

*Review Article*

## Visualising Global Trends in Soil Infiltration Study by using Bibliometric Analysis

Nor Farah Atiqah Ahmad\*, Siti Nooraiin Mohd Razali, Suhaila Sahat, and Muhammad Azraie Abdul Kadir

*Department of Civil Engineering, Centre for Diploma Studies, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, 84600 Pagoh, Johor, Malaysia*

### ABSTRACT

Soil infiltration plays a crucial role in the hydrological cycle, water resource management, and sustainable agricultural practices. It is important to identify the emerging trends and research gaps for this study. Therefore, this study aims to present a comprehensive and systematic academic review of soil infiltration in the field using bibliometric analysis with the aid of VOSviewer to evaluate global research trends in soil infiltration based on author keywords, affiliated countries, and co-authorships. This study retrieved 494 articles published between 2000 and 2025, as of January 16th, 2025, from the Scopus database. Results have shown a steady decrease and increased for annual number of publications, with the lowest drop in 2024 with 22 publications and the highest rise in 2021 with 30 publications. The leading contributors are from China and the USA, leading by 28% and 21% respectively. Meanwhile, Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering contributed the most publications. Although the Science of The Total Environment (STOTEN) journal ranked second after Water (Switzerland) in the top journal, the CiteScore 2023 for STOTEN is the highest with 17.6. This study underscores

the effectiveness of a water management system, which includes it supports for flood risk mitigation, enhances agricultural productivity and improves groundwater recharge. Future research should focus on optimising the soil infiltration model by adapting AI tools to consider climate change factors

### ARTICLE INFO

*Article history:*

Received: 01 August 2025

Accepted: 16 March 2026

Published: 30 April 2026

DOI: <https://doi.org/10.47836/pjst.34.2.17>

*E-mail addresses:*

[norfarah@uthm.edu.my](mailto:norfarah@uthm.edu.my) (Nor Farah Atiqah Ahmad)

[snoraiin@uthm.edu.my](mailto:snoraiin@uthm.edu.my) (Siti Nooraiin Mohd Razali)

[suhailasa@uthm.edu.my](mailto:suhailasa@uthm.edu.my) (Suhaila Sahat)

[mazraie@uthm.edu.my](mailto:mazraie@uthm.edu.my) (Muhammad Azraie Abdul Kadir)

\* Corresponding author

*Keywords:* Bibliometric analysis, hydrology, research trends, scopus database, soil infiltration, VOSViewer

## INTRODUCTION

In the study of the hydrological cycle and environmental science, soil water infiltration is a crucial process as it determines how the water enters and moves through the soil. The process influences groundwater recharge, surface runoff and soil moisture availability, which not only has an impact on agriculture, but it is also a key study for urban drainage and ecosystem sustainability. An adequate knowledge of soil infiltration rate is essential to ensure the effectiveness of water resource management, erosion control and flood mitigation. The factors such as soil texture, moisture, vegetation cover and land use directly influenced the soil infiltration capacity.

Bibliometrics is one of the qualitative analyses that is used to reduce the number of unrelated articles in a scholar's research area (Donohue, 1972). It can build firm foundations that enable scholars to gain an overview, identify research gaps, develop new, novel ideas for their investigation and focus on the aim of their contribution to the field (Donthu et al., 2021). Bibliometric analysis has gained immense popularity in various fields, including medicine, social science, computer science, engineering, pharmacology, neuroscience, and psychology. As of January 2025, a total of 31,536 documents focused on bibliometric analysis. The accessibility of bibliometric software tools such as Leximancer, Gephi, Bibexcel, Sci2, SciMat, Pajek, UCINET, CiteSpace and VOSViewer might have an impact on bibliometric analysis popularity. The most popular tool is the VOSViewer software, which has gained 7,797 documents recorded in the Scopus database. Visualisation of similarities (VOS) was first introduced by (Van Eck et al., 2006) as a new method to provide visualisations of the insight into the subfield relationship to another subfield, such as map co-occurrence, citations and authorship patterns. This advantage helps authors conducting research by identifying influential authors, highly cited papers and identifying research gaps quickly. Using VOSviewer, which has a user-friendly interface, free accessibility, and compatibility with Scopus and Web of Science databases, makes it valuable for authors with limited resources. The goal of this study was as follows: i) to examine journal article temporal patterns for soil infiltration, ii) to present the contributions of prominent authors, top countries, and most prolific academic institutions, and iii) to identify the dominant country based on major applications. This study is beneficial to academics, policymakers, as well as individuals who examine soil infiltration research patterns and discuss the current and possibilities for future research.

## METHODS

This section explained the sequential process of data collection and analysis regarding soil infiltration extracted from the Scopus database. The procedure comprised outlining the source of data and search strategy, the screening process to choose relevant documents and the criteria for selecting the final dataset for bibliometric analysis by using VOSviewer.

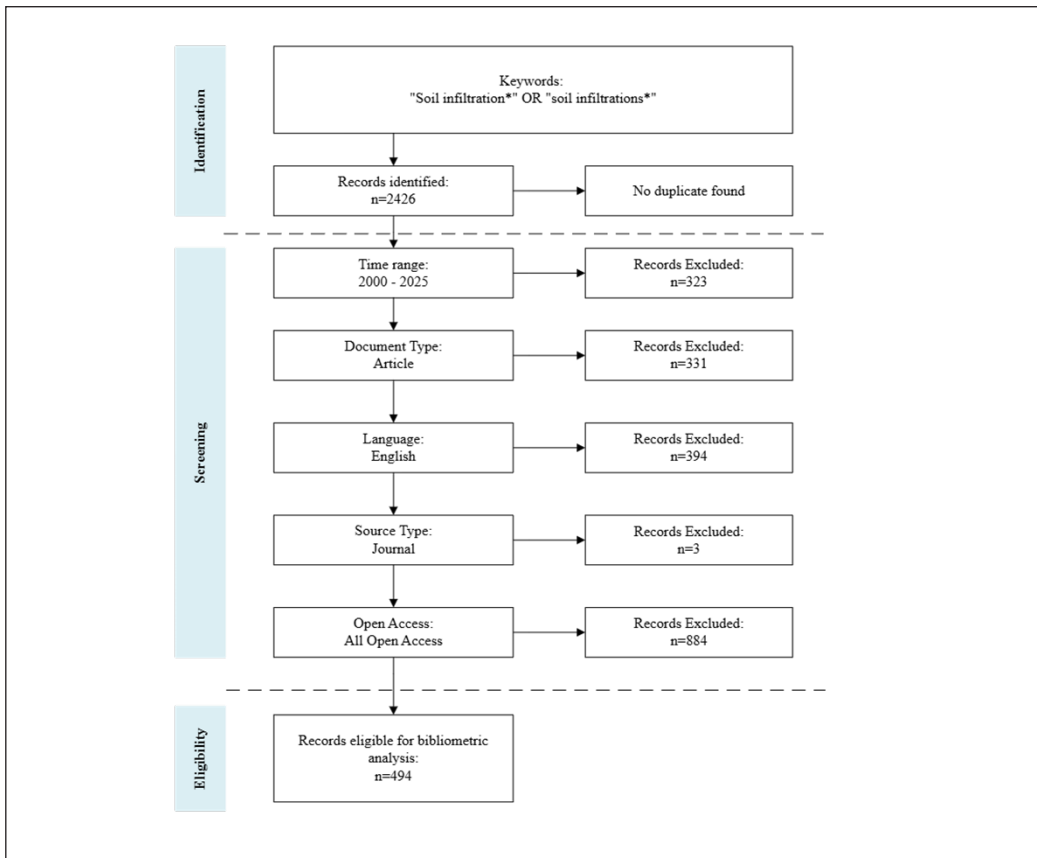


Figure 1. Systematic process of research stages and selection

The formation of a thematic cluster in VOSviewer is influenced by parameters such as keyword thresholds and normalisation methods. Although different parameter settings may slightly modify cluster boundaries, the major thematic structures identified in this study remained generally consistent.

### Data Source and Search Strategy

Data mining was conducted on January 16<sup>th</sup>, 2025, using the search query: (“soil infiltration\*” OR “soil infiltration\*”) using the Scopus database. The main theme in this study was articles containing “soil\* infiltration\*” in the title and abstract. The initial search retrieved a total of 2426 documents with the earliest publication dates to 1936, and more recent ones are from 2025. The search strategy focused on the keyword “soil infiltration” in the title and abstract to ensure the retrieval of studies directly related to the core topic. It is acknowledged that the other related terms, such as infiltration capacity, infiltration modelling and soil hydraulic processes, may capture additional relevant publications that

were not included in this dataset. After the screening process, as shown in Figure 1, 494 documents remained for deeper analysis, which includes duplicate keywords: singular and plural forms. This step is done by using the OpenRefine application. To focus on the relevance, the time range was set from 2000 to 2025, which excluded 323 articles. After considering papers that were classified as articles and published only in English journals, 728 documents were excluded. Consequently, 494 articles were considered suitable for the soil infiltration bibliometric analysis.

### **Screening Data**

To ensure the only relevant and high-quality studies were included, the final stage of this study was data extraction and filtering. A total of 494 articles containing their citations, bibliographical and author keywords information were exported as comma-separated values(.csv) file to VOSviewer software (version 1.6.20). The object of interest known as items are keywords, country, authors, and co-authorship. Based on the VOSviewer user manual by (Eck & Waltman, 2023). A link that connects two objects is unique, as it cannot be shared with any other pair of objects. Only positive numerical number denotes the strength for each link, and it increases as the strength increases.

## **RESULTS AND DISCUSSION**

### **Publications Output and Trend**

The annual publications trends in soil infiltration from January 2000 to January 2025 are shown in Figure 2 shows an eminent increase in research interest throughout this period. The data indicates that from 2000 to 2018, the annual number of publications fluctuates and on average the increment of 5 publications annually during this period. This may be influenced by several factors beyond technological developments, such as increasing global concern regarding climate change, water resources management and sustainable agricultural practices. Furthermore, the variations may reflect in research funding priorities, environmental challenges, and extreme weather. From 2020 onwards, a prominent upward trend in 2020 the number of publications was observed, in 2020 jumped to 57 publications compared to the previous year. The increasing of interest can be linked to the emerging Artificial Intelligence (AI) applications. The AI applications allow researchers to conduct various applications, such as soil infiltration models and simulations. It is crucial to point out that most of the articles require payment to access the material, and if the publication is in an open-access journal, it is likely to receive a larger number of citations. Overall, 1375 publications on soil infiltration were published during the 2000 to 2025 period, and 35% of the publications are open access type.

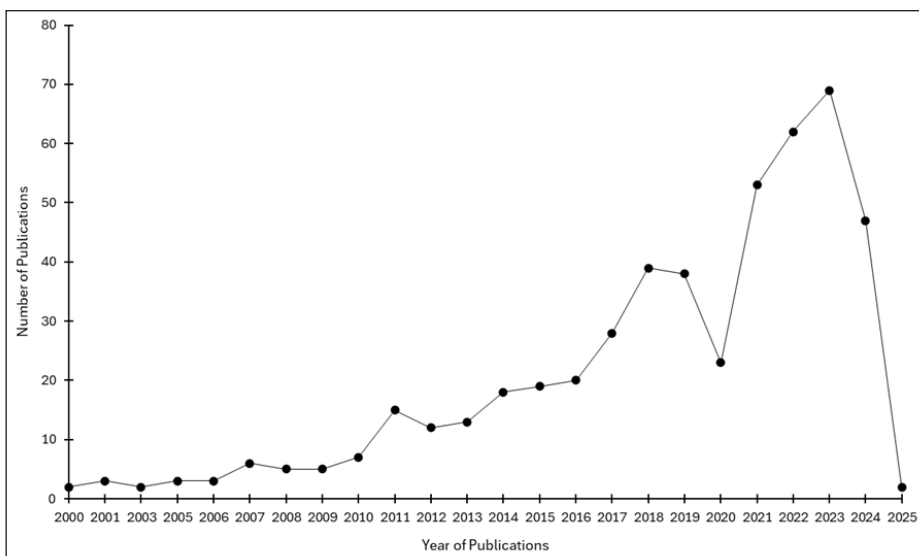


Figure 2. Number of publications and publication trend in the soil infiltration study for the last 24 years until January 16<sup>th</sup>, 2025

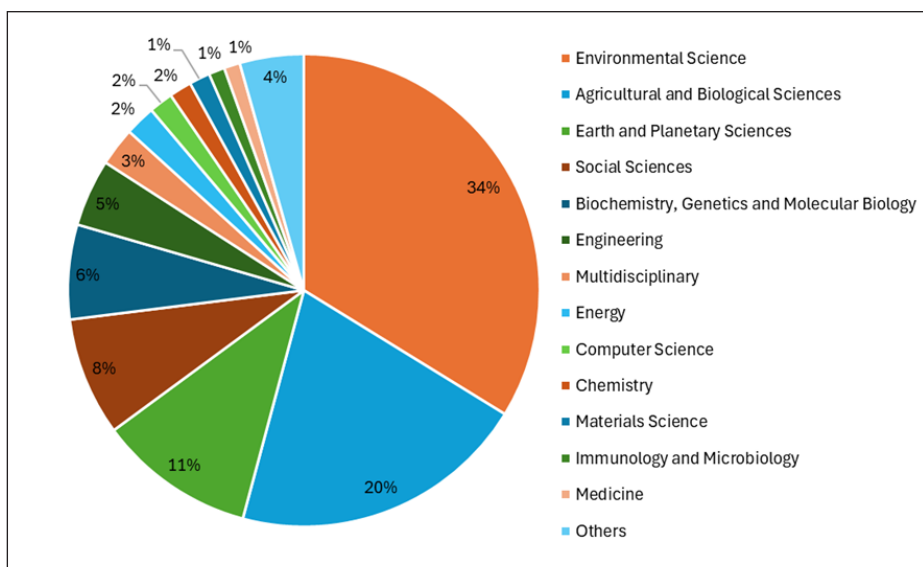


Figure 3. Distribution percentage by subject area for soil infiltration

Figure 3 demonstrates the distribution of documents by subject area regarding soil infiltration. The most representative areas for this research area are Environmental Science (308 articles), Agricultural and Biological Sciences (186 articles), Earth and Planetary Sciences (98 articles) and Social Sciences (74 articles). A total of 40 articles

were classified under Others: chemical engineering, pharmacology, toxicology, and pharmaceuticals, among others. Indeed, soil infiltration is a multidisciplinary area, as one of the publications was categorised under Art and Humanities. Although it is like the rest of the soil infiltration experiments, Sittisom et al. (2022) researched designing bioretention for urban areas in Chiang Mai, Thailand, to increase the efficiency of soil infiltration in urban areas. This approach can be used to enhance the enforcement of policymakers for future development.

Results also showed that a total of 8 different languages were used to publish studies regarding soil infiltration from 2000 to 2025. English (494; 94%) was the commonly used language, followed by Portuguese (16; 3%) and Spanish (8; 1%). Other languages (10; 2%) include French, Chinese, Turkish, Japanese and Czech. Nevertheless, when a scholar submits an article in a foreign language, it is compulsory to have an English title and abstract.

### **Preferred Journal**

Table 1 shows the top 10 most productive journals for the hydrology field. Three journals were published by the Multidisciplinary Digital Publishing Institute (MDPI) and Elsevier, respectively. Others were published by the Public Library of Science, Copernicus Publications, IWA Publishing and John Wiley & Sons. Water Switzerland, with 37 articles covering 7.5% of the total publications, has been identified as the most productive journal, followed by Science of The Total Environment (STOTEN) with 20 articles (4.0%), PLoS ONE (16, 3.2%) and Sustainability Switzerland (13, 2.6%). Although Hydrology and Earth System Sciences ranked 5<sup>th</sup>, their article ranked 2<sup>nd</sup> in highest citations with 145 after STOTEN's with 165 citations. CiteScore plays a significant role among authors in journal selection as it is the metric for measuring the annual average number of citations to the articles published in the journal. Based on the CiteScore 2023 report, eight journals had a CiteScore of 6 and above. Journals of the highest and lowest CiteScore belonged to STOTEN (17.6) and Water Science and Technology (4.9), respectively. Water Science and Technology journal ranked 6<sup>th</sup> with 11 publications in Scopus; the total citation and CiteScore were significantly lower compared to other journals. This was likely due to the primary scope of this journal being the technology of wastewater and stormwater management.

Cumulatively, over 2424 articles were published among 170 journals on soil infiltration in which 5 from the top 10 were published by Elsevier, as tabulated in Table 2. Although the most productive journal was Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering, led by 0.1% compared to STOTEN with 3.4%, the CiteScore of the STOTEN journal is the highest, with 17.6 among the top 10. Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering

Table 1  
*Top 10 productive journals on soil infiltration study*

	Journal	TP (%)	TP (%)	TC	CiteScore 2023	The most cited article	Times cited	Publisher
1	Water (Switzerland)	37 (7.5)	37 (1.7)	90,757	5.8	Effects of rainfall intensity and slope gradient on runoff and soil moisture content on different growing stages of spring maize (Mu et al., 2015).	103	Multidisciplinary Digital Publishing Institute (MDPI)
2	Science of the Total Environment	20 (4.0)	20 (3.4)	550,528	17.6	Pollution pathways and release estimation of perfluoro octane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) in central and eastern China (Liu et al., 2017).	161	Elsevier
3	PLoS ONE	16 (3.2)	16 (3.2)	331,118	6.2	Comparing infiltration rates in soils managed with conventional and alternative farming methods: A meta-analysis (Basche & DeLonge, 2019).	142	Public Library of Science
4	Sustainability (Switzerland)	13 (2.6)	13 (2.6)	432,964	6.8	Effects of super-absorbent polymer on soil remediation and crop growth in arid and semi-arid areas (Yang et al., 2020).	49	Multidisciplinary Digital Publishing Institute (MDPI)
5	Hydrology and Earth System Sciences	12 (2.4)	12 (2.4)	12,167	10.1	Comparison of the impacts of urban development and climate change on exposing European cities to pluvial flooding (Skougaard Kaspersen et al., 2017).	145	Copernicus Publications
6	Water Science and Technology	11 (2.2)	11 (2.2)	9,579	4.9	A simplified approach for the design of infiltration trenches (Campisano et al., 2011).	21	IWA Publishing
7	Agronomy	11 (2.2)	11 (2.2)	76,029	6.2	Effect of bacterial manure on the properties of complex soil and growth of ryegrass (Zhang et al., 2021).	7	Multidisciplinary Digital Publishing Institute (MDPI)
8	Journal of Hydrology	10 (2.0)	10 (2.0)	64,858	11.0	A novel approach to model dynamic flow interactions between the storm sewer system and the overland surface for different land covers in urban areas (Chang et al., 2015).	132	Elsevier
9	Water Resources Research	9 (1.8)	9 (1.8)	21,005	8.8	The role of land use and soils in regulating water flow in small headwater catchments of the Andes (Roa-García et al., 2011)	96	John Wiley & Sons
10	Catena	9 (1.8)	9 (1.8)	34,802	10.5	Influence of soil moisture and plant roots on the soil infiltration capacity at different stages in arid grasslands of China (Liu et al., 2019).	130	Elsevier

*Note.* TP: total publications; TC: total citations.

journal was not listed under the top 10 journal after the screening process for bibliometric analysis in this study, as 99% paper from this journal were written in Chinese, resulting in it being difficult for English readers to comprehend.

### Leading Countries and Top Institutions

The top 15 most productive countries that contribute to the soil infiltration study are shown in Figure 4 and Table 3. China and the USA contributed about 28% of the global publications, indicating their significant role in the progression of soil infiltration studies. With 137 publications from a total of 69 journal, China was the top-ranked country. Whereas the USA ranked second with 102 publications. Although the Chinese Academy of Sciences produced more papers than the USDA Agricultural Research Service, considering that the Chinese Academy of Sciences has 124 branches, and direct comparison might be biased (Khudzari et al., 2018). The dominance of China and the United States in this research may

Table 2  
*Top 10 productive journals on soil infiltration study (cumulatively)*

	<b>Journal</b>	<b>TP (%)</b>	<b>TC</b>	<b>CiteScore 2023</b>	<b>Publisher</b>
1	Nongye Gongcheng Xuebao/ Transactions of the Chinese Society of Agricultural Engineering	85 (3.5)	14,939	4.1	Chinese Society of Agricultural Engineering
2	Science of the Total Environment	82 (3.4)	550,528	17.6	Elsevier
3	Journal of Hydrology	76 (3.1)	64,858	11.0	Elsevier
4	Water Science and Technology	46 (1.9)	9,579	4.9	IWA Publishing
5	Hydrological Processes	47 (1.9)	7,127	6.0	John Wiley & Sons
6	Catena	46 (1.9)	34,802	10.5	Elsevier
7	Water (Switzerland)	42 (1.7)	90,757	5.8	Multidisciplinary Digital Publishing Institute (MDPI)
8	Journal Of Irrigation and Drainage Engineering	35 (1.4)	853	3.2	American Society of Civil Engineers (ASCE)
9	Journal Of Environmental Management	31 (1.3)	158,269	13.7	Elsevier
10	Geoderma	29 (1.2)	24,328	11.8	Elsevier

Note. TP: total publications; TC: total citations



Figure 4. Top 15 most productive countries and academic institutions in soil infiltration publications

Table 3  
 Top 15 most productive academic institutions in soil studies

Rank	Country	TP	The most productive academic institutions
1	China	137	Chinese Academy of Sciences
2	USA	102	USDA Agricultural Research Service
3	Spain	35	Consejo Superior de Investigaciones Científicas
4	UK	29	UK Centre for Ecology & Hydrology
5	Germany	28	helmholtz Zentrum für Umweltforschung
6	Netherlands	23	Wageningen University & Research
7	Italy	22	Wageningen University & Research
8	Australia	21	Commonwealth Scientific and Industrial Research Organisation
9	India	20	King Saud University
10	France	19	INRAE
11	Indonesia	17	Brawijaya University
12	Brazil	16	Universidade de São Paulo
13	Sweden	15	Luleå University of Technology
14	Japan	15	Tohoku University
15	Iran	14	University of Tehran

be associated with their substantial research funding, extensive agricultural environmental research programmes and large scientific communities in soil science and hydrology.

Figure 5 The co-authorship network map reveals twelve clusters, each represented by a different colour. The size of the frame corresponds to the occurrence frequency, and a thicker line represents a strong connection between two countries. Figure 5 represents the global nature of research collaboration on soil infiltration which strong connection seen with the USA, Spain, Brazil and Colombia.

Table 4 shows the leading countries contributing to soil infiltration ranked according to total link strength (TLS). The total number of documents produced, total citations, and TLS average citations per document are taken as the primary data for this study. The USA is identified as the most affiliated country based on co-authorship data, which is linked to 25 countries. The Netherlands followed with 23, the UK (22) and China and Germany with 21 countries each. Although China ranked first in total documents and has a strong connection with other countries with 45 TLS, the average citations are significantly low (17.2). This suggests that China studies may focus on the plateau climate or be written in a non-English language. Differences in citation performance may also be influenced by factors such as journal visibility, international collaboration networks and accessibility of publications. The research that focuses on regional environmental conditions may attract fewer global citations despite its scientific importance.

## Authors

Table 5 lists the 15 most prolific authors in soil infiltration based on authors' contributions to the field for the last 5 years, affiliated to 7 countries as follows: China (6 authors), USA (4 authors), Germany, Hong Kong, France, Australia and Singapore, each with 1 author. The first author's publications between 1987 and 2005, in which 2 authors had a role as the first author, 9 as co-author and 4 as the last author. The affiliation of the authors showed that soil infiltration was within fields related to geotechnical engineering, soil mechanics, environment, and water conservation.

The first prolific author is Rattan A. Lal from the USA, with the first publication in 1970, who currently has 1332 publications, 146 h-index and 95,254 citations. The second and third top authors, Harry Vereecken and Jiri Simunek, are from Germany and the USA, respectively, shared 23 co-authorship documents, and the most cited article was on modelling soil processes (Vereecken et al., 2016). Charles Wang Wei Ng from Hong Kong ranked 4<sup>th</sup> on the list with 79 h-index. Dani Or on 5<sup>th</sup> with 77 h-index also shared 3 co-authorships with Harry Vereecken and Jiri Simunek, where the minimum citations of 45 for an article on Kirkham's Model on soil infiltration (Jury et al., 2011). There are several influential authors who have long academic careers that extend beyond the analysed period. Consequently, their prominence in the dataset sustained as scholarly contributors

rather than being actively limited to the recent publication period. While a co-authorship network provides insights into international collaboration patterns, they do not necessarily distinguish between deep research integration and institutional collaboration related to field data collection or experimental activities.

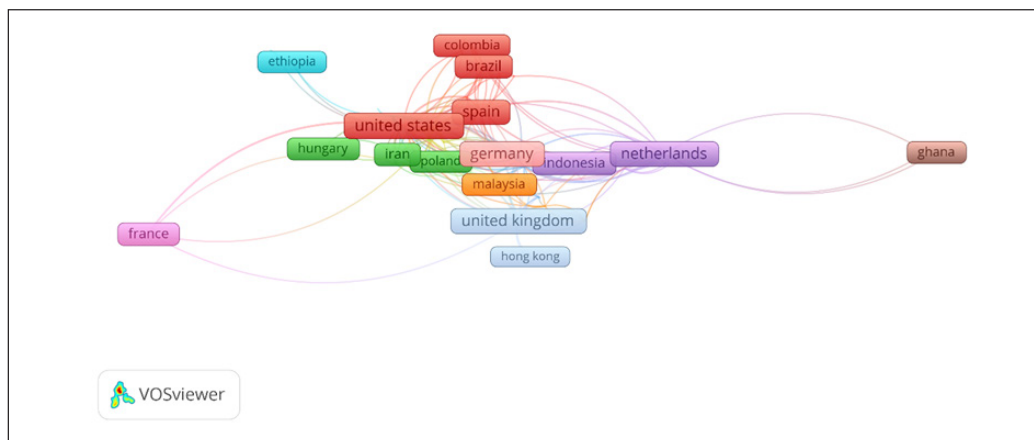


Figure 5. Co-authorship countries contributed to soil infiltration research

Table 4  
Leading 15 countries publishing on soil infiltration

Country	Cluster	TLS	Documents	Citations	Avg. citations
United States	1	60	99	2983	30.1313
China	4	45	136	2340	17.2059
Netherlands	5	39	22	377	17.1364
Germany	10	34	27	1360	50.3704
United Kingdom	12	32	28	1461	52.1786
Spain	1	28	34	801	23.5588
Australia	3	25	20	377	18.85
Italy	1	24	21	325	15.4762
Sweden	3	22	15	181	12.0667
Brazil	1	14	15	110	7.3333
India	6	14	19	455	23.9474
Kenya	5	14	6	111	18.5
Switzerland	7	12	8	181	22.625
France	9	11	17	355	20.8824
Saudi Arabia	4	11	7	78	11.1429

Table 5  
List of 15 most prolific authors in soil infiltration research area

	Author	Scopus ID	Year of first publication *	TP	h-index	TC	Current Affiliation	Country
1	Lal, Rattan A.	55444564800	1970 <sup>c</sup>	1332	146	95254	The Ohio State University, United States	USA
2	Vereecken, Harry	7004082452	1988 <sup>b</sup>	757	83	29065	Forschungszentrum Jülich GmbH, Jülich, Germany	Germany
3	Šimůnek, Jiří	35561493700	1988 <sup>b</sup>	459	83	28101	University of California, Riverside, Riverside, United States	USA
4	Ng, Charles Wang Wai	55454271800	1991 <sup>b</sup>	642	79	23323	Hong Kong University of Science and Technology, Hong Kong	Hong Kong
5	Or, Dani	57204340741	1992 <sup>b</sup>	378	77	22243	College of Engineering, Reno, United States	USA
6	Cui, Yujun	55497053200	1996 <sup>b</sup>	545	70	19654	Laboratoire Navier, Marne-la-Vallée, France	France
7	Xia, Jun	7402327199	1987 <sup>a</sup>	614	63	16169	Wuhan University, Wuhan, China	China
8	Fletcher, Tim D.	56251580300	1994 <sup>b</sup>	220	65	15451	Faculty of Science, Melbourne, Australia	Australia
9	Wang, Kelvin	12240170600	2003 <sup>b</sup>	490	62	15451	Chinese Academy of Sciences, Beijing, China	China
10	Rahardjo, Harianto	7004487503	1983 <sup>c</sup>	313	58	13420	School of Civil and Environmental Engineering, Singapore City, Singapore	Singapore
11	Blanco-Canqui, Humberto	8558145900	2002 <sup>a</sup>	168	52	10993	University of Nebraska-Lincoln, Lincoln, United States	USA
12	Tang, Chao-Sheng	11640513400	2005 <sup>b</sup>	269	50	10880	Nanjing University, Nanjing, China	China
13	Mu, Xingmin	56346174400	1993 <sup>c</sup>	216	51	9274	Institute of Soil and Water Conservation Chinese Academy of Sciences, Yangling, China	China
14	Li, Xiaoyan	35205746400	1998 <sup>b</sup>	291	50	9056	Qinghai Normal University, Xining, China	China
15	Peng, Jianbing	57204721822	2000 <sup>c</sup>	402	48	8980	Chang'an University, Xi'an, China	China

Note. Role in publications, superscripts, <sup>a</sup> First author, <sup>b</sup> Co-author, <sup>c</sup> Last author.

## Keywords

A total of 1614 author keywords were recorded and were used at least once; 239 (14.8%) were used twice, 101 (6.3%) were used thrice, and 31 (2%) were used more than 5 times, which were used for mapping in VOSviewer.

## Keyword Cluster

It has been identified that there are four main theme clusters for soil infiltration, as shown in Figure 6. The first theme is climate change impacts on soil infiltration, with the main keyword being ‘runoff’ (22 occurrences, 22 links). The second theme is urbanization, land use and hydrological response with ‘soil infiltration’ (35 occurrences, 10 links) as their main keyword followed by soil management, conservation and adaption strategies with the main keyword is ‘infiltration’ (41 occurrences, 27 links) and the last theme is modelling and measurement approaches with ‘hydraulic conductivity’ (9 occurrences, 5 links) as its main keyword. For each theme, several other keywords contribute to the theme, as shown in Table 6.

### Theme 1: Climate Change Impacts on Soil Infiltration

In this theme, it highlights a strong linkage between infiltration process and hydrological aspects represented by keywords such as precipitation intensity, temperature, soil moisture and soil erosion. The bibliometric analysis indicates an increasing presence of climate

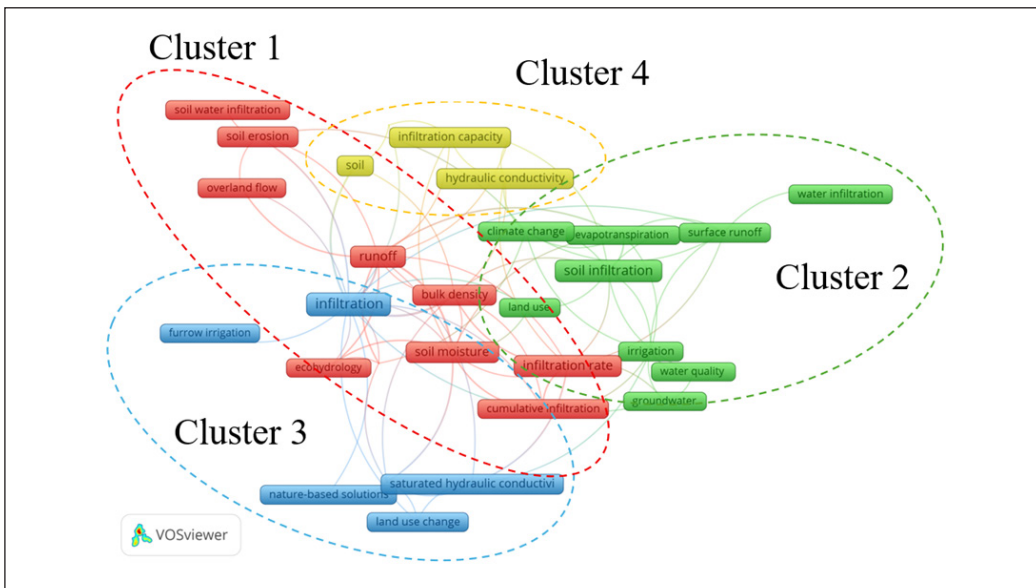


Figure 6. Author keywords co-occurrence with overlay visualisation mode, with a minimum of 5 occurrences

Table 6  
*Keyword cluster and its representative focus area*

Theme cluster	Keywords	Research questions	References
1. Climate change impacts on soil infiltration	Cumulative infiltration Climate change Ecohydrology Infiltration rate Overland flow Rainfall intensity Runoff Soil erosion Soil moisture Soil water infiltration	How does climate change alter soil infiltration patterns, which later leads to groundwater recharge and irrigation efficiency?	(Arredondo et al., 2025; Ebrahim et al., 2019; Si et al., 2023)
2. Urbanisation, land use and hydrological response	Evapotranspiration Groundwater Infiltration models Irrigation Land use Soil infiltration Surface runoff Water infiltration Water quality	To which extend the soil properties and precipitation interact to influence infiltration-soil erosion?	(Hernández-Atencia et al., 2023; Mejía-Veintimilla et al., 2024; Senadi et al., 2025)
3. Soil management, conservation and adaptation strategies	Furrow irrigation Infiltration Land use change Nature-based solutions Saturated hydraulic conductivity Soil infiltration rate	What are the best management strategies to mitigate runoff and erosion?	(Abu-hashim et al., 2023; Lammers et al., 2022; Louis et al., 2024)
4. Modelling and measurement approaches	Hydraulic conductivity Infiltration capacity Soil Soil properties Stormwater	How can infiltration models be improved to predict infiltration-runoff?	(García Martínez et al., 2025; Layth Alrubaye et al., 2020; Sadeghi et al., 2024)

change-related keywords in recent publications, suggesting a growing focus on the interaction between soil infiltration processes and climate change impacts. A study that emphasises the relation between soil physical properties and rainfall characteristics leads to a better understanding of infiltration behaviour, which subsequently affects the overland flow and cumulative infiltration. These processes are crucial in civil engineering to have proper flood risk management, soil conservation and eco-hydrology for water resources management.

## **Theme 2: Urbanisation, Land Use and Hydrological Response**

This cluster assesses the effects of urbanisation and land use change on infiltration capacity. Based on the keywords, it suggests an integrated perspective of infiltration across agricultural, urban and hydrological dynamics. Studies in this cluster apply the infiltration model to evaluate the effects of land use change and irrigation practices on hydrological balance. This knowledge supports strategies for sustainable water management.

## **Theme 3: Soil Management, Conservation and Adaptation Strategies**

The third cluster closely linked the soil properties and their influence on stormwater control. With keywords such as hydraulic conductivity, infiltration rate and furrow irrigation, this highlights the role of soil infiltration in urban drainage and sustainable stormwater management systems. By understanding the soil characteristics, ensure the long-term functionality and effectiveness of stormwater infiltration practices in the design of infiltration trenches, permeable pavements and green infrastructure for civil engineering practices.

## **Theme 4: Modelling and Measurement Approaches**

The last cluster centres on the advancement of developing and comparing infiltration and runoff models, SWMM, HEC-RAS, and HYDRUS to improve predictions of hydrological responses to climate change and land use changes. In this cluster, an integration of remote sensing, big data and machine learning to monitor and predict the soil hydrological processes has also been developed, as proven by the presence of the “remote sensing” and “machine learning” keywords in this cluster generated in VOSviewer. Although it is not as prominent as the top 5 keywords listed.

## **Topics of Interest**

Soil water infiltration is a crucial element in the hydrological cycle, primarily in the rate of water absorption into the soil. This study is important not only to the hydrologists and irrigation engineers but also to the soil scientists. This field of study helps in determining the soil moisture levels, the dynamics of surface runoff behaviour also related to the sediment transport. Studies such as determination of the optimal empirical infiltration rate model (Jejurkar & Rajurkar, 2015; Rasool et al., 2021; Salahou et al., 2020), relationship between rainfall-runoff and soil infiltration (Chen et al., 2025; Hu et al., 2021), development of irrigation system (Zhang & Flerchinger, 2001) and groundwater (Cui et al., 2019; Tedoldi et al., 2016; Xu et al., 2025) are common among researchers. Water resources problems are increasing day by day, and research trend phase change where studies on climate change linked to land use and ecohydrology in conjunction with the United Nations Agenda

2030 for Goal 6 (Clean water and sanitation) and Goal 13 (Climate action). With that, soil infiltration studies are now more extensive, encompassing sustainability with the aid of an Artificial Intelligence (AI) technique. It is undeniable that this field is a dynamic study between soil and water, and employing AI tools can effectively demonstrate the soil physical properties as well as infiltration process, such as (Mehta et al., 2024; Sihag et al., 2020; Singh et al., 2017; Singh et al., 2021).

### **Limitation of Study**

The result of the search may not cover all studies related to soil infiltration available on Scopus, as the search is restricted to “soil infiltration\*” in titles and abstracts. Some publications with a lag publication process may also not be mentioned in this article. For future work, it is proposed that extensive studies be performed by using several databases, such as Scopus and Web of Science, to reduce the potential level of selection bias. Although, Zeng et al. (2023) mentioned that integration of multiple databases for bibliometric analysis is tedious work. Moreover, this study is limited to English-language articles and 30% of the eliminated articles were written in the Chinese language. As this study only considered English language publications, it may exclude relevant research conducted in non-English language regions. As a result, the global representation of soil infiltration research may be partially limited. This bibliometric analysis was conducted on 16<sup>th</sup> January 2025, and it is expected that the number of publications on soil infiltration will keep increasing in the days to come. Citation counts may also be influenced by the year of publication, as recently published open-access articles may not yet have accumulated their full citation potential. Therefore, citation comparison between open access and non-open access should be interpreted with caution. An alternative to journal metrics other than CiteScore values, such as Field-Weighted Citation Impact and journal percentile rankings, could also provide additional perspective for evaluating journal impacts.

### **CONCLUSION**

This study offers a comprehensive bibliometric analysis and visualisation of the soil infiltration study domain. For the last 24 years, the growth of publications has been strong, and it is anticipated to continue to rise. Relevant literature review on the topic from 2000 to 2025 in the Scopus database employing VOSviewer software. This bibliometric analysis study not only covered countries, institutions, journals, authors, references, keywords and research trends. The most prominent research topics in the field of soil infiltration were found to be: (1) soil erosion, (2) urban storm water infiltration, and (3) irrigation systems. The findings of this study offer an overview of soil infiltration for researchers before proceeding, and to some extent help to identify research gaps.

The growth in publication output shows global recognition of infiltration as a critical process in sustainable land and water management. Thus, the research analysis for soil infiltration is becoming a fundamental discipline, integrating aspects of hydrology, agricultural, environmental engineering, and climate change adaptation. The integration of advanced technologies such as remote sensing, machine learning and field-based monitoring systems should be emphasised for future research collaboration among developed countries, which may enhance the accuracy of hydrological modelling in future research. The need to explore the implications of climate variability and land use change on infiltration capacity should also be encouraging in this field.

By identifying emerging trends, influential contributors and potential research gaps, the soil infiltration study potentially contributes to shaping the future research innovation in achieving sustainable soil and water resource management. The bibliometric analysis manages to provide a valuable reference for researchers, practitioners and policymakers to explore innovation strategies in soil infiltration management.

## ACKNOWLEDGEMENT

This research was supported by Universiti Tun Hussein Onn Malaysia (UTHM) through Tier 1 (vot Q978).

## REFERENCES

- Abu-Hashim, M., Lilienthal, H., Schnug, E., Lasaponara, R., & Mohamed, E. S. (2023). Can a change in agriculture management practice improve soil physical properties? *Sustainability*, *15*(4), Article 3573. <https://doi.org/10.3390/su15043573>
- Arredondo, A. M., Mirzaei, M., Wu, G. L., Keshavarzi, A., Durán-Zuazo, V. H., Bernardo, F. S., & Rodrigo-Comino, J. (2025). Evaluating soil respiration and water infiltration in esparto grasslands: The effects of hillslope position and soil management in arid, human-affected Mediterranean environments. *Discover Sustainability*, *6*(1), 1-15. <https://doi.org/10.1007/s43621-025-01282-x>
- Basche, A. D., & DeLonge, M. S. (2019). Comparing infiltration rates in soils managed with conventional and alternative farming methods: A meta-analysis. *PLOS ONE*, *14*(9), Article e0215702. <https://doi.org/10.1371/journal.pone.0215702>
- Campisano, A., Creaco, E., & Modica, C. (2011). A simplified approach for the design of infiltration trenches. *Water Science and Technology*, *64*(6), 1362-1367. <https://doi.org/10.2166/wst.2011.170>
- Chang, T.-J., Wang, C.-H., & Chen, A. S. (2015). A novel approach to model dynamic flow interactions between storm sewer system and overland surface for different land covers in urban areas. *Journal of Hydrology*, *524*, 662-679. <https://doi.org/10.1016/j.jhydrol.2015.03.014>
- Chen, C., Li, B., Xiao, Y., Li, H., & Zhang, T. (2025). Hydrological and hydrodynamic coupling simulation under composite underlying surfaces in urban polder areas. *Journal of Hydrology: Regional Studies*, *57*, Article 102154. <https://doi.org/10.1016/j.ejrh.2024.102154>

- Cui, Z., Wu, G., Huang, Z., & Liu, Y. (2019). Fine roots determine soil infiltration potential more than soil water content in semi-arid grassland soils. *Journal of Hydrology*, 578, Article 124023. <https://doi.org/10.1016/j.jhydrol.2019.124023>
- Donohue, C. (1972). A bibliometric analysis of certain information science literature. *Journal of the American Society for Information Science*, 23(5), 313-317. <https://doi.org/10.1002/asi.4630230506>
- Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Marc, W. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, 133, 285-296. <https://doi.org/10.1016/j.jbusres.2021.04.070>
- Ebrahim, M. N., Che Man, H., Mohamed Zawawi, M. A., & Hamzah, M. H. (2019). Prediction of groundwater contaminants from cattle farm using Visual MODFLOW. *Pertanika Journal of Science and Technology*, 27(4), 2265-2279.
- García Martínez, M., Osornio Berthet, L. J., Meléndez Estrada, J., & Cruz Castro, O. (2025). Identification of flood-prone areas using the HEC-RAS 2D model in a region of the Valley of Mexico. *Chemosphere*, 386, Article 144609. <https://doi.org/10.1016/j.chemosphere.2025.144609>
- Hernández-Atencia, Y., Peña, L. E., Muñoz-Ramos, J., Rojas, I., & Álvarez, A. (2023). Use of soil infiltration capacity and stream flow velocity to estimate physical flood vulnerability under land-use change scenarios. *Water*, 15(6), Article 1214. <https://doi.org/10.3390/w15061214>
- Hu, C., Xia, J., She, D., Song, Z., Zhang, Y., & Hong, S. (2021). A new urban hydrological model considering various land covers for flood simulation. *Journal of Hydrology*, 603, Article 126833. <https://doi.org/10.1016/j.jhydrol.2021.126833>
- Jejurkar, C. L., & Rajurkar, M. P. (2015). An investigational approach for the modelling of infiltration process in a clay soil. *KSCE Journal of Civil Engineering*, 19(6), 1916-1921. <https://doi.org/10.1007/s12205-014-0149-3>
- Jury, W. A., Or, D., Pachepsky, Y., Vereecken, H., Van Genuchten, M. T., & Horton, R. (2011). Kirkham's legacy and contemporary challenges in soil physics research. *Soil Science Society of America Journal*, 75(5), 1589-1601. <https://doi.org/10.2136/sssaj2011.0115>
- Khudzari, J., Kurian, J., Tartakovsky, B., & Raghavan, G. S. V. (2018). Bibliometric analysis of global research trends on microbial fuel cells using Scopus database. *Biochemical Engineering Journal*, 136, 51-60. <https://doi.org/10.1016/j.bej.2018.05.002>
- Lammers, R. W., Miller, L., Bledsoe, B. P., & ASCE, M. (2022). Effects of design and climate on bioretention effectiveness for watershed-scale hydrologic benefits. *Journal of Sustainable Water in the Built Environment*. <https://doi.org/10.1061/JSWBAY.0000993>
- Layth Alrubaye, Y., Yusuf, B., & Hamad, S. N. (2020). Development of a self-regulated bubble irrigation system to control the size and shape of wetting fronts. *Pertanika Journal of Science & Technology*, 28(4), 1297-1313. <https://doi.org/10.47836/pjst.28.4.09>
- Liu, Y., Cui, Z., Huang, Z., López-Vicente, M., & Wu, G.-L. (2019). Influence of soil moisture and plant roots on the soil infiltration capacity at different stages in arid grasslands of China. *Catena*, 182, Article 104147. <https://doi.org/10.1016/j.catena.2019.104147>

- Liu, Z., Lu, Y., Wang, P., Wang, T., Liu, S., Johnson, A. C., Sweetman, A. J., & Baninla, Y. (2017). Pollution pathways and release estimation of perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) in central and eastern China. *Science of the Total Environment*, 580, 1247-1256. <https://doi.org/10.1016/j.scitotenv.2016.12.085>
- Louis, P., Delgado-Gonzalez, L., Lassabatère, L., Czarnes, S., Aubert, J., Imig, A., & Clément, R. (2024). Woodchip-filled trenches: A solution to enhance urban water infiltration capacity? *Geoderma*, 451, Article 117057. <https://doi.org/10.1016/j.geoderma.2024.117057>
- Mehta, V., Hasanvand, S., Sepahvand, A., Sihag, P., & Beiranvand, N. (2024). A benchmark comparison of AI-based modelling of soil infiltration rates. *Journal of Hydroinformatics*, 26(12), 3060-3079. <https://doi.org/10.2166/hydro.2024.086>
- Mejía-Ventimilla, D., Ochoa-Cueva, P., & Arteaga-Marín, J. (2024). Evaluation of the hydrological response to land use change scenarios in urban and non-urban mountain basins in Ecuador. *Land*, 13(11), Article 1907. <https://doi.org/10.3390/land13111907>
- Mu, W., Yu, F., Li, C., Xie, Y., Tian, J., Liu, J., & Zhao, N. (2015). Effects of rainfall intensity and slope gradient on runoff and soil moisture content on different growing stages of spring maize. *Water*, 7(6), 2990-3008. <https://doi.org/10.3390/w7062990>
- Rasool, T., Qayoom, D. A., & Wani, M. (2021). Comparative evaluation of infiltration models under different land covers: Comparison of infiltration model parameter estimation techniques under different land use/land covers. *International Journal of Hydrology Science and Technology*, 12(4), 448-476. <https://doi.org/10.1134/S0097807821040175>
- Sadeghi, M., Shayannejad, M., Sadraddini, A. A., & Salehi, S. (2024). Estimation of soil infiltration coefficient in furrow irrigation using the combination of the hydrodynamics model and Richard's equation. *Physics and Chemistry of the Earth, Parts A/B/C*, 135, Article 103649. <https://doi.org/10.1016/j.pce.2024.103649>
- Salahou, M. K., Jiao, X. Y., & Lu, H. S. (2020). Assessment of empirical and semi-empirical models for estimating a soil infiltration function. *Transactions of the ASABE*, 63(4), 833-845. <https://doi.org/10.13031/trans.13639>
- Senadi, I., Zeroual, A., & Meddi, H. (2025). From urban sprawl to aquifer strain: The hydrological consequences of land use/land cover changes in the Mitidja plain, Algeria. *Physics and Chemistry of the Earth, Parts A/B/C*, Article 103951. <https://doi.org/10.1016/j.pce.2025.103951>
- Si, J., Li, J., Lu, S., Qi, X., Zhang, X., Bao, W., Zhang, X., Zhou, S., Jin, C., Qi, L., Qi, Y., Zheng, X., Gong, Y., & Wang, Z. (2023). Effects of climate change on surface runoff and soil moisture in the source region of the Yellow River. *Water*, 15(11), Article 2104. <https://doi.org/10.3390/w15112104>
- Sihag, P., Kumar, M., & Singh, B. (2020). Assessment of infiltration models developed using soft computing techniques. *Geology, Ecology, and Landscapes*, 5(4), 241-251. <https://doi.org/10.1080/24749508.2020.1720475>
- Singh, B., Ebtehaj, I., Sihag, P., & Bonakdari, H. (2021). An expert system for predicting infiltration characteristics. *Water Science and Technology: Water Supply*, 22(3), 2847-2862. <https://doi.org/10.2166/ws.2021.430>

- Singh, B., Sihag, P., & Singh, K. (2017). Modelling of the impact of water quality on the infiltration rate of soil by random forest regression. *Modelling Earth Systems and Environment*, 3(3), 999-1004. <https://doi.org/10.1007/s40808-017-0347-3>
- Sittisom, P., Tangsongsuwan, R., Munlikawong, S., Wongsapai, W., Sitthikankun, S., & Rinchumphu, D. (2022). The determination of soil infiltration rate of urban bioretention design process in Chiang Mai, Thailand. *Nakhara Journal of Environmental Design and Planning*, 21(3), Article 228. <https://doi.org/10.54028/NJ202221228>
- Skougaard Kaspersen, P., Høegh Ravn, N., Arnbjerg-Nielsen, K., Madsen, H., & Drews, M. (2017). Comparison of the impacts of urban development and climate change on exposing European cities to pluvial flooding. *Hydrology and Earth System Sciences*, 21(8), 4131-4147. <https://doi.org/10.5194/hess-21-4131-2017>
- Tedoldi, D., Chebbo, G., Pierlot, D., Kovacs, Y., & Gromaire, M. (2016). Impact of runoff infiltration on contaminant accumulation and transport in the soil/filter media of sustainable urban drainage systems: A literature review. *Science of the Total Environment*, 569-570, 904-926. <https://doi.org/10.1016/j.scitotenv.2016.04.215>
- Van Eck, N., Waltman, L., Berg, J. D., & Kaymak, U. (2006). Visualising the computational intelligence field. *IEEE Computational Intelligence Magazine*, 1(4), 6-10. <https://doi.org/10.1109/CI-M.2006.248043>
- Vereecken, H., Schnepf, A., Hopmans, J., Javaux, M., Or, D., Roose, T., Vanderborght, J., Young, M., Amelung, W., Aitkenhead, M., Allison, S., Assouline, S., Baveye, P., Berli, M., Brüggemann, N., Finke, P., Flury, M., Gaiser, T., Govers, G., ... Young, I. (2016). Modeling soil processes: Review, key challenges, and new perspectives. *Vadose Zone Journal*, 15(5), 1-57. <https://doi.org/10.2136/vzj2015.09.0131>
- Xu, Y., Luo, L., Guo, W., Chen, Z., Tian, P., & Wang, W. (2025). Vegetation roots-induced changes of loess infiltration: Greatly promoting lateral flow. *Catena*, 250, Article 108803. <https://doi.org/10.1016/j.catena.2025.108803>
- Yang, F., Cen, R., Feng, W., Liu, J., Qu, Z., & Miao, Q. (2020). Effects of super-absorbent polymer on soil remediation and crop growth in arid and semi-arid areas. *Sustainability*, 12(18), Article 7825. <https://doi.org/10.3390/su12187825>
- Zeng, Y., Cao, S., & Yang, H. (2023). Globalresearch trends on COVID-19 and stroke: A bibliometric analysis. *Frontiers in Neurology*, 14, Article 1147867. <https://doi.org/10.3389/fneur.2023.1147867>
- Zhang, N., Yan, J., & Liu, P. (2021). Effect of bacterial manure on the properties of complex soil and growth of ryegrass. *Agronomy*, 11(3), Article 568. <https://doi.org/10.3390/agronomy11030568>
- Zhang, X., & Flerchinger, G. N. (2001). Infiltration into freezing and thawing soils under differing field treatments. *Journal of Irrigation and Drainage Engineering*, 127(3), 176-182. [https://doi.org/10.1061/\(ASCE\)0733-9437\(2001\)127:3\(176\)](https://doi.org/10.1061/(ASCE)0733-9437(2001)127:3(176))