A Systematic Review of Innovation Ecosystem Subcategory Metaphors:
Towards Evidence-Based Policymaking

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Abstract: In recent years, ecological metaphors have been widely used in the field of innovation. Such excessive preoccupation of researchers with common ecological metaphors such as ecosystems and lack of due attention to the development of other ecological axioms challenges its systematic conceptual web. This renders such metaphor a “boundary object” which would hinder linking theoretical discussions on innovation ecosystem to practical usages and policy making. Therefore, there is a need for an evidence-based approach to define and map the innovation ecosystem metaphorically so that the deployed concepts would constitute a part of the conceptual network of the innovation ecosystem. As an endeavor to EBP in the field of the innovation ecosystem, this study draws on Scaringella’s and Radziwon’s (2019) systematic review framework and the

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comparative-qualitative content analysis method based on the structured matrix which grounded in metaphor mapping. Upon analyzing the content of the selected articles, the ecological metaphors grounded in innovation ecosystems can be classified into two general categories: metaphors concerned with actor (species, population, and community) and metaphors concerned with environment (landscape, biome, and ecotone). As a tool, the developed framework enables innovation policymakers to make decisions based on an effectual understanding of seven hierarchical metaphorical layers of innovation ecosystems. Consequently, policymakers should not restrict their governance to the recommendations provided by the literature on ecosystems that is popular at the present time; rather, with the same energy, they should consider the multiple dimensions of innovation ecosystems in terms of actors, environment, and the relationships between them based on an ecological perspective.

Keywords: Innovation, Ecosystem, Ecology, Metaphor, Evidence-Based Policymaking (EBP)

1. Introduction

In recent decades, numerous researchers have metaphorically used ecological concepts to propose and develop theoretical frameworks, as well as to gain scientific insights (e.g., Moor, 1993; Iansiti and Levien, 2004; Iansiti and Richards, 2006; Allen et al., 2013; Zahra & Nambisan, 2012; Clarysse, 2014; Nambisan & Baron, 2013; Cornelissen, 2004; Morgan, 1980; and Veit & Ney, 2021). In fact, the wide range of metaphorical ideas in ecology (Shaw & Allen, 2018) enables researchers to uncover new dimensions in the realms of innovation, business, and management, and to gain fresh insights into the concealed aspects of phenomena (Cornelissen, 2004). This particularly holds true in the sphere of innovation, as there is significant compatibility between innovation and the ecological environment in terms of systematicity, complexity, dynamism, and other factors (Shaw & Allen, 2018) (Table 1).

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Table 1. Similarity of natural ecosystem with innovation ecosystem

Dimensions	Key components	description (Shaw & Allen, 2018)
systematicity	Interdependence and organization	'Natural ecosystems and innovation ecosystems are both systems that are made up of entities joined by relationships and some of these relationships are organized in similar ways.'
	Entities	'The entities in both types of systems are heterogeneous and appear to behave at different spatial scales and at different natural frequencies.'
	Relationships	'In both types of ecosystems entities compete, attack, consume and also help each other in mutualistic situations.'
	Resource flows	'Natural ecosystems use solar energy to power their use of nutrients to live, grow and reproduce. Innovation ecosystems also use physical energy sources to power processes that use other resources and they also use value creation in a similar way to energy, as a way to motivate and influence processes that involve their human elements.'
	Sources	'Both types of systems use information as a resource for streamlining their behaviors at different system levels.'
complexity	Numerous and varied feedback	'The interconnectedness of both types of systems with positive and negative feedback loops on different scales and with different lags makes each system difficult to study.'
	Inevitable error of studies	'Both ecology and business studies share errors such as collecting data for the sake of it, reifying particular phenomena because they are tangible while ignoring other phenomena because of bias.'
dynamism	Constant change	'Natural and innovation ecosystems change continuously and change happens at different scales requiring different levels of analysis.'
	Processes of adaptation	'Both types of systems adapt to internal and external disruption.'
managerial	outputs management	'There is a great interest by researchers in managing their outputs.'

Note. Own elaboration inspired from Shaw & Allen (2018)

Nevertheless, most researchers in this field have primarily focused on the metaphor of ecosystems and the relationships between actors (e.g., Adner, 2006; Jackson, 2011; Nambisan & Baron, 2013; Brusoni & Prencipe, 2013; Gobble, 2014; Autio & Thomas, 2014; Scozzi et al., 2017; Tamayo-Orbegozo et al., 2017; Bomtempo et al., 2017; Walrave et al., 2018; Gomes et al., 2018; Ding & Wu, 2018). As a result, other ecological levels (Figure 1), except in a few cases (such as biome and landscape (Shaw & Allen, 2018); ecotone (Ghazi Nouri et al., 2020); biosphere (Mercier-Laurent, 2015)), have been understudied. Such excessive preoccupation of researchers with common ecological metaphors, such as ecosystems, and lack of due attention to the development of other ecological principles (Ritala & Almpanopoulou, 2017), challenges the systematic conceptual framework (Lakoff & Johnson, 1980). The first characteristic of an innovation ecosystem as a conceptual metaphor is its systematization. It means that when we use a metaphor, we are transferring a thought system from one element to another. For example, in the 'argument is war' metaphor, terms such as Attack, defense, retreat, maneuver, counterattack, stalemate, withdrawal, surrender, victory, etc., are used systematically about aspects of the debate. The use of these terms is not accidental. A part of the conceptual network of war partially defines this concept of discussion and aligns with the appropriate language (Lakoff & Johnson, 1980). This characteristic of the conceptual metaphor also applies to the systemic conceptual web of the innovation ecosystem metaphor.

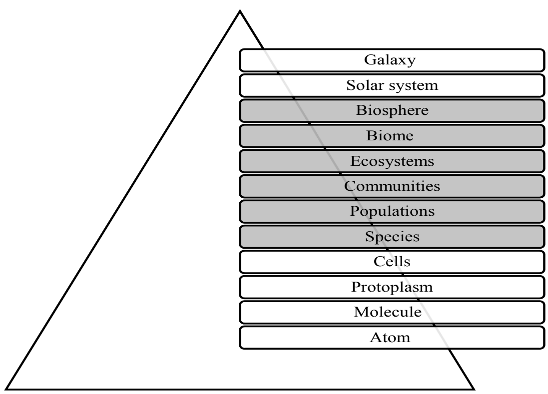

Figure 1. Ecological hierarchical levels (from species to biosphere)[1]

1. The definition of each level is presented in Table 1

Ignoring this feature reduces the metaphor of innovation ecosystems to a mimetic quality (Oh et al., 2016). On the other hand, this undermines the effectiveness of using the metaphor of a "boundary object" (Eppler and Platts, 2009; Romme, 2016; Spee & Jarzabkowski, 2016) in connecting theoretical discussions on innovation ecosystems to practical application and policy-making. This somehow leads to policy-making based on opinions rather than evidence (Sanderson, 2002). A boundary object is defined as "flexible epistemic artifacts that exist in multiple intersecting social worlds and fulfill the informational requirements of each" (Star & Griesemer, 1989). Therefore, there is a need for an evidence-based approach to redefine and map the innovation ecosystem in a metaphorical manner. The concepts deployed would then become integral components of the conceptual network within the innovation ecosystem. Evidence-based policymaking is based on making informed decisions, having a thorough understanding of the problem, using reliable evidence, achieving consensus and rationality in policymaking, and having access to a wealth of information (Campbell et al., 2007). However, opinion-based policy-making relies on preferences or expert judgment rather than relying on reliable and high-quality evidence as the basis (Sutcliffe & Court, 2005).

The systematic review has become widely recognized as an aid to evidence-based decision-making (Petticrew, 2003). By synthesizing the best available research on a specific topic, systematic reviews can make a significant contribution by summarizing existing knowledge and identifying areas of uncertainty (Petticrew, 2003). As a result, the pursuit of evidence-based policy has increasingly relied on systematic reviews of previous investigations in the relevant policy area (Pawson, 2002). To apply evidence-based policy in the field of innovation ecosystems, this study utilizes Scaringella and Radziwon's (2019) systematic review framework to redefine and conceptualize the metaphorical representation of the innovation ecosystem. Therefore, the structure of this study is designed as follows: The first section briefly reviews the theoretical background of the research. The second part explains the research methodology. The third part presents the findings of the research. The fourth part of the research discusses the findings and presents the policy and research implications.

2. Literature Background

There are two distinct approaches in literature toward metaphor (Lakoff & Johnson, 1980): classical and conceptual. In the classical view, metaphor is a rhetorical device in which one or more words are used in a non-literal sense to convey similar meanings. Its main function is to enhance and modify speech and writing. However, the conceptual metaphor is the act of "understanding and experiencing something" through "the terms and expressions of something else" (Lakoff & Johnson, 1980). Lakoff & Johnson (1980) refer to the foundation of this relationship, which occurs through correspondences between two sets, as "mapping". According to metaphor mapping, there is a mutual correspondence between two domains in ecological metaphors. The domain that contains objective and conventional concepts is called the source domain (in this research: natural ecosystem), while the one that contains abstract and subjective concepts is called the target domain (in this research: innovation ecosystem) (Figure 2). In the following, both semantic domains will be explained briefly:

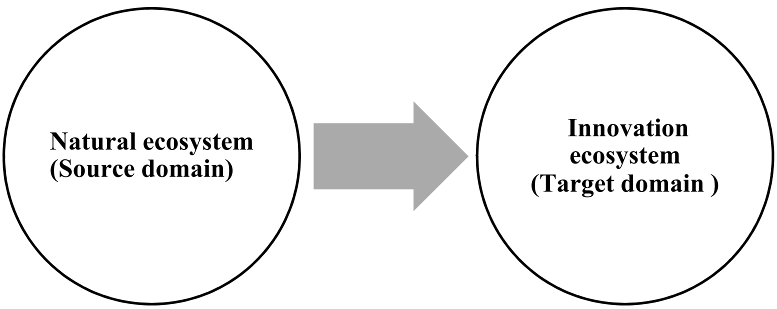

Figure 2. Mapping the framework of ecological metaphor

Innovation ecosystem: The innovation ecosystem, as a target domain, has been defined by many researchers. Ander (2006) defines an innovation ecosystem as "a collaborative arrangement" in which companies combine their individual offerings, such as technologies, to create integrated and customer-centric solutions. Nambisan & Baron (2013) define an innovation ecosystem as "a network of loosely connected actors and entities that co-evolve capabilities around a shared set of technologies, knowledge, or skills, and work collaboratively or competitively to develop products and services." Gobble (2014) defines an innovation ecosystem as dynamic and purposeful communities with complex and interconnected relationships based on cooperation, trust, and the co-creation of value. These communities specialize in leveraging a shared set of technologies and complementary competences. Gomes et al. (2018) define an innovation ecosystem as a group whose goal is the "co-creation or joint creation of value." It consists of interconnected and independent network actors, including the focal company, customers, suppliers, complementary innovators, and other regulatory institutions. Also, this definition includes the two components of cooperation and competition in innovation ecosystems and considers the life cycle of innovation ecosystems as the outcome of a co-evolutionary process. Granstrand & Holgersson (2020) define an innovation ecosystem as "a complementary whole that consists of actors, activities, byproducts (products, technologies, etc.), rules, and relationships that are vital for innovative performance for one or a group of actors."

Natural ecosystem: In ecology, an ecosystem consists of all the organisms and the abiotic components (or physical environment) with which they interact. The biotic and abiotic components are interconnected through nutrient cycles and energy flows (Odum & Barrett, 1971). From a biological perspective, the conceptual network of ecological concepts related to ecosystems has a diverse hierarchical range that spans from the biosphere to species (Odum & Barrett, 1971) (Figure 1). The most prominent concepts related to the ecosystem are presented in Table 2.

Table 2. Conceptual network of ecological concepts related to ecosystem

Ecological concept	Definition
Species	A species refers to a group of living organisms that have the possibility of gene transfer and reproduction, and their offspring have reproductive power in the future (Zachos, 2016).
Population	Population denotes organisms belonging to a specific species located in a specific time and place and have the possibility of gene exchange (Wells & Richmond, 1995).
Community Definition	Community designates a set of population of different species that live in an assumed area and interact with each other.

Ecological concept		Definition
	Food Network	The food dependence of all living organisms on each other in the community can be compared to chained links, which is called a food chain. The interaction between food chains forms a food network (Allen & Hoekstra, 2015)
Landscape		A landscape is geographical proximity in an area whose features have structural constraints and facilitators for the flow of materials and energy (Wu & Hobbs, 2007).
Biome		Biome denotes relatively wide geographical areas, in each of which there are almost homogeneous plant and animal groups. The existence of biome depends on the macroclimate of the region. And among different climatic factors, the effect of temperature and humidity is more important than others in determining the characteristics of the biome and its living organisms (Bowman & Hacker, 2021).
Ecotone	Definition	An ecotone is an area that acts as a boundary or a transition between two ecosystems. Ecotone refers to species diversity and differentiation (called border species (Goldstein et al., 2000)) in the border areas of ecosystems (Attrill & Rundle, 2002).
	Ecocline	Ecocline refers to the change in gradient of physicochemical characteristics (such as pH changes, salinity changes, water density changes and chemical changes) between two ecosystems (Attrill & Rundle, 2002).
Evolution	Definition	In ecology, if a change in the genetic form of a species leads to a change in its behavioral characteristics and appearance, evolution is bound to happen (Hall & Strickberger, 2008). This change, in fact, occurs within the following four mechanisms:
	Mutation	Changes in the genes of a species in such a way that its hereditary characteristics change leading to phenotypic change (Futuyma & Kirkpatrick , 2013).
	Migration	Changes in the frequency of genes in a given population due to the movement of species in long distances (for example, between two ecosystems (Morjan & Rieseberg,2004).
	Natural Selection	Change in environmental conditions in a way that leads to the survival, reproduction and evolution of organisms with genes adapted to new conditions and the elimination of weaker competitors (Lewontin ,1970).
	Gene Drift	Change in the frequency of genes in a population because of random reasons such as floods, storms, etc (Futuyma & Kirkpatrick, 2013)).

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Ecological concept		Definition
Coevolution	Definition	It is notable that evolution can lead to a change in the genetic composition or the evolution of interacting species, whereby co-evolution occurs (Wade, 2007).
	Mutual Mutualism	Both parties of the interaction benefit from each other, and inevitably, the continuation of the relationship in case of evolution of one party necessitates the evolution of the other party of the interaction (Bronstein, 2015).
	Competition	The concerned parties compete over shared sources and the evolution of one party in the interaction leads to the evolution of the competitor in case it leads to more exploitation of resources (Connell, 1980)).
	Predation Parasitism	A relationship in which one party in the interaction benefits and the other party loses (Woolhouse and et al., 2002; Ballard, 2011).

3. Methodology

In order to accurately map the ecological metaphors in the field of innovation ecosystems, this paper utilizes Scaringella & Radziwon's (2019) systematic literature review framework. This framework combines the stages of a systematic review outlined by Tranfield et al. (2003) with the phases of a metanarrative review described by Greenhalgh et al. (2005). It offers a comprehensive and integrated approach to systematically investigate and analyze research. Table 3 outlines the seven-step process of the systematic review conducted in the present study, including its objectives and outcomes. Also, since maintaining the storyline and providing a comprehensive and detailed description of the research process is one of the most crucial factors for ensuring dependability (Guba, 1981), credibility (Shenton, 2004), and transferability (Lincoln and Guba, 1985) in qualitative research (McGinley et al., 2021), it is necessary to present the actions, outputs, and findings for each step. On the other hand, by explaining the details of the protocol, such as keywords, search strings, selected databases, etc., the present research also provides an opportunity to ensure the conformity of the research (Lincoln and Goba, 1985, as cited by McGinley et al., 2021).

Table 3. Review Design

Steps		Objectives	Expected outcomes
Search protocol	Scoping studies (Step 2)	Identifying Authentic database; Identifying keywords	1- Selecting the database 2- Initial list of keywords search
	Initial search (Step 1)	Estimating the size and scope of the literature; defining search criteria; defining the criterion of relevance of articles with objectives	1- Determining inclusion and exclusion criteria 2- Search protocol
Data collection & evaluation	Article search (Step 3)	Creating a database including all relevant documents to the search protocols	Relevant documents with bibliographic information
	Article selection (Step 4)	Identifying the main categories of articles	Articles that best match with the objective of the research, which are put into related categories.
	Reference backtracking (Step 5)	Identifying the articles which do not fit the first and second category but are referred to in the articles.	The complete list of articles relevant to the research
Analysis	Content analysis (Step 6)	Identification of key terms, definitions, and theoretical frameworks	Content information analysis Identification of key invariants
	Invariant analysis (Step 7)	Comparison of invariants	Development of a categories & framework

Search protocol (step 1-2): In order to provide a comprehensive review of the research background concerning the metaphorical redefinition and mapping of the innovation ecosystem, this section of the paper examines the studies conducted on subcategory metaphors of the innovation ecosystem in a step-by-step process based on primary and secondary research. The primary search aimed to identify articles that discuss the ecological redefinition of innovation ecosystems, while the secondary search focused on reviewing studies that explore the metaphorical mapping of innovation ecosystems. Upon conducting an initial search and adopting a comprehensive approach to obtain a manageable and representative sample of studies, keywords were identified. These keywords can be found in Table 4.

Table 4. Search protocol

Primary search			Secondary search		
Search database			**Search database**		
database 1	**database 2**	**database 3**	**database 1**	**database 2**	**database 3**
WoS	-	-	Google Scholar	Scopus	WoS
Search keywords			**Search keywords**		
Term type 1	**Term type 2**	**Term type 3**	**Term type 1**	**Term type 2**	**Term type 3**
ecosystem*	Innovation	biology	Mapping	Innovation	ecosystem*
-	-	ecology	Design	-	-
-	-	metaphor	Model	-	-
-	-	analogy	Business model	-	-
-	-	lens	Framework	-	-
-	-	symbol	Strategy	-	-
-	-	-	Template	-	-
-	-	-	Structure	-	-
Search protocol			**Search protocol**		
Criterion	**import**	**export**	**Criterion**	**import**	**export**
Type of document	Non-article documents	articles	**Type of document**	Articles, books, theses, dissertation	industrial trail; the internet sources, etc.
Language	non-English articles	English	**Language**	English	-
Domain	Non-business-economics articles	BUSINESS ECONOMICS	**Domain**	-	-
Timespan	-	Up to January 2022	**Timespan**	Up to June 2020	-
Type of search	-	TOPIC	**Type of search**	-	-

Data collection & evaluation (step 3-5): The aim of this step was to identify the studies that best align with the research objective. To do so, in this step, a database containing all studies related to the search protocol, along with their bibliographic information, was created. From this database, 795 items were identified in the primary search and 1321 items were identified in the secondary search. Search strings and the number of records for each search are listed in Table 5.

Table 5. Search strings

Search Strings	Scopus	Google scholar	WoS	Duplicates	Total
ecosystem* AND innovation* AND analogy*	-	-	9	-	9
ecosystem* AND innovation* AND biology*	-	-	343	-	343
ecosystem* AND innovation* AND ecology*	-	-	598	-	598
ecosystem* AND innovation* AND lens*	-	-	101	-	101
ecosystem* AND innovation* AND metaphor*	-	-	22	-	22
ecosystem* AND innovation* AND symbol*	-	-	6	-	6
Total	-	-	1079	-	1079
Total (excluding duplicates)	-	-	795	-	795
Search Strings	**Scopus**	**Google scholar**	**WoS**	**Duplicates1**	**Total**
ecosystem* AND innovat* AND business model*	16	29	8	9	44
ecosystem* AND innovat* AND design*	21	20	5	9	37
ecosystem* AND innovat* AND mapping*	7	6	6	5	14
ecosystem* AND innovat* AND model*	56	90	21	43	134
ecosystem* AND innovat* AND structure*	7	19	3	4	25
ecosystem* AND innovat* AND framework*	0	0	0	0	0
ecosystem* AND innovat* AND template *	0	0	0	0	0

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ecosystem* AND innovat* AND strategy *	21	29	7	13	44
Total	128	193	50	83	288
Duplicates2	-	-	-	-	64
Total (excluding duplicates2)	-	-	-	-	224
Total (excluding language)	-	-	-	-	210
Search Strings	**Scopus**	**Google scholar**	**WoS**	**Duplicates1**	**Total**
ecosystem* AND business model * AND mapping *	0	0	1	-	1
ecosystem* AND business model * AND design*	6	11	2	-	19
ecosystem* AND business model * AND strategy *	4	3	0	-	7
ecosystem* AND design * AND mapping *	1	5	2	-	8
ecosystem* AND model * AND business model *	132	181	45	-	358
ecosystem* AND model * AND design *	47	61	23	-	131
ecosystem* AND model * AND mapping *	48	28	37	-	113
ecosystem* AND model * AND strategy *	49	32	14	-	95
ecosystem* AND model * AND template *	1	0	0	-	1
ecosystem* AND structure * AND business model *	2	1	1	-	4
ecosystem* AND structure * AND design *	6	10	3	-	19
ecosystem* AND structure * AND model *	127	122	114	-	363
ecosystem* AND structure * AND mapping *	9	5	6	-	20
ecosystem* AND structure * AND strategy *	12	15	7	-	34

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ecosystem* AND strategy * AND design *	10	8	2	-	20
ecosystem* AND strategy * AND mapping *	6	18	3	-	27
Total	460	500	260	-	1220
Duplicates2	36	93	17	-	109
Total (excluding duplicates)	418	407	243	-	1111

Subsequently, the extracted items were evaluated in a step-by-step process, which involved checking the title, abstract, and text (refer to Table 6). Upon evaluation based on Greenhalgh et al. (2005) approach, reference backtracking was conducted to identify all related articles available in the references of the selected articles. According to the literature review, it is evident that no research has been conducted to redefine or map innovation ecosystems from an ecological perspective.

Table 6. Summarizing the process of article selection

Primary search		Secondary search[1]	
No. of initial sources	795	No. of initial sources	1321
Accepted sources according to title review	111	Accepted sources according to title review	225
Accepted sources according to abstract review	12	Accepted sources according to abstract review	29
Added sources according to reference backtracking	0	Added sources according to reference backtracking	1
Accepted sources according to text over-review	4	Accepted sources according to text over-review	12
Final accepted sources according to text review	0	Final accepted sources according to text review	0

1. In the secondary search, although books, theses, and dissertations treatises were included in the import criteria the authors decided to limit the scope of their research after a general review of the extracted studies. In accordance with Webster and Watson (2002) claim that high-quality contributions are mainly found in authentic sources such as academic journals and conferences, only articles (both journals and conferences) were selected for evaluation, the output of which is available in Table 1.

As the systematic review of the existing literature indicates a lack of research background regarding the objective of this study, the authors adopt an exploratory approach. They base their agenda on the results of the evaluated articles in the systematic reviews, as well as highly cited research in innovation ecosystems. The aim is to identify the most significant studies on the definition or mapping of innovation ecosystems, which are selected as the unit of analysis. The output of the exploratory search is listed in Table 7.

Table 7. Relevant studies

search Type	Authors	Year	Title	Focused ecological concepts
Primary	Shaw & Allen	2018	Studying innovation ecosystems using ecology theory	Species; population; community; biome; landscape; natural ecosystem
Primary	Breslin et al.	2021	Developing a co-evolutionary account of innovation ecosystems	natural ecosystems; coevolution
Primary	Ghazinoory et al.	2021	Innovation lives in ecotones, not ecosystems	Ecotone
Secondary	Adner	2006	Match your innovation strategy to your innovation ecosystem	natural ecosystems; Relationships of organisms (cooperation)
Secondary	Engler & Kusiak	2011	Modeling an innovation ecosystem with adaptive agents	Natural ecosystem (modeling perspective)
Secondary	Tie & Lei	2014	A Multi-Agent System model framework of Regional Technology Innovation Ecosystem	Natural ecosystem (modeling perspective)
Secondary	Oksanen & Hautamäki	2014	Transforming regions into innovation ecosystems: A model for renewing local industrial structures	Natural ecosystem (modeling perspective)

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search Type	Authors	Year	Title	Focused ecological concepts
Secondary	Dubina, Igor N	2015	A business simulation game as an approach to model an innovation ecosystem	Natural ecosystem (modeling perspective)
Secondary	Rabelo & Bernus	2015	A holistic model of building innovation ecosystems	Natural ecosystem (modeling perspective)
Secondary	Adner	2017	Ecosystem as Structure: An Actionable Construct for Strategy	Natural ecosystem (modeling perspective)
Secondary	Bushueva et al.	2017	Representation of the business model of textile cluster as an innovating network ecosystem	Natural ecosystem (modeling perspective)
Secondary	Talmar et al.	2018	Mapping, analyzing and designing innovation ecosystems: The Ecosystem Pie Model	Natural ecosystem (modeling perspective)
Secondary	Iyawa et al.	2019	Building a Digital Health Innovation Ecosystem Framework through Design Science Research	Natural ecosystem (modeling perspective)
Secondary	Asefi et al.	2019	Modeling a successful innovation ecosystem toward a sustainable community: The I-Reef (a review study)	Natural ecosystem (modeling perspective)
Secondary	Battistoni et al.	2020	Design of an ecosystem to foster systemic eco-innovation	Natural ecosystem (modeling perspective)
supplementary	Rubens et al.	2011	A Network Analysis of Investment Firms as Resource Routers in Chinese Innovation Ecosystem	natural ecosystems; natural biome; Relationships between organisms

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search Type	Authors	Year	Title	Focused ecological concepts
supplementary	Jackson	2011	What is an innovation ecosystem	natural ecosystems; food network; Population/ community; Environmental resources
supplementary	Nambisan & Baron	2013	Entrepreneurship in innovation ecosystems: Entrepreneurs' self–regulatory processes and their implications for new venture success	natural ecosystems; Relationships of organisms (cooperation and competition); co-evolutionary; Environmental resources
supplementary	Brusoni & Prencipe	2013	The organization of innovation in ecosystems: Problem framing, problem solving, and patterns of coupling	natural ecosystems; community; food chain/ network; Relationships of organisms (cooperation and competition)
supplementary	Clarysse et al.	2014	Creating value in ecosystems: Crossing the chasm between knowledge and business ecosystems	natural ecosystems; Relationships of organisms(collaboration); co-evolutionary; food network; community / population;
supplementary	Gobble	2014	Charting the innovation ecosystem	community; food network; Relationships of organisms (cooperation)
supplementary	Autio & Thomas	2014	Innovation ecosystems: implications for innovation management?	Natural ecosystems, relationships of organisms, food network, keystone species
supplementary	Scozzi et al.	2017	Managing open innovation in urban labs	natural ecosystems; Relationships of organisms (cooperation and competition)
supplementary	Tamayo-Orbegozo et al.	2017	Eco-innovation strategic model. A multiple-case study from a highly eco-innovative European region	natural ecosystems; Relationships between organisms

search Type	Authors	Year	Title	Focused ecological concepts
supplementary	Bomtempo et al.	2017	Developing new platform chemicals: what is required for a new bio-based molecule to become a platform chemical in the bio-economy?	natural ecosystems; Society ; Relationships between organisms; keystone species
supplementary	Ding & Wu	2017	Innovation ecosystem of CNG vehicles: A case study of its cultivation and characteristics in Sichuan, China	natural ecosystems; community; Relationships between organisms
supplementary	Walrave et al.	2018	A multi-level perspective on innovation ecosystems for path-breaking innovation	natural ecosystems; community; Relationships between organisms; food network
supplementary	Gomes et al.	2018	Unpacking the innovation ecosystem construct: Evolution, gaps and trends	natural ecosystems; community; relationships of organisms (cooperation and competition); co-evolutionary; life cycle
supplementary	Granstrand & Holgersson, M.	2020	Innovation ecosystems: A conceptual review and a new definition. Technovation, 90, 102098.	Natural ecosystems, evolution, relationships between organisms (cooperation and competition)

Analysis (steps 6-7): In order to analyze the content of the selected articles, this study utilizes the comparative-qualitative content analysis method proposed by Elo & Kyngäs (2008) (Figure 3) and the structured matrix (Hsieh & Shannon, 2005) grounded in metaphor mapping (Table 6). In comparative qualitative content analysis, the researcher conducts a qualitative analysis of the text by applying certain concepts and searching for instances of definitions and generalizations throughout the entire text (Elo and Kyngäs, 2008; Hsieh & Shannon, 2005). The ultimate goal is to reexamine existing data in a new context (Catanzaro, 1988). These data can also include categories, concepts, models, or hypotheses (Marshall

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& Rossman, 1995). Also, in this type of analysis, depending on the purpose of the research, an analysis matrix (structured or unstructured) can be used (Kyngäs & Vanhanen, 1999), which is based on a theory, model, mind map, or literature review. (Sandelowski, 1995; Polit & Beck, 2004; Hsieh & Shannon, 2005). After designing the matrix, all data is reviewed and coded to ensure compliance or exemplification of identified categories (Polit & Beck, 2004). The matrix mentioned in the research was established based on the framework of conceptual metaphor mapping.

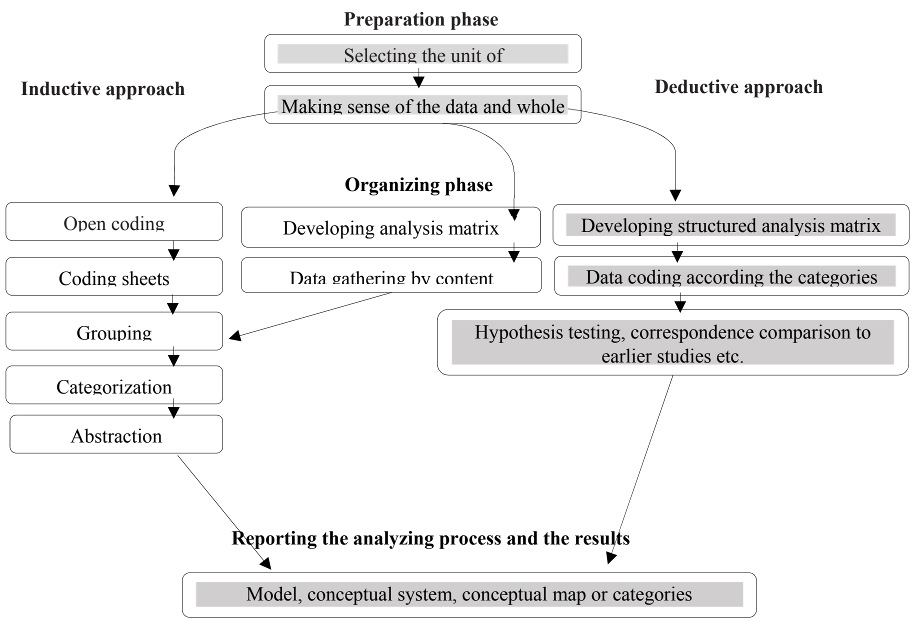

Fig 3. Preparation, organizing and resulting phases in the content analysis process (Elo and Kyngäs, 2008)

4. Findings

Upon analyzing the content of the articles, the ecological metaphors used in innovation ecosystems can be classified into two general categories: metaphors related to the environment (nonliving) (such as landscape, biome, and ecotone) and metaphors related to actors (living) (such as species, population, and community). Each category has sub-metaphors that are hierarchically related to each other. Table 8 illustrates metaphorical mappings of the mentioned concepts.

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Table 8. Innovation ecosystem metaphor mapping matrix

source domain			Target domain	Metaphor mapping	Key element of metaphor mapping	References referring to concept (explicitly or implicitly)	Distinction with similar metaphors
Dimension	Concept	Core					
Living	Species	Gene	Innovation ecosystem actor	Innovation gene	Unique business model (as a gene); Evolution of the actor	Explicit: Shaw and Allen (2018)	Development of the concept of gene to the mechanisms of evolution of the actors
Living	Population	Possibility of gene exchange	Innovation ecosystem actors (homogenous)	Innovation population	Exchanging tacit knowledge between actors with similar business model	Explicit: Shaw and Allen (2018) Implicit: *population of knowledge actors* (for example Dubina (2015); Rabelo and Bernus (2015); Iyawa et al. (2019); Battistoni and Barbero (2020)), *population of business actors* (for example Dubina (2015); Rabelo and Bernus (2015); Tie and Lei (2014); Iyawa et al. (2019); Bushueva et al. (2017)), *population of policy-making actors* (for example Asefi et al.(2020) ; Dubina (2015); Tie and Lei (2014); Rabelo and Bernus (2015); Iyawa et al. (2019)) and *population of civil actors* (for example Dubina (2015); Rabelo and Bernus (2015) ; Talmar (2020)).	Focusing on the exchange of tacit knowledge between the same actors

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source domain			Target domain	Metaphor mapping	Key element of metaphor mapping	References referring to concept (explicitly or implicitly)	Distinction with similar metaphors
Dimension	Concept	Core					
Living	Community	Network relationships of species	Innovation ecosystem actors (heterogeneous)	Innovation community	Value network focused on co-evolutionary relationships	Implicit: Jackson (2011); Gobble (2014); Guerrero et al. (2016); Bomtempo et al. (2017); Witt et al. (2018); Gomez et al. (2018); Ding and Wu (2018); Granstrand and Holgersson (2020) [value network]: Jackson (2011) Brosni and Principe (2013); Gobble (2014);	Focusing the value network of innovation ecosystems into one of the four co-evolutionary mechanisms
Non-living	Landscape	Geographical proximity	Innovation ecosystem environment	Innovation ecosystem landscape	Tangible environment of the ecosystem; immutability at least in the short term; regional/national approach; Directing ecosystem value flows through structural facilitators/ constraints	Explicit: Shaw and Allen (2018) Implicit: macro-geographic coordinates (for example Asefi et al.(2020); Battistoni and Barbero (2020); Bushueva et al. (2017)), the ruling political structure; (for example, Asefi et al.(2020)) and the economic situation and macro competitive environment; (For example, Asefi et al.(2020; Talmar (2020)).	Focusing on any immutable factor

source domain			Target domain	Metaphor mapping	Key element of metaphor mapping	References referring to concept (explicitly or implicitly)	Distinction with similar metaphors
Dimension	Concept	Core					
Non-living	Biome	Climate	Innovation ecosystem	Innovation biome	Homogeneous variety of actors; regional/national approach; Determining the framework of how the actors act by defining the rules of the game; Impact of the landscape	Explicit: Shaw and Allen (2018) Implicit: for example Asefi et al.(2020); Dubina (2015); Rabelo and Bernus (2015); Iyawa et al. (2019); Engler and Kusiak (2011)	Focusing on the formal and informal institutional environment
Non-living	Ecotone	Areas with extreme species diversity in the border areas	Innovation ecosystem boundary	Innovation ecosystem ecotone	Special areas of innovation; transition zone ;buffer zones; border actors; Variety of actors; strong differentiation of actors in border areas	Explicit: Ghazi Nouri et al. (2021) Implicit: Leader (for example Dubina,(2015); Battistoni & Barbero (2020); Adner, (2017); Engler and Kusiak (2011)), investor(s) (for example Dubina (2015); Tie and Lei (2014); Rabelo and Bernus (2015)) and champion(s) (for example Talmar, (2020))	Focusing on boundary actors

5. Discussion and Conclusion

Following Scaringella and Radziwon's (2018) study, we conducted a systematic literature review on the metaphorical redefinition and mapping of innovation ecosystems. Our review included 2116 references, with 795 items in the primary search and 1321 items in the secondary search. As the systematic review of the existing literature indicates a lack of research background, we focused our systematic literature review (SLR) on 29 selected items. These items were derived from three different searches: three from the primary search, twelve from the secondary search, and fourteen from the supplementary search. Through metaphor mapping, we identified two major metaphors that are rooted in innovation ecosystems. The first set of metaphors is concerned with actors and includes species, population, and community. The second set of metaphors is concerned with the environment and includes landscape, biome, and ecotone. According to the metaphorical network of ecosystems, innovation ecosystems can be defined as follows: "An interconnected and complex community comprising various populations of actors (in terms of business models) that, within a specific landscape and biome, establish evolutionary and co-evolutionary relationships to form a value network with the goal of eco-innovation." Figure 4 provides a macro diagram illustrating the position of each metaphorical concept in relation to each other within this definition. The dimensions of each concept will be explained in detail below:

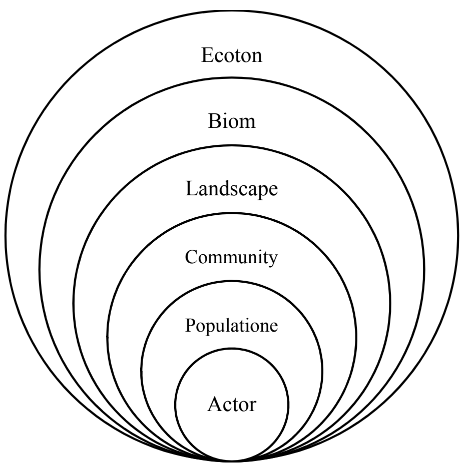

Figure 4. Ecological diagram of Innovation ecosystem

1- Innovation actor (gene): In all research, the species is considered an actor in the innovation ecosystem. Shaw and Allen (2018) focus on the evolution of innovation ecosystem actors and their business models, using genes as a metaphor for the actor's business model and mutations as innovations within that model. However, they have paid little attention to other mechanisms of evolution that can lead to innovation. Extrapolating from Shaw and Allen's (2018) study from a metaphorical perspective, the occurrence of innovation in an ecosystem can be divided into two different levels.

Evolutionary-oriented innovations include mutation, which refers to the spontaneous change in the actor's business model, and migration, which involves imitating the business model of other ecosystem actors. Survival-oriented innovations include predictable Variation-Selection-Retention, which occurs when an actor's business model is forced to change in order to adapt to predictable environmental changes. Additionally, random Variation-Selection-Retention/Drift can occur when an actor's business model is forced to change in response to a random environmental change.

2- Innovation population: According to Shaw and Allen (2018), population studies focus on the spatial proximity of similar business models, examining their historical foundations and the factors that contribute to the dominance of certain models over others. These studies also provide insight into the capacity and fluctuations of market size. Since the source domain of this metaphor emphasizes gene exchange as the primary factor in identifying a specific population, the population metaphor should focus on the interaction of similar individuals. The innovation population is a group of actors with the same business model who potentially share implicit knowledge about various aspects of their business model. In the existing literature on the modeling of innovation ecosystems, the population of actors is divided in different ways. The most common divisions include: population of knowledge actors with universities as a prominent example (Dubina, 2015; Rabelo & Bernus, 2015; Iyawa et al., 2019; Battistoni & Barbero, 2020), population of business actors with industries as a prominent example (Dubina, 2015; Rabelo and Bernus, 2015; Tie & Lei, 2014; Iyawa et al., 2019; Bushueva et al., 2017), a population of policy-making actors with government organizations as a prominent example (Asefi et al., 2020; Dubina, 2015; Tie & Lei, 2014; Rabelo &

Bernus, 2015; Iyawa et al., 2019), and a population of civil actors with NGOs as a prominent example (Dubina, 2015; Rabelo & Bernus, 2015; Talmar, 2020).

3- Innovation community: Regarding the source domain, the community's focus is on the interaction among a diverse population of actors within the food network. Therefore, from a metaphorical perspective, an innovation community can be defined as a group of diverse actors who interact with each other, resulting in the creation of a value network and the collaborative generation of innovation. This mapping of the innovation community metaphor differs from Shaw and Allen's (2018). According to Shaw and Allen (2018), the difference between the community lens and the ecosystem lens lies in their respective emphases. The community lens focuses on the integration of business models, while the ecosystem lens emphasizes the flow of resources and services, among other factors. But the flow of resources involves multiple levels of interaction among diverse actors within a community. On the other hand, the innovation ecosystem goes beyond the community of actors, as it encompasses not only the relationships between actors, but also the interactions between actors and their environment. Also, it is notable that in terms of the dominant metaphorical definitions, the concept of the innovation ecosystem has been simplified to that of an innovation community. As a result, significant attention is given to the actors and their relationships, particularly the concept of co-evolution and the value network (Table 7).

4-Innovation landscape: Considering the relative stability and immutability of this concept in the source domain, necessitates taking into consideration relatively stable and immutable environmental components during metaphor mapping. Therefore, from a metaphorical angle the landscape can be defined as a relatively stable environment. In other words, the innovation landscape denotes a tangible environment of the actors in innovation ecosystem in which changes occur slowly beyond the actors' will to change or exert influence. Its components are often defined at national/regional level and direct the value flow of the ecosystem through structural facilitators/constraints. The macro-geographic characteristics of a region (natural, economic, and political) (for example Asefi et al. (2020); Battistoni & Barbero (2020); Bushueva et al. (2017)); the political structure (for example Asefi et al. (2020)); and the economic condition and macro competitive environment (for example Asefi et al. (2020); Talmar (2020)) are exemplar instance of this metaphor. Shaw & Allen (2018) use the landscape metaphor to explain the limiters and facilitators of the flow of resources, services, etc., such as the physical, cultural, and legal condition of a smart city.

5- Innovation biome: Considering the metaphorical background, Shaw and Allen (2018) argue that the term "biome" can be used interchangeably with cultural, regulatory, and tax support climates in specific regions. Extrapolating from Shaw and Allen's (2018) study, the biome can be metaphorically defined as the institutional environment that governs the ecosystem. This environment can be supportive or non-supportive and it determines the rules of the game, resulting in a homogeneous diversity of actors. As the innovation landscape directly influences it, the scope of innovation is defined regionally or nationally. Both formal rules (e.g., Rabelo & Bernus, 2015; Iyawa et al., 2019) and informal rules, such as culture, values, principles, and freedom (e.g., Asefi et al., 2020; Dubina, 2015; Rabelo & Bernus, 2015; Iyawa et al., 2019; Engler & Kusiak, 2011), have been mentioned in the literature.

6- Innovation ecotone: Considering the metaphorical background, Ghazinoori et al. (2021) define an ecotone as a flexible boundary between the knowledge ecosystem and the business ecosystem, characterized by a high exchange of ideas. The quality of this exchange is enhanced by greater diversity. By developing Ghazinoori et al.'s (2021) metaphorical idea and as diversity and distinctiveness of species is the distinguishing feature of this concept in the source domain, the innovation ecotone is where the landscape of the ecosystem gradually fades, which is conducive to the emergence of the borderline actors. Borderline actors are actors who, given the fluidity of their role and the variety of examples, can be placed/located in many of the populations inside or outside of the ecosystem. The keystone actor (for example Dubina (2015); Battistoni and Barbero (2020); Adner (2017); Engler and Kusiak (2011)), investors (for example Dubina (2015); Tie and Lei (2014); Rabelo and Bernus (2015)) and individual(s) (for example Talmar et al. (2020)) are exemplar instance of this metaphor. In this study, "individuals" refers to those who act as champions in the ecosystem and are willing to develop its innovation for personal reasons (Dedehayir et al., 2017).

Based on the provided definitions and cross-relationships between ecological concepts and innovation, the metaphorical mapping of innovation ecosystems can be presented as Figure 5. As a tool, developed framework enables innovation policymakers to make decisions based on the dynamics of actors and environment with based on an ecological perspective. It provides a comprehensive understanding of the various aspects of innovation ecosystems, including the actors involved, the environment in which they operate, and the relationships between these elements in the context of innovation policy making. Our results suggest that when defining the innovation ecosystem, it is important to consider the conceptual network of this metaphor, particularly the six hierarchical layers. This consideration will lead to a more precise understanding of the dynamics of the relationships between innovation actors and their environment, viewed through the lens of ecology. Consequently, policymakers should not limit their governance to the recommendations provided by the current popular literature on ecosystems. Instead, they should also devote equal attention to the various dimensions of innovation ecosystems, including actors, environment, and relationships.

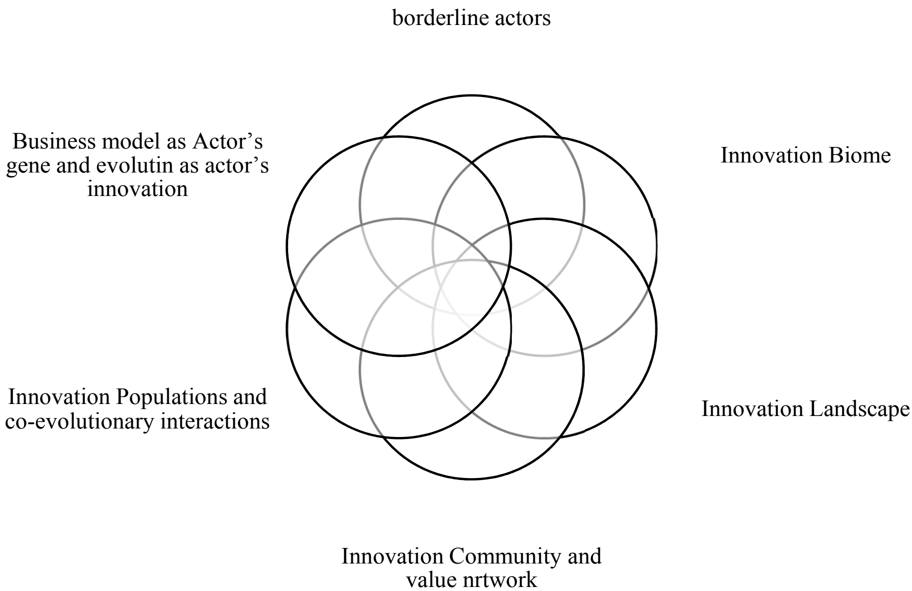

Figure 5. Metaphorical dimensions of Innovation ecosystem

Additionally, future research could explore the expansion of the metaphorical concepts presented in this study to gain a more comprehensive understanding of the metaphorical perspective of the innovation ecosystem. For example:

Eco-innovation typology: Eco-innovation typology: Future research could focus on the ecological classification of actor-level innovations. To explain, the key point in extrapolating the metaphors of actor-level innovation is that these innovations do not function independently. Instead, they emerge as a result of a dynamic combination with each other in the form of the following four metaphorical types of innovation (Table 8): active innovation (the combination of mutation and predictable variation-selection-retention conditions), recombinant innovation (the combination of migration and directed change in variation-selection-retention conditions), imposed innovation (the combination of mutation and random variation-selection-retention conditions), and passive innovation (the combination of migration and random variation-selection-retention conditions).

Table 8. Ecological Typology of Innovation (at Actor Level)

		Evolution-oriented innovations mechanism	
		Mutation	Migration
Survival-oriented innovations	Predicable	Active innovation	Recombinant innovation
	Random	Imposed innovation	Passive innovation

Co-evolution: Future research could focus on the co-evolutionary relationship between innovation actors, particularly keystone actors, and its impact on ecosystem-level innovations. To explain this, each actor-level innovation, within the network structure of the innovation ecosystem, has the ability to change the business model of the interacting actors (co-evolution) and spread throughout the ecosystem in a domino-like fashion. In terms of creating a sustainable value network, it ultimately leads to ecosystem-level innovation (Figure 12). The more evolved an actor is, with multiple and distinct relationships, the greater influence it will have on the formation of the final innovation of ecosystems. For example, the evolution and co-evolution of the leader in the innovation ecosystem (which is referred to as keystone companies or hubs in the existing literature) is of vital significance to the formation of the value network and innovation within the ecosystem.

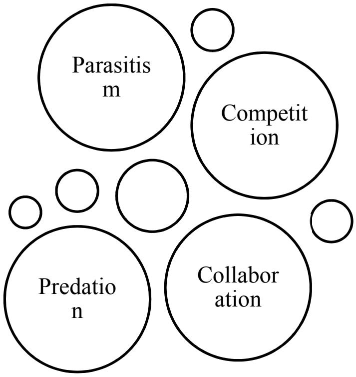

Figure 8. Keystone co-evolutionary intractions

Innovation Biosphere: Future research could focus on the global innovation ecosystem using the biosphere metaphor. In ecology, the biosphere refers to all the actual or potential habitable areas on the planet that support life or have the potential to support life (Levin, 1998). Given the broad scope of this concept in the target domain, which encompasses almost the entire globe, a universal metaphorical mapping is necessary. Therefore, from a metaphorical perspective, the biosphere of innovation can be seen as a macro (hyper) ecosystem that comprises innovation ecosystems that are interconnected and relevant to the ecosystems being studied. We encourage further research to take into consideration the metaphorical aspects of this concept and to explore the relationships between innovation ecosystems in this context.

Public sector innovation ecosystem: Future research could focus on extending the metaphorical ideas of this study to the public sector. To explain this, although the concept of an innovation ecosystem has not been explicitly discussed in the public sector literature, the transition from New Public Management (NPM) to New Public Governance (NPG) in public management literature suggests that the solution to the lack of innovation in the public sector lies in inter-organizational relationships. In fact, the main premise of NPG, which draws inspiration from recent theories of private sector innovation (Lundvall, 1992; Freeman, 1990; Edquist, 1997) and collaborative governance (Hartley, 2005; Ansell and Gash, 2008), is to focus on collaborative innovation in the public sector. An important example of this is the innovation ecosystem. Based on the ecosystem as a structural approach

(Adner, 2016), the formation of an innovation ecosystem necessitates designing and modeling. The metaphorical ideas presented in this study can be utilized as a new tool for public governance in the public sector, by taking into account the contrived constructs. However, this suggestion has its limitations. First, the public sector ecosystem is citizen-oriented instead of customer/user-oriented because it aims to realize collective interests and the public will (Fuglsang & Rønning, 2014). Therefore, the use of metaphors proposed in this research requires attention to public values. Especially regarding metaphors such as predators and prey's mutual competition. Second, it does not provide or guarantee ethical and equal treatment of its citizens. Thus, further work is needed to improve the model and any practices related to it (Rantanen et al., 2019).

The Research Framework Exploration: Furthermore, future research could also concentrate on implementing and validating the ecological framework presented in this study. Not only qualitative exploratory research, but also early quantitative studies, would facilitate the development of this framework by offering recommendations to policymakers. It would be advantageous to consider both different regions and industries, as well as different levels of analysis. Taking a multilevel perspective into consideration could provide more insights into the perceptions of various actors within the ecosystem. Therefore, new research questions will be raised: How can the framework be implemented based on quantitative measurements?

This paper has some limitations, with the most significant one being the selection of only peer-reviewed articles written in English. Accordingly, we suggest conducting further research to examine additional databases, non-article sources, and materials written in languages other than English.

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