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Trend and network analysis to reveal disciplinary position of soil science and its sub-disciplines

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Abstract

Soil science, a relatively young field of research with a history of fewer than two centuries, experienced an exponential expansion in scientific output in the last decades. While the output of all sub-disciplines is growing, research efforts in these sub-disciplines differ, reflecting the importance of the subjects. The broadening focus of soil science can be detected by the content of the increasing number and diverting thematic sessions of the World Soil Science Congresses, which are held every four years since the beginning of the 20th century. The structure of the current world congress is supposed to reflect the contemporary understanding of the internal structure of soil science, including its subdivision by major themes. Considering these soil themes/sub-disciplines, we assessed the evolution of soil science in the last three decades using scientific publications as indicators. Furthermore, we evaluated the inter-linkages of soil topics within soil research using network analysis and assessed the contribution of science to the broader fields of studies, from agriculture to engineering and environmental sciences. Results show that scientific interest towards all sub-disciplines is exploding, but environment-related topics, including subjects related to climate and contamination, show an even sharper increase. As far as the internal structure of soil science is concerned, research efforts are organised around the major topics of microbiology, soil contamination, nutrients, soil physics and water management. Our study reveals that currently the highest interest towards soil is coming from ecology and environmental sciences, followed by agriculture, engineering, geology and plant sciences, respectively.

Keywords: soil science trends, mapping soil science, soil science research system, the position of soil science

Introduction

Despite the interest of humankind in soil cultivation and the first books in ancient ages about the nature and management of soils, modern soil science is a relatively young field of study that started in the late 19th century from geology and agronomy. The initial interest in soil science from agricultural aspects gradually broadened and currently comprises many subjects, from the environment to global

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security and climate change. With integrating much knowledge from different disciplines, soil science is built on the basic sciences - chemistry, biology, physics, and mathematics - and the applied sciences - earth sciences, hydrology, geo-statistics and ecology (BREVIK & HARTEMINK, 2010). Man has an immense relationship with soil from prehistoric times together with civilizations show knowledge about soil in the 4th century BC, but soil science as a separate discipline with more focus on scientific research emerged in the 19th century. Dokuchaev in genetic soil science, C. F. Marbut and later H. Jenny paved the way for the modern era of soil science, mainly how soils are formed (BREVIK, 2010; HARTEMINK et al., 2001).

The International Union of Soil Science (IUSS), bears an essential role in the expansion and development of soil science as a discipline. The Fourth International Conference of Soil Science (or pedology) in Rome (1924), lead to the establishment of the International Society of Soil Science (ISSS) which is later renamed as IUSS in 1998. IUSS is a scientific union member of the International Council of Science (ICSU) since 1993 and a member of the International Science Council (ISC) since 2018. Twenty-one World Soil Congresses were held by the IUSS over the past 97 years with a scientific structure of Divisions, Commissions and Working Groups, contributing to the dissemination of scientific knowledge through journals and publications. In 2015, the International Year of Soils is celebrated by 60,000 soil scientists around the world indicates the awareness of soil science as a natural resource on which our life depends (VAN BAREN et al., 2000; HARTEMINK, 2015a).

With 200 years of study in soil science as a discipline with the help of IUSS and other international organisations, the dissipation of soil knowledge to the societies depends on good communication and gap identification in the research areas, which can be the basis for future scientific activities. The future of soil science as a discipline appears to reflect a great deal of pessimism to some scientists that the interest of students in the field of soil science is declining from the 1980s through the early 2000s especially in the United States (COLLINS, 2008). One of the main reasons is less funding from the Government. Besides that, soil science started addressing global issues and the study of soil science anticipated to be widened by merging soil science to the environment and ecosystem services (HOPMANS, 2007). Furthermore, the relabelling of soil science departments is also a major concern (HARTEMINK et al., 2014). Meanwhile, some other soil scientists have a different view, for example, the journal Science published a special issue dedicated to soils (11.06.2004) showing that “interest in the soil is booming”. Moreover, some emphasis on the renewed role that soil is playing at present. “Soil is back to the global agenda” (HARTEMINK, 2008), “A soil science renaissance” (HARTEMINK & MCBRATNEY, 2008) and “Soils are back on the global agenda: Now what?” (BOUMA, 2009) are some articles, in which the above-mentioned authors reflect the importance of soil science as a discipline and the roles of international organisations in upbringing the awareness of soil (DÍAZ-FIERROS VIQUEIRA, 2015). The number of soil scientists, as well as publications, is increasing every year, but the audience for the soil research papers are lesser than the other disciplines like physics and chemistry (MINASNY et al., 2007).

The publication patterns in each sub-discipline imply an indicator of the impact of the research content to know how soil science research works. The bibliometric method of analysing scientific publications, which gives the quantitative research output in each sub-discipline, demonstrating the research work in each field, but cannot show how much of this research is used by society (RAINA et al., 2006).

In this paper, we aim to analyse the development and status of soil science and its sub-disciplines from several aspects, including:

1. Analysis of the changing focus in soil science and its sub-disciplines over the last hundred years. Here, we look at the pluralisation of soil sub-disciplines and changing emphasis on soil issues.
2. Assessment of the current structure of sub-disciplines within soil science, including inter-linkages between the soil subjects. Here, we were interested in the internal structure of soil science based on the interest and understanding of soil scientists reflected in their publications.
3. Review the current position of soil science within the arena of all broader scientific fields. Here we assess the interest of different major disciplines (agricultural sciences, engineering, environmental sciences, etc.) in soil issues.

Materials

The investigation of the research is done in four steps, namely the analysis of trends in the soil science as a discipline, the evolution of the sub-disciplines of soil science, the network analysis of keywords of soil science publications and the transdisciplinary position of soil science. All the analyses are done by different materials as described below even though the database used is the same 'Web of Science Core Collection'.

- **Symposia and abstracts of IUSS congresses**

Agenda of 21 IUSS world congresses and their predecessors were studied. First, we gathered information on the symposia of IUSS World Soil Congresses, as we believe that these reflect the best contemporary understanding and interest in soils. All the abstracts are downloaded from each IUSS World Soil Congress. The keywords were assembled from each abstract for extraction of publications from the database Web of Science. The abstracts are only used to construct keywords that are used to extract soil science publications from the Web of Science for the analysis of trends in soil science as a discipline and to indicate the evolution of its sub-disciplines. The data for network analysis (co-occurrence map) and the assessment transdisciplinary position of soil science is not done with the help of the abstracts downloaded from the World Soil Congress.

- **Web of Science data**

1. The analysis of the trends in soil science as a discipline and the evolution of sub-disciplines (time-series graphs of 30 years) were carried out with the help of predefined (already assembled) keywords from the abstracts downloaded from the IUSS World Soil Congress. These keywords are used to extract the publications from the Web of Science for each year from 1990 to 2020.

2. The data for network analysis or co-occurrence map of the free keyword/soil terms from the soil science publications are downloaded from the Web of Science with the keyword "soil" for the year 2020.
3. The assessment of the transdisciplinary position of soil science is done with the help of data from the Web of Science with the keyword "soil" for the year 2015–2020.

Methods

Analysis of the trends in soil science as a discipline and the evolution of sub-disciplines

- **Symposia of IUSS congresses**

The World Soil Congress is an international soil conference held every 4 years in different countries attended by soil scientists. There are 21 soil congresses conducted by the IUSS which give insights into the developments in soil science from 1927 to 2018. For each soil congress, several abstracts were submitted, which are proposed under the symposium. All the abstracts were downloaded from the web page of the World Soil Congress and symposia were counted and classified based on the area they cover, which shows the overall growth of soil science.

- **Classifications by sub-disciplines of soil science**

To see the trends in the sub-disciplines of soil science for the past three decades (1990–2020), keyword-based stock-taking was implemented from the abstracts submitted to the World Soil Congress. About 763 abstracts were selected from the downloaded abstracts because some of the abstracts with the same idea can make the same type of keywords. All possible keywords are made from each abstract depending upon our knowledge. These keywords are used to draw publications from the database Web of Science core collection. We divided the discipline soil science into 31 sub-disciplines as shown in *Figure 2*, depending upon our knowledge in the field and with the help of various reference books like "Encyclopedia of soil science" (CHESWORTH, 2007), "Handbook of soil science" (SUMNER, 1999) and "The Nature and Properties of Soils" (WEIL & BRADY, 2017). The publications extracted from the Web of Science with the assistance of keywords are categorized under the previously formulated 31 sub-disciplines of soil science.

- **Time series analysis of research outputs from the last 30 years**

The time-series analysis is made from the same data extracted from keyword-based stock-taking from the Web of Science based on the abstracts submitted to the world soil congress. We counted the number of publications derived with the help of keywords from the Web of science core collection for each year from 1990 to 2020. The number of publications of five consecutive years is combined under each sub-discipline for making the time-series graphs. For the time-series graphs, we categorised sub-disciplines into four diagrams by frequency of the number of publications. The time series graph is made with the help of the ggplot2 package in the R software (R CORE TEAM., 2020).

Network analysis and the transdisciplinary position of soil science

- **Network analysis of keywords in soil science publications**

The abstract and title of the scientific literature were gathered with the keyword “soil” for the year 2020 from the bibliographic database file, **Web of Science Core Collection.** We created a co-occurrence map based on text data collected from abstracts and title fields of the publications within the soil science domain. The downloaded abstract and title of publications from the database Web of Science are run through another software VOSviewer (VANECK & WALTMAN, 2010) to extract the most frequent terms (free keywords) within the abstract and title fields of the publications. The expression “term/ free keyword” is used here to define the most frequent words that occur in abstract and title fields of different soil science publications for one year. In this process, 751,474 terms related to soil science were extracted. The attribute used for the term (free keyword) selection was binary counting, which shows the number of documents in which a term occurs, regardless of the number of occurrences within the text. As the number of different terms extracted by the software was too high to make a clear co-occurrence map, we set the frequency (minimum number of occurrence) for individual terms as 50 (each term appears in 50 publications at least once) in the program. Out of the 751,474 terms, 4909 met this criterion of selection and were picked out for further analysis. We calculated a relevance score for each of the 4909 terms and chose relevant terms based on this score to select the nouns to exclude other types of words like prepositions, verbs, etc. With these criteria, the number of terms extracted was 2945 together with a manual selection of these 2945 terms is to avoid irrelevant terms.

In the network visualization, each circle represents the chosen term (keyword). The higher the occurrence of the keyword, the bigger the circle. For some keywords with a low occurrence, the circle may not be displayed. This is done to avoid the overlapping of circles. Keywords and their visualisation circles are coloured based on common clusters. The cluster to which related keywords belong is shown by the same colour. Lines between keywords represent links, showing their connections with each other.

- **Assessment of the position of soil science concerning broader scientific fields based on their interest in soil topics**

We assessed the transdisciplinary position of soil science using the database Web of Science core collection. Publications including the keyword "soil" were extracted from the database covering the years 2015–2020. We found 276,819 documents (including articles, proceeding papers, reviews, book chapters, early access, editorial material, meeting abstract). With the help of the Web of Science Category (Research areas), we could classify 276,819 publications to their respective broader scientific fields. With the help of this, we found out that soil science contributes mainly to 10 research areas (Web of Science categories)/ disciplines of Science.

Results

Analysis of the trends in soil science as a discipline and the evolution of sub-disciplines

Figure 1 illustrates the number of symposia of the world soil congress from 1927 to 2018. There is a gradual increase in the number of papers from 1927 to 2018, however, the number of symposia increased abruptly in the 1930s and showed a sudden decrease in the 1950s, which again started increasing from the 1960s. In 1927, the papers were submitted under the six commissions; the symposium was not structured at that time. The results showed a regular gradual increase after the 1990s, which is again decreased in 2002 during the 17th world soil congress. The number of the symposium is more than double in 2018 from the 1990s.

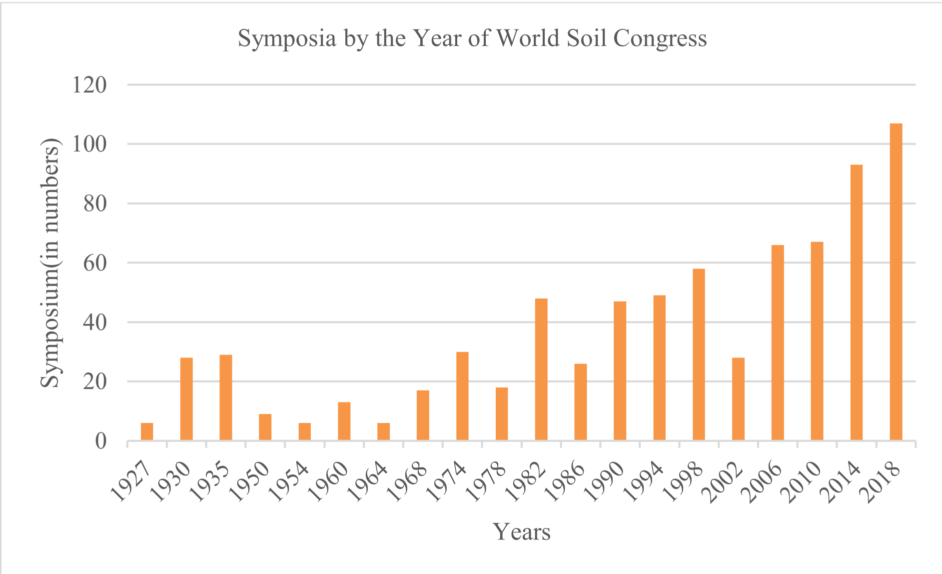

Figure 1
The number of symposia conducted in the World Soil Congresses from 1927 to 2018

With 1,129,611 publications extracted from the database Web of Science Core Collection since 1990–2020 as reflected in *Figure 2*, the research on soil nutrients and plant nutrition, and soil physics contribute the maximum, which is about 10% of the total publication. The least contribution in the number of publications is done by soil mineralogy, soil science and land use, soil education and research and geographic soil information, which is even negligible when compared to the total number of publications.

The quantity of publications in soil science and environment/soil ecology is about 8% of the total publications followed by both soil organic matter and soil classification is nearly 7%. The portion in the research of soil water is 6% followed by soil organic carbon, soil pollution, soil degradation contributes 5% respectively.

The study in soil pollution combined with soil degradation and soil remediation contributes higher than any other discipline in the field of soil science. The sub-disciplines soil colloids and soil remediation each has a share of 4% of the total publication. The assessment in the number of publications in the sub-disciplines soil and climate, soil phosphates and potassium, soil biology, soil morphology and genesis contribute 3% each to the total publications.

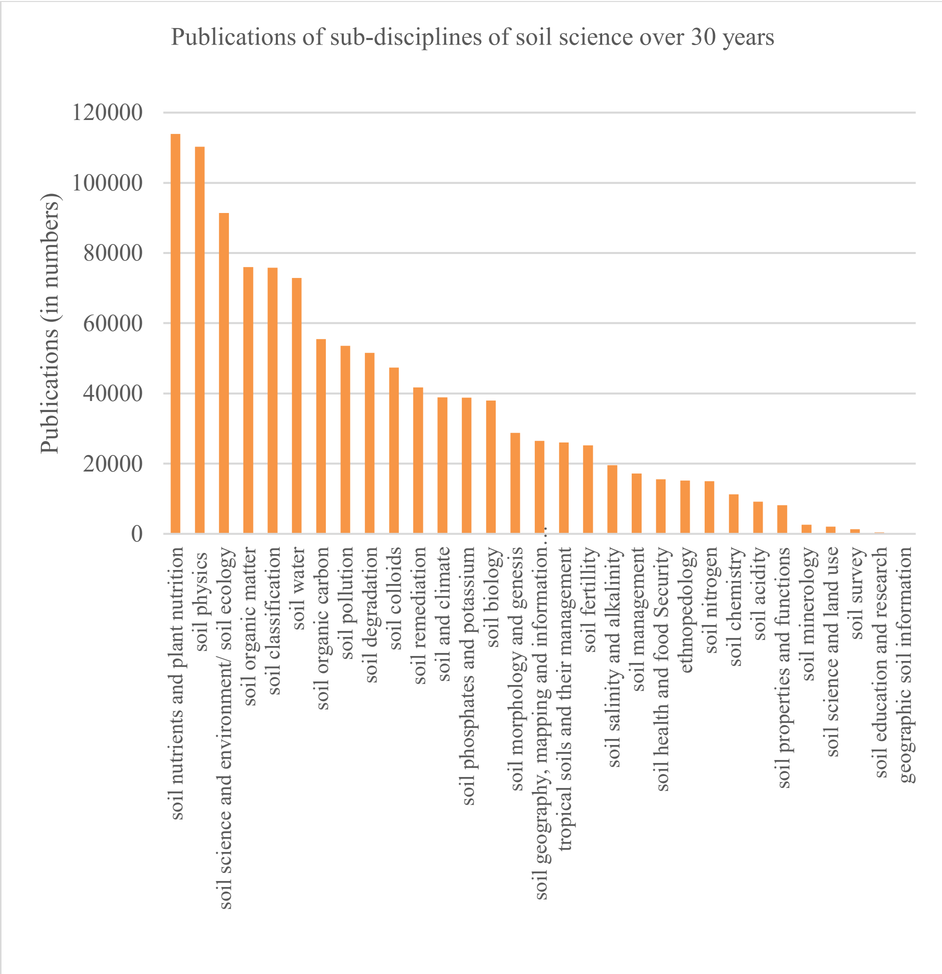

Figure 2
The number of publications of the sub-discipline of soil science for 30 years (1990–2020)

Figure 3(a), (b), (c) shows an overall increasing trend in the sub-disciplines except for sub-disciplines such as soil survey, soil and land use, soil mineralogy, soil education and research depicted in *Figure 3(d)*. *Figure 3(a)* demonstrates that the research on soil pollution is flourishing after 2010. Furthermore, the research in soil pollution in recent years is indistinguishable from the research of soil nutrients and plant nutrition for the three decades. The study of soil organic carbon which, was much less to soil organic matter in the 1990s, has increased tremendously in present time, more preciously the progress in the research of soil organic carbon is almost 99.98% in late 2015's than 2010 when compared to soil organic matter which is only 72.4% in these years. The development in the study of soil degradation together with soil remediation and soil and climate is compounding at an advanced pace than other sub-disciplines after 2010, as presented in *Figure 3(b)*. Study in soil morphology and genesis as well as soil geography, mapping and information system shows stable growth nowadays compared to other sub-disciplines of soil science. *Figure 3(c)* illustrates the evolution in the study of soil health and food security, which exhibited a drop off in the early 1990s, has increased tremendously after the 2010s. *Figure 3(d)* displays that there is a gradual advancement in soil acidity related research areas but the study in soil properties and functions are insignificant when compared to other sub-disciplines of soil science.

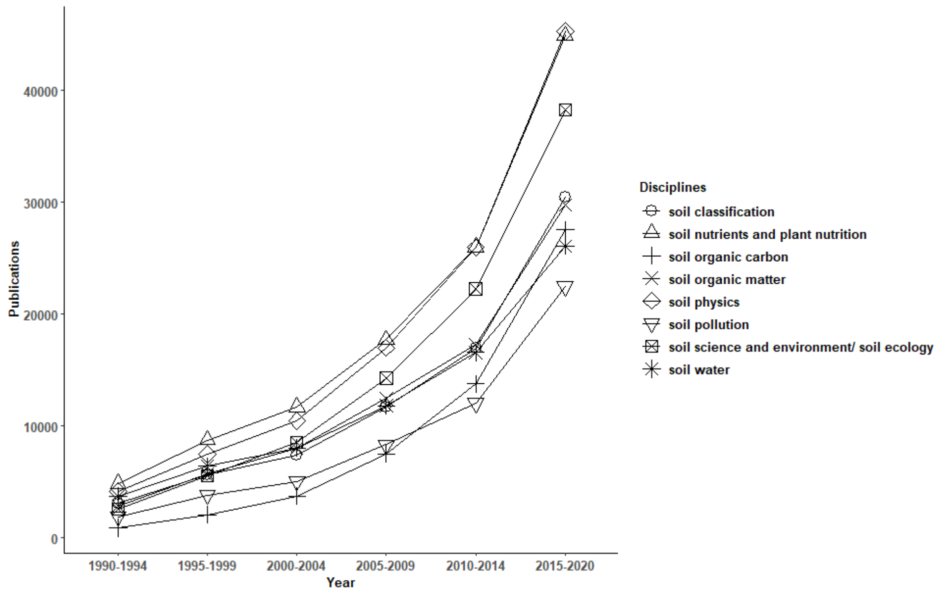

Figure 3(a)

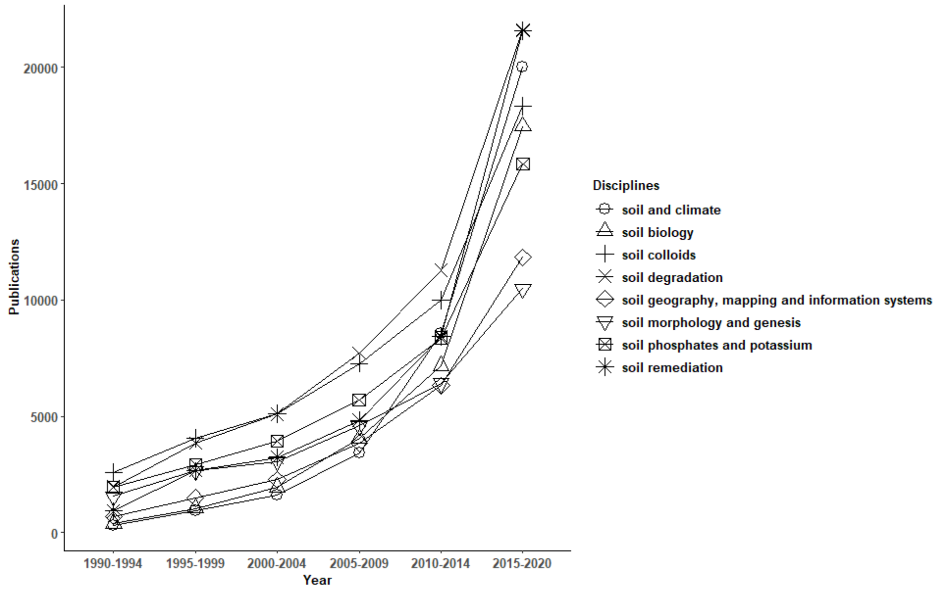

Figure 3(b)

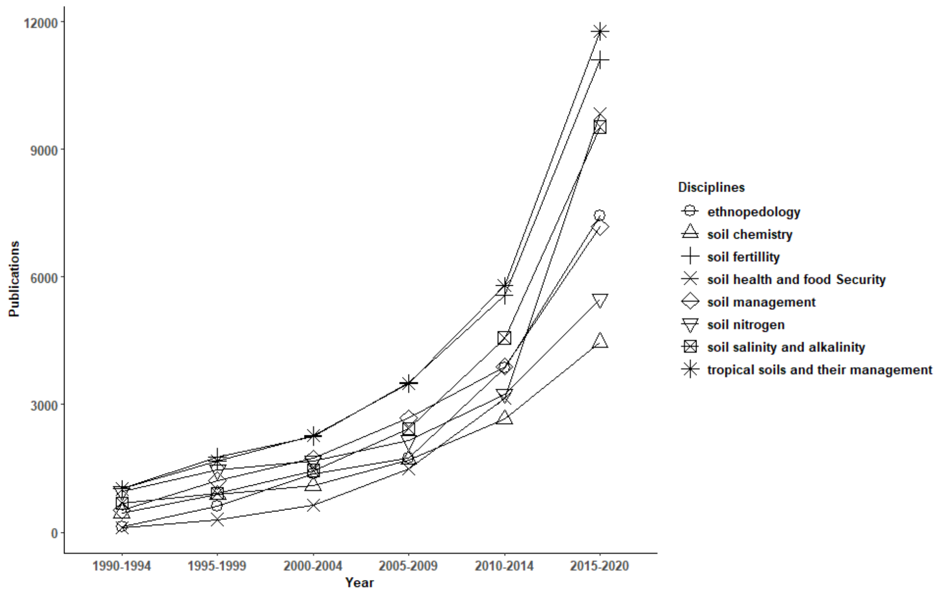

Figure 3(c)

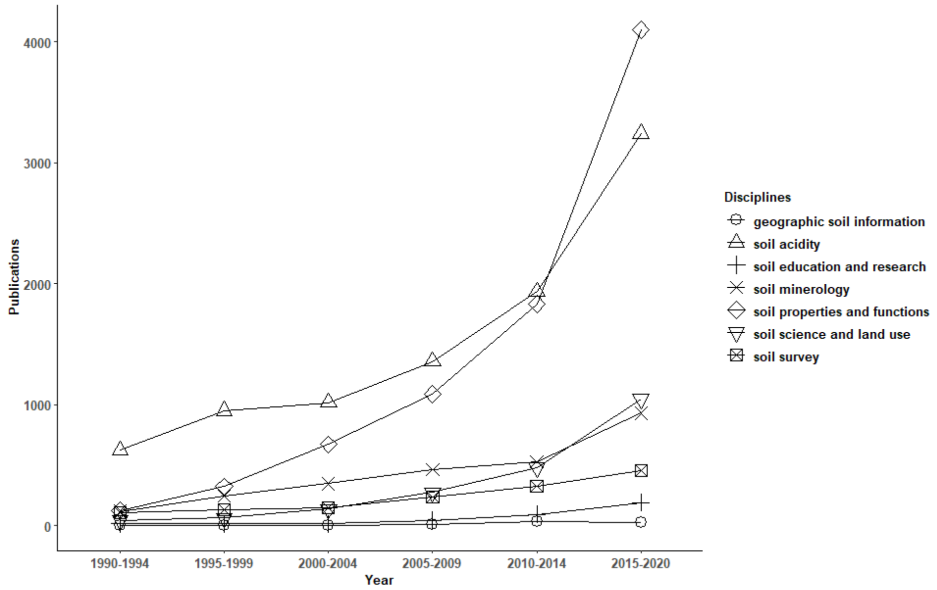

Figure 3(d)

Figure 3(a), (b), (c), (d)
Trends in the sub-disciplines of soil science over the last three decades. The figure is divided into four according to the frequency of publication to avoid the overlapping of lines

Network analysis and the transdisciplinary position of soil science

The results of the network analysis depict seven clusters with different colours, which show the highest occurred term (free keyword) in the publications of soil science for the year 2020 and its inter-linkage between other terms of the discipline (*Figure 4*). The first cluster has the term (free keyword) heavy metal with the highest number of occurrences which is linked to cadmium, which appears in 995 publications along with the smaller circle showing chromium, cancer risk with 156 and carcinogenic risk with 155 occurrences. The term bioremediation can represent studies related to soil degradation or soil pollution. The second cluster can be correlated with soil biology or soil and plant nutrients with the micro-organism and microbial community. The microbial community with 665 times occurrence is associated with the fungal community with 539 times occurrence, mycobacterium, etc. This cluster is having a strong connection with phosphorus, heavy metal and nitrogen clusters. The term phosphorous displays a noticeable number in the third cluster and is closely related to microbial activity, fertilizers, long-term fertilization. In the fourth cluster, the prominent term is nitrogen and is linked to nitrogen loss, nitrogen uptake, fertilization, soil N_2O emission, green manure, nitrification, nitrate leaching, N_2O. The term soil organic carbon has foremost occurrence in the fifth cluster is linked to soil carbon, CO_2 emission, C stock, CH_4 with 323, 302, 403 times of occurrences respectively. The sixth cluster demonstrates that the term soil moisture has a prominent number of occurrences, which is closely connected to the terms land use, erosion, policy-making with groundwater recharge, water use efficiency, surface soil moisture, GIS, cropland, etc. The seventh cluster indicates that the term sand and rock with the highest occurrence in the publications and it links to porosity, clay soil, soft clay, expansive soil, soil slope, loess, mineralogy, earthquakes with 581 and landslide with 433 times occurrence.

In fact, in *Figure 4*, there are closely related or synonym terms (e.g. microbial community/microbiota, Soil Organic Carbon/SOC, etc.), of which one might have been disregarded from the analysis. However, as the overlaps were difficult or impossible to identify in all cases, we decided that we leave all keywords, that are over the threshold and display the result of the network analysis as such. Interestingly, keywords that seem to have the same meaning appear with slightly different positions and with relationships in the diagram.

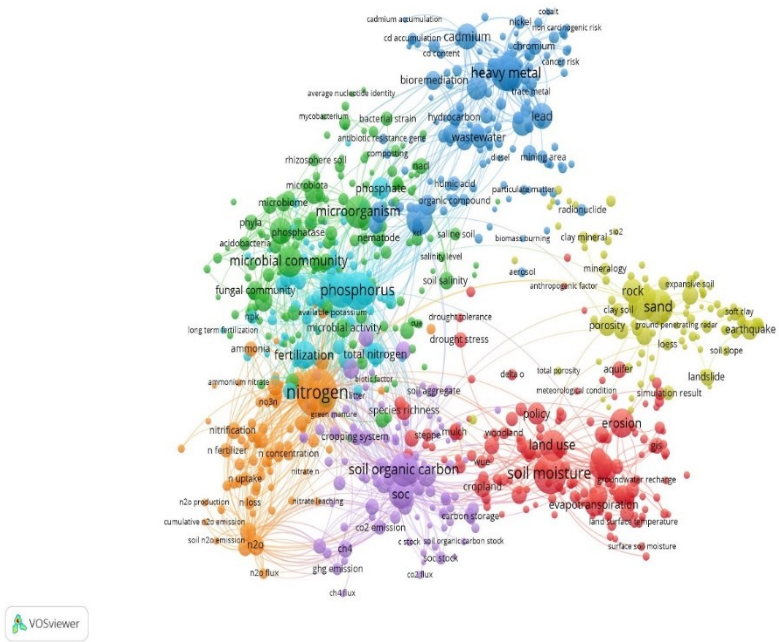

Figure 4
Network analysis map of the terms extracted from soil publications of 2020

Figure 5 demonstrates the proportion of the number of publications related to different broader disciplines of science underlines the transdisciplinary nature of soil science. From the results, soil science contributes the most to environmental science and ecology, with about 29.68% (82,148) out of 276,819 soil science papers submitted from 2015 to 2020. The proportion of Agriculture is 61,324 publications which are more than double that is contributed by geology (28,817). The share of publications from the discipline engineering to soil science is not a lesser amount than Agriculture which is about 54,725 articles. The contribution of the disciplines like Plant Science and Water Resources to soil science is nearly equal, which is about 21,580 and 21,276 publications respectively. The share of Science and Technology to soil science is around 17,182 publications which are followed by Chemistry with 12,263 publications. The sub-discipline Microbiology contributes 10,561 publications to soil science which is significant compared to other disciplines mentioned above even though the number of publications is much lesser than them.

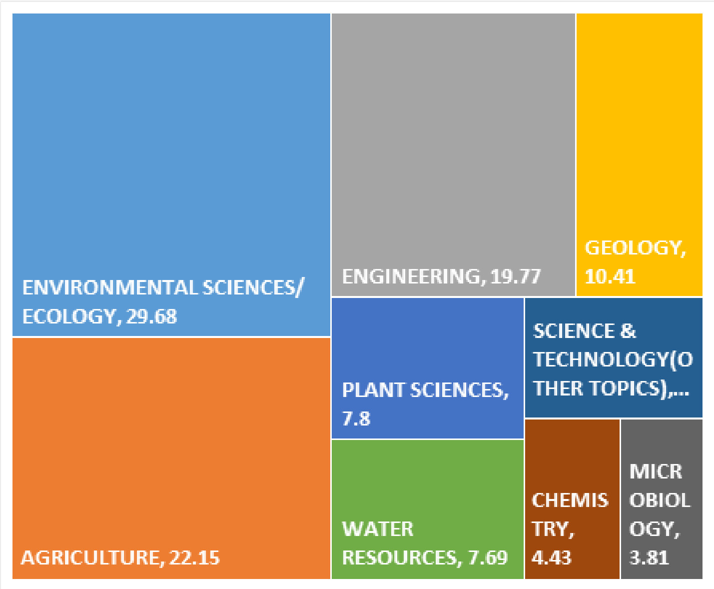

Figure 5
The contribution of soil science to different disciplines of science (research areas, percentages)

Discussion

The paper tries to quantify the trends in soil science, the evolution of its sub-disciplines, the major soil terms in recent times and the transdisciplinary position of soil science. Soil science as a discipline strengthens, both in the output volume of research results and in the diversity of subjects covered. The number of symposiums in the World Congress shows a gradual increase from 1927 to 2018, which reflects the increased activity of soil scientists. Although the scientific activity decreased after 1935, and especially because of World War II, it recovered and rapidly grew from 1960 until today. *Figure 1* shows that congress expanded from six commission sessions in 1927 to 107 symposia in 2018 along with a growing number of divisions, commissions, and working groups of the organisation. The increasing number of soil papers are matched those of soil science reference books, which also leave their legacy with seven major pillars of soil science namely soil physics, soil chemistry, soil biology, pedology/soil classification/mapping, mineralogy, soil fertility & plant nutrition, and soil & environment (HARTEMINK, 2012). Considering the 7 pillars as the major sub-disciplines of soil science but in recent times the topics got diversified which enables the expansion of soil science to different topics like soil degradation, soil pollution or soil organic matter as reflected from the increased number of publications in this field. The pessimism to soil science is quite incomprehensible as it is indispensable from human life and was a part of scientific literature in the past, in the present and will be in the future also. In this study, the abstracts and symposiums are chosen to show the relative growth of soil science along with other disciplines of science in recent years. The abstract submitted to the IUSS congress reflects the recent developments in soil science. In contrast, nowadays, there are several conferences held more focused on sub-disciplines for experts. These conferences are more effective in terms of discussion and scientific development as they are specialized. Thus, some scientists prefer to attend those against a general forum. Moreover, the IUSS conference limits the number of abstracts submitted to them as they receive a lot of abstracts recently, so we cannot select this as the main criteria for the bibliometric analysis. Here, we selected the IUSS conference only as a basis which allows us to construct the appropriate keywords as it covers all the major areas of research under soil science to extract the exact amount of soil publications from the database Web of Science.

Regarding the evolution of soil science sub-disciplines, the modern discipline of soil science has diversified topics or sub-disciplines that cannot be constrained by boundaries and are changing over time. The recent concern should be the research tradition of sub-disciplines, how they are maturing and developing? Which area is more emphasized, and which one needs more focus? In *Figure 2*, we divided the sub-disciplines of soil science into 31 categories based on the keywords extracted from the abstract submitted to the soil congresses, whereas the fundamental ones are pedology, soil physics, soil chemistry, soil biology, soil mineralogy and often soil fertility (CHURCHMAN, 2010). The result from *Figure 2* and *Figure 3(a), (b), (c)* indicate the drift in the sub-disciplines of soil science, which manifest the major fields of application of soil science from 1990 to 2020. The soil nutrients and plant nutrition, soil physics, soil science and environment/soil ecology, soil organic matter, soil classification, soil water and soil carbon, which holds more than 50% of the total scientific publications extracted from the Web of Science database for the last three decades. Individually, each discipline has a different trajectory, soil science and environment/ecology and soil carbon are booming after late 2010, soil organic carbon is more concerned in recent years than soil organic matter. The reasons for this increase in the study of soil organic carbon can be different, primarily due to the carbon sequestration-climate change nexus. Secondly, the trend is related to the development of carbon markets allow companies to buy or sell greenhouse gas (GHG) emissions allowances or to offset their carbon footprint to meet voluntary emissions reduction targets which represent the great appeal for financial institutions and government (ABDUL-SALAM et al., 2019). The investigation shows the soil science as a discipline is evolving according to the needs of humans over time, the past needs are less prominent currently and it is battling to resolve the future needs. There has been an upsurge in the scientific activity of sub-disciplines like soil nutrients and plant nutrition and soil physics from 1986 because of the introduction of posters-papers in World Soil Congress under the Commission IV (soil fertility and plant nutrition) and Commission VI (soil technology) (VAN BAREN et al., 2000). In the *Figure 3(a)*, soil classification is displaying a rising trend over the last three decades mainly due to the categorization of different types of soil around the world. Meanwhile, in the network analysis of 2020, it seems missing, probably due to the reduced number of research on soil classification as we cannot see any of the soil types or the term/keyword 'soil classification' itself. HARTEMINK (1999) reported that abstracts on Soil Classification & Soil Types have a declining trend. The awareness of soil degradation along with soil pollution and soil remediation are increasing with the concern on heavy metals like cadmium (Cd), lead (Pb), copper (Cu). Environmental pollution and its effects on human health and other living beings are implicated currently (MERMUT & ESWARAN, 2001). The modern world generates large quantities of pollutants that overload the environment with toxic materials affecting soil health. At the same time, we should not ignore the importance of soil bioremediation as the intensive use of soil used for agriculture and large scale deposition of chemicals into the soil over the past years increase the significance of bioremediation of soil for humankind. Moreover, soil scientists have become more concerned with issues related to the sustainable development of the Millennium Development Goals, such as climate change, environmental degradation, biofuels, and alleviating hunger, which complies with the results of this paper (MOL & KEESSTRA, 2012). The western world is contributing to the research mainly dealing with soil problems related topics that communicate with the environment. Other than heavy metals, soil erosion is another problem in soil degradation, which had a vital concern for 100 years and still going on; addressing these problems alone is creating negative impacts in the research field of soil science even it helped to get soils in the global agenda (BOUMA, 2009; HARTEMINK, 2015b). The new technologies, which started in recent decades like remote sensing, GIS, integrated with computerised modelling, can help in future research of soil threats but the study in these fields seems to be stable from the 1990s. The study in soil functions that need to be given more attention is not so prominent compared to other sub-disciplines. The IUSS has working groups focused on digital soil mapping, hydropedology, pedometrics, proximal soil sensing (RODRIGO-COMINO et al., 2020) which could emphasise the research activities in these fields and enhance awareness globally. Soil education and research as a sub-discipline need much focus, which is a vital topic for the curriculum for future generation; soil science is a natural science that has a broad holistic role in society, which need a unique set of principles different from other disciplines of science (FIELD et al., 2011). Soil science can also be taught through an online platform but need better communication between the teacher and students (FIERRO & QUICHIMBO, 2018). Soil history is another topic, which lost its importance among other sub-disciplines needs fundamental attention as it can display the legacy of soil science and how it passed from generation to generation. The study in soil biology, in general, was not promising from 1990 to 2020 but the term microorganism, microbial activity, fungal activity is quite discussed topic in 2020 in the field of soil science. Soil moisture was more connected to soil physical properties in the past likely in the study of soil moisture variability for analysing hydrological models (STOLTE et al., 2003) and in control erosion (FITZJOHN et al., 1998). However, in this paper, we can see the connection between soil moisture and land use patterns. Likewise, the separation of soil organic carbon and soil nitrogen from the soil organic matter and the emergence as two independent keywords recently. It is fascinating to see the evolvement of each discipline and keywords individually and their relations with other keywords.

Assessment of the proportion of the thematic research areas with the search title "soil" shows not only environmental studies or ecology and agriculture contribute to the soil but also other disciplines like engineering, chemistry, water resources impart to the soil. Environmental science or ecology is showing a significant interest in the study of soil science, which shows how research work in soil science changed from pedology to agriculture in the 19th century to environmental science for the last five years. There can be an increase in the number of publications, with the search title "soil" which cannot reflect that the exact study is conducted under soil science, as the number of corresponding soil scientists did not increase, it can be under engineering, geology, chemistry or physics and not exactly the pedologist (DÍAZ-FIERROS VIQUEIRA, 2015). The soil knowledge can be dissipated to the society only by good communication between soil scientists, a soil scientist with other scientists as the soil has a transdisciplinary nature, the soil scientist with public and policymakers to solve global problems (BOUMA et al., 2012). A review made by BAVEYE & JACOBSON (2009) said that we should not be frightened to accept the perishing nature of soil science if the soil expertise needs are met and interrogated about the current position of soil science whether it is going to serve as a discipline or be merged with other disciplines. In the USA, the beginning of the 20th century was favourable for soil science, but it hit hard in the 1980s and 1990s and again seems to regain its strength in the 21st century because of the future technologies innovations like remote sensing, GIS, etc., (BREVIK et al., 2016). Again the question arises from the trans-disciplinary position of soil science allows it to distribute itself under different disciplines or to integrate different disciplines under soil science. Anyways the works in soil science are indispensable to humankind whether it can standstill as a discipline or it is going to be merged into other disciplines of science.

Conclusion

We did the trend and network analysis to reveal the disciplinary position of soil science and its sub-disciplines to identify the knowledge gaps and future research needs. Soil science as a discipline is prospering for the last three decades and most of the sub-disciplines have firm and secure growth, except some sub-disciplines like soil education and research, soil mineralogy, soil survey. The transition of soil studies from pedology to agriculture to more recently in environmental studies, especially after the 2010s is obvious in this analysis. In the early 1990s, soil as a part of agriculture show more focus on plant nutrition and soil fertility now the soil science is showing more trend towards soil degradation and soil pollution where the main topics like heavy metals, soil compaction, soil sealing, depletion of organic carbon are the major study area. The study of soil organic matter has changed the focus to soil organic carbon after 2010 as it helps to mitigate climate change. Concerning the internal structure of soil science, the key topics discussed in 2020 are heavy metals, micro-organisms in the soil, phosphorous and nitrogen content, soil organic carbon, soil moisture, erosion. The transdisciplinary position of soil science is clear, soil science as a discipline cannot be marginalized into one area, it has got wider reach and scope for future studies, whether in environmental studies or agriculture or engineering. Will this nature allow the discipline to grow as a separate field of science than merging into different scientific disciplines? It is a question of insight to the soil scientist and a future call for the scope and prospects of soil science.

The limiting factor to the study conducted can be the keywords made only from the abstracts submitted to the world soil congress and the recurrence of some publications when collected from the Web of Science database.

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