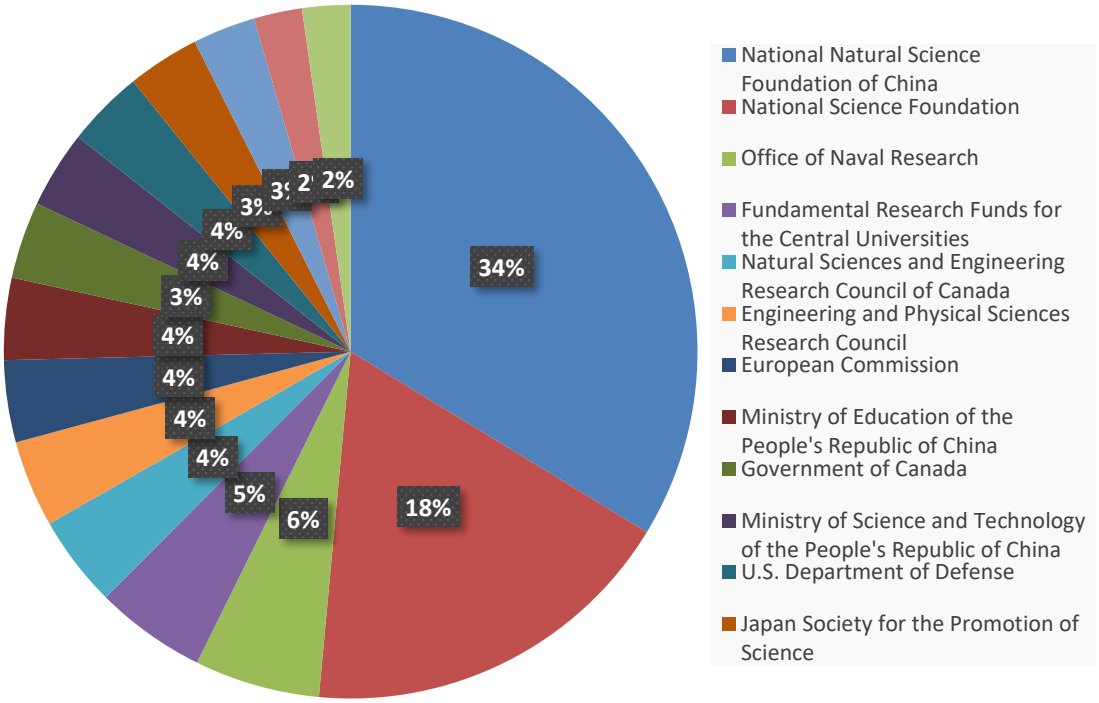

Fig. 12. Contribution of funding agencies

5. Conclusion and Future Scope

The results obtained by using the keywords in Scopus database yielded total of 5199 scientific products. We have analysed publications which deals with the mathematical modelling of water table fluctuation in an aquifer by considering different aspects like intellectual interaction between the researchers, strengths of various emerging topics, research interests of various groups, institutions' contributions and funding agencies share.

It is noted that integrating scientific efforts helps environmental managers to plan sustainable activities for improving the quality and quantity of natural resources. This data shows the wide picture of the research production and a community in various aspects. The number of publications in this area in the year 2021 shows the exponentially increasing trend of the research output. USA and China demonstrate a greater contribution as compared to the rest of the world.

Bibliometric analysis is useful to scholars in many ways such as to figure out the research gap, limitations of the topic Since the research is related to the sustainable development of water reservoirs, it is important to perform some field work along with the mathematical modelling using different software like Modflow, Modpath, MT3DMS, etc, various algorithms like genetic algorithm, ANN, etc. to test the validation of the model.

Research can be extended by considering many other aspects such as mathematical modelling in tidal wave propagation, complex geological situations related to water flow, heat flow, fluid (other than water) flow, and surface water flow where turbulence is involved.

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References

[1] Mohanty, Minakshi, Saumya Ranjan Jena, and Satya Kumar Misra. "Mathematical Modelling in Engineering with Integral Transforms via Modified Adomian Decomposition Method." *Mathematical Modelling of Engineering Problems* 8, no. 3 (2021). https://doi.org/10.18280/mmep.080310
[2] Jalasabri, Jafirdaus, Fairuz Izzuddin Romli, and Mohammad Yazdi Harmin. "Mathematical modelling for effects of fineness ratio, altitude and velocity on aerodynamic characteristics of an airship design using computational analysis." *CFD Letters* 12, no. 10 (2020): 90-110. https://doi.org/10.37934/cfdl.12.10.90110
[3] Ji, Yingchun. "CFD modelling of natural convection in air cavities." *CFD Letters* 6, no. 1 (2014): 15-31.
[4] Bryant, Daniel John Ebrahim, and K. C. Ng. "Numerical Modelling of Hydraulic Jump Using Mesh-based CFD method and Its Comparison with Lagrangian Moving-Grid Approach." *Journal of Advanced Research in Micro and Nano Engineering* 10, no. 1 (2022): 1-6.
[5] Abobaker, Mostafa, Abdulhafid M. Elfaghi, and Sogair Addeep. "Numerical Study of Wind-Tunnel Wall Effects on Lift and Drag Characteristics of NACA 0012 Airfoil." *CFD Letters* 12, no. 11 (2020): 72-82. https://doi.org/10.37934/cfdl.12.11.7282
[6] Bahambary, Khashayar Rahnamay, and Brian Fleck. "A study of inflow parameters on the performance of a wind turbine in an atmospheric boundary layer." *Journal of Advanced Research in Numerical Heat Transfer* 11, no. 1 (2022): 5-11.
[7] Chapman, T. G. "Modeling groundwater flow over sloping beds." *Water Resources Research* 16, no. 6 (1980): 1114-1118. https://doi.org/10.1029/WR016i006p01114
[8] Lande, Chhaya K., and Arundhati Warke. "Estimation of groundwater variations in an anisotropic leaky aquifer: A ditch drain model." *Journal of Mathematics and Computational Science* 12 (2022).
[9] Lande, Chhaya K., Rajeev K. Bansal, and Arundhati Warke. "Simulation of two dimensional subsurface seepage flow in isolated anisotropic aquifer." *Materials Today: Proceedings* 23 (2020): 329-337. https://doi.org/10.1016/j.matpr.2020.02.032
[10] Bansal, Rajeev K., and Samir K. Das. "Analytical study of water table fluctuation in unconfined aquifers due to varying bed slopes and spatial location of the recharge basin." *Journal of Hydrologic Engineering* 15, no. 11 (2010): 909-917. https://doi.org/10.1061/(ASCE)HE.1943-5584.0000267
[11] Boussinesq, J. "Du mouvment non permanent des eaux souterraines." *Essai sur la théorie des eaux courantes. Memories presents par divers savants a l'Academic des Science de l'Institut de France* 23, no. 1 (1877): 252-260.
[12] Theis, Charles V. "The effect of a well on the flow of a nearby stream." *Eos, Transactions American Geophysical Union* 22, no. 3 (1941): 734-738. https://doi.org/10.1029/TR022i003p00734
[13] Hantush, Mahdi S. "Wells near streams with semipervious beds." *Journal of Geophysical Research* 70, no. 12 (1965): 2829-2838. https://doi.org/10.1029/JZ070i012p02829
[14] Bear, Jacob. *Dynamics of fluids in porous media*. Elsevier, 1972.
[15] Zlotnik, Vitaly A., and Daniel M. Tartakovsky. "Stream depletion by groundwater pumping in leaky aquifers." *Journal of Hydrologic Engineering* 13, no. 2 (2008): 43-50. https://doi.org/10.1061/(ASCE)1084-0699(2008)13:2(43)
[16] Upadhyaya, A., and H. S. Chauhan. "Falling water tables in horizontal/sloping aquifer." *Journal of Irrigation and Drainage Engineering* 127, no. 6 (2001): 378-384. https://doi.org/10.1061/(ASCE)0733-9437(2001)127:6(378)
[17] Marino, M. A. "Water-table fluctuation in semipervious stream-unconfined aquifer systems." *Journal of Hydrology* 19, no. 1 (1973): 43-52. https://doi.org/10.1016/0022-1694(73)90092-9
[18] Moutsopoulos, Konstantinos N. "Solutions of the Boussinesq equation subject to a nonlinear Robin boundary condition." *Water Resources Research* 49, no. 1 (2013): 7-18. https://doi.org/10.1029/2012WR012221
[19] Manglik, A., S. N. Rai, and R. N. Singh. "Response of an unconfined aquifer induced by time varying recharge from a rectangular basin." *Water Resources Management* 11 (1997): 185-196.
[20] Moench, A. F., and P. M. Barlow. "Aquifer response to stream-stage and recharge variations. I. Analytical step-response functions." *Journal of Hydrology* 230, no. 3-4 (2000): 192-210. https://doi.org/10.1016/S0022-1694(00)00175-X

[21] Akylas, Evangelos, and Antonis D. Koussis. "Response of sloping unconfined aquifer to stage changes in adjacent stream. I. Theoretical analysis and derivation of system response functions." *Journal of Hydrology* 338, no. 1-2 (2007): 85-95. https://doi.org/10.1016/j.jhydrol.2007.02.021
[22] Bansal, Rajeev K., and Samir K. Das. "Effects of bed slope on water head and flow rate at the interfaces between the stream and groundwater: analytical study." *Journal of Hydrologic Engineering* 14, no. 8 (2009): 832-838. https://doi.org/10.1061/(ASCE)HE.1943-5584.0000048
[23] Bansal, Rajeev K., Chhaya K. Lande, and Arundhati Warke. "Unsteady groundwater flow over sloping beds: analytical quantification of stream-aquifer interaction in presence of thin vertical clogging layer." *Journal of Hydrologic Engineering* 21, no. 7 (2016): 04016017. https://doi.org/10.1061/(ASCE)HE.1943-5584.0001362
[24] Lande, Chhaya K., Rajeev K. Bansal, and A. Warke. "Simulation of 2-dimensional subsurface seepage flow in an anisotropic porous medium." *Perspectives in Science* 8 (2016): 276-278. https://doi.org/10.1016/j.pisc.2016.04.051
[25] Bansal, Rajeev K. "Groundwater flow in sloping aquifer under localized transient recharge: Analytical study." *Journal of Hydraulic Engineering* 139, no. 11 (2013): 1165-1174. https://doi.org/10.1061/(ASCE)HY.1943-7900.0000784
[26] Rai, S. N., and A. Manglik. "An analytical solution of Boussinesq equation to predict water table fluctuations due to time varying recharge and withdrawal from multiple basins, wells and leakage sites." *Water Resources Management* 26 (2012): 243-252. https://doi.org/10.1007/s11269-011-9915-x
[27] Childs, E. C. "Drainage of groundwater resting on a sloping bed." *Water Resources Research* 7, no. 5 (1971): 1256-1263. https://doi.org/10.1029/WR007i005p01256
[28] Adomian, George. *Solving frontier problems of physics: the decomposition method*. Kluwer: Boston, 1994. https://doi.org/10.1007/978-94-015-8289-6
[29] Daga Bhandari, Amruta, V. H. Pradhan, and Rajeev K. Bansal. "New analytical solution for stream-aquifer interaction under constant replenishment." *Applied Water Science* 8 (2018): 1-8. https://doi.org/10.1007/s13201-018-0814-7
[30] Yeh, Hund-Der, and Ya-Chi Chang. "Recent advances in modeling of well hydraulics." *Advances in Water Resources* 51 (2013): 27-51. https://doi.org/10.1016/j.advwatres.2012.03.006
[31] Herrera-Franco, Gricelda, Paúl Carrión-Mero, Néstor Montalván-Burbano, Carlos Mora-Frank, and Edgar Berrezueta. "Bibliometric analysis of groundwater's life cycle assessment research." *Water* 14, no. 7 (2022): 1082. https://doi.org/10.3390/w14071082
[32] Pande, Mandaar, and Preeti Mulay. "Bibliometric survey of quantum machine learning." *Science & Technology Libraries* 39, no. 4 (2020): 369-382. https://doi.org/10.1080/0194262X.2020.1776193
[33] Cascajares, Mila, Alfredo Alcayde, Esther Salmerón-Manzano, and Francisco Manzano-Agugliaro. "The bibliometric literature on Scopus and WoS: the medicine and environmental sciences categories as case of study." *International Journal of Environmental Research and Public Health* 18, no. 11 (2021): 5851. https://doi.org/10.3390/ijerph18115851
[34] Priyono, Dwi Sendi, Fajar Sofyantoro, Wahyu Aristyaning Putri, Nur Indah Septriani, Annas Rabbani, and Tuty Arisuryanti. "A bibliometric analysis of Indonesia biodiversity identification through DNA barcoding research from 2004-2021." *Natural and Life Sciences Communications* 22, no. 1 (2023): e2023006. https://doi.org/10.12982/NLSC.2023.006
[35] Shaikh, Bushra Y., Rajeev K. Bansal, and Samir K. Das. "Propagation of tidal wave in coastal terrains with complex bed geometry." *Environmental Processes* 5 (2018): 519-537. https://doi.org/10.1007/s40710-018-0314-7
[36] Marino, M. A. "Water-table fluctuation in semipervious stream-unconfined aquifer systems." *Journal of Hydrology* 19, no. 1 (1973): 43-52. https://doi.org/10.1016/0022-1694(73)90092-9
[37] Tang, Yuehao, Qinghui Jiang, and Chuangbing Zhou. "Approximate analytical solution to the Boussinesq equation with a sloping water-land boundary." *Water Resources Research* 52, no. 4 (2016): 2529-2550. https://doi.org/10.1002/2015WR017794
[38] Veena, B. S. "Bibliometric analysis of effect of applied magnetic field on blood flow in stenosed artery." *Journal of Mathematical and Computational Science* 12 (2021).
[39] Mozaffari Nejad, Amir Sasan, Tehjeeb Noor, Ziaul Haque Munim, Mohammad Yousef Alikhani, and Amir Ghaemi. "A bibliometric review of oncolytic virus research as a novel approach for cancer therapy." *Virology Journal* 18, no. 1 (2021): 98. https://doi.org/10.1186/s12985-021-01571-7