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Synopsis

Carbon Sequestration – a Research Subject of a Present Importance

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Abstract. The current study investigates published data, concerning carbon sequestration on a global scale. The investigation is based on the use of the search engine of Nature Research Journal in order to acquire information about the studies, concerning carbon sequestration – the latter words were used as key words. Two main periods are examined, covering the years 1845-1999 and 2000-2019. During the first period - 1845-1999 29 manuscripts, regarding carbon sequestration were published. The second period saw an unprecedented boom when a total count of 513 results came into being. Some of the most important among them are a part of several scientific journals, including *Scientific Reports*, *Nature Communications*, *Nature Journal*, *Nature Sustainability* and *Nature Climate Change* with *Nature Journal* having an impact factor of *43.070* in 2018. This can serve as a proof of the quality of the scientific research. The results also show a division by country for several of these scientific works. The author stress on the need of such an overview study in order to reveal the present day importance of this subject.

Key words: scientific articles, Nature Research Journal, impact factor.

Introduction

Carbon sequestration is among the most discussed subjects in present day scientific investigations. Many consider this process as being vital for climate change mitigation. In its essence it represents a long-term capture and storage of atmospheric carbon dioxide in plants, soils, ocean, etc. via a series of chemical, biological and physical processes. Then carbon becomes part of stocks that are keeping it away from the atmosphere, thus weakening its influence on any planetary warming processes. Carbon dioxide is regarded as one of the most potent greenhouse gases, therefore its removal from the atmosphere adds weight to climate regulation. Earth's systems may be considered as carbon sources and carbon sinks. Anthropogenic activities lead to the release of carbon by burning of fossil fuels (coal, petroleum, natural gas), for example. Another part of the carbon cycle is its release via decomposition of biogenic material. Among the most prominent carbon sinks are forests, the edaphic sphere and major water bodies. Terms, such as, blue carbon, green carbon and black carbon are gaining more popularity throughout the society and are linked with carbon sequestration. Blue carbon refers to that part of carbon, mainly captured by mangroves, salt marshes and sea grasses, thus it is the carbon of ocean ecosystems. Green carbon is captured by vegetation and soil of natural ecosystems,

while black carbon is regarded as a particulate matter component, forming through the combustion of fossil fuels and biomass.

Scholars are becoming more and more aware of the importance of carbon sequestration and this is proved by the increase of scientific studies, focused on this process. Major effort is being put on studying carbon sequestration from a global point of view and there are several examples of such studies. Freibauer et al. (2004) studied agricultural soils. Scharlemann et al. (2014) investigated the terrestrial carbon pool and Achat et al. (2015) carried a global forest analysis, aimed at carbon dynamics. Schuur et al. (2015) focused their study on climate change. Corbeels et al. (2016) investigated limited carbon contents. Zomer et al. (2017) conducted a research on global sequestration potential of soils in agricultural territories and it is among the most significant investigations on this subject up-to-date. Piñeiro et al. (2017) focused their efforts on conducting a world assessment about fine root biomass and soil carbon levels. Gosling et al. (2017), Hagemann et al. (2017), Kroeger et al (2017), Macreadie et al. (2017), Sanderman et al. (2017) and Tang et al. (2017) provided more insight about carbon storages. Bulgarian scientists also acknowledged carbon sequestration importance. In 2017 Zhiyanski et al. (2017) and Bratanova-Doncheva et al. (2017) worked on a methodology for assessment and mapping of ecosystems. Yaneva et al. (2018) assessed and mapped areas in Central Balkan National Park, focusing on carbon sequestration in the context of ecosystem services. At the same year Di et al. (2018), Espenberg et al. (2018), Hodgkins et al. (2018) and Leifeld & Menichetti (2018) provided additional data regarding carbon sequestration. Adamczyk et al. (2019) and Bhardwaj et al. (2019) also provided manuscripts, based on organic carbon. The research papers of Iizumi & Wagai (2019), Kravchenko et al. (2019), Ogle et al. (2019) and Sayer et al. (2019) added even more data about carbon pools.

The current paper presents an informative insight of the scientific studies, focused on carbon sequestration, allowing for making assumptions. It represents an attempt of an overview study about the significance of this matter in the scientific world.

Materials and methods

An attempt was made for summarization of the number of studies, connected to carbon storage investigation. A specific search engine was used in order to fulfill the main aim. The authors acknowledge it as being one of the most up-to-date engines, providing an insight about that specific issue. It is also clear that it cannot provide the fullest list of articles, based on carbon sequestration. However, the engine gives an opportunity to search for scientific journals with a very high impact factor, thus it can be regarded as thorough enough. The carried search aimed at publications that are part of Nature Research Journal. It was based on the two key words - "carbon sequestration" (www.nature.com/search?q=carbon+sequestration). Generally, the search refinement allows for "article type choice", "journal" and "date choice". Database searches were performed in English. The first option differentiates research, reviews, news and views, comments and opinion, correspondence, special features, books and arts, etc. The current investigation focuses only on those studies that are a part of the "research" section. The advanced journal search gives an option to choose between several major journals and the date search allows for a search by years. The advanced search provides opportunity for a search by "authors", "terms" or "title" and exactly here "carbon sequestration" was applied. The current investigation covers two major periods: from 1845 to 1999 and from 2000 to 2019. The start of the new millennium marks the beginning of the new investigated period. It was chosen because it serves the role of a major baseline in chronological terms. Moreover, it marks a beginning of the acknowledgement of the importance of carbon sequestration as an important climate change mitigation tool. The adoption of the current methodology provided a basis for the revelation of interesting results.

Results and Discussion

The outcomes are summarized in the following lines. The examination of the two periods displays a significant imbalance of the total number of articles. During the first or the old period, spanning from 1845 to 1999, a total count of 29 manuscripts were published in Nature Research Journal and the other scientific journals, included in the Nature Research engine. These scientific papers are issued about carbon sequestration or are at least mentioning it several times. The analysis points out that they are focused on carbon storage as a chemical component in ecosystems, but are not aiming directly at climate change issues and this is rather interesting. It may be said that climate change obsession had not started yet during that period, explaining the lack of such focus in scientific papers.

Since the start of the new millennium a major boom in carbon sequestration articles occurred. Studies, concerning carbon sequestration, emerged with an immense power. A total count of 513 results (397 research manuscripts) were found in the Nature Research engine. They were published from 2000 till the end of 2019 in a wide array of scientific journals. The number of those that were published in *Scientific Reports*, *Nature Communications*, *Nature Journal*, *Nature Sustainability* and *Nature Climate Change* is 315. The total breakdown of the results includes: 67 reviews, 9 news, 11 news and views, 16 comments and opinion, 5 research highlights, 3 correspondences, etc. These numbers are neglected in the current analysis, which is focused on research articles and they serve only as an illustration of the immensity of published research, based on carbon sequestration. Their yearly distribution is displayed on Fig. 2. The aforementioned five scientific journals are well acknowledged in the current study due to their high impact factor ratings. There are 181 research works, published in *Scientific Reports* (impact factor 4.011 for 2018) - an open-access, multidisciplinary journal from Nature Research, accounting for 35% of the research articles for the period. This journal is not taking the first place, regarding impact factor ratings; however the large number of studies published in it speaks for themselves. Research articles in *Nature Communications* (impact factor 11.880 for 2018) were at the count of 69 or 13.5% of all. This journal represents an open access journal that publishes high-quality research from all areas of the natural sciences. It has a higher impact factor rating than the previous one and that may be regarded as a reason for the lower count of published investigations – it is more difficult to earn a place in this scientific platform. Research works in *Nature Sustainability* (with a five-year impact factor of 12.092) were at the count of 19 or almost 3.7 %. Research articles in *Nature Climate Change* (impact factor 19.181 in 2017) - a monthly journal dedicated to publishing the most significant and cutting-edge research on the nature, underlying causes or impacts of global climate change, was accounting for 3.1% of all articles, equaling 16 articles. These two scientific journals are having increased impact factor ratings, which normally leads to a decrease of the published articles. Moreover, the specificity of their scientific area – including climate change processes may have led to a restricted number of published investigations. The weekly international publishing source *Nature Journal* (impact factor 43.070 in 2018) included 30 articles, equaling to 5.8 % of the total count. This result is in conflict with the already observed principle – the higher the impact factor rating, the lower count of published articles. One possible reason is that authors are putting their best efforts to publish in a journal with such a sky high impact factor (Fig. 1).

An interesting discussion topic is the way research articles increase during the second period, peaking in 2019. The number from 2000 to 2019 growed more than 20 times, which is significant enough. Once again significant efforts are put into the revelation of the mechanisms for climate change mitigation.

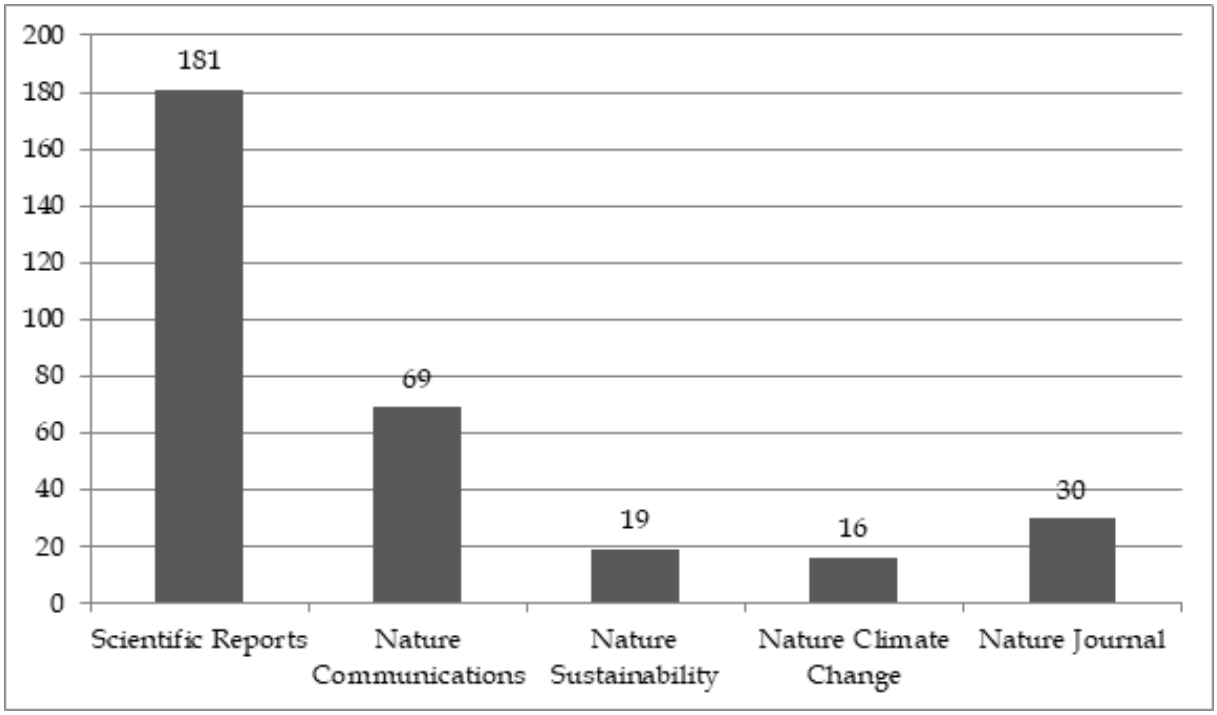

Fig. 1. Count of research articles (2000-2019) in five significant scientific journals.

Research centers are investing more and more finances in this subject and the results of the current study present indisputable proof of this. A large difference is observed from 2013 till 2019. The exponential growth is showing almost seven times more research in the end of the period. The explanation for this at least, regarding EU territory, may be hidden in the document, regarding the adoption of EU Strategy on adaptation to climate change, discussed in Brussels at 16.4.2013. Along with the expectation of the adoption in 2014 of the 5th Assessment Report of the IPCC, this document acknowledges the urgent need for quick measures, regarding climate change adaptation. Moreover, the Multiannual Financial Framework (MFF) draft 2014-2020 discusses a proposed raise of expenditure, regarding climate issues to be at least 20% of the EU budget. Obviously, the Commission started to acknowledge the importance of taking climate change measures by proposing relevant finance initiatives.

An interesting outcome of the investigation focuses on the distribution of research articles by countries. Only data, concerning soil investigation, will be discussed as soils are representing the largest terrestrial reservoir of organic carbon. They also possess the ability to act as a carbon pool, playing a central role in the mitigation of climate change. The information is summarized in Fig. 2 where several countries stand out. Along with the incontestable leader – China, the other leading countries here include the USA, Australia, Brazil and the UK. They may have been chosen by research teams, as their soils are representing a significant unit in carbon sequestration around the world. Moreover, scientific teams aimed at placing them on the global carbon sequestration map. Climate change adaptation and mitigation measures are adopted in each of the aforementioned countries, resulting in a rise of scientific research. An essential programme that deserves attention is the one, implemented by the Chinese government. In 1999 officials adopted the so-called "Grain for Green" (GFG) programme in order to battle over-

cultivation, erosion and deforestation. This programme allowed for immense financial injections, including those for research studies, regarding this issue. The results of these efforts are apparent, as it can be seen from the provided data in Fig. 2.

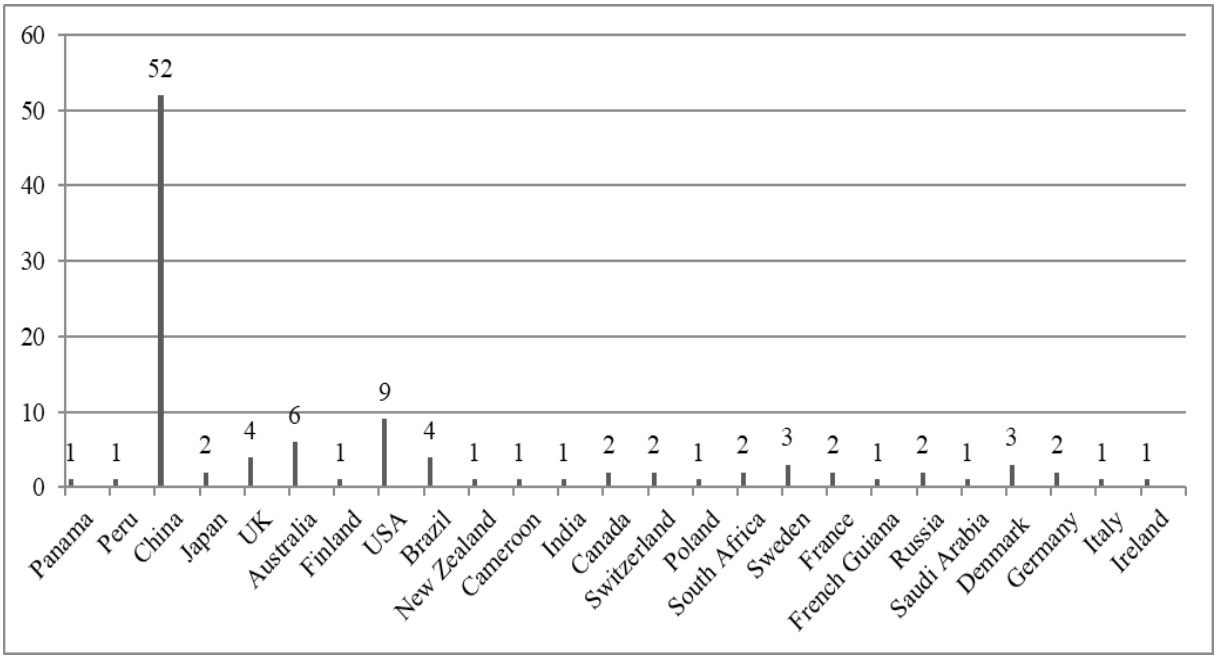

Fig. 2. Distribution of the conducted research by countries.

Conclusions

The current study was focused on carbon sequestration as one of the most discussed processes by scientists in recent years. It plays a major role for climate change mitigation and its significance is being more and more acknowledged throughout the scientific world. The results of the present study show a boom of published research. A special focus is put on five major scientific journals (*Scientific Reports*, *Nature Communications*, *Nature Journal*, *Nature Sustainability* and *Nature Climate Change*), because of their wide recognition among scientists. It can be concluded that the impact factor plays an essential role when it comes to addressing your article. Generally speaking, the higher the impact factor, the lower the number of published manuscripts. However, when it comes to N*ature Journal*, there is a conflict with the established principle. This may be explained by the efforts and desire of the authors to publish their data in the highest ranked journal.

When it comes to research articles in general, there is a high increase, especially after 2013. This is a proof for the importance that scientists are rendering to carbon sequestration investigations. It also became clear that when the investigation of carbon sequestration becomes a major part of countries' programmes then research is steadily increasing. When it comes to a differentiation by countries, then China and the USA are the leaders in scientific studies.

The authors of the present investigation are stressing on its successful outcomes and evaluate it as being thorough enough. Yet, efforts should be put at the investigation of more scientific journals' data, regarding carbon sequestration in order to increase the comprehensiveness of such overview studies.

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