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Food-Energy-Water (FEW) Nexus for Productive Community Design: Review and Prospect

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Abstract

In the context of the acute contradiction between supply and demand of resources, urban communities are faced with the difficult problem that how to achieve sustainability. The combination of productive city theory and food-energy-water nexus research provides a way to realize the sustainable design and development of communities. This paper reviews the development status of the two theories and puts forward suggestions and prospects for the research of productive community's design based on FEW nexuses.

Keywords: Food-energy-water nexus; Productive city; Community design; Optimization tools; Resource system

Introduction

The advancement of global urbanization and the increase in population have caused many problems such as food safety, energy depletion, ecological pollution, etc. As an important component unit of urban structure, community occupies a huge proportion in urban development in terms of spatial scale and resource consumption. In the face of environmental degradation and social demand, that how to achieve sustainable development is a difficult problem for community construction. The theory of productive city provides a way for communities to comprehensively use resources, improve overall carrying capacity, and realize the sustainability of human beings and nature. However, the balance and interaction between resources have not been studied in depth. To realize the sustainable use of food, energy, and water in community design, it is necessary to comprehensively consider food-energy-water nexus and determine a solution to coordinate multiple resources. The combination of the two makes the healthy and sustainable development of the community possible. This article reviews the research status of productive city theory and food-energy-water nexus study and points out the research direction and prospect of community design based on the combination of the two theories, for the purpose of creating a resilient community environment that can support urban development and is more suitable for human habitation.

Review

Research on productive cities

People realize that complex urban problems cannot be solved through the exploration of a single resource due to the resource and economic crisis, and it is necessary to actively excavate urban productivity potential of multiple resources. In 2012, the Local Government for Sustainability held an annual meeting with the theme of "productivity", dedicated to calling for production [1] and the theory of productive city came into being. In the Fab city prototype course of IAAC in 2015, self-sufficient neighborhood prototype was designed from food, energy, water and other aspects. In 2016, the productive Atelier Rotterdam integrated production and consumption, learning, work and manufacturing spaces at the community scale [2]. In 2016, Zheng put forward the theoretical framework and strategic system of

productive city [3]. Under the guidance of this theory, Zhang [4] & Yu [5] discussed the integration and design strategies of different resources in the community.

The concept of a productive city requires the comprehensive utilization of resources in community space in the process of renewal and construction. However, the interdependence and interaction of resources in the community is still unclear, and that how to quantify and determine the utilization of resources and space has not been further studied. Therefore, it is necessary to seek self-sufficient methods for productive communities from the perspective of food-energy-water nexus.

Research on food-energy-water nexus

In 2011, the Bonn Conference was held in Germany. At the conference, the focus was officially shifted from the previous research on the pairwise relationship between food, energy, and water to FEW nexus [6], with a view to improving the efficiency of resource utilization. Since then, FEW nexuses has attracted much attention, especially after 2015, many achievements have emerged, including the optimization of the food-energy-water-waste nexus under the background of the COVID-19 pandemic in 2020 to alleviate environmental concerns [7], which further illustrates the necessity of FEW nexus research. In this paper, FEW nexuses were used as a keyword and searched in the core collection of Web of Science. After being screened, 192 documents were obtained. With the CiteSpace.5.7. R2 tool, keyword clustering analysis was performed (Figure 1) and the top 5 research hotspots were found, including "Bibliometric Analysis", "Circular Service", "Using Satellites", "Benefit-risk tradeoff", "Food Waste" and "Solar Photovoltaic Electricity Generation". The literature research content is mainly concentrated in three aspects of theoretical research of FEW nexus, development of model framework and empirical application [8]. What needs to be focused on is how to sustainably meet the needs of food, energy and water in spatial design and decision support.

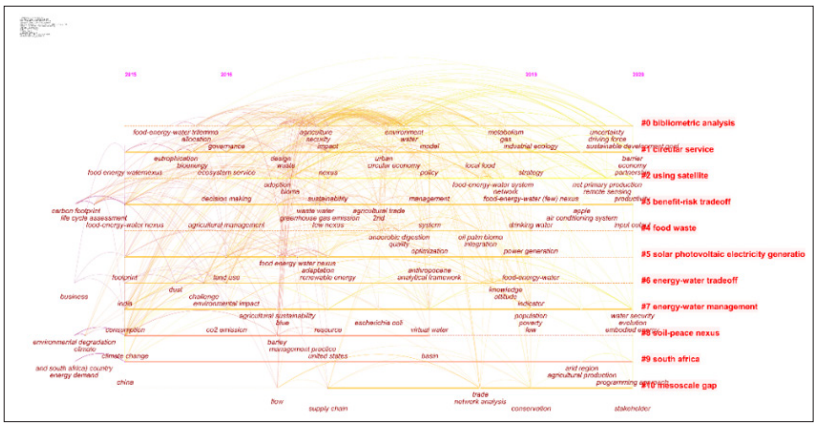

Figure 1: Keyword clustering analysis.

In terms of design research based on FEW systems, Tien used new integrated system design practices to improve resilience of buildings and their linked food-energy-water systems [9]; Karan et al. [10] designed a small-scale FEW system that can meet the needs of a family of four for producing food, collecting and recycling water and getting energy from solar photovoltaic panels [10]; Toboso-Chavero et al. [11] developed Roof Mosaic, a method of using roofs to produce food and renewable energy and to collect rainwater, which provides a variety of options for productive development of roofs; Salvador et al. [12] took a technology park as the research object and explore the potential of realizing self-sufficiency through Roof Mosaic method; Hang et al. [13] established integrated local production systems to make the best use of the existing local renewable resources.

At the level of design decision support based on the FEW system, Whitney et al. [14] introduced a Micro FEWs approach from the energy perspective to help remote communities in Alaska make informed decisions to increase FEW security ; Yuan et al. [15] proposed an environmental impact minimization model to optimize the spatial distribution of three kinds of energy crops in Taiwan Province; Yan et al. [16] developed a participatory design support platform for developing FEW solutions in cities, gradually realizing joint development and improving land and resource efficiency.

Through the analysis of FEW nexus, it is found that the current research is at a preliminary stage and there are certain limitations as follows: (1) FEW nexus is mostly concentrated in the global, cross-regional and national scale, and gradually expanded to the city scale in recent years. There are relatively few studies on the scale of communities and other scales; (2) Research hotspots show that more attention is paid to food waste and energy-water respectively, and the relationship between the three requires further exploration; (3) There have been some achievements in the design and application of FEW systems, but that how to apply FEW systems to the community productive spaces still needs to be solved.

Challenge and prospect

In the light of the challenge of systematically excavating urban productivity potential, FEW nexuses will become a bottleneck restricting the circulation and metabolism of productive communities if it cannot be further studied. There are relatively few studies in this area at present, and that how to quantify design methods in productive communities to make optimal design decisions to achieve FEW nexus coordination is a direction for future community design. Future research can focus on the following two aspects:

(1) How to evaluate productive community design from the perspective of food-energy-water nexus. The evaluation index system of productive community can be transformed into indicators that can be measured by FEW system status and residents' evaluation. For example, residents' satisfaction reflects the degree of social co-construction, co-governance and sharing, the self-sufficiency of life represents the self-sufficiency ratio of community resources, the mixing degree of productive function represents the completeness of production facilities and modes, etc. Afterwards, the deficiencies and limitations of the subsystem can be analyzed through evaluation indicators.

(2) How to design a set of decision-support tools to balance the interaction of food, energy and water resources in the community through the quantitative spatial design strategy, and maximize utilization in the production, consumption and recycling links. The three resources combined with different spaces in the community design can produce different benefits. By quantifying the space design strategy, it is possible to design decision-support tools to combine the strategies of food-energy-water nexus dynamic to maximize resource utilization and guide the design optimization of productive communities.

Conclusion

FEW nexuses for productive communities is not only a resource issue, but also a problem of space utilization, system flexibility and quality of life of residents. At present, the study on the application of FEW nexus for the community is still in the early stage, and the complex interrelation and interdependence of FEW nexus still needs more research. In the context of urbanization, the design of productive communities based on FEW nexuses will provide new ideas for the sustainable development and transformation of cities and communities, providing greater flexibility to cope with comple x challenges such as resource shortages.

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