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Co-designing poultry for crop-poultry systems: Genetic and organizational needs for agroecological transition

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Introduction

Food and farming system faces major challenges, such as climate change, biodiversity loss, and the need for food sovereignty, pushing to seek sustainable alternatives to industrial agriculture. Among these alternatives, the shift toward agroecology—a move to farming methods that work with nature, use fewer external inputs, and build resilience—has become a key solution (Wezel *et al*., 2020). A core idea in agroecology is the reintegration of crop and livestock production, which historically co-evolved but have been progressively separated by agricultural specialization (*Ibid.*). While systems that combine crops and ruminants have been well studied for their benefits (e.g. improving soil health, controlling pests, and diversifying farm income), crop-poultry systems (CPS) (arboriculture, market gardening, or field crops with laying hens or broilers) have received much less attention. Yet, these systems also offer important advantages, such as providing ecosystem services and economic benefits (Bosshardt *et al*., 2022). The development of this type of system raises questions about the adaptation of current poultry breeds for agroecological conditions. These breeds have been selected for high productivity in controlled environments and may lack essential traits such as robustness, ecological functionality, and adaptability to variable local contexts (Canario *et al*. 2024; Phocas *et al*. 2017). Poultry breeding is dominated by a few industrial actors, with little transparency or farmer involvement. While there are successful examples of community-based breeding programs in the Global South and participatory breeding methods in plant agriculture (Berthet *et al*., 2020), similar approaches for poultry in the Global North are rare. Most importantly, no study has yet carefully examined whether the poultry breeds available today actually meet the needs of CPS**,** which require considering animal traits, farming practices, and local conditions all at once. This study addresses a key research gap: **What are the genetic and organizational challenges and opportunities for developing poultry adapted to CPS ?**

Materials & Methods

Our work is part of the COBREEDING research project (2023-2028) funded by the high priority program PEPR AgroEcoNum (https://www.pepr-agroeconum.fr/eng) as part of the France 2030 strategy. This program places genetic resources as a major lever for the agroecological transition. To identify challenges and opportunities for developing poultry genotypes adapted to agroecological systems, we implemented a four-phase, multi-scale co-design process (Fig. 1). 63 farmers and 41 livestock professionals (farmers' facilitators, institutional and technical actors, researchers) were involved in at least one of the four phases. To do this, we combined, in particular, the innovative KCP (Knowledge-Concept-Proposals) design method which promotes the exploration of disruptive ideas (Hatchuel and Weil, 2009) with a socio-technical diagnosis to identify the opportunities and obstacles to innovation (Casagrande *et al*., 2024). This iterative approach alternated between national and

regional levels, integrating scientific and local knowledge, and addressed challenges at the animal, farm, and territory scales. The process ensured both local relevance and broader applicability of results. The CPS observed had a rather small number of animals compared to the national average for poultry farms. It was not a specific choice on our part, but it turned out that the systems seeking to maximize the interactions between poultry and crops were rather small. All interviews**,** workshop exchanges and webinars were recorded and fully transcribed using the Whisper software (Radford *et al*., 2022). The data were then analyzed using an inductive thematic approach (Paillé et Mucchielli 2016). Rather than organizing the results chronologically by phase, we have chosen to present them according to three thematic axes.

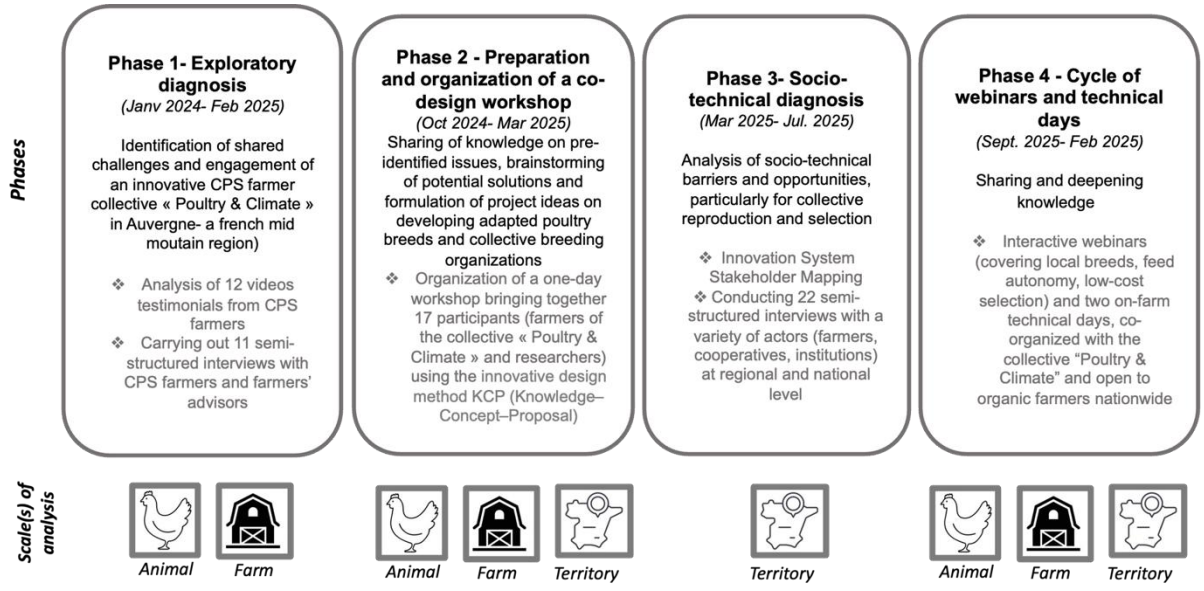

Figure 1. The different phases of the method implemented

Results

Interests and challenges of CPS. Farmers interviews showed that CPS bring many benefits. For example, these systems help farmers become more self-sufficient in feed and provide important ecological services. Chickens and other poultry help control pests naturally, which reduces the need for mechanical weeding, and their manure enriches the soil. At the same time, trees and crops provide shelter and protection for the poultry. Overall, these systems improve the economic stability of farms by diversifying income sources. This is especially important in sectors like fruit farming, where harvests can vary greatly from year to year due to weather conditions or diseases.

However, farmers also face several major challenges: i) Small farms often struggle to get chicks because hatcheries prioritize large producers, ii) The poultry lines that perform well in industrial systems are not always suited to alternative farming methods like CPS. Meanwhile, local breeds generally underperformed and iii) Current rules, such as those related to biosafety and slaughterhouse requirements, are designed for large-scale operations and do not work well for small, outdoor systems. Farmers criticized industrial breeding companies for their lack of transparency and for not involving farmers in decision-making. Attempts at on-farm breeding face several obstacles: high costs (€4 per chick vs. €0.6–1.2 in hatcheries), small flock size and cost of pedigree recording, leading to high inbreeding and poor hatching rates and legal restrictions on chick distribution (movement of animals between farms). Additionally, managing CPS demands diverse skills and labor, leading many farmers to abandon on-farm reproduction. These challenges which span animal genetics, farm

management, local conditions, and industry dynamics, show the need for new, collective, and practical solutions to fully realize the potential of CPS.

Animal-level solutions: breeding poultry adapted to CPS. Farmers in CPS seek a balance: they want to maintain the high productivity of industrial poultry lines while also incorporating traits that are better adapted to agroecological conditions. Their priorities reflect both economic necessity and the need for adaptability. Four essential criteria stand out: strong productivity (for both meat and egg production), feed efficiency, minimal aggression between animals and ease of handling. For laying hens, early sexual maturity and nest-laying behavior are also essential to minimize losses from dirty or broken eggs. These requirements explain why most farmers continue to use commercial lines, which they find satisfactory in terms of performance, while also looking to add traits that better suit their systems.

Beyond these basics, farmers identified several innovative traits or practices. They want poultry that can optimize local feed resources, such as homegrown grains and insects in order to strengthen the autonomy of their farm and decrease the environmental impact associated with imported feed. In direct-sales systems, longevity and egg-laying persistency are valued, and egg size standards are less rigid. Predation resistance is critical in regions with high raptor populations like mid-mountain region, where dark plumage or escape behaviors could reduce annual losses—one farmer with 5,500 hens reported €25,000 in annual revenue lost from predation. Climate adaptation is another priority, particularly in regions with harsh winters or heatwaves. Farmers also want distinctive products, such as uniquely colored eggshells or high-quality meat. While some imagine seasonal or intra-flock diversity, dual-purpose breeds (for both eggs and meat) attract little interest due to logistical challenges and trade-off to accept (i.e. meats or eggs).

Operationalizing these traits presents three major challenges. First, the concept of *"rusticity"* remains unclear as it includes various aspects such as disease resistance, adaptability to climate variations, and the ability to forage effectively. In addition, it is difficult to isolate the components of rusticity which would be needed for a breeding program. Second, it is hard to measure pest-regulation behaviors, as farmers cannot easily measure daily insect consumption or translate it into reduced pesticide costs. Third, farmers now acknowledge the need to find a balance between productivity and traits that lower costs. Profitability can still be achieved with slightly lower production levels if costs are reduced and fair prices are offered to consumers. This realization opens the door to compromises, but it will require collaboration between farmers and geneticists to define measurable indicators and evaluate the economic impact of these trade-offs.

Collective solutions: toward a farmers' poultry network for CPS. For farmers, viability of CPS depends on their ability to organize collectively. There is a strong agreement on the need to develop new forms of collaboration to reduce dependency on industrial actors, redistribute value, and strengthen autonomy. The most popular proposal is the creation of a Local Farmers' Poultry Network. This collective would bring together farmers, researchers, veterinarians, technical advisors, unions, and possibly independent breeding centers. Its goals would include developing locally adapted genotypes, facilitating exchanges of selected animals between farmers, pooling costs (e.g., for genetic analyses or vaccines), and building a shared commercial strategy, such as a brand or quality label. A network of farmers would support the development of alternative systems, better suited to local conditions. Several opportunities could help realize this vision. Inspiring models exist in other sectors, such as the *Réseau Semences Paysannes* (the French farmer seed network), which has successfully fostered participatory plant breeding for 20 years. However, farmers acknowledge that poultry selection presents unique challenges, such as small population sizes and complex

inbreeding management. Successful examples of local poultry breed valorization demonstrate the potential feasibility of such approaches, particularly when a quality label is obtained which supports sharing of animals between farmers and builds trust with consumers.
However genetic selection on agroecological traits, such as feed autonomy or predator resistance, remains the major challenge. Furthermore, structural barriers persist. CPS represent less than 1% of French poultry production, leaving them underrepresented in decision-making bodies and subject to standards designed for industrial systems. Farmers also face a lack of resources: limited data on local breed performance, insufficient funding for experimentation, and regional disparities in support programs. Tensions between actors further complicate progress. Dominant industry players (hatcheries, feed firms, and integrated producers) either dismiss CPS as economically unviable or oppose them outright, viewing them as a sanitary risks or threats to their control. Conversely, farmers in CPS deeply distrust the dominant industrial sector. Yet, intermediary actors—such as technical institutes, agricultural chambers, and producer groups—could help bridge this gap. Some farmers expressed satisfaction that research is now engaging with their practices. These intermediaries, along with researchers, may play a key role in facilitating dialogue, adapting regulations, and scaling up innovative models.

Discussion

The co-construction of selection criteria for CPS presents significant scientific and technical challenges, requiring long-term participatory research that integrates practical and scientific knowledge. Several key priorities are identified: (i) Developing selection criteria for complex traits such as robustness and resilience including the ability to maintain stable production despite climatic fluctuations, disease tolerance, and adaptability to diverse local feed resources. (ii) Creating new genetic evaluation methods, including on-farm protocols to assess traits like predator avoidance behaviors, the protective effects of plumage, and ecosystem services. (iii) Evaluating trade-offs between productivity, resilience, and ecosystem services, with a focus on economic viability using *"income minus feed costs"* (Hagger 1990), which could be adapted for CPS. (iv) Selecting founder populations, whether local breeds, commercial lines, or crosses, and assessing the benefits of genetically diverse flocks. These key priorities require new form of organization and large volumes of data.

Conclusion

This study highlights the need for systemic innovation—combining genetic adaptation, farm organization, and territorial networks—to support poultry-crop systems and for organizational support as well. Future work will focus on field-testing solutions on farms.

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