Using percolation theory and an ecological optimum to understand water partitioning on the Earth's surface, including streamflow and vegetation response to climate change

Allen Hunt

Wright State University, Dayton, United States

Quantifying partitioning of rainfall P into run-off Q and evapotranspiration ET at the terrestrial Earth's surface is the central problem of hydrology. ET of plants is by far the best single predictor of plant net primary productivity (NPP) since it expresses simultaneously limitations from insufficient solar energy (potential evapotranspiration, PET, equal to a depth of water that could be evaporated) and P, simultaneously. Because the input of solar energy into ecosystems limits all subsequent transformations of energy, this is a central problem of ecology and climate change as well. Human civilization depends on run-off/streamflow for drinking, agriculture, industry, transportation, and power. The planet's thermal regulation and atmospheric composition depend on ET, the working fluid of the vegetation engine. Percolation theory governs soil formation rate through the process of solute transport-limited chemical weathering, and thus the conversion of atmospheric carbon to carbonate rock reservoirs. Percolation theory also governs the rate of ET through plants in its definition of the optimal paths for advective nutrient transport to plants and the associated paths along which roots grow in order to access these nutrients. Since lateral spreading of plant roots is thus related to the 2D fractal dimension of percolation theory and to the evapotranspiration fluxes, but the soil depth is determined through run-off by the 3D backbone fractal dimensionality, it is possible to find a maximum in plant root mass through a procedure assuming that ecosystem dominance is guaranteed by its optimal conversion of atmospheric carbon dioxide to biomass. This optimality principal is extended to arid regions by applying it only to vegetated ground, a fraction P/PET of the surface, and to humid regions by applying it only to that portion of P equal to PET. This zero-parameter result has been verified to equal the best-fit function of (PET/P) for a global FLUXNET study on evapotranspiration across climate regimes and biomes. Including storage S changes, observed behavior of elasticity (P/Q)(dQ/dP in global and continental scale studies as well as Budyko's catalogued observations of NPP as a function of P and PET simultaneously. Finally, the input relationships for soil depth and vegetation growth are verified across the world's precipitation regimes, from the Atacama desert to the tropical and temperate rainforests and for time scales of up to 130,000,000 and 100,000 years, respectively.