Controlled-Environment Agriculture and the Geography of Food, Energy and Water Resilience in the United States

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Background/Objectives. USDA guidelines call for an increase in fruit and vegetable consumption in U.S. households to promote healthier diets. Access to fresh fruits and vegetables are especially lacking in food deserts and food swamps (characterized by a prevalence of food that is highly processed and lacking in nutritional value). Adoption of the recommended healthy diet, which more than doubles the consumption of fruits and vegetables, would have a wide variety of health benefits and would reduce the land footprint of U.S diets. However, adopting a healthy diet would increase phosphate and nitrogen impacts associated with fertilizers and pesticides and would significantly increase freshwater consumption and energy use because of the resource intensity of field cultivation of fruits and vegetables.
The majority of these crops are grown in just a few states, including California and Arizona, which are increasingly impacted by climate change. In addition, rural communities are rapidly becoming food deserts, while food produced in these areas is transported long distances to market. In recent years, highly intensified controlled environment (CE) agricultural systems, (i.e., vertical farming) have been developed to provide fresh food closer to consumers. Fruits and vegetables, many of which are amenable to CE culture, occupy a uniquely impactful segment of the food supply-chain, including their value in improving nutrition for vulnerable communities. The objective of this work is to elucidate the location dependency of the energy and water impacts of adoption of distributed CE farming for an important portion of the food system.

Approach/Activities. This paper evaluates the potential for CE food systems to take advantage of integration, sustainability and circular economy opportunities afforded by their location within the built environment and, if deployed at scale, to displace water and energy intensive and environmentally damaging aspects of the conventional supply chain for fruits and vegetables. County and state level data provided in USDA databases and reports is used to derive baseline geographically-resolved vegetable production, water use, and fertilizer/pesticide use. Literature values are used to derive relevant water and energy use and lifecycle impact values for both conventional and CE agriculture. Food-related demographic data from the USDA Economic Research Service are used as the primary food consumption inputs for modeling of energy and water inputs, agricultural production and community impacts.

Results/Lessons Learned. According to USDA data, California accounted for nearly half (47%) of U.S. tomato utilized production in 2018. Water use for that production was nearly double the national average of about 37.5 liters/kg, and California's agricultural water use as a percentage of the total water available for all uses has more than doubled in dry years. In contrast, tomatoes grown in vertical farms require only about 20% of the water needed for field production, and the closed environment and recycling greatly reduces fertilizer use and largely eliminates pesticide use. However, the significant energy demands of indoor farming as well as opportunities for integration into the built environment must be better understood to support its broader adoption. The analysis outlines the geographically-dependent energy and water impacts for deploying CE agriculture for the fraction of the food supply chain that is most suited to indoor farming. The research evaluates the premise that energy and water impacts of agriculture are highly location-dependent, and that distributed CE food production can improve the resilience and sustainability of the food system when these dependencies are factored into analyses.