The challenges facing agricultural systems – biodiversity loss, climate change, and corporate consolidation of food production, to name a few – demand transitions to more environmentally and socially sustainable agricultural systems [Hebinck\_Klerkx\_Elzen\_Kok\_König\_Schiller\_Tschersich\_van Mierlo\_von Wirth\_2021](https://www.zotero.org/google-docs/?rSRxF3). Supporting sustainability transitions, however, is no easy task. While the decision to adopt a new technology or change behavior is made at the individual level [Buttel\_Jr\_Larson\_1990\_Rogers\_2003](https://www.zotero.org/google-docs/?Y0Mte3), individuals are shaped by the broader innovation system in which they are nested [Klerkx\_van Mierlo\_Leeuwis\_2012](https://www.zotero.org/google-docs/?DvQAj1). An innovation system is the complex of interactions between actors and institutions that nurture and diffuse new technologies or practices based on several interdependent processes, such as policymaking, knowledge creation, and market formation [Bergek\_Jacobsson\_Carlsson\_Lindmark\_Rickne\_2008](https://www.zotero.org/google-docs/?sr9u3m). The interplay between individual behaviors and system level processes is at the core of successful innovation and transitions. Which processes to foster for successful transitions, at what scale, and by whom are core questions in the niche management and innovation system literature [Binz\_Truffer\_2017\_Musiolik\_Markard\_Hekkert\_Furrer\_2020\_Smith\_Raven\_2012\_Suurs\_2009](https://www.zotero.org/google-docs/?Y02tfR).

Across three chapters, this dissertation addresses questions about sustainability transitions at both the individual and system levels using the case of organic seed. Among the inputs necessary for supporting a sustainable agricultural system, seeds are one of the most foundational. While the dominant seed breeding approach in countries like the United States is based on high-input, low-diversity and highly centralized conventional agricultural practices [Lammerts van Bueren\_Struik\_van Eekeren\_Nuijten\_2018](https://www.zotero.org/google-docs/?QxCtrS), several alternatives (so-called "niches") have developed to support a more sustainable system. This work focuses on the organic agriculture niche, in which seed production systems are typically low-input and high diversity with polycentric management [Colley\_2022\_Rohe\_Oltmer\_Wolter\_Gmeiner\_Tschersich\_2022\_Shelton\_Tracy\_2015](https://www.zotero.org/google-docs/?ZMVKpi). The focus on organic seeds was inspired by the Organic Seed Alliance's (OSA) *State of Organic Seed Reports* [Dillon\_Hubbard\_2011\_Hubbard\_Zystro\_2016](https://www.zotero.org/google-docs/?T9FO7R). OSA's research conceives of organic seed as part of a broader system – not just breeding and agronomy, but also policy support, funding mobilization, community building, and small business development. This framing mirrors the innovation systems approach, where environmental challenges require system-level assessments that connect and transcend disciplines.

The focus of Chapter 1 is on the organic standards in the United States, specifically, the so-called "seed loophole" whereby growers can use conventional seed if organic seed is not commercially available and still retain their organic status. We investigate whether this loophole helps reduce organic growers' seed sourcing burden, as the policy intends, or enables them to free-ride by using conventional seed despite commercial availability. Drawing on organic grower survey data from three cross-sections over the last 15 years, we use beta regression to model individual growers' seed sourcing behavior. The results of the regression suggest that the loophole is a double-edged sword in that it both helps growers facing seed sourcing barriers, and allows some growers to take advantage of the flexibility by reducing their efforts in sourcing organic seed. The chapter concludes with several policy recommendations, which align with the 2022 *State of Organic Seed Report* [Hubbard\_Zystro\_Wood\_2022](https://www.zotero.org/google-docs/?XzyfRv). Beyond, it opens up a wider discussion about competing motivations and identities in sustainability transitions to be considered in future research.

Chapters 2 and 3 broaden the scope of study from the individual-level to the system-level. Both of these chapters draw on innovation system theory, combined with policy network and social network literature, to quantify and explain the relationships within the organic seed innovation system as a network. We use survey data of over 200 organic seed stakeholders within and outside the United States, collected between 2020-2022, to create a multi-functional innovation system network comprising 645 actors and 1206 connections between them. These connections operationalize knowledge and market-based relationships between organic seed producers, researchers, companies, and non-profit organizations.

In detail, Chapter 2 focuses on explaining the spatial structure of the US organic seed network, testing the propositions defined by the Global Innovation Systems framework [Binz\_Truffer\_2017](https://www.zotero.org/google-docs/?Gd8gyP). Using n-clan compositional analysis and Exponential Random Graph Modeling, we find support for the framework's proposition that types of innovation and production valuation are two key conditions predicting the innovation network's spatial structure. In line with these conditions, we find that the organic seed system has a "spatially sticky" network structure, in that both knowledge creation and product valuation are territorially embedded in different regions of the country. But even in a regionally sticky innovation system, we find that national-scale actors (e.g. the US national germplasm repository) serve a prominent role in connecting regional networks. These results highlight both the importance of tailoring policies to the place-specific needs of regional organic seed systems, and the importance of coordination from higher-scale actors.

Chapter 3 investigates the processes and actor composition of the organic seed innovation system. Again using Exponential Random Graph Modeling on the organic seed networks, we test two theories in parallel: resource-based theory of system building [Musiolik\_Markard\_Hekkert\_Furrer\_2020](https://www.zotero.org/google-docs/?H6obWt) and the institutional logics of the multi-actor perspective [Avelino\_Wittmayer\_2016](https://www.zotero.org/google-docs/?pNAlBv). In line with the expectations from the resource-based theory, we find that the organic seed network is shaped primarily by "partner mode" structures, suggesting that cooperative and complementary resource-sharing relationships drive system formation. Second, our results align with the proposition that actors' "institutional logics" affect their activity in certain network functions. For example, non-profit actors are generally more active in pre-competitive activities like knowledge creation, while for-profit actors are more active in market-based functions like value chain creation. The one exception is governmental actors, who are more active in market-based functions, pointing to their innovation-nurturing role when niches are not yet competitive.

Together, the chapters in this dissertation make the following contributions. Chapter 1 analyzes the effects of the "seed loophole" in the United States organic standard, and makes several policy recommendations for achieving the intended effects of the policy while curbing free-riding behavior on the part of organic growers. Chapters 2 and 3 contribute to the field of sustainability transitions by empirically testing and extending innovation system theory using inferential network analysis. By employing Exponential Random Graph Models, these chapters not only describe the organic seed network, but also investigate its structural determinants to help build a more generalizable understanding of innovation system formation. This work combines theory and methods from the two otherwise disparate bodies of knowledge on innovation systems and policy networks, to help deepen our understanding of managing and supporting sustainability transitions.

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