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Editorial

Biogeochemistry: Historical and Future Perspectives

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Editorial

Biogeochemistry is a very recent branch on the "tree" of natural sciences, where chemistry emerged from Alchemy in the 18th century, leading to Geochemistry in the 19th and to Biogeochemistry in the 20th century [1]. While chemistry deals with the understanding of substances, the focus of geochemistry is the earth crust and the cycling of elements. It was the insight of modern times, that most reactions that drive geochemical cycles are regulated by organisms. The prefix "Bio" represents this fact. This new "twig" of the "tree" of science would have remained purely "academic", if other "branches", mainly Meteorology, would not have signaled early signs of global climate change. It was the Intergovernmental Panel on Climate Change that identified "Bio" including human actions as the most likely cause for observed changes in climate, and that made Biogeochemistry a prominent "branch" of science [2]. Biogeochemistry investigates the linkage between organisms and the global element cycles from ecosystem level up to the global surface where human actions emerge as main driver also of natural processes.

Humans influence the global system mainly through human activities (Figure 1), ranging from agriculture to recreation. These activities result in land use and land-use change (LULUC), in biotic changes, and in changes of global biogeochemistry. Each of these sectors results eventually in climate change and in changes of biological diversity, which again feedback on the original drivers. Predictions, however, are beyond natural science, because they include human decisions, which are not science based. It is one "success" of biogeochemistry to make the public aware of the fact, that biogeochemical processes have a legacy effect, i.e. decisions in the past affect the future irrespective of further regrets. Nevertheless, for the science of Biogeochemistry there is plenty of room for further progress.

Biological processes are physiologically regulated to maintain non-equilibrium between environment and organisms, which makes organisms distinct from the non-living world. We know that the physiology of an organism is extremely complex at the molecular level. Nevertheless, in global models the carbon cycle of a biome eventually collapses to a single characteristic number, the turnover time of carbon in ecosystems, in order to make these models "useful". Major progress has been made to bridge these scales. Carvalhais et al. [3] quantified the carbon turnover-time of ecosystems, starting from photosynthesis and ending at net biome productivity [4]. It was a surprise to see how volatile carbon is. The global mean carbon turnover time is only 23 years. This contrasts nature conservation which embraces old trees, or soil science which highlights old carbon in soils. Old trees and old carbon make up only a minute fraction of all trees and all soil carbon. Thus, biogeochemistry has helped to quantify simple terms of reference in the element cycles of the earth, even though we lack understanding of the regulation of major processes in organisms.

The carbon cycle has been the primary focus of Biogeochemistry in the past because of the climate forcing by CO_2. However, biogeochemistry will remain descriptive without recognition of the nitrogen and phosphorous cycle [5-7]. The problem is that these cycles do not directly affect the radiation balance of the globe, but they are part of global Climate Change controlling the physiological activity of the earth surface [8].

The Global element cycles are generally assuming a natural vegetation cover even though the total earth surface is meanwhile affected by human activities. A main problem, however, remains with including LULUC. Even though deforestation and afforestation has been recognized as main component in the global carbon cycle [9], it has only recently entered global biogeochemical models [10]. Even more complicated is the recognition of land use intensity, including fertilizer- and harvest intensity [11]. Future progress is needed to include these human actions and their transformations of organic N in a global element cycle [12].

It becomes increasingly obvious, that the political climate target of sealing temperature increase at 2K will not be met. The demand for energy and food and fiber is such that we run out of natural mitigation options. Geo-engineering emerges as technology but it is presently mainly used to extracting even higher amounts of fossil carbon from the Earth crust. Nevertheless, Geo-engineering is ready

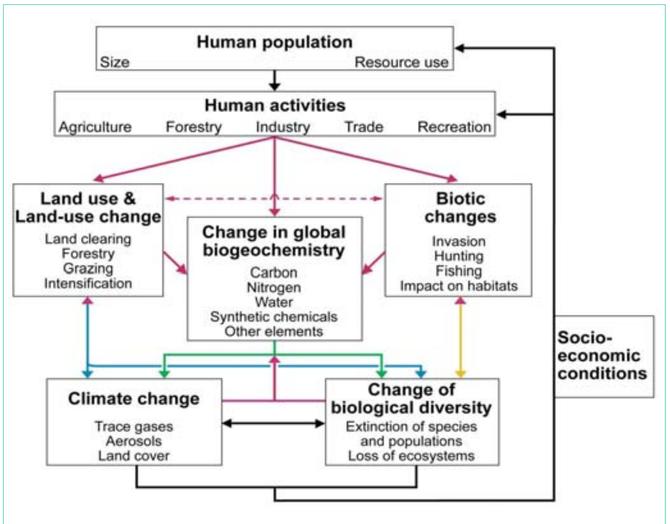

Figure 1: Schematic drawing of the interactions between human populations, land use, Biological diversity, Climate change, and Biogeochemistry.

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to manipulate Earth climate. Biogeochemistry will have to play a major role in quantifying the biological effects.

Besides all venues in climate change research it remains a worry that Biogeochemistry has not made the link to Biodiversity. The public is presently more concerned about the loss of biodiversity (the 6th event of extinction in the history of life, Pimm et al. [13]) than about biogeochemistry and climate change. The views are controversial about the importance of species in regulating biogeochemical cycles. Modern approaches combine species into traits, such as albedo. However, if only traits are important, we may not need species on the globe, and traits could be man-made. Again, there are also subtle societal effects when dealing with biodiversity. Hunting, as executed by about 1% of the population in industrialized nations, results in overpopulations of ungulates and thus in large scale loss of diversity [14] and increasing risk of ecosystem collapse [15] with unknown effects on biogeochemistry.

The linkage of biogeochemistry with social sciences and biodiversity may lead to the next branch on the science "Tree" with Earth System Science.

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