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Global trends in nitrate leaching research in the 1960–2017 period

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HIGHLIGHTS

- A rising interest in last decades in nitrate leaching research worldwide
- Most research dealt with nitrate leaching from agroecosystems and farmlands
- Dominance of soil nitrogen cycle, fertilizer use and water quality research topics
- Most research on nitrate leaching conducted in the United States and China
- Increasing relevance of research with maize, wheat and grasses from 1990

GRAPHICAL ABSTRACT

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ABSTRACT

Nitrate leaching is the process whereby the nitrate (NO_3^-) anion moves downwards in the soil profile with soil water. Nitrate leaching is commonly associated with chemical nitrogen (N) fertilizers used in agriculture. Nitrate leaching from different sources and contamination of surface and groundwater is a global phenomenon that has prompted social and political pressure to reduce nitrate leaching and contamination of water bodies. This bibliometric study analyzed global trends in nitrate leaching research. The results showed a rising interest in the last decades in this topic; given the growth tendency over the last years, it was envisaged that the importance on nitrate leaching research will continue increasing in the future. Knowledge on nitrate leaching was mostly disseminated through scientific publications (90% of total documents recovered), both as journal articles and reviews, classified in the Scopus database in the Agricultural, Biological and Environmental Sciences areas. Most publications dealt with soil nitrogen losses from agroecosystems and farmlands and the associated impact on the environment; they were published in journals with a focus on the influence of anthropogenic and soil-crop-animal systems in the environment, and on how such changes in the environment impact agroecosystems. Most documents published on nitrate leaching were indisputably from the United States, followed by China, the United Kingdom and Germany. An analysis of the main keywords showed an overall dominance of the soil nitrogen cycle, fertilizer use in agriculture and water quality aspects. The evolution of main crop species involved in nitrate leaching research showed a rising relevance of research conducted with maize, wheat and grasses from 1990 onwards. The most productive institutions in terms of number of documents dealing with nitrate leaching research, h-index and total citations, were located in the United States, China and the Netherlands. The United States Department of Agriculture stood out, followed by the Chinese Academy of Sciences and Wageningen University and Research. There were clusters of institutions with intercontinental interaction, on nitrate leaching research, between institutions from Europe, Asia and South and North America. Overall, this study has highlighted,

Abbreviations: IF, Impact factor; JCR, Journal Citation Report; N, Nitrogen; N_2, Dinitrogen gas; N_2O, Nitrous oxide; NH_3, Ammonia; NH_4^+, Ammonium; NO_2^-, Nitrite; NO_3^-, Nitrate.

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from a bibliometric perspective, the rising concern on nitrate leaching. Progress in this field has been made particularly on the impact of the soil-plant-animal system on the environment and agroecosystems, and on fundamental and applied aspects of plant-soil interactions with an emphasis in cropping systems.

1. Introduction

Nitrogen (N) is an essential element for all life process in plants (Hester et al., 1996); it is a structural component of all proteins, including enzymes involved in photosynthesis, growth and development, and is an important component of nucleic acids and chlorophyll (Gianquinto et al., 2013; Lawlor et al., 2001). At the same time, N is one of the major limiting nutrients in most ecosystems and agricultural soils (Vitousek et al., 1997), which commonly contain between 0.1% and 0.6% N in the top 15 cm, depending on the soil type (Cameron et al., 2013). Soil N is present in four major forms: (a) organic matter, such as plant material, fungi and humus; (b) soil organisms and microorganisms; (c) ammonium ions (NH_4^+) held by clay minerals and organic matter, and (d) mineral N forms in soil solution, including NH_4^+, nitrate (NO_3^-) and low concentrations of nitrite (NO_2^-) (Cameron et al., 2013; Hester et al., 1996). However, any N in the soil that is available to plants is likely to be present as NO_3^-, or as NH_4^+, which microbes of the soil soon convert to NO_3^- (Hester et al., 1996). Mineral N forms are mainly prone to losses through: (a) ammonia (NH_3) volatilization (i.e., the loss of gaseous NH_3 from the soil surface), (b) denitrification and gaseous losses of nitrogen (mainly as dinitrogen gas (N_2) and nitrous oxide (N_2O)), and (c) leaching (i.e. removal in drainage water) (Cameron et al., 2013; Gillette et al., 2018). Nitrogen losses by leaching occur mainly in the NO_3^- form but some leaching of NH_4^+ may occur in sandy soils (Moreno et al., 1996). It is leaching of the NO_3^- anion that is analyzed in this article.

Fig. 1 summarizes the nitrogen cycle and the nitrate leaching process, whereby the NO_3^- anion moves downwards in the soil profile with soil water (Gianquinto et al., 2013; Hester et al., 1996). Nitrate is completely soluble in water and is prone to be leached, because the negatively-charged NO_3^- anion is repelled by negatively charged surfaces of clay minerals and soil organic matter. This keeps nitrate dissolved in the soil solution and moves freely in the soil by percolating rainfall or irrigation (Gianquinto et al., 2013; Hester et al., 1996).

Nitrate leaching is commonly associated with chemical fertilizers used in agricultural crops (Cameron et al., 2013; Fowler et al., 2013; Lemaire and Gastal, 1997; Pratt, 1984), but some of the soil nitrate that is vulnerable to leaching is produced by microbes that break down plant residues and other nitrogen-containing residues in the soil (Hester et al., 1996). Localized sources of nitrate leaching can be animal organic waste effluents; some of these being dairy shed effluent, dairy pond sludge, pig slurry or sewage sludge (Di and Cameron, 2002; Power and Schepers, 1989). Published data indicate that nitrate leaching losses typically would follow the order: forests < cut grassland < grazed pastures < arable cropping < ploughing of pastures < horticultural and vegetable crops (Cameron et al., 2013; Di and Cameron, 2002). Nitrate leaching losses are generally lowest from forest systems because there is usually zero or only low rates of N fertilizer applied, and the N is cycled efficiently through the forest ecosystem (Di and Cameron, 2002). However, logging and burning of forests can release large amounts of N that can be leached or washed off slopes through soil erosion (Cameron et al., 2013). In grassland systems, NO_3^- comes from fertilizers (i.e., mineral or urea-based fertilizers) or from mineralization of soil organic N. Grasslands that are mown or cut for hay or silage have very low nitrate leaching losses, because grass and pasture plants are usually very efficient at taking up the N applied in fertilizer or N fixed by legumes such as clovers that are grown in the pasture sward (Cameron et al., 2013). The nitrate leaching potential

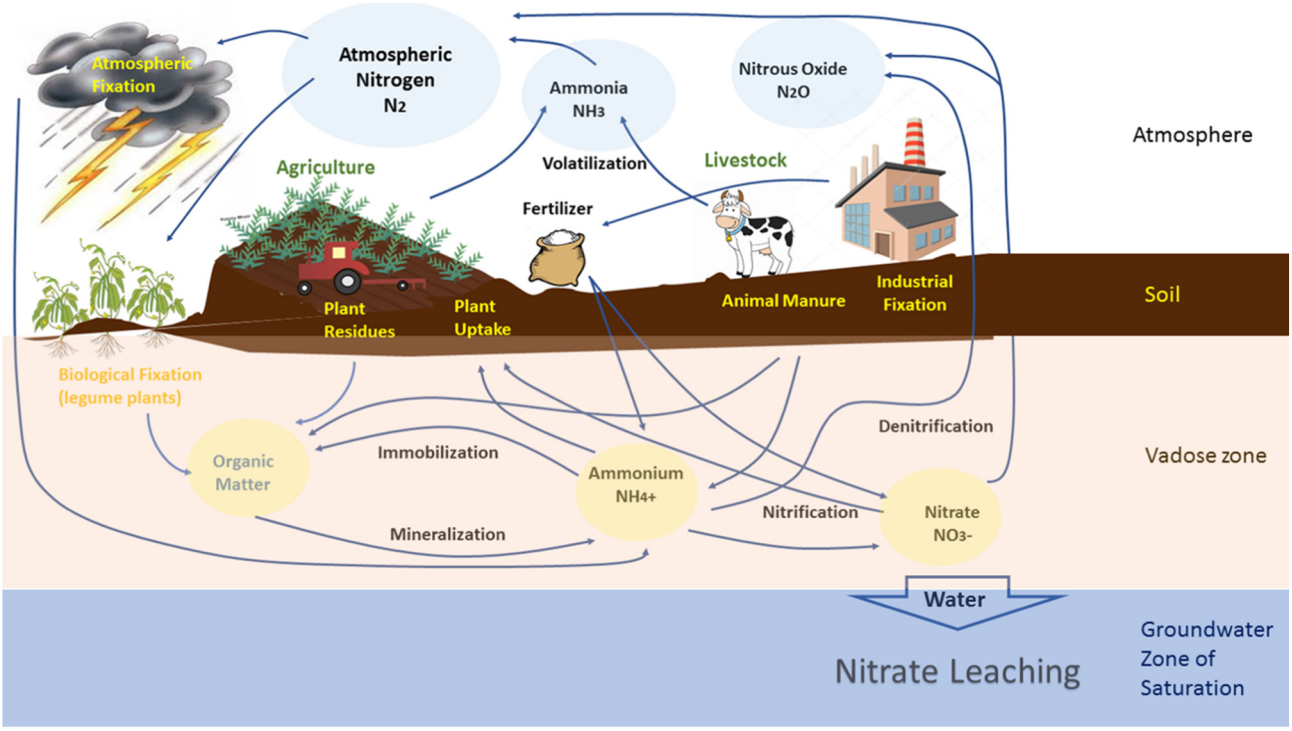

Fig. 1. The nitrogen cycle and the nitrate leaching process.