

Spatiotemporal Dynamics of Water, Energy and Biogeochemical Budgets

Evrendilek F*

Department of Environmental Engineering, Abant Izzet Baysal University, Bolu 14280, Turkey

*Corresponding author: Evrendilek F, Department of Environmental Engineering, Abant Izzet Baysal University, Golkoy Campus, 14280 Bolu, Turkey, Tel: 5356645729; E-mail: fevrendilek@ibu.edu.tr

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Editorial

“Invariably, changing land use alters the quality of air that we breathe and the quality of water that we drink...More importantly; both population growth and advancing technology continually generate major changes in land use.” — Mohan K. Wali & Robert L. Burgess, Syracuse Journal of International Law and Commerce 1985.

Materials (i.e. elements, nutrients, and biomass) recycle indefinitely unlike energy (i.e. the unidirectional and entropic flow of chemical energy through successive trophic levels). Energy flows from the sun to the earth drive biogeochemical cycling. Biogeochemical cycles, and energy flows interconnect biosphere, atmosphere, hydrosphere, pedosphere, lithosphere, cryosphere, and anthroposphere to one another in a holistic way [1]. The steady-state global biogeochemical budgets such as Carbon (C) and Nitrogen (N) and energy budgets such as solar radiation, and their spatiotemporal distributions among ecosystem components are the manifestation of the dynamic balance between dissipative/source (respiration, decomposition, and mineralization) and ordering/sink (net primary and secondary production, humification, and carbonization) processes [2]. Biogeochemical cycles exhibit stoichiometrically coupled and non-linear behaviors. Locally anthropogenic disturbance regimes (type, magnitude, severity, and frequency) alter biogeochemical and energy budgets globally which in turn trigger changes in ecosystem structure and function locally and endanger the sustenance of ecological goods and services [3]. Local anthropogenic disturbances generally result from the misuse, overuse and undervaluation (externalities) of ecological goods and services at the local and regional scales. The underlying causes of the disruption of biogeochemical cycles include rapid growth of human population and consumption, poverty and unequal economic growth, use of ecologically incompatible technologies, and degradative management practices [4].

Specifically, the global N mobilization in 1997 was about 150 Tg N, of which 80% (120 Tg N) was due to food and feed production and 20% (30 Tg N) to energy production [5]. Out of the global N mobilization by food production in 1997, fertilizer production and human-induced N fixation through the cultivation of legumes and rice constituted 80 and 40 Tg N, respectively [5]. Agricultural production (50%), energy production (15%), and biomass burning (10%) are the major sources of anthropogenic N emissions at the global scale [6]. Human inputs of nutrients surpass the natural aquatic and terrestrial fluxes of nutrients, thus exerting attendant qualitative and quantitative ecological constraints on ecosystem productivity, sustainability and well-being. Fossil fuel combustion and ecologically incompatible changes in land use and cover such as deforestation, and loss of biodiversity, prime farmlands and Soil Organic Matter (SOM) play an important role in increasing the atmospheric concentration of carbon dioxide (CO₂). Climate change anticipated during the next century is most likely to have significant ecological and economic consequences

at the regional and global scales ranging from food security to environmental refugees.

Key to understanding the effects of climate change on ecosystem health and well-being and to devising preventive and mitigative measures in the process of policy-making is the development of biogeochemical simulation models. Predictive performance of model simulations is in turn dependent upon the quantity and quality of input data, quantification of interaction effects, and assumptions used in the model. Therefore, there is a growing need to compile comprehensive datasets not only to understand spatiotemporal patterns of biogeochemical and energy exchanges among biomes as well as ecosystem components but also to validate and refine the current understanding. Validated regional models play a significant role in designing specific management policies and practices tailored to the soils, climate and economic conditions of a given area. In this context, the integration of Geographic Information Systems (GIS) and remote sensing techniques with mechanistic ecosystem models are the significant tools to quantify spatiotemporal patterns of biogeochemical cycles and their responses to how humans use and manage natural capital [7]. The major deficiency of the mechanistic biogeochemical models is the inability to internalize effects of international cooperation, economic decisions/incentives, consumer and producer behaviors, land-use decisions, and management practices about publicly or privately owned natural capital with market and/or non-market values. For example, the atmosphere is a property of the global environmental commons of humans, and increasing rates of national Greenhouse Gas (GHG) emissions beyond sequestration capacities of ecosystems, without impunity in the short-term, endanger the long-term chemical stability of the atmosphere globally (“tragedy of the commons”). International cooperation is needed about (1) the determination of global stabilization levels for GHG emissions in the atmosphere (safe minimum standards) through a scientific consensus, (2) the identification of emission sources and sequestration sinks of GHG through a methodology common to all nations, (3) the adoption of economic measures to enforce the GHG stabilization targets both within and among nations such as incentives, subsidies, taxes, and regulations, and (4) the distributive justice of the historically, ecologically and economically placed burden to stabilize GHG emissions among nations. To increase the utility of simulation models in the processes of ecologically compatible, economically viable, and socially acceptable decision- and policy-making calls for meeting the challenge of linking biogeochemical responses of ecological systems with behaviors of economic and socio-cultural systems.

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