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Research paper

A Conceptual Framework to Assess the Emergence, Development and Viability of Rural Circular Bioclusters

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Abstract

Current environmental challenges call for the replacement of fossil resources with bioresources. Bioclusters – innovation ecosystems centered on bioresource use – provide solutions to achieve both environmental and economic objectives by balancing ecosystem preservation with the economic exploitation of bioresources. The literature on the role of bioclusters in transitions emphasizes the need for specific frameworks that account for their unique characteristics. In this context, the aim of this paper is to present an original conceptual framework for analyzing the emergence, development, and viability of rural circular bioclusters by integrating rural development literature with discussions from circular economy and economic geography. The framework outlines three steps to study bioclusters: identifying the resources that form the biocluster (*emergence*), examining the activation process of these resources and the network of players (*development*), and detailing governance for resource allocation that balances commodification with heritage-based preservation (*viability*).

Keywords: Circular Bioclusters · Rural Development · Viability · Heritage

1. INTRODUCTION

Current environmental imperatives (adaptation and mitigation of climate change, preservation of natural ecosystems and biodiversity) require to substitute bioresources originating from agriculture, agrifood, and forestry for fossil resources (Ingle et al., 2020; Krozer and Narodoslawsky, 2019; Hoff et al., 2018). The benefits of bioresources reside mostly in their renewability due to their biological nature and their photosynthetic origin even though the impacts of their utilization in terms of energy consumption and pollution can sometimes be debated (Kopta et al., 2025). Bioclusters – i.e., firmbased ecosystems of innovation centered on the utilization of bioresources – provide responses to solve the apparent contradiction and reach both environmental and economic objectives by simultaneously preserving natural ecosystems and economically exploiting bioresources (D'Amato and Korhonen, 2021). Circular bioclusters may display improved benefits through the reutilization of used bioresources and the valuation of by-products in an attempt to make more compatible the objectives of sustainability and economic growth, a common question in circular economy research work (Kirchherr et al., 2023).

Bourdin and Torre (2024) demonstrated that the potential of the circular economy can only be realized by taking into account the specific characteristics of the geographical context and the dynamics of the territory. The emergence of bioclusters may contribute to the development of innovative processes and original territorial development pathways in rural areas (Hermans, 2021; Ingrao et al., 2018; Dai et al., 2015). Indeed, the design of productive processes based on bioresources often requires settling productive activities in rural areas where the conditions for effective innovation processes are not necessarily met. Unlike urban areas where agglomeration effects facilitate the reaping of the benefits of social and geographical proximities (Martinus and Sigler, 2018; Martin and Simmie, 2008), the longer distances and the lower densities which characterize rural areas may slow down innovation processes despite an overall easier access to bioresources (Labrouche and

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Levy, 2019). In addition, the often-conflictual utilization of bioresources, the usually lower investment capacity of rural players[4], and the weaker profitability of most food supply chains, as well as current climate change trends, all tend to impact negatively the emergence of circular bioclusters in rural areas.

The investigation of the role of bioclusters in the societal transitions ahead has highlighted that considering bioclusters as traditional clusters may impede the analysis of their specificities, especially for bioclusters which rely on low-tech innovations (Hermans, 2018). Bioclusters' multidimensional role is exacerbated by their complex adaptive system nature, which displays patterns of agency, structural dynamics, and of agency-structure interactions driven by the interventions of green-tech entrepreneurs, institutional entrepreneurs, and place leaders (Kamath et al., 2023). More recently, voices have however also underlined the limitations of bioclusters, while recognizing the intertwining of their material, social and ideational aspects (Wilde and Hermans, 2021).

In this context, the goal of this paper is to provide an original conceptual framework to analyze the emergence, the development and the viability of circular bioclusters from an operational point of view (Figure 1). In order to assess the innovative processes stemming from the need to break up bioresources to isolate compounds and reach targeted functionalities, this conceptual framework originally integrates the literature on rural development in a discussion that considers the literature on circular economy and the one on economic geography. A dynamic analysis of the stocks and flows of resources based on the community capitals framework (CCF) fosters an analysis of the synergies, complementarities or incompatibilities of resources within biocluster strategies. In the CCF, capitals are understood in a Bourdieusian way as something that provides an advantage to its owner (Bourdieu, 1986) and which is compatible with the resource-based view where resources are either material and immaterial (Wernerfelt, 1984). The utilization of the resource activation process within bioclusters induces the integration of the concepts of production externalities and ecosystem services connected to the biological nature of bioresources. Finally, the economic/ecological tradeoff underpinning the sustainability of bioclusters is scrutinized in light of circular loops that blurs the line between commodification and heritage preservation.

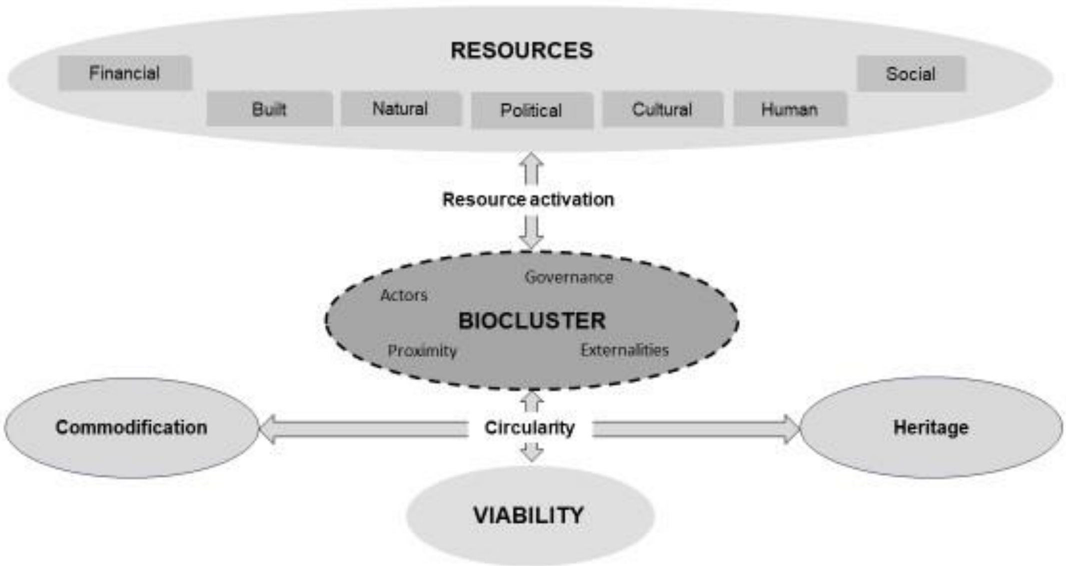

Figure 1. Biocluster Analysis Conceptual Framework

In this article, we adopt a resource-based view approach driven by the assumption that bioclusters emerge from the identification and activation of a set of resources before incorporating additional resources (Wernerfelt, 1984; Barney, 1991). The conceptual framework is presented in three steps before being discussed. The following section identifies the resources on which the biocluster is founded (emergence). Next, the process of activation is adapted to the characteristics of bioclusters through the inclusion of the concept of externalities and ecosystem services (development). Finally, the characteristics of the governance responsible for resource

[4] In this article the term player, in opposition to traditional stakeholders, is used to include the human and nonhuman entities of the geographical area where bioclusters affect the functioning of socio-ecosystems.

allocation towards more commodification or more heritage preservation are detailed (viability) in the following section.

2. GATHERING RESOURCES FOR THE EMERGENCE OF BIOCLUSTERS

In this section the diversity of resources is analyzed in light of the Community Capitals Framework (CCF). In particular, the critical role of biocluster players[5] who adopt cooperative behaviors is understood as a resource. We then discuss the respective roles of the industrial sector and the territory/place[6] in the emergence of bioclusters.

The diversity of resources that are articulated during the emergence of bioclusters can be organized in seven capitals (Table 1): financial, built, natural, political, cultural, human and social capitals (Flora and Flora, 2013). In line with Stegmann et al.'s (2020) definition, this flexible framework considers both bio and non-bio resources dynamically, where stocks and flows of resources are connected. This connection aims to assess dynamically the impact of circular productive systems on the depletion or regeneration of resources. During the emergence stage, planning decisions tend to impact meaningfully the short- and long-run viability of bioclusters. The relevance of the CCF is thus to provide a framework through which the utilization of resources, considering their complementary, antagonistic, or substitutable natures can be discussed to define development strategies and identify sustainable pathways. Finally, from an economic point of view, while some resources seem to be more easily commodified due to their private legal status, others appear to remain more collective or even public (Salmon and Akimowicz, 2022), opening a discussion on their (in)tangibility–i.e., the likelihood of their economic valuation as assets (Allaire,2018).

Table 1. The Seven Types of Capital (Flora & Flora, 2013)

Capital	Description
Financial	Money, charitable donations, grants, access to capital
Built	Buildings and infrastructure – schools, roads, water networks, road systems – within a community
Natural	The natural environment, lakes, rivers and streams, forests, wildlife, flora, soil, or local landscape
Political	Connections with people in power, access to resources, leverage, and influence to achieve goals
Cultural	Ethnicity, histories and traditions, spirituality, customs
Human	All the skills and abilities of individuals, leadership, knowledge, health status
Social	Groups, organizations, networks within the community, sense of belonging, connections between people

The reliance of bioclusters on biological raw material entails a straightforward dependence towards well-functioning natural ecosystems and emphasizes the significance of ecosystem services. The durable provision of bioresources drives a commitment to avoiding their decline. Thus, biocluster players tend therefore to be involved in the management of healthy natural ecosystems (Costanza, 2012). According to this author, they may contribute to improving the supply of ecosystem services upon which their activities depend, either by mitigating the negative impacts of their own activities or by addressing other anthropogenic and natural disturbances, particularly those related to climate change. Often viewed as a kind of productive support that contributes to productive efficiency, ecosystem services (provisioning, regulating, supporting, and cultural) are in fact deeply related to the well-functioning of bioclusters (D'Amato et al., 2020). While ecosystem services may enhance each other, they may also in some cases impair each other, especially when competing land uses are at stake (Archer and Predick, 2014; Schneider et al., 2020). Understood as resources, ecosystem services challenge biocluster players who need to arbitrate their extraction and preservation during the activation process detailed in Section 2.

[5] In this paper, the term player is preferred to stakeholders to reflect the diversity of interests and situations of entities at play within the dynamics of bioclusters.
[6] While place and territory display some differences (Akimowicz et al., 2023), in this paper they are assimilated since the relevance of these concepts regards the geographical inclusion of bioclusters.

Given biocluster players' interests, these arbitrations may affect biocluster dynamics. In particular, the evolution of biocluster players' beliefs and values systems in relation to societal values and preferences makes this arbitration dynamic and leaves room for transitions toward more sustainable practices (Biggs et al., 2015). According to these authors, bioclusters are socioecological systems where ecosystem services are not solely consumed for the development of bioclusters, but are key mediators between the social and ecological components of the system. In this sense, they are not produced by nature alone, but rather result from the interactions between natural ecosystems' capacity to supply ecosystem services, on the one hand, and human values, technology, and skills, on the other (Biggs et al., 2015). While one may distinguish 'hard ecosystem services', which encompass provisioning services that are key to the supply of biological raw material and the renewal of its stocks, from 'soft ecosystem services', which encompass cultural services that contribute to bioclusters' identity (Vejre et al., 2010), this distinction does not seem to apply as straightforwardly in the case of bioclusters since their material/tangible and immaterial/intangible dimensions are tightly intertwined. Therefore, the development of bioclusters depends on players' ability to enhance ecosystem services to improve resilience.

The network of players involved in bioclusters may be understood as a community. While the concept is strongly multidimensional, in the case of bioclusters, it refers simultaneously to three types of communities. First, the utilization of bioresources and the development of specific industrial processes refer to the concept of a community of practice–i.e., a place where contextual competences are defined based on the collective understanding of what the biocluster is about, players' mutual engagement, which establishes norms and mutuality, and a shared repertoire of communal resources (Wenger 1998). Second, as communities, bioclusters also relate to a group of actors governing resources under private, collective or public status; a distinction which depends critically on users' relative point of view, whether it be the biocluster, a firm of the biocluster, or even a worker within a firm (Schlager and Ostrom 1992; Lemeilleur and Allaire 2018). In this perspective, the meaningfulness of commons stems from the necessary handling of tensions among bioclusters' players and the regulation of their activities. Third, the creative process behind the emergence of bioclusters also relates to learning communities–i.e., a group of learners who share (in)formally, locally or distantly, the will to learn together, which is a necessary step within the innovation processes at stake within bioclusters (Cristol 2017; Blackmore et al. 2018).

The industrial processing of bioresources also sets bioclusters at the crossroads of the organization of industrial sectors and territories. On the one hand, the commodification of bioresources relies on finely tuned interactions among biocluster players, which involve interactions, interdependencies and interplays (Vicente, 2018). Given the origin of the bioresources and the diversity of their utilization, the concept of a supply chain relevant to the analysis tends toward the one of an agro-industrial complex–i.e., the agglomeration of activities with those that have historically relied on the use of agricultural commodities slowly replaced by synthetic products (Malassis and Ghersi, 1996). For these authors, this complex can be represented as a network of interbranch exchanges including both (im)material flows of production factors, goods, services, information and knowledge, as well as people. On the other hand, bioclusters also rely on the processing of biological resources whose production is geographically anchored, usually in rural areas. From an industrial point of view, the location of processing plants relatively close to the production area of raw materials provides an economic advantage due to lower transportation costs (Polèse and Shearmur, 2005) as well as an asset for innovation due to stronger proximities and more frequent interactions between producers and processors (Labrouche and Levy, 2019). Territories emerge from the encounter of biophysical characteristics with social projects in line with the vision of residents. In this perspective, bioclusters are framed by and frame in return both supply chains and territories as mediating metaorganizations, which stem from the implied complex emergence of social institutions such as norms (normative dimension), (in)formal rules (regulatory dimension), and (situated) knowledge (cognitive dimension) which facilitate players' coordination (Scott, 2005).[7]

3. ACTIVATING RESOURCES FOR THE DEVELOPMENT OF BIOCLUSTERS

[7] The reliance of bioclusters on tight connections among firms as well as among firms and their bioresources might be considered as a co-evolution process based on the existence of interactions, interdependencies, and interplays. While Commons' concept of trans-action might have also been used for firms, its generalization to the firms/resource's connections would have needed a longer development outside of the scope of this article. As a result, the concepts of externalities and ecosystem services have been used in an attempt to simplify the understanding of this conceptual framework.

Territorial development approaches which consider territories as a competitive factor may shed light on the current and future competitiveness of circular bioclusters (Camagni & Capello, 2013) through the analysis of local economic capacities and potentials (Colletis & Pecqueur, 2018)[8]. It offers a place-based approach which significantly differs from spatially-blind strategies (Barca et al., 2012).

3.1 Resource activation and asset specification

Biocluster development processes require a prior understanding of the resource activation and asset specification mechanisms (Figure 2), which can be defined as processes of meso-economic coordination that go beyond inter-individual processes (Colletis-Wahl and Pecqueur, 2001). For these authors, the activation process of ′latent′ factors is essentially driven by social representations. In this perspective, biocluster players are driven by a vision in which material conditions and ideational representations mutually influence each other (Colletis and Pecqueur, 2018) or, in other words where tangible assets are transformed by intangible ones (Camagni and Capello, 2013). Biocluster players' social representations may thus affect the organization of bioclusters through a modification of the nature and long-term availability of resources, the different forms of proximity that structure bioclusters, and the significant aspects of the projects carried out in the area, among other factors.

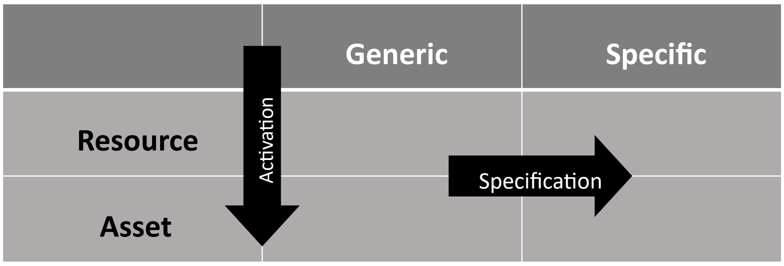

Figure 2. Resource Activation and Asset Specification (Colletis and Pecqueur, 2005)

In short, the specification of resources is a conversion of resources into assets that effectively provide an economic advantage. While everything may be seen as a resource, not everything can mechanically become an asset. Activation involves constructing an object (know-how, raw material, etc.) and linking it to a system of production or rules (Colletis and Pecqueur, 2018; Kebir, 2006). A 'virtual' resource–i.e. one that is not valued-becomes an asset integrated into socio-economic circuits if a particular process of 'commitment' gives this resource a socially recognized utility (Colletis and Pecqueur, 2005). In the end, the metamorphosis of resources is based on three characteristics that are particularly relevant for bioclusters: specificity, potentiality and renewability (Table 2).

[8] Several references used to design this conceptual framework and based on the concept of proximity have been published in French. They stem from the now traditional French school of proximity (see Zimmermann et al., (2022) in English). We have explicitly outlined and translated the key conceptualizations of these works that are useful for our analysis, such as the concept of resource activation and asset specification developed by Colletis and Pecqueur.

Table 2. The 3 Characteristics for Resource Metamorphosis (Colletis and Pecqueur, 2018)

Specificity	A resource becomes specific when it is territorially anchored. This can include cultural, geological, historical, or other aspects that root the resource in a particular territorial context.
Potentiality	A resource only becomes valuable once it is revealed and transformed into an asset. Collaborations among different players are essential to unlock the potential of local resources.
Renewability	Unlike commodities, activated territorial resources are not exhaustible since they do not pre-exist the activation process. They are renewed through their continued utilization.

The leveraging of territorial resources thus has three dimensions: a collective, a technical, and a cognitive dimension (Colletis and Pecqueur, 2018; Kebir, 2006). The quality of the network of players is therefore a key feature which deserves attention during the development stage of bioclusters.

3.2 Networks of actors and proximities

In order to leverage the benefits of industrial concentration to increase productivity (Vicente, 2018), bioclusters rely on territorial synergies and the formation of networks and partnerships (Velenturf, 2017; Sanz-Hernandez and Garrido, 2019). Bioclusters can be seen as decentralized means of coordination for processing biomass, which play a key role in the formation of new value chains, paving the way for innovative business models. The densification of bioclusters' networks highlights the benefits of distributing R&D costs; better adapting to the dynamic needs of the market and the natural environment; better identifying potentially interesting innovation opportunities; expanding into new markets and reducing time-to-market; accessing complementary assets, financial resources, knowledge, and cooperation (Van Lancker et al., 2016). Bioclusters may also facilitate access for both small and large players to infrastructure, financing, technologies, and innovations. Overall, the development of bioclusters involves a process of reconsidering, encouraging, and facilitating interdependencies that are more effective economically, socially, and ecologically.

Territorial proximity plays a key role in the development of these synergies, as it combines geographical proximity with organized proximities – i.e., organizational, cognitive, social, and institutional (Torre and Beuret, 2012). Proximity emerges when actors use common characteristics to establish coordination and develop projects. The main idea of proximity is that similarity enables individuals to better know and understand each other, thereby fostering trust (Bezzon et al., 2024). The interdependencies that actors open themselves to are based on the fact that these collaborations are primarily established between companies and organizations within the same territory, which are therefore geographically close. Geographic proximity exists from the outset, but it remains neutral if it is not leveraged (Torre and Beuret, 2012). Entities that are geographically close but do not decide to exploit the advantage of this proximity cannot unlock the potential of their collaboration. Knowledge externalities are geographically bounded thanks to interactions; the leveraging of geographic proximity facilitates learning, knowing that the successful experiences of other local companies (especially rivals) do not go unnoticed and can be easily replicated at almost no cost (Balland et al., 2015). The four other forms of non-spatial proximities – or organized proximities (Table 3) – denote the different forms of closeness among biocluster players, where organized refers to the structured nature of human activities.

Table 3. Types of Non-spatial Proximities Playing a Role in Bioclusters (Balland et al., 2015)

Proximity	Description
Cognitive	Biocluster players share the same knowledge base and expertise and can learn from one another.
Organizational	Biocluster players share organizational arrangements, either within or between organizations (e.g., level of autonomy and degree of control).
Social	Socially embedded relationships between biocluster players; they are anchored when they involve trust based on friendship, kinship, and experience.
Institutional	Sets of habits, routines of established practices, common rules, or laws that govern relationships and interactions between individuals and groups.

The analysis of the different forms of proximity highlights the strengths and weaknesses of the structure of the network of territorial players. This diagnosis is critical for structuring bioclusters and designing development pathways. However, in the case of bioclusters, the externalities that bind together the network of players are insufficient for its development, which also involves considering its relationship with the natural ecosystems in which it operates. The viability of bioclusters seems to depend on trade-offs between economic performance and socio-ecosystem preservation.

4. THE VIABILITY ARBITRATION BETWEEN COMMODIFICATION AND PATRIMONIALIZATION

The viability of bioclusters can be assessed quantitatively when a critical mass of bioresources is both secured and qualified. The arbitration between commodification and patrimonialization of resources, which eventually leads to viable bioclusters, implies the design of a legitimate governance. In this context, circular bioclusters may adjust more easily to the balance between the two modalities.

4.1 Viability Threshold

The viability of bioclusters and the subsequent embedded companies depend on the supply of a critical mass of raw materials, the bioresources, in order to make their productive investments profitable. This critical amount is the minimum threshold of bioresources that enables each company to be viable (Lewandowski, 2015), whether extracted from natural ecosystems or by-products used for cascading valorization. The quantitative assessment of the availability of raw materials contributes to the planning of an optimized supply capacity, bioresources processing, and product distribution (Ciria and Barro, 2016). Sufficient availability, meaning reaching the viability threshold for companies, also implies managing risks of chronic or temporary shortages and cost overruns, particularly when supply takes place on volatile markets (Lewandowski, 2015).

In this regard, the critical mass is based on three dimensions. The first relates to bioresources supply in general. From this perspective, the activity is viable if the supply is sufficient and predictable (Ciria and Barro, 2016). The second relates to the availability of bioresources stemming from seasonality and competitiveness. Both the seasonal nature of bioresources and eventual competition for heterogeneous uses have significant planning implications, in particular the location and accessibility of bioresources since their dispersion can be prohibitive (Ciria and Barro, 2016). The third concerns the adequacy of the various logistical components. Since facilities and infrastructures are constrained by their capacity, supply and processing capacities need to be adjusted while their optimization determines the viability of bioclusters (Lewandowski, 2015).

4.2 Balance Between Commodification and Patrimonialization

The viability of circular bioclusters implies understanding the arbitration between the exploitation of bioresources and heritage preservation, which, in addition to the biological renewal of bioresources, also includes the will to pass them on to the next generations (Labadi, 2022). The introduction of the concept of heritage enriches the economic/environmental focus of the assessment with a complex human dimension which relates to players' identity. Indeed, these choices depend heavily on the values and belief systems which frame players' decision-making. While heritage preservation views resources as a stock to preserve and pass on, commodification considers them as a flow to exploit and value financially (Salmon and Akimowicz, 2022). The commodification of resources focuses on market or exchange values (Landel and Senil, 2009; Talandier et al., 2020). When commodified, resources are viewed as a flow, which can be exploited with the risk of depletion, until market mechanisms allow for securing another cheaper source of resources. The exchange value resulting from the commodification process does not account for the specificities of resources, such as cultural, social, or other values, due to the market's failure to consider these aspects (Guerrien, 2003). However, this conception can undermine the durability of territorial resources and, consequently, the very purpose of bioclusters. A political regulation of market mechanisms might therefore contribute to a better valuation of bioresources (Theret, 1994).

The concept of heritage involved in patrimonialization processes refers both to the assets and to an inheritance that contributes to the identity of a community (Nieddu, 2007)[9]. For this author, heritage resources result from a process of identification, unlike those of accumulation that result from commodification processes. Heritage preservation is carried out by biocluster players who select and qualify what holds value, whether it be aesthetic, historical, ecological, etc. Consequently, patrimonialization processes create something that takes on the name and value of heritage (Pottier, 2014). This can be manifested through a transformation via reshaping, reconstruction, elaboration, construction, or restoration of buildings, landscapes, with the aim to bring them into the realm of heritage (Hueso-Kortekaas and Carrasco-Vayá, 2024). Engaging in a vision of heritage preservation is a way of (re)thinking desirable futures that influence the present under the constraint of inheritances (Nieddu, 2007). The resource is thus viewed as an inheritance to be passed on, embodying the link between past and future generations (Landel and Senil, 2009). This perspective is also economic, as it sometimes necessitates an allocation of complementary resources since the production of identity incurs costs and requires trade-offs (Nieddu, 2007).

The challenge lies in the ability to find the right balance between commodification and patrimonialization. In this perspective, circular economy approaches strengthen the viability of bioclusters since they introduce some degrees of flexibility between these two stereotypical approaches and a balance emerges for each biocluster (Hériard-Dubreuil and Dewoghélaëre, 2015). Circular exploitation, which allows for cascading uses of bioresources, is a lever for the viability of bioclusters. Based on the principles of reduction, reuse, recycling, and recovery (D'Amato and Korhonen, 2021), it becomes possible for the biocluster players to extract bioresources while allowing for the preservation of heritage. Thus, biocluster players seek a trade-off point, even if it requires introducing a degree of commodification, while enhancing the heritage dimension for bioresources that are already exploited.

4.3 Governance

The governance of circular bioclusters is therefore a critical aspect of their viability since the synergistic actions of circular biocluster players imply a need for the coordination of cooperation while also acknowledging their potentially divergent interests as competitors (Dietz et al., 2018). The establishment of arrangements like formal and informal rules as well as the determination of overarching directions (goals and strategies) and decision-making (inclusion, fairness, and equity) are necessary for circular bioclusters to realize their ambitions (Starke et al., 2024). The governance of circular bioclusters impacts all aspects of its development and viability. It will allow for identifying potential conflictual tensions and resolving those that exist, for example concerning resource exploitation (Torre and Beuret, 2012; Ostrom, 1990). Conflicts related to the competition for the access to bioresources and to the benefits of ecosystem services may be particularly frequent (Biggs et al., 2015), especially during the arbitration for a sustainable balance between commodification and patrimonialization. Such divergences can be exacerbated by the diversity of values and beliefs systems as well as social representations (Colletis and Pecqueur, 2005).

It is also worth noting that the densification of the network of actors would not be possible without a governance capable of conducting a territorial diagnosis (Vicente, 2018) that would identify the levers for network densification (the combination of various proximities) and the design of viable development pathways (Torre and Beuret, 2012). Governance modes are also opportunities to manage the multi-level/scale dimensions of bioclusters. At the local scale, which is primarily focused on engaging local players, governance mainly deals with aspects such as integration and participation. Without this form of governance, other levels would not have sufficient visibility of local dynamics and needs (Wohlfahrt et al., 2019). At the scale of the political-

[9] In this analytical framework, we refer to M. Nieddu's work, published in French, and part of the University of Reims's (France) school of thought represented by authors such as D. Barthélemy or F-D. Vivien. These authors developed the concept of the "heritage economy". The main contributions are presented and translated into English.

administrative arena, strategic decisions are made; they may depend on political support, availability of resources, and facilitated connections with a broader range of players that can provide significant contributions to the biocluster, such as support for innovation, market opportunities, and reputation.

5. DISCUSSION

The objective of this conceptual framework is to design a theoretical tool to analyze the emergence, development, and viability of potential of circular bioclusters in a given area through the study of three major sets of factors: the necessary resources, the development factors, and the viability conditions. This framework is useful for calibrating development policies for localized circular sectors, as it allows for identifying the strengths and weaknesses of circular bioclusters under investigation. From a methodological standpoint, this initially translates into the need to collect data in order to identify the resources that are present or required. In particular, it will involve identifying the territorialized resources activated by the circular biocluster players and the subsequent creation of territorial value. Doing so, it is necessary to map the players' networks and identify the resource flows between them. This empirical analysis can be conducted using mixed methods (Watkins and Gioia, 2015), combining quantitative data based on available statistics with qualitative data through interviews or focus groups in order to capture social dimensions and context-related aspects. Furthermore, network analysis methodologies are useful for specifying the structural characteristics of the network, the main nodes, strengths, and weaknesses, in particular in cases of clusters (Wasserman and Faust, 1989; Lucena-Piquero and Vicente, 2019). The governance mechanisms of bioclusters need to be updated, whether formal or informal, particularly regarding the way in which bioresources are managed on a continuum between commodification and patrimonialization. Circular logics, through material flows, need to be adjusted and promoted to strengthen the resilience of the biocluster. Furthermore, highlighting the characteristics of the biocluster should allow for the consideration of development scenarios aimed at territorial development and rural resilience.

In this article, circular bioclusters have been conceptualized as systems going through three stages – i.e., emergence, development, and viability – while being anchored in place. Interestingly, this argumentation structured around three development stages aligns well with the literature on system thinking (Costanza, 2012). In the system thinking literature, systems like circular bioclusters are assessed using three criteria: vigor (a measure of metabolic activity or primary productivity), system organization (referring to the number and diversity of interactions between the system's components), and resilience (its ability to maintain structure and functioning under stress). The vigor criterion connects with the utilization of resources during the processing steps of bioclusters' productive activities. The organization criterion resonates with the structuring of the network of biocluster players. The resilience criterion echoes the issue of the arbitration between commodification and patrimonialization. As a result, a longitudinal assessment of bioclusters' evolution might eventually be conducted through the use of a grid which would consider these diverse elements. Table 4 provides an example of a grid that may be used to characterize resources and actor networks according to the different phases of circular bioclusters' consolidation.

Table 4. Example of Assessment Grid for a Dynamic Evaluation of the Evolution of Bioclusters.

	Emergence	**Development**	**Viability**
Vigor			
Organization			
Resilience			

At the viability stage, the system must achieve a symbiosis between productive activities that provide resources (extraction) and activities focused on the recovery of these resources (regeneration) and the processing of by-products (reutilization). These kinds of approaches have been developed for example in the analysis of the Japanese circular economy model through the concepts of arterial and venous industries (Ling, 2016). Although the more technical perspective on the management of material flows is critical, this article has focused more on a development planning perspective. This perspective is well captured by the Community Capitals Framework that highlights the complementarity and antagonism of bioclusters' resources. The consideration of material flows and their regulation by the circular biocluster system is likely to foster conflicts management issues that will add another layer of complexity to the governance of circular bioclusters.

6. CONCLUSION

This article is a starting point for the design of an analytical framework. This framework will need to be refined through confrontation with empirical data from the field. Several dimensions can be integrated such as the role of non-humans in governance (Gray and Curry, 2020) and the concept of productive communities (Nieddu and Vivien 2015). The inclusion of non-humans is particularly interesting to analyze in relation to the place of humans within natural ecosystems. The existence of non-human entities is often discussed in terms of their economic valuation, whereas their preservation could also be considered from an ethical perspective. The current development of bioclusters might benefit from adopting a methodological animism stance, in which non-human entities would participate in the governance of bioclusters (Caillé, 2020). Similarly, at this initial stage, the proposed analysis aims to capture the biocluster at a given time. To enrich the analysis, it would be important to conceptualize a more dynamic model that considers the role of information and communication technologies such as digital tools and A.I. in the development of bioclusters.

Last but not least, the impacts on regional development, which may stem from the emergence of bioclusters in rural areas, may also deserve more attention (Hermans, 2021). Rural innovations, which do not rely as much on patented innovations may imply more open innovations. As a result, rural bioclusters' innovation processes, which depend on well-functioning natural ecosystems that sustain ecosystem services, may gain from the development of both frugal innovation and naturebased solutions (Schneider and Belousova, 2019). Beyond the issue of innovation, the development of rural circular bioclusters offers interesting prospects for strengthening enabling environments. Indeed, in such environments, the existence of alternatives and the opportunity to select one of them contributes to the empowerment of individuals who may feel left behind by the processes of globalization. In this perspective, future research could also engage in exploring the rural-urban nexus, where rural areas (as producers of bioresources) and urban areas (as consumers or transformation centers) may collaborate to close economies.

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DECLARATIONS

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