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Toward Nexus Equation: A Conceptual and Mathematical Framework for Water- Energy-Food Nexus

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Water, energy, and agriculture are highly interdependent that attempts to achieve sustainability in any of those three domains will directly impact the others. These interdependencies, collectively known as the Water-Energy-Food Nexus, become more complex and more critical as the climate changes, the population grows, habits and lifestyles alternate, and the prices of water, energy, and food increase. However, and despite several attempts to incorporate the nexus, the global research community continues to focus on different subsets of the problem with limited holistic attempts to address the full problem. At best, interactions between two of the three domains were studied, often neglecting the impact of such interaction on the third domain. For example, agricultural researchers tracked water costs by applying concepts like virtual water or water footprint, or using large-scale system models to investigate food and water security, ignoring most often the corresponding energy footprint. Similarly, investigators quantified water-energy tradeoffs in the highly engineered, centralized systems of water and power management, paying no attention to water diversion from agriculture. Most nexus initiatives focused on reviews and data collection of existing knowledge and relevant facts, but unfortunately lacked a conceptual and mathematical framework that can integrate all the gathered knowledge and account for multiple interactions, feedbacks, or natural processes that occur across all three domains of the nexus. Here, we present an integrated conceptual and mathematical framework (roadmap) for the nexus. This framework is driven by spatiotemporal demands for water, energy, and food to be satisfied by resource management of the three domains, envisioned as a stepwise process, with each step requiring inputs from the three nexus domains and creating waste products. The efficiency of each step, combined with mass balances, create the linkages and feedback loops within the nexus. Such an approach allows for a compact, single representation of the 'nexus equation' that generally represents all interactions, material pathways, feedback loops and embedded resource echoes.