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Effects of land use and land cover on Soil-Water Infiltration: A Literature Review and Bibliometric Analysis

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A B S T R A C T

The impact of land use and land cover (LULC) on hydrology is gaining increased attention due to global concerns about water sustainability. Although various studies have been conducted related to the topic, there were only a few publications that specifically focused on the effects of LULC on soil-water infiltration. This study gathered and synthesized relevant research publications and performed co-occurrence and co-citation analyses to identify the existing themes and the research development trend on LULC-soil infiltration relation. Analysis of 103 Scopus-indexed articles from as early as 2000 revealed four major themes: soil characteristics, hydrology and watershed, hydrology and management, and groundwater and LULC. These findings highlight key areas of focus and can assist in identifying research gaps and topics requiring further exploration. The paper offers a concise overview of the current research trajectory in the realm of LULC and soul water infiltration.

Keywords: *Ecosystem services, Land use planning, VOSviewer*

1 Introduction

Soil-water infiltration is a crucial process in the hydrologic cycle (Pahlavan-Rad et al. 2020, Xiao et al. 2019, Ghorbani-Dastaki et al. 2016, Neris et al. 2012). It is the process wherein the water on the ground surface enters the soil (Liu et al. 2018, Tashayo et al. 2020). It is also vital in groundwater recharge and influences potential topsoil loss by erosion and runoff (Zomlot et al. 2017). Throughout the years, soil infiltration and other hydrologic processes have been affected by changes in the environmental conditions of watersheds. LULC, as well as climate change, especially in watersheds, are considered the foremost drivers of changes in the hydrologic processes (Anand et al. 2018, de Almeida et al. 2018, Nyutuame et al. 2020). The rapid changes in land use, along with climate change, can significantly influence hydrologic processes (Shawul et al. 2019), which include soil-water infiltration. Land use affects surface runoff as it alters interception, infiltration, and evapotranspiration (Han et al. 2011).

As emphasized by Daneshi et al. (2021), changes in LULC are mainly anthropogenic. They are characterized by the removal or alteration of vegetation along with changes in land use practices (Anand et al. 2018). Human decisions such as land allocation for urbanization, agriculture intensification, or deforestation influence LULC (Liu et al. 2018), and consequently on the infiltration process. Understanding the dynamics between LULC and the infiltration process is important in improving policy and public decision-making process. In particular, it involves having a better understanding of its spatial variabilities and accurate estimations that could support efforts toward water conservation and agricultural management (Pahlavan-Rad et al. 2020, Tashayo

et al. 2020). It also leads to optimizing natural resource management (Zomlot et al. 2017).

With the importance of understanding the effects of LULC, it is imperative to understand the current research landscape on this topic. Conducting a systematic and unbiased collection of existing publications establishes a benchmark as to how the research community has progressed in the context of the effects of LULC on soil-water infiltration. Thus, this paper aims to gather and synthesize relevant articles primarily dealing with the quantification of the effects of LULC change on soil-water infiltration. Using bibliometric analysis, the study also assesses the trends in scientific outputs that deal with the relationship between LULC and soil-water infiltration.

2 Materials and Methods

Selection of studies

To identify relevant research, a search was made in the Scopus database for open-access journal articles expressed in English and published not earlier than the year 2000. The Scopus database was used as it is the largest collection of peer-reviewed journals (Leong 2021). It provides uniform records and resources that can be used conveniently for citation analysis (Singh et al. 2021). This database has also been used in various bibliometric research as it is considered to be the largest repository of peer-reviewed research and literature citations (Piwowar-Sulej et al. 2021). The search includes keywords from titles, abstracts, and keywords.

The queries with keywords and Boolean operators used were as follows:

"land use" AND "infiltration"

"land use change" AND "infiltration"

"LUC" and "infiltration"

"LULC" and "infiltration"

After gathering all the results using the Scopus database search engine, they were manually screened based on duplicity, titles, and abstracts. Figure 1 shows the summary of the screening process, while Table 1 shows the detailed results of the search.

Bibliometric analysis

Bibliometric analysis is an analytical method that is designed to assess the status and map out the development trends of a particular research topic (Biswas et al. 2021, Mas-Tur et al. 2021). Among its uses include systematic identification, organization, and analysis of research topics (Zeng et al. 2021). This technique establishes a structure of a field without subjective biases. It is a cross-disciplinary procedure that allows effective mapping of directions and themes in the process of development of a particular research field (Tandon et al. 2021, Kim et al. 2021). Bibliometrics also classifies and provides a quick overview of bibliometric documents (Robertson et al. 2020). Since the trends are set, this gives decision-makers as well as researchers a better analysis for a comprehensive understanding of the development of the topics of concern.

In performing the bibliometric analysis, VOSviewer was used. This tool produces cluster-based maps that enable easy classification of the research outputs and is commonly used to visualize

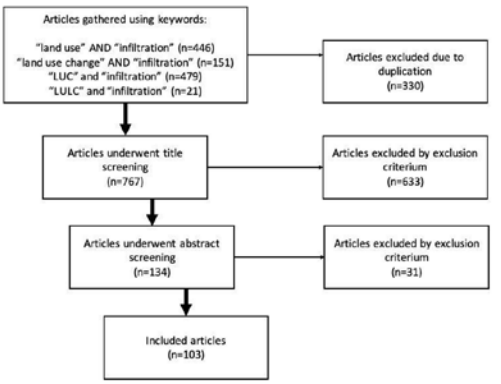

Figure 1. Summary of the selection process (modified and adapted from Piwowar-Sulej et al. 2021)

Table 1. Search criteria results.

Keywords used	Database	Document Type	Results
"land use" AND "infiltration"	Scopus	Article (open access)	446
"land use change" AND "infiltration"			151
"LUC" and "infiltration"			479
"LULC" and "infiltration"			21

and analyze bibliometric networks (Di Ciacco and Troisi 2021, Hamidah et al. 2021). Furthermore, it is an open-source software that provides features to map the literature networks (Singh et al. 2021). In this study, bibliometric analysis was used to measure the co-occurrence and co-citation.

Co-occurrence. This measures the frequency where keywords co-occur which enables the visualization of the main content of research publications (Tandon et al. 2021). It counts the number of appearances of a group of words in literature and becomes the measure of the affinity between two papers (Zhang et al. 2021). This also provides an overview of the trend or potential trends of the focused research area. The analysis was based on keywords used in the literature search.

Co-citation. This is the frequency of texts or words cited together. This occurs when at least two journal articles cite the same journal article (Chang et al. 2021). The higher number of co-citations translates to higher similarity and more positive correlation between and among different journal articles. (Zhang et al. 2021). The unit of analysis used is the cited references.

3 Results and Discussion

Descriptive statistics

The results show that the research published in Scopus-indexed journals focusing on the relationship between LULC and infiltration has increased over the years. Figure 2 shows the distribution of journal articles published from 2000 to 2021. It shows that only a few journal articles were published on the effects of LULC on soil-water infiltration. Although there were 18 journal articles published in 2018, the rest of the years had less than 10 journal articles (Figure 2). This further underscores the limited published work on the topic, particularly within the journals cataloged in the Scopus database.

Table 2 shows the top 10 countries with the most citations. Although China had more related publications than the USA (i.e., a difference of 3 publications), the USA had a greater number of citations than China (Table 2). The USA leads with 789 citations. It was followed by China with only 327 citations. This indicates that even with the higher number of China-based publications on the topic, more researchers cited the papers published in the USA.

Among the journals that published papers about the effects of LULC on infiltration from 2000 to 2021, the Journal of Hydrology has the most number that was found in the Scopus database, with a total of seven publications. It is followed by Water (Switzerland) and Land Degradation and Development. Figure 3 shows the rest of the top 3 journals with the most publications regarding LULC and infiltration.

Keyword co-occurrence and research thematic areas

Figure 4 provides an overview of the co-occurrence between and among the different papers about the keywords associated with the topics on the effects of LULC on soil-water infiltration. The blue line or connection between nodes denotes a more recent co-occurrence of the keywords used by authors (Figure 4). The smaller blue nodes indicate that the focus on this research domain is now branching out and is now developing new

Table 2. Top countries with the most citations on LULC and infiltration, 2000-2021

Keywords used	Number of Citations	Number of Publications
United States of America (USA)	789	20
China	327	23
Netherlands	260	3
Germany	208	7
Australia	157	7
Spain	145	4
Brazil	123	14
Iran	93	3
Switzerland	91	3
France	80	3

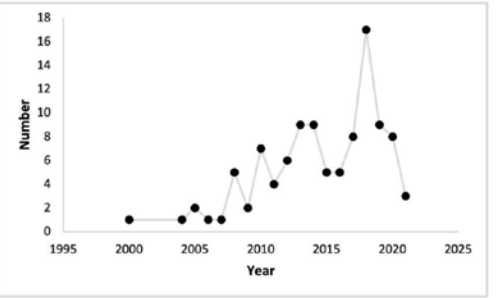

Figure 2. Number of yearly publications, 2000-2021

relevant subtopics. For instance, from research areas on LULC and infiltration, new research projects are shifting their focus to other research areas such as ecosystems and groundwater.

Although 'land use' and 'infiltration' are the two most used keywords among the publications gathered, the timeline shows that both terms were most commonly used for papers published around 2014. Figure 4 shows that the research related to land use and infiltration during the earlier years was more on physical sciences. Furthermore, the recent trend of the relevant studies is now incorporating ecosystems and their dynamics with infiltration (Figure 4). This demonstrates how the themes and specific topics have evolved from soil science to a more holistic approach that captures the role that the ecosystems and human system take in the process of soil-water infiltration and hydrology in general.

The different keywords were clustered together through the assistance of VOSviewer. These clusters form 4 research themes, which are (1) soil and its characteristics, (2) hydrology and watershed dynamics, (3) LULC and methods, and (4) groundwater and LULC. Each of these thematic

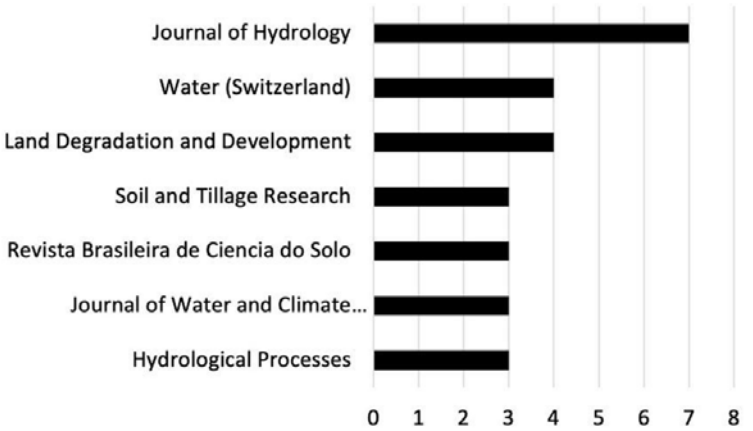

Figure 3. Top 3 journals with most published articles on LULC and infiltration, 2000-2021

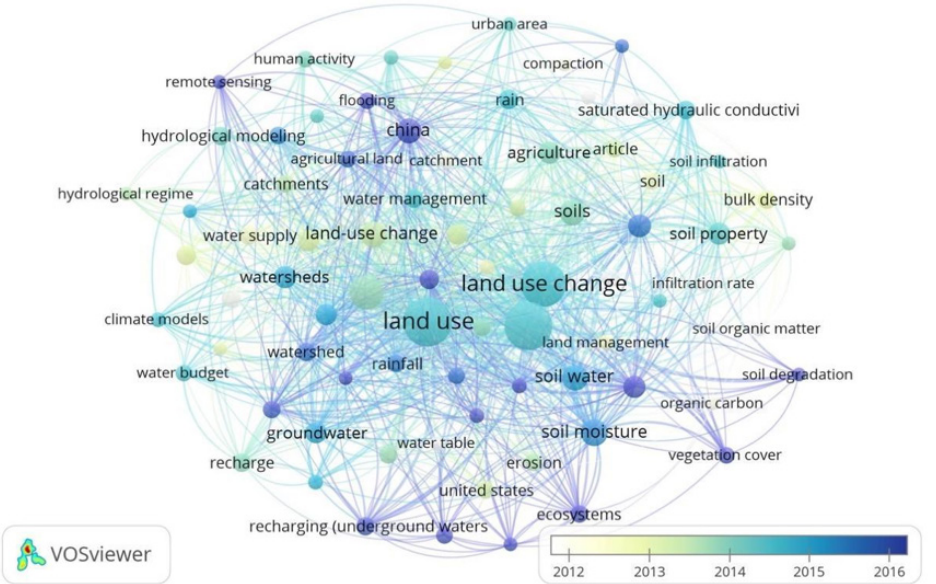

Figure 4. The most commonly occurring keywords on the effects of LULC on soil-water infiltration

areas covers a varying number of keywords. It is also important to note that these thematic areas are interconnected and interrelated. This further explains how different keywords may fall under different thematic areas.

Soil and its characteristics. This theme covers 39 keywords associated with the effects of LULC on soil-water infiltration. Soil-specific terms like bulk density, erosion, seepage, porosity, soil degradation, and soil property were among the keywords, which are under this theme. This theme illustrates the physical, chemical, and hydrological characteristics of soil. This highlights focused research in understanding, classifying, and managing soils, with potential applications in environmental science, agriculture, and resource management.

Hydrology and watershed dynamics. A total of 35 keywords fall under this theme. Their prominence in the co-occurrence analysis signifies a robust scholarly interest in understanding the relationships between hydrological processes and the dynamics of the watershed ecosystem. This may also imply a recognition of the crucial role that watershed plays in addressing water-related challenges and environmental conservation. This also suggests potential collaboration and knowledge exchange between experts on hydrology and watershed dynamics. This information is relevant for stakeholders to gain insights into the current trends, gaps, and collaborative networks within this area of interest.

LULC and methods. This emergence as a theme suggests a notable concentration of research initiatives in the interdisciplinary field that includes the study of land use, land cover, and their associated methodologies. This also means that there is a strong focus on understanding the developments in land use, including the methodologies used to analyze and assess these changes.

Groundwater and LULC. This thematic focus indicates research focus on the dynamic relationship between groundwater dynamics and the patterns of LULC. This suggests a keen interest in learning more about how LULC affects groundwater dynamics, especially as urbanization, agricultural practices, and other land-related activities influence groundwater resources. Furthermore, the theme implies a potential emphasis on water resource management, as groundwater is a crucial component of the hydrologic cycle.

Co-citation among related research papers

As earlier discussed, co-citation is a bibliometric method that highlights the connection between research articles based on their citations in other publications. In the context of understanding the effects of LULC on soil-water infiltration, the result shows that there is a strong conceptual relationship between two or more cited journal articles. This relationship and connections between and among these journal articles are illustrated in Figure 5. It highlights the greatest number of co-cited journal articles on the topic (i.e., effects of LULC on soil-water infiltration). The size of the individual nodes illustrates the weighted co-citation of each journal article. It provides a quantitative measure of the potential contribution of these journal articles to academic discourse.

Among the cited journal articles, the most notable was the study of Neris et al. (2012) titled 'Vegetation and land use effects on soil properties and water infiltration of andosols in Tenerife (Canary Islands, Spain)'. With a total of 7 citations, this journal article recorded the highest weight making it the central node in Figure 5. This could further indicate that this journal article was recognized by different scholars, who are researching the topic. By understanding these co-citation networks and relationships, scholars could have insights into the current research landscape through an identification of key studies and their relationship.

Understanding the current research landscape

The different studies covered in the bibliometric analysis offer insights into the scholarship on the effects of land use change on water infiltration. In particular, these insights focus on (1) methods in measuring the infiltration, and (2) effects of land use change or various uses on the soil-water infiltration. It is also interesting to note that these studies are grounded in different biophysical conditions such as temperature, soil type, vegetation type, and elevation.

Approaches. The collection of journal articles presents the different available approaches, which could be used to understand the effects of LULC on soil-water infiltration. These approaches include actual measurements of the water infiltration under different soil cover types (de Almeida 2018, Liu et al. 2018, Neris et al. 2012). Measurements were done either in situ (Liu et al. 2018, Neris et

al. 2012) or using controlled plots (de Almeida 2018). The in-site sampling procedure involves identifying sampling plots within the study site with varied land uses such as forest areas, agricultural areas, and built-up areas (Liu et al. 2018, Neris et al. 2012). On the other hand, de Almeida (2018) implemented an experimental design using plots with different "soil covers and management". Among the measurement techniques mentioned in these studies was the use of the double-ring method.

In some studies, the infiltration was indirectly measured through groundwater recharge. For instance, a study used a drought severity index to understand the effects of vegetation restoration (see Han et al. 2020). This drought severity index was based on anomalies in groundwater storage. The increase in groundwater in the area was attributed to the increase in afforested areas. The study corroborates other studies where afforestation has a positive effect on soil and water conservation. It includes an increase in the infiltration rate.

Findings. All of the studies covered in the bibliometric analysis led to one direction – LULC has an influence on soil-water infiltration. These studies offer explanations on how changes in LULC influence the infiltration process (Lie et al. 2018). Sun et al. (2018) highlights that changes in LULC alter properties of soil, which consequently affect the infiltration rate. For instance, a decrease in infiltration rate could be observed as agricultural and forested areas are converted into urbanized [or built-up areas] areas (Bawa and Dwivedi 2019). The decrease in infiltration rate was attributed to the increase in more resistant impervious surfaces. Wu et al. (2015) reported the same observation, and how the phenomenon affects both the quality and quantity of surface water. The increasing urban areas have also increased impervious areas significantly decreasing the volume of the water that could have infiltrated the soil (Anand et al. 2018). This affects the hydrologic processes that lead to various phenomena, like reduction of groundwater recharge and lowering of water level (Nath et al. 2021).

This further highlights that vegetation cover could result in the improvement of soil-water infiltration. Unfolding the interaction of vegetation and water balance at the surface level also leads to a better understanding of soil-water infiltration (Canora et al. 2008). To cite an example, areas covered with grass protect the soil from erosion and help in the infiltration process (Yenehun et al. 2017). Recent climate-soil-vegetation research showed that vegetated soils can keep more infiltrating rainfall compared to bare soils (Zhang and Schilling 2006). As indicated in various studies, vegetation and the physical properties of soil, which includes the presence of organic matter, are the main factors that dictate the infiltration capacity (Sun et al. 2018).

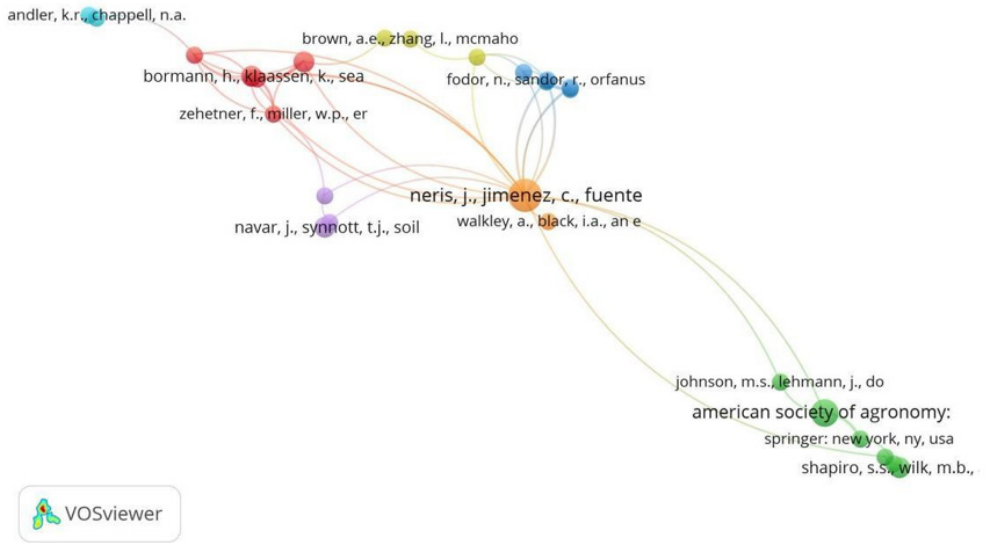

Figure 5. Co-citation of articles on the effects of LULC on soil-water infiltration

Considering the effects of vegetation, Neris et al. (2012) found that infiltration is higher in forested areas than in agricultural or crop areas. This could be attributed to the changes in the different soil characteristics such as structural stability (Neris et al. 2012). According to Ding et al. (2019), the structure and stability of soil aggregates highly dictate soil-water infiltrability. The soil-water infiltration rate strongly demonstrated Der jaguin-Landau-Verwy-Overbeek (DLVO) theories and depended on hydration forces between particles of soil (Ding et al. 2019). There were observed strong specific ion effects in soil-water infiltrability for Li+, Na+, K+, and Cs+, thus influencing both DLVO and hydration forces wherein Hofmeister energies of cations come into play at the soil and water interface.

Soil management methods were also found to affect the infiltration rate (de Almeida 2018, Liu, et al. 2018). Finally, in the case of seasonally frozen areas such as in the Qinghai-Tibet plateau, the deep soil-water infiltration is primarily dependent on volumetric soil moisture—which also explains the result of 80.05% in terms of seasonal variability (Dai et al. 2019). Rainfall was seen to have a weak impact, most of which already returns to the atmosphere through evapotranspiration even before the water starts to infiltrate.

4 Conclusion and Recommendations

The paper presented a critical issue that is proven to be relevant across different countries within various regions across the globe. It poses important questions related to environment and land use planning at different scales and levels (municipal, provincial, regional, and national). However, it is important to note that this paper has its limitations as bibliometric research. First, the paper was designed only to focus on the studies collated through Science Direct. The next limitation is regarding the use of the English language as a main filter. As explained by Gao et al. (2019), the use of this filter exhibits "language bias" in the selection of the journal articles. As with the first limitation, this may likewise result in missing other journal articles on the topic when they are not written in English.

This study attempts to provide a collection of papers that focus on the effect of LULC on soil-water infiltration. The results of this paper can establish a wider and consolidated picture of the research on LULC and soil-water infiltration. The findings using bibliometric analysis will enable researchers to understand further the multi-disciplinarity of this research interest and discover what other themes and topics have been studied alongside LULC and soil-water infiltration. The collection of the gist of other related research in this paper can also uncover gaps that can become the focus of future research.

The selection of papers has presented evidence that LULC could affect soil-water infiltration. It is worth noting though that the tillage done has more influence on soil-water infiltration compared to the vegetation type. It was revealed that the themes of the research papers revolving around LULC and soil-water infiltration are: (1) soil and water characteristics, (2) hydrology and watershed dynamics, (3) LULC and methods, and (4) groundwater and LULC. These results show that the trend of research relevant to the topic of interest is geared towards ecosystems and human systems, their dynamics, and how they affect soil-water infiltration.

Although this paper has limitations, it provides valuable insights into current research on how LULC affects soil-water infiltration. Understanding their research can contribute to improving both development theory and practice. The perspectives in the paper can influence decision-making in areas like land use planning, biodiversity conservation, and landscape ecology. By recognizing trends in this research area, policymakers can better understand the connection between ecological processes and human activities. This understanding helps design strategies for socio-economic development that prioritize environmental sustainability. Overall, the paper's findings lay the groundwork for informed decision-making, promoting a holistic approach to development that integrates ecological considerations into broader socio-economic plans.

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Statement of Conflict of Interest

There are no conflicts of interest to report since the research was not funded externally and there are no financial, personal, or professional relationships that could influence the study.

Author Contribution Statement

Gemmalyn M. Trespalacio: Data collection, bibliometric analysis, synthesis of literature, drafting of manuscript. Nico Jayson C. Anastacio: Data collection, synthesis of collected additional data, editing of manuscript.

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