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Retro-Innovation as an Alternative Innovation Paradigm in Agriculture: Evidence from Portugal

Retroinnovación como paradigma alternativo de innovación en la agricultura: evidencia de Portugal

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Abstract

This article examines how retro-innovation processes differ from dominant agricultural research and innovation regimes and under what conditions they may influence broader research agendas and public policy. Drawing on an inductively derived analytical framework based on the Gioia methodology, the study identifies five key dimensions of retro-innovation: temporality and knowledge reactivation, hybridisation with present conditions, innovation rationale, knowledge regime, and innovation output. These dimensions are applied to the recovery of traditional cereal varieties in Portugal, with particular focus on the CERTRA project.

The findings reveal a differentiated pattern of alignment. While strong alignment is observed in terms of knowledge reactivation, hybridisation, and the production of context-specific socio-ecological outputs, only partial alignment emerges regarding innovation rationale and knowledge regimes. This reflects the coexistence of alternative and dominant innovation logics, resulting in hybrid and tension-filled processes.

The study shows that retro-innovation is particularly relevant in contexts where standardised technological solutions are not easily applicable, highlighting the importance of territorially embedded knowledge and practices. Rather than fully replacing dominant paradigms, retro-innovation contributes to their reconfiguration by introducing diversity, contextualisation, and epistemic plurality into agricultural innovation systems.

Keywords: Portugal; Traditional Varieties; retro-innovation; cereals; sustainable transition

Resumen

Este artículo examina cómo los procesos de retro innovación difieren de los regímenes dominantes de investigación e innovación agrícola y en qué condiciones pueden influir en las agendas de investigación y en las políticas públicas. A partir de un marco analítico derivado inductivamente mediante la metodología Gioia, el estudio identifica cinco dimensiones clave de la retro innovación: temporalidad y reactivación del conocimiento, hibridación con condiciones actuales, racionalidad de la innovación, régimen de conocimiento y resultados de la innovación. Estas dimensiones se aplican al caso de la recuperación de variedades tradicionales de cereales en Portugal, con especial atención al proyecto CERTRA.

Los resultados muestran un patrón diferenciado de alineación. Mientras se observa una fuerte alineación en la reactivación del conocimiento, la hibridación y la generación de resultados socio ecológicos específicos del contexto, la alineación es solo parcial en la racionalidad de la innovación y los regímenes de conocimiento. Esto refleja la coexistencia de lógicas de innovación alternativas y dominantes, dando lugar a procesos híbridos y tensionados.

El estudio demuestra que la retro innovación es especialmente relevante en contextos donde las soluciones tecnológicas estandarizadas no son fácilmente aplicables, destacando la importancia del conocimiento y las prácticas territorialmente arraigadas. Más que sustituir los paradigmas dominantes, la retro innovación contribuye a su reconfiguración mediante la incorporación de diversidad, contextualización y pluralidad epistemológica.

Palabras clave: Portugal; Variedades tradicionales; Retro innovación; Cereales; Transición sostenible

1. Introduction

Alternative modes of agricultural production, including agroecological and low-input systems, are frequently portrayed as less productive and insufficient to ensure food security for a growing global population. Numerous studies and meta-analyses suggest that conventional agriculture tends to achieve higher yields per unit area, particularly in the short term, largely due to intensive management practices and the extensive use of external inputs (Connor, 2024; de la Cruz *et al*., 2023; De Ponti *et al*., 2012; Knapp & van der Heijden, 2018; Seufert *et al*., 2012). At the same time, a growing body of evidence indicates that the long-term productivity of conventional systems may be undermined by the progressive degradation of natural resources, especially soils, raising concerns about their capacity to sustain yields and food security over time(Carswell *et al.,* 2025; Gomiero, 2016; Kopittke *et al*., 2019; UNEP, 2025).

The remarkable productivity gains associated with conventional agriculture are inseparable from political and economic decisions concerning the orientation of research, innovation and knowledge production. Research agendas, funding priorities and technological trajectories are not neutral. Instead, they are socially and politically constructed, reflecting interactions between actors with unequal power and resource endowments. This raises fundamental questions about who benefits from scientific innovation and at what social, territorial and environmental cost. The limited allocation of research funding to agroecology compared to the substantial investment in agribusiness-oriented research illustrates this imbalance (Bruil *et al*., 2019). These structural asymmetries reveal deeper dynamics in the organization of agricultural knowledge and innovation regimes.

Within mainstream policy and scientific debates, the concept of sustainable intensification has emerged as a key framework for addressing the environmental limits of industrial agriculture while maintaining or increasing productivity (Garnett *et al*., 2013; Rockström *et al*., 2017; Royal Society, 2009). Sustainable intensification seeks to increase output per unit of land without expanding cultivated areas or exacerbating environmental degradation, broadening the concept of productivity to include resource efficiency and ecosystem impacts. This framework is typically articulated through two complementary pathways: technological intensifications and ecological intensification. Technological intensification emphasizes precision agriculture, plant breeding, digital technologies and, in some cases, genetically modified organisms. As stated by Marsden, (2009), although not denying the need for sustainable change, this pathway constrains such change within its own industrial and technological paradigm. Ecological intensification, by contrast, seeks to mobilize ecological processes such as soil fertility, biodiversity and biological regulation to reduce dependence on industrial inputs. Moreover, while technological intensification tends to generate patentable products and private returns on investment, thereby attracting corporate funding, ecological

intensification primarily produces knowledge as a public good, rendering it more dependent on public research agendas (Lima Santos, 2016).

Despite their differences, both pathways often remain embedded within a productivity-oriented logic that seeks to optimize existing agricultural systems rather than fundamentally questioning their historical, social and territorial foundations (Doré et al., 2011; Rockström *et al*., 2017). As Pigford et al. (2018) argues, agricultural innovation systems continue to prioritize sectoral and technological innovation within the dominant industrial paradigm, rather than adopting a genuinely multifunctional perspective integrating ecological, social and territorial dimensions.

It is within this context that concepts such as retro-innovation or retrovation, referring to the selective reactivation and reconfiguration of historically embedded knowledge, practices, and biological resources, can respond to contemporary socio-ecological challenges and build new supply chains and action spaces in which more value can be added at the local level (Marsden, 2009; Stuiver, 2006; Zagata *et al.,* 2020). Farmers have long relied on practices such as intercropping, catch crops, green manuring and the cultivation of locally adapted varieties. When reinterpreted and recombined with present-day institutional, technological and market conditions, these elements may constitute not merely heritage preservation but a distinct mode of innovation. Unlike linear models of technological progress, retro-innovation entails a reflexive engagement with the past that repositions territorial knowledge and socio-ecological processes at the centre of agricultural transformation.

However, retro-innovation should not be romanticized. Processes that reactivate traditional practices operate within contemporary regulatory frameworks, market structures and value chains that may both enable and constrain their transformative potential. The critical question is therefore not only whether such initiatives exist, but how they differ from dominant research and innovation regimes, and whether they can influence broader research agendas and public policy orientations.

This article addresses the following research question: How do retro-innovation processes differ from dominant agricultural research and innovation regimes, and under what conditions can they reshape broader research agendas and public policy orientations? The recovery of traditional cereal varieties in Portugal is examined as an empirical case through which these broader dynamics can be analysed. By clarifying the defining characteristics of retro-innovation and assessing its structural implications, the paper contributes to ongoing debates on the politics of agricultural knowledge, sustainability transitions and territorial development.

2. Theoretical Framework

Innovation is commonly understood as the process through which new or significantly improved products, processes or organisational forms are developed and brought into use, thereby transforming economic and social practices (OECD, 2018). In the agricultural sector, dominant models of innovation have historically been shaped by a linear and technology-driven paradigm, in which scientific knowledge produced within formal research institutions is transferred to end-users, particularly farmers, through extension systems. This model is typically characterised by a strong emphasis on productivity growth, efficiency gains, standardisation and scalability, often supported by private investment and oriented towards the generation of marketable and, in some cases, patentable outputs. Such approaches have been closely associated with the expansion of industrial, input-intensive agriculture, particularly in the Global North (Baret, 2017). However, several barriers, such as the high cost of new technologies and farmers' lack of skills to use them, as well as perceived lack of performance, relevance, and complementarity with existing tools, have prevented the scaling of new technologies in many rural and farming contexts. A growing body of literature highlights the limitations of this dominant paradigm, pointing to its social, environmental and territorial impacts,

and opening space for alternative visions of innovation that emphasise diversity, contextualisation and the co-production of knowledge (Klerkx *et al*., 2012; Pigford *et al*., 2018).

As recognised in early diffusion theory (Rogers, 2003), innovation does not necessarily stem from objectively new ideas but may instead involve the reinterpretation and adoption of existing knowledge within specific contexts. In this sense, innovation can also draw on practices and resources rooted in the past, whose relevance is context dependent (Zagata *et al*., 2020). While new technologies often replace older ones, the reverse can also occur. Such choices depend on farmers' individual circumstances, including their capacity to adopt new technologies, their ability to repurpose older ones, and the functional or symbolic value they attribute to them (Rose *et al*., 2023).

The concept of retro-innovation, proposed by Stuiver (2006) provides an analytical lens through which to examine such processes, by recognising diverse epistemes, practices and spatialities emerging from territories, rather than imposing universal, externally defined solutions. Retro-innovation is defined as the development of knowledge and expertise that combines elements and practices from the past, particularly those predating agricultural modernization, with present conditions, reconfiguring them for new and future purposes. Within this perspective, innovation is no longer conceived as a universal and linear pathway, but rather as a plural and context-dependent process that reflects the diversity of actors and their heterogeneous goals (Liopa-Tsakalidi, 2025; Loucanova *et al*., 2015; Stuiver, 2006; Wilbur, 2014; Zagata *et al*., 2020). Retro-innovation shares several features with other alternative approaches to agricultural innovation, such as co-innovation, interactive innovation and participatory innovation frameworks. Like these perspectives, it challenges linear models of knowledge transfer and emphasizes the importance of actor diversity, contextualized knowledge and collective learning processes. However, retro-innovation places particular emphasis on the reactivation and reconfiguration of historically embedded knowledge, practices and biological resources, a dimension that distinguishes it from broader constructivist approaches to innovation.

Retro-innovation does not necessarily imply a nostalgic return to the past, but a reflexive engagement with historical practices, combining them with present-day needs, constraints and opportunities. By grounding innovation in territorial knowledge, social relations and ecological processes, retro-innovation challenges the linear narratives of progress embedded in dominant development and sustainability discourses (Rose *et al*., 2023).

Instead of enforcing a centralised, prescriptive viewpoint, retro-innovation approaches better take into account local agroecological diversity and farmer knowledge. In situations where actors wish to pursue sustainable agriculture, which is highly context-dependent, the existing scientific knowledge, which is often based on the notion of universal validity and replication, may be of little use. According to a study conducted in Italy (Wilbur, 2014), newcomers to sustainable agriculture are unlikely to participate in capital-intensive "industrial" farming and may occasionally conflict with "conventional" farming methods, or techniques based on formal or standardised agricultural knowledge.

As stated by De Noni *et al*. (2026), retro-innovation can complement forward-looking innovation in developed regions but may be particularly important in contexts with limited R&D capacity, where historical knowledge can compensate for institutional and resource constraints. By reintroducing past practices, it can also provide relevant alternatives under increasing sustainability pressures, helping to address systemic challenges in ongoing transitions (Sixt *et al*., 2018).

The core attributes of retro-innovation, such as the integration of diverse knowledge systems and contextual specificity, align with territorial approaches to rural development, while also providing a useful framework for analysing local innovation processes and alternative development pathways (Marsden, 2009; Zagata *et al.,* 2020). Numerous examples in the agricultural sector illustrate how the rediscovery and reconfiguration of marginalised or forgotten knowledge can generate viable

alternatives for rural development. These include, among others: traditional water harvesting practices in Jordan (Sixt *et al.*, 2018); urban and peri-urban agriculture and short food supply chains, which reconnect production and consumption within local contexts (Aguiar *et al*., 2018; Tissone *et al*., 2019); organic farming in the Czech Republic (Zagata *et al*., 2020); the Italian grapevine *coltura promiscua* system (Ferrario, 2021); biological pest control and direct marketing in Latvia (Kilis *et al*., 2022); and biodynamic agriculture initiatives in Egypt and several European countries (Liopa-Tsakalidi, 2025).

Similar dynamics can be observed in the food sector. In Italy, the revival of traditional processing methods has been associated with improvements in food quality and health attributes (León-Bravo *et al*., 2019). In Chile, raw milk cheese producers and peasant wineries combine traditional and modern practices to sustain territorial socio-ecological systems while resisting the pressures of large-scale industrialisation and afforestation (Cid Aguayo *et al*., 2019; Jerez Henríquez *et al*., 2024). Shieling systems in Scandinavia have been revalorised for their contributions to biodiversity conservation, cultural heritage and climate adaptation (Svensson *et al*., 2026).

This body of literature suggests multiple dimensions along which retro-innovation processes may differ from dominant innovation regimes. These dimensions are explored through the empirical analysis that follows.

3. Methodology

3.1 Data Sources

This study is based on qualitative documentary research drawing on multiple sources. The analysis combines peer-reviewed academic literature on agricultural innovation, agroecology, traditional crop varieties and retro-innovation with empirical materials related to the Portuguese context. These include scientific publications on traditional cereals, previous research conducted by the author on territorial food systems, and documentation from research and development initiatives, with particular emphasis on the CERTRA project (Traditional Cereals – Developing Value Chains for Sustainable Food in Portugal).

Additional sources comprise policy documents and strategic frameworks related to agricultural research, rural development and sustainability, as well as technical reports and historical accounts describing the evolution of cereal production in Portugal.

3.2 Literature Analysis and Conceptual Development

The analytical framework developed in this article is grounded in an inductive and iterative analysis of the literature, inspired by the Gioia methodology (Gioia *et al*., 2013). This approach is particularly suited to emerging or under-conceptualised phenomena, such as retro-innovation, as it enables the systematic development of theoretical constructs from qualitative data.

First, a careful examination of selected literature on retro-innovation was carried out. An initial search conducted in the B-on database using the keywords “retro-innovation” AND “agriculture” returned a total of 64 publications. These records were subjected to a screening process based on relevance to the research objectives of this study. Articles were excluded when the term “retro-innovation” was used only tangentially, without conceptual development, when the focus was not related to agricultural or rural systems, or when the content did not provide empirical or theoretical insights relevant to the analysis of innovation processes.

Following this screening, a final sample of 24 articles was retained for in-depth analysis. From this material, a set of first-order concepts was identified, reflecting recurring empirical observations and conceptual categories within the literature.

These concepts were subsequently grouped into second-order themes based on their underlying conceptual similarities. Through further abstraction, these themes were synthesised into a set of aggregate analytical dimensions that capture the distinctive features of retro-innovation processes in contrast to dominant agricultural research and innovation regimes.

3.3 Case Study: Traditional Cereals and the CERTRA Project

The empirical analysis focuses on the recovery and valorisation of traditional cereal varieties in Portugal, with particular attention to the CERTRA project. The selection of this case is theoretically driven. Traditional cereals represent a context in which historically marginalised genetic resources and associated knowledge systems are being reactivated within contemporary agricultural and food systems.

Cereal production in Portugal has undergone a significant decline over the past decades, with self-sufficiency decreasing from 39% in 1993 to 18% in 2023 (Statistics Portugal, n.d.). Compared to other European countries, this contraction has been particularly pronounced, with a reduction of approximately 77% in production over the last thirty years (European Commission - DG Agriculture and Rural Development, n.d.). This trajectory reflects broader processes of agricultural modernisation and increasing integration into global commodity markets that included the replacement of traditional, locally adapted varieties with high-yielding, genetically uniform cultivars. As a result, many traditional cereal varieties—such as *Pirana* and *Barbela* wheat or local maize landraces—have been progressively marginalised and largely excluded from dominant agri-food chains (Dinis *et al*., 2025).

In recent years, however, emerging consumption patterns, particularly in urban contexts, have generated renewed interest in product quality, origin and production methods, creating new opportunities for the revalorisation of traditional cereals (Kušar *et al*., 2023; Oehen *et al*., 2015; Wendin *et al*., 2020). This shift has been accompanied by a growing recognition of the need to strengthen domestic production and reduce external dependency, as reflected in policy debates and research agendas (Barreiros *et al*., 2018).

It is within this context that the CERTRA project (Development of Traditional Cereal Value Chains for Sustainable Food in Portugal) was developed. The project was funded under the Portuguese Recovery and Resilience Plan (PRR) and coordinated by the Polytechnic Institute of Bragança, involving several universities, research centres, farmers' organisations, milling companies and bakeries. Implemented between 2022 and 2025, the project had a national scope, with activities concentrated in regions where traditional cereal varieties were still cultivated or held potential for reintroduction. Its main objective was to strengthen the value chain of traditional cereals by combining agronomic research, genetic characterisation, technological and baking evaluation, market analysis and stakeholder engagement. Through this integrated multi-actor approach, CERTRA sought to improve the economic viability of traditional cereal production, promote sustainable food systems, valorise local genetic resources and contribute to rural development in Portugal. Although the project was not conceptually centered on the notion of retro-innovation, the combination of historical reactivation, knowledge hybridisation and institutional involvement makes the case particularly suitable for examining whether and how retro-innovation processes emerge within contemporary research and development contexts through retrospective analytical interpretation. The analytical dimensions derived from literature are applied to this case to assess the extent to which the recovery of traditional cereals can be understood as a form of retro-innovation and to explore its broader implications for agricultural research and policy.

4. Results and discussion

As described in the Methodology section, the first-order concepts identified in the literature were iteratively grouped into second-order themes based on conceptual similarity and subsequently synthesised into aggregate analytical dimensions, following an approach inspired by Gioia *et al*. (2013). The results, displayed in Table 1, are structured around five analytical dimensions derived from the literature, including: 1) Temporality and knowledge reactivation; 2) Hybridisation with present conditions; 3) Innovation rationale; 4) Knowledge regime; 5) Innovation output.

Table 1 - Analytical dimensions of retro-innovation.

Analytical dimension	Definition (derived from literature)	Dominant innovation regime	Retro-innovation processes
Temporality and knowledge reactivation	Extent to which innovation is oriented towards future technological breakthroughs or involves the reactivation and reinterpretation of historically embedded knowledge and resources	Forward-looking, based on rupture with past practices	Reconfiguration and mobilisation of past knowledge and practices that have been lost/ discontinued
Hybridisation with present conditions	Degree to which historical elements are adapted and recombined with contemporary socio-economic, technological and institutional contexts	Technology-driven solutions designed independently of historical practices	Contextual recombination of past and present to address current challenges
Innovation rationale	Underlying motivations driving innovation processes	Productivity growth, efficiency and profit maximisation	Sustainability and nostalgia; reaction to the productivist paradigm
Knowledge regime	Dominant forms and sources of knowledge mobilised in innovation processes	Centralised, science-led and expert-driven; standardised and codified forms of knowledge	Hybrid configurations combining scientific and territorially embedded knowledge
Innovation output	Nature of outputs generated by innovation processes	Technological artefacts, standardised, scalable and often patentable	Socio-ecological practices, frequently context specific

These dimensions do not necessarily play the same role. While the two first dimensions relate to the core conditions that enable a process to be considered retro-innovation, the others capture recurrent characteristics associated with retro-innovation in rural and agricultural contexts and help assess the degree to which a particular case approximates or departs from the ideal-type described in previous studies. The empirical analysis therefore examines both the extent to which the recovery of traditional cereal varieties fulfils the fundamental conditions of retro-innovation and the extent to which it aligns with its characteristic features.

4.1. Temporality and knowledge reactivation

Traditional cereal varieties have largely been excluded from dominant agri-food systems in Portugal (Dinis *et al.*, 2025). As in other European contexts, public policies favouring private investment, such as intellectual property rights regimes and the development of standardised seed markets, have promoted the replacement of locally adapted varieties with genetically uniform elite cultivars, while limiting farmers' access to traditional seeds (Chable *et al*., 2020; Louwaars & Burgaud, 2016; OECD, 2012; Oehen *et al*., 2015).

This process was accompanied by the marginalisation of knowledge associated with on-farm selection practices and the use of traditional varieties in local food systems (Dinis *et al*., 2018). Although these varieties did not entirely disappear, they became forgotten and were dismissed by society and markets, corresponding to what De Noni *et al*. (2026) describe as processes of discontinuity.

In this context, the recovery of traditional cereal varieties for human consumption, which is central to the CERTRA project, can be interpreted as a process of reactivation and reinterpretation of historically embedded knowledge and biological resources, following the concept of retro-innovation presented in the literature (De Noni *et al*., 2026; Kilis *et al*., 2022; Liopa-Tsakalidi, 2025; Loucanova *et al.,* 2015; Stuiver, 2006; Zagata *et al*., 2020). Rather than a simple return to the past, this process involves the reconfiguration of previously marginalised elements within contemporary socio-economic and institutional settings, thereby illustrating a core feature of retro-innovation.

4.2. Hybridisation with present conditions

The recovery of traditional cereal varieties in Portugal goes beyond the preservation of past practices. In the case of the CERTRA project, traditional varieties are reintroduced into agricultural systems that differ significantly from those in which they originally evolved, requiring adjustments in cultivation techniques, processing methods and market integration strategies (CERTRA, n.d.).

This process involves the articulation of historically embedded knowledge with scientific research and innovation. Agronomic studies on landraces performance, adaptation to low-input systems and baking qualities are combined with traditional practices related to seed selection and local food production. Such interactions reflect a combined knowledge in which past and present elements are selectively integrated to address current challenges, including sustainability, market differentiation and consumer preferences.

At the same time, the reintegration of traditional cereals into contemporary value chains implies their positioning within niche markets oriented towards quality, origin and artisanal production. This often requires compliance with modern regulatory frameworks, quality standards and certification schemes, which may reshape traditional practices and introduce new constraints.

The case illustrates a process of hybridisation in which traditional resources are not simply preserved but actively reconfigured in response to contemporary needs, therefore meeting one of the most distinguishing characteristics of retro-innovation (De Noni *et al*., 2026; León-Bravo *et al*., 2019; Liopa-Tsakalidi, 2025; Stuiver, 2006; Wilbur, 2014; Zagata *et al*., 2020).

4.3. Innovation rationale

Building on Schumpeter (1934) view that innovation involves both commercialisation and market diffusion, De Noni *et al*. (2026) argue that the mere use of past knowledge at the household level, without a clear orientation towards wider application, cannot be considered retro-innovation. Accordingly, some form of market engagement or, as highlighted by Kilis *et al.* (2022), a broader social motivation must be present. The literature identifies a range of drivers underpinning retro-innovation

processes, including nostalgia, sustainability concerns and the search for differentiated market opportunities (De Noni *et al*., 2026; Kilis *et al*., 2022; Svensson *et al*., 2026; Zagata *et al*., 2020).

In particular, nostalgia can play a significant role in shaping consumer preferences, contributing to the revalorisation of traditional products associated with authenticity, heritage and sensory quality. In this sense, nostalgia operates not merely as an emotional attachment to the past, but as a socio-cultural driver that influences market demand and creates opportunities for the commercialisation of products based on traditional varieties and practices.

At the same time, retro-innovation is frequently rooted in a critical stance towards the dominant agricultural innovation regime (Stuiver, 2006; Wilbur, 2014; Zagata *et al*., 2020). As discussed in previous sections, increasing concerns regarding environmental degradation, biodiversity loss and the erosion of local knowledge systems have led to a growing questioning of input-intensive, productivity-oriented models. In this context, the mobilisation of past practices and resources can be interpreted not only as an economic strategy, but also as a response to the perceived limitations of conventional innovation pathways.

In the case of the CERTRA project, these different motivations coexist. On the one hand, the recovery of traditional cereal varieties is associated with sustainability objectives, including the promotion of low-input farming systems, the valorisation of agrobiodiversity and the strengthening of territorially embedded food systems. On the other hand, it is closely linked to emerging market dynamics, including demand driven by both product differentiation and nostalgia-informed preferences for traditional and locally rooted foods.

The coexistence of these motivations highlights a key tension within retro-innovation processes. While the recovery of traditional cereals challenges dominant innovation logics by foregrounding ecological and territorial values, it remains partially embedded in productivity-oriented and market-driven dynamics that shape its viability and scaling. The case therefore reflects a sustainability-oriented form of retro-innovation, while also benefiting from nostalgia-based market dynamics associated with traditional foods.

4.4. Knowledge regime

Contrary to the widespread perception that retro-innovation consists of merely replicating past practices, often seen as requiring little scientific knowledge, these processes are in fact highly knowledge-intensive for all actors involved (Kilis *et al*., 2022). They require not only the recovery and understanding of past knowledge and practices, but also their critical reinterpretation, integration with contemporary technologies, and adaptation to current socio-technical contexts.

In contrast to standardised and codified models of knowledge diffusion, retro-innovation relies on the interaction between formal and informal networks that connect actors sharing common interests and combine science with territorially embedded forms of knowledge (Kilis *et al*., 2022; Liopa-Tsakalidi, 2025; Stuiver, 2006; Wilbur, 2014). These processes are therefore characterised by knowledge pluralism, iterative learning and the co-existence of different epistemic traditions.

In the case of traditional cereal varieties in Portugal, and particularly within the CERTRA project, the knowledge regime reflects a hybrid configuration that combines elements of both dominant and alternative models. On the one hand, the project is embedded in formal research structures, involving scientific institutions and drawing on agronomic studies related to varietal performance, adaptation to low-input systems and processing quality, aligning with conventional science-led approaches to innovation. On the other hand, the project's participatory research approach, which involves farmers, milers, bakers, and consumers, encourages forms of knowledge creation that have historically been rooted in farming practices and local food cultures. Knowledge about seed selection, cultivation

techniques, and the use of specific varieties in traditional products is frequently practice-based and territorially embedded. Within CERTRA, these knowledge systems are not simply replaced, but partially reactivated and articulated with scientific knowledge, contributing to knowledge hybridisation processes.

However, this interaction does not occur on entirely equal terms. Scientific knowledge tends to retain a dominant role. The case illustrates a hybrid knowledge regime in which scientific and territorially embedded knowledge coexist, although not necessarily on equal terms.

4.5. Innovation output

The outputs of retro-innovation processes differ significantly from those associated with dominant innovation regimes. Rather than generating standardised technologies or universally applicable solutions, retro-innovation typically produces socio-ecological practices, systems and value-chain reconfigurations that are highly context-specific. These outputs are shaped by the interaction between ecological conditions, local knowledge systems and contemporary socio-economic dynamics, resulting in innovations that are embedded within particular territories rather than easily transferable across contexts (Wilbur, 2014).

In the agricultural sector, such outputs are often aligned with environmental conservation and sustainability practices, for instance by reducing reliance on synthetic inputs and promoting the use of locally adapted resources (Loucanova *et al*., 2015). In this sense, retro-innovation contributes not only to practical outcomes but also to the enrichment of agroecological knowledge, generating principles that can inform the design of more sustainable farming systems (Koohafkan & Altieri, 2011). However, the effectiveness of these outputs depends on their capacity to be integrated into the specific socio-technical environments in which they are implemented, highlighting the importance of alignment between innovation processes and local conditions.

In the case of traditional cereal varieties in Portugal, the outputs of the CERTRA project reflect this socio-ecological and contextualized concerns. Rather than producing a single technological innovation, the project contributes to the reconfiguration of low-input agricultural practices and the valorisation of local genetic resources Like in other retro-innovations the idea is not to improve scalability and transferability but to produce outputs that remain strongly dependent on local ecological conditions. The case therefore shows a strong alignment with the innovation output dimension of retro-innovation, illustrating how innovation can materialise in the form of context-specific socio-ecological systems rather than standardised technological artefacts. This output profile is consistent with the forms of innovation frequently associated with retro-innovation in the literature.

Table 2 synthesises the main findings of the empirical analysis, assessing the alignment between the recovery of traditional cereal varieties in Portugal and the analytical dimensions of retro-innovation.

Table 2 – Alignment of traditional cereal varieties recovery with the analytical dimensions of retro-innovation

Analytical dimension	Evidence from case	Assessment
Temporality and knowledge reactivation	Recovery of marginalized cereal varieties (e.g., Barbela, Pirana) and associated farming and food practices	Strongly Present
Hybridisation with present conditions	Integration of traditional varieties with agronomic research, modern value chains and regulatory frameworks	Strongly Present
Innovation rationale	Combination of sustainability goals, market differentiation and nostalgia-driven demand	Sustainability-led
Knowledge regime	Interaction between scientific research and practice-based, territorially embedded knowledge involving multiple actors	Hybrid but science-led
Innovation output	Development of context-specific socio-ecological practices and value-chain innovation	Context specific

Overall, the case shows a distinct pattern of alignment across dimensions, indicating that retro-innovation for traditional cereal varieties is a hybrid and tense process that still somehow held captive by the dominant innovation structures.

5. Conclusion

This article examined how retro-innovation processes differ from dominant agricultural research and innovation regimes, and under what conditions they may reshape broader research agendas and public policy orientations, using the recovery of traditional cereal varieties in Portugal as an empirical case. The findings reveal a differentiated pattern of alignment across the analytical dimensions identified, indicating that retro-innovation in this context constitutes a hybrid and tension-filled process, rather than a fully autonomous alternative to dominant innovation systems.

The analysis shows that CERTRA fulfils the core conditions of retro-innovation identified in the literature, namely the reactivation of discontinued resources and knowledge and their reconfiguration within contemporary socio-technical contexts. At the same time, the project exhibits a specific configuration characterised by sustainability-oriented motivations, a hybrid knowledge regime and context-specific innovation outputs.

The case also highlights that retro-innovation becomes particularly relevant in situations where solutions generated by dominant innovation regimes cannot be easily generalised or adopted across diverse agroecological and socio-economic contexts. In such cases, including the production of traditional cereal varieties, which are strongly shaped by local environmental conditions and cultural practices, territorially grounded and knowledge-intensive innovation processes emerge not as complementary, but often as necessary alternatives. These processes rely on the reactivation and reinterpretation of historically embedded knowledge, combined with contemporary scientific and institutional frameworks, to address context-specific challenges.

From a broader perspective, the results suggest that the transformative potential of retro-innovation also lies in helping to reconfigure dominant innovation paradigms from within by introducing more diversity, contextual sensitivity, and epistemic plurality. This has significant implications for the designs of agricultural reserac policies. It specifically calls for funding frameworks that go beyond a limited focus on standardised, scalable, and market-driven innovations, more inclusive and multi-actor research approaches, and increased recognition of territorially embedded knowledge systems.

Finally, this study contributes to ongoing debates on sustainability transitions and the politics of knowledge by demonstrating that the recovery of traditional practices is not a nostalgic return to the past, but a dynamic and knowledge-intensive process capable of generating viable and context-sensitive innovation pathways. At the same time, the findings should be interpreted in light of certain limitations. The analysis is based primarily on documentary sources and a single case study, which may limit the generalisability of the results to other contexts. In addition, the identification of analytical dimensions relies on an interpretative reading of the literature, which may be influenced by the scope and selection of sources considered. Future research could build on this work by exploring comparative cases across different regions and sectors, incorporating empirical data from interviews and participatory research, and examining the long-term impacts of retro-innovation processes on agricultural systems, value chains and policy frameworks.

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