Towards a meaningful functioning of food systems: performance, resilience and scaling of underutilized crops in Europe



Marie-Fleur Nguyen Brémaud

Propositions

1. For farmers growing underutilized crops, good varieties are the ones that provide resilience, rather than high yields. (this thesis)

2. Policy support for underutilized crops in the fields starts with societal awareness about crop diversity. (this thesis)

3. It is a prejudice to state that more environmentally friendly farming and food systems are financially more costly for society.

4. As living organisms evolve genetically to adapt over time, agricultural policies based on stability of organisms over time hinder resilient farming.

5. Over-reliance on technology reduces society's resilience.

6. The number of job vacancies in Europe that truly support the future of humanity is too low.

7. Raising societal awareness on biodiversity is one way to counter nationalism.

Propositions belonging to the thesis, entitled

"**Towards a meaningful functioning of food systems: performance, resilience and scaling of underutilized crops in European food systems.**"

Marie-Fleur Brémaud

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Towards a meaningful functioning of food systems: performance, resilience and scaling of underutilized crops in Europe

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Towards a meaningful functioning of food systems: performance, resilience and scaling of underutilized crops in Europe

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1

Chapter 1

General Introduction

1.1 Background

Industrialized high-input food systems are mostly based on a few crop species and varieties (Elia & Santamaria, 2013; Padulosi et al., 2002) and a monocropping production system (Altieri et al., 2015). Low levels of agrobiodiversity in situ may have consequences for our food security, as it reduces the tolerance of cropping systems towards biotic and abiotic stresses (Padulosi et al., 2002). In the face of these issues, several alternative farming and processing practices have emerged in European food systems. Low-external input farming, organic agriculture or agroecology, combined with local value chains processing farm products are some of these alternatives, which share similarities, such as including nature and biodiversity into the food system, reducing external inputs and supporting farmers' income (Korpetis et al., 2023; Vermunt et al., 2022).

In addition to the need to enhance biodiversity, concerns regarding climate change and uncertainties in the international political context also prompt the European Commission to improve the sustainability and resilience of the European Union's farming and food systems (European Commission, 2025; Loi et al., 2024). In this context, the Farm-to-Fork strategy explicitly mentions the need to reintroduce more diversity of varieties into the fields (European Commission, 2020). The latest vision of European agriculture and food also highlights the need to restore biodiversity, although not specifying crop diversity (European Commission, 2025). This demand for diversification and adapted farming practices creates new opportunities for underutilized crops (UCs). UCs are identified as potential contributors to more sustainable food systems.

1.2 What are underutilized crops?

I define UCs as underutilized varieties, i.e. as both varieties of underutilized species and underutilized varieties of major species, as long as they are adapted and adaptable

(i.e. genetically diverse[1]) to farmers' needs. Another way to define "underutilized crops" is that my thesis focuses on all the underutilized "cultivated biodiversity" adapted and adaptable to farmers' needs, i.e. crops that support them to achieve their specific goals e.g. sufficient farm income, resilience to face climate change, and provision of ecosystem services. I explain the choice of defining "underutilized crops" at variety level below. In Chapter 6, Section 6.3, I discuss the consequences of using the term UCs.

The main reason for defining UCs as underutilized varieties rather than species in this thesis is that while diversity of species is usually not overlooked by economists, the potential impacts of diversity of "varieties" on farm businesses are much more overlooked. "Variety" in this thesis does not mean solely genetically uniform material protected by plant variety protection laws.

By underutilized varieties, I mean any landraces, local varieties, farmers' varieties, old cultivars, 'populations' or primitive varieties (Negri, 2005; Spataro & Negri, 2013a) that are underutilized while they are adapted and adaptable to farmers' needs. Also, as underutilized varieties are "adapted and adaptable" varieties, they represent a reservoir of genetically diverse crops that can be used by breeders to create selected registered 'elite' varieties (Negri, 2005; Spataro & Negri, 2013a). In the rest of the thesis, I thus refer to "underutilized crops" (UCs), which should be interpreted as underutilized varieties as defined above.

Most UCs are agronomically unused in Europe and only retrievable in small quantities from seed banks (Raggi et al., 2021), or sometimes found informally in remote areas where farmers still use them. A number of these UCs have been fully lost, as they have been replaced by varieties bred for specific traits such as higher yields (Petrovic & Dimitrijevic, 2012). In general, UCs are rare and thus difficult to access by farmers (Riu-Bosoms et al., 2014b; Thanopoulos et al., 2021b).

[1] When vegetatively propagated, crops can be reproduced without using (true) seeds. In this case, genetic adaptation is not possible. Since all plants are genetically identical, they may be collectively vulnerable to pests, diseases, or changing climate conditions (Nybom & Lācis, 2021; Salgotra & Chauhan, 2023). However, sexual reproduction is also possible for crops propagated through vegetative materials; the downside is that it may imply a loss of the parents' characteristics. In this thesis, I do not investigate the case of vegetatively propagated materials. Indeed, for the case studies encountered in this thesis, interviewed farmers saved most of their seeds, including for biennial crops such as onions (for autonomy purposes mostly). Crops reproduced through vegetative materials were thus largely minor.

Recent literature shows that some farmers made the deliberate choice to use UCs again for various purposes (Fenzi & Couix, 2022a; Martin, Shoemark, et al., 2023; Ortman et al., 2023). For instance, UCs are often characterized by their adaptability to the environmental conditions of the place they are cultivated, and their ability to grow in low-input systems, organic systems, and under harsh environmental conditions due to their tolerance to biotic and abiotic stresses (Martin, Shoemark, et al., 2023; Negri, 2005; Pérez y Pérez et al., 2019; Petrovic & Dimitrijevic, 2012; Sangiorgio et al., 2021; Timpanaro et al., 2022). This adaptability is attributed to their genetic heterogeneity (Korpetis et al., 2023; Ortman et al., 2023). In addition to adaptability, UCs are often described as having relatively low but stable yields (Martin et al., 2023; Negri, 2005; Ortman et al., 2023). Also the potentially high levels of nutrients (Biasi et al., 2015) might be a favoring factor in the renewed interest in UCs.

Genetic crop diversity is governed by international regulations. The international Union for the Protection of New Varieties of Plants (UPOV) stipulates that new crop varieties bred by breeders should be stable, uniform and distinct to be accepted for registration and subsequently sold to farmers (*UPOV Lex*, 1961). The European Union has signed this treaty and registered crops are listed in the European catalogue (*EU Plant Variety Portal*, n.d.). This means that bred crops have, by definition, limited genetic heterogeneity and therefore little adaptability (Korpetis et al., 2023). Additionally, registered varieties are often F1-hybrid[2] varieties. In 2013, this already pertained to 54% of the European catalogue for vegetable varieties (Elia & Santamaria, 2013a). While F1-hybrids outperform their parental varieties, they give poor yield when resowing the offspring, or are even sterile (Tripp, 1996). Hence, farmers have to re-purchase seeds every year from breeders to benefit from similar yields, making them dependent on seeds from external suppliers. When reproducible, some varieties of the catalogue are even forbidden to be resown or require the payment of a royalty to the breeder (European Commission, 1995). In contrast, most UCs are not registered and their seeds are freely reproducible from one generation to the next. When there is a need to exchange genetic material across national borders, the Nagoya protocol needs to be taken into account. The

[2] In sexual reproduction, F1 stands for first filial generation of two different inbred lines which are genetically stable and uniform. This type of hybrid usually combines desirable traits from each parent line making them stronger and more productive than either parent yet not able to produce seeds as productive as their parents (Tripp, 1996). Thus, farmers must repurchase new seeds for the next sowing season.

Nagoya protocol, under the Convention on Biological Diversity of 1992, adopted an "ownership system" where genetic resources are discrete and traceable material that can be exchanged via "Access benefit sharing" contracts. It moved away from a "common heritage" approach to a transactional one and affirmed national sovereignty over genetic resources (Wynberg et al., 2021). It also assumes that providers and users negotiate usually bilateral agreements (one provider, one user) and exchange physical material with clear provenance, ownership, and value (Wynberg et al., 2021). In practice, genetic materials evolve and are difficult to trace, and in many farming systems seeds are collectively used and improved rather than owned. In fact, UCs are highly genetically diverse and evolve through dynamic interactions with farmers (Halewood et al., 2006). Traditional agricultural communities manage UCs as a common heritage. Seeds are exchanged and shared, their provenance is ambiguous, and natural and artificial selections are intertwined (Wynberg et al., 2021). Thus, access benefit sharing contracts are hard to apply, and do not align with farmers' practices and perspectives (Girard & Frison, 2021). Farmers would need to change their behavior aimed at maximizing their food security and livelihoods, especially their exchange practices (Halewood et al., 2006).

Additionally, access benefit sharing involves lengthy and complex negotiations, which create obstacles for both academic and commercial research on landraces (Wynberg et al., 2021). Breeders must demonstrate the origin of seeds and prove legal access. If documentation is missing, breeders may avoid using them. This restricts conservation and taxonomy research, and leads to less work to improve UCs, and less use of diverse UCs in research (Prathapan et al., 2018). Cross-border seed exchange is also more complicated, as it may trigger access benefit sharing requiring proof of legal access (Wynberg et al., 2021).

The right of farmers to save, use, exchange and sell farm-saved seeds, i.e. from non-bred crops like UCs, has been recognized by the International Treaty on Plant Genetic Resources for Food and Agriculture (*ITPGRFA*, 1983). However, the ITPGRFA also stipulates that this right is subject to national laws, i.e. each country decides for itself. As such, the European Union prohibits all seed exchange between farmers who conserve seeds from their farms (European Parliament, 2024). Still, some EU countries allow the exchange and sometimes the sale of these UC seeds but only in minor quantities and under specific conditions (*Raad Voor Plantenrassen*, n.d.; *Légifrance*, 2020). UCs might

contribute to support the food sovereignty of territories as locally adapted crops require reduced levels of inputs (Korpetis et al., 2023; Timpanaro et al., 2022), and are reproducible by farmers. By being grown and sold by local people and farmers on a local scale, UCs might also support the existence of small businesses in rural areas, benefiting the local economy and social life in these places (Fenzi & Couix, 2022; Martin et al., 2023; Thanopoulos et al., 2021). More generally, UCs also contribute to landscape diversification by using more different crops themselves being more genetically diverse, in comparison to monocultures (FAO, 2018a). However, several challenges arise when it comes to growing and processing UCs, as explained in the next section.

1.3 Problem statement

In this section, four major issues regarding producing and processing UCs in Europe are explained. First, UCs do not fit well in the current seed regulations. According to the International Convention for the Protection of New Varieties of Plants, crops need to be registered to be sold and exchanged as seeds, and this registration requires stability over generations, uniformity and distinctiveness of crop varieties (*UPOV Lex*, 1961). Because UCs have a large genetic diversity, they are mostly not uniform and stable enough to comply with registration rules, and are most of the time not officially registered crops (Didonna et al., 2024). No registration means these crop seeds can be saved and reused by farmers without paying property rights fees to a breeder, but also that exchange (including selling) of UC seeds is prohibited (*UPOV Lex*, 1961). This makes access to UCs in most countries difficult or illegal for farmers. Although some more recent regulations (European Commission, 2009; European Commission, 2021) have attempted to solve these issues, they have failed to release UCs from their informal status (Didonna et al., 2024).

Second, in addition to institutional challenges, societal changes, such as rural migration and abandonment of farming as a profession (Pérez y Pérez et al., 2019), have transformed rural landscapes, leading to the loss of several local crops (Gomes et al., 2024), and isolation of some farmers and rural communities (Giupponi et al., 2018; Martin et al., 2023). Disregard for farming as a profession, and a change of lifestyle with little time allocated to cooking, also led to an abandonment of UCs, as well as knowledge and

practices to grow and use UCs (De Ron et al., 2018). Availability of adapted machinery for UCs is sometimes also challenging to access (Douma et al., 2016; Fenzi & Couix, 2022a).

Third, UCs are also affected by an unfavorable historical context of post-war productivism logic, modernization of agriculture and spread of monocultures, and standardization and mechanization in food chains (Ahokas & Poukkula, 1999; Elia & Santamaria, 2013a; Matson et al., 1997; Negri, 2005). UCs are not only genetically diverse, they are also often morphologically diverse (Spataro & Negri, 2013a), i.e. less standardized, with possibly less transportation and storage quality compared to selected cultivars (Elia & Santamaria, 2013a). This leads to challenges in globalized value chains. Hence, UCs are often restricted to local and short value chains. Local food systems, although allowing tighter connections within communities of customers and food producers (Enthoven & Van den Broeck, 2021), can also be precarious, because they depend on a few local actors (Martin et al., 2023), with unsuitable farming, food processing and marketing regulations applied to them (Ahokas & Poukkula, 1999; Didonna et al., 2024; Spataro & Negri, 2013a). As an example of precarity, in the Netherlands, the only company selling organic seedlings to all local vegetable growers suddenly stopped in November 2025, threatening the whole Dutch community of local agroecological growers.

Fourth, former examples of scaling underutilized species from their underutilized status have shown drawbacks. Quinoa in Andean regions is a well-known example. It first benefited from international interest (Andreotti et al., 2022), yet several drawbacks followed. For instance, farmers changed their genetically diverse varieties for selected ones, thus modifying polyculture farming practices into intensive monocultures, with negative environmental effects (Bazile et al., 2021). They also became more dependent on international market prices, which inevitably decreased due to increasing production volumes (Andreotti et al., 2022). This highlights the need for a careful approach and a clear vision when reinvigorating and scaling UCs in Europe.

1.4 Research gaps

In the literature, case studies about the farm economics of UCs in Europe are relatively rare when compared to cases reported from Africa or South America, see e.g. Feyisa et al. (2022) and Vijayalakshmi et al. (2023). In Europe, the environmental value of UCs (e.g. low inputs, little irrigation, resistance to pests and diseases or drought, use of

their genetic variability for breeding) has been documented (André et al., 2024; Korpetis et al., 2023), but the socio-economic value of UCs remains underreported (Bjarklev et al., 2019a). In terms of UC characteristics, yield is the most investigated trait by agronomists and geneticists (Annicchiarico et al., 2007; Malvar et al., 2007; Sanchez-Martin et al., 2017). However, limited farm-level economic analyses exist (e.g. Karelakis & Tsantopoulos, 2017; Sardaro et al., 2016, 2017; Varia et al., 2021). Moreover, the rare studies reporting on the socio-economic performance of UCs are scattered across various disciplines: yields are covered in genetics and agronomy disciplines (Annicchiarico, 2006; D'Antuono & Rossini, 2006; Giupponi et al., 2020), ethnographic studies report on food provision (Berni et al., 2019; Petrovic & Dimitrijevic, 2012) and traditional heritage value (Mahon et al., 2016a; Montesano et al., 2012), and nutrition value are reported in nutrition journals (Biasi et al., 2015; Siracusa et al., 2013a). As a result, the socio-economic value of UCs, in particular in Europe, is unclear because (1) studies reporting on concrete European case studies of UCs are still rare compared to other continents, and (2) evidence about the socio-economic value of UCs in Europe is dispersed among large disconnected bodies of literature. This dispersion of information across several non-economic disciplines may reduce scientists' and especially economists' understanding of the economic value of UCs in Europe.

While recent studies have highlighted farmers' motivations to maintain UCs, knowledge regarding processors' motivations to process UCs is still limited. In short, while some benefits of using UCs are captured in the literature, the understanding of why some local actors across Europe choose to use UCs rather than other varieties is still limited. Exploring the motivations of farmers and value chain actors for producing and processing UCs may bring a better understanding of their specific contribution to the economic performance and resilience of UC farms and value chains.

The rare studies on economic features of UCs focus on the farm level (Karanikolas et al., 2018; Karelakis & Tsantopoulos, 2017; Korpetis et al., 2023; Sardaro et al., 2016, 2017a; Thanopoulos et al., 2021b), while socio-economic consequences may apply to entire value chains or even the community. Additionally, the studies that report on the socio-economic value of UCs in Europe mostly focus on the direct monetary profits. However, due to the local and cultural nature of UCs, there are likely also indirect or non-monetary outcomes, such as partnerships (Fenzi & Couix, 2022a), rural job creation

(Martin, Shoemark, et al., 2023), local food provision (Petrovic & Dimitrijevic, 2012), and tourism and cultural heritage valorization (Mahon et al., 2016a; Thanopoulos et al., 2024). Focusing on farm-level economic indicators only may undervalue the true potential socio-economic benefits from UCs. Consequently, new approaches that can capture these indirect aspects are needed.

Due to their adaptability, UCs are frequently connected to risk reduction (e.g. stabilization of yields, resistance of crops). However, whether UCs can also play a role in the anticipation of and response to a wide set of disruptions and stresses (Meuwissen et al., 2019a) is not known. Resilience thinking provides a relevant analytical lens here, in order to understand the capacity of farming and food systems to anticipate and absorb shocks, or adapt and reorganize while maintaining essential functions. A structured assessment of whether and how UCs contribute to resilience in farms and value chains as conceptualized by recent resilience attribute frameworks (De Steenhuijsen Piters et al., 2022; Meuwissen et al., 2022) is lacking.

The literature reports past examples of underutilized species scaled out to become widely produced as new monocultures (Andreotti et al., 2022). This demonstrates the possibilities to grow underutilized species in larger commercial settings, and to provide more underutilized species for the human diet. However, these examples are not from Europe, and they report a large amplification of the crop production and mostly negative consequences of the crop scaling. In particular, several negative impacts for farmers are described, such as environmental degradation, an abandonment of most of the local varieties to focus on specific bred varieties, a decrease in farmers' autonomy and increased vulnerability of farmers in the face of global economic shocks (Andreotti et al., 2022, 2023; Bazile et al., 2021). To foresee a future for UCs in Europe, scaling pathways for UCs need to be anticipated up-front and not only reported ex post. Furthermore, UC scaling needs to be conceptualized from an integrative thinking perspective, i.e. not focused on UC multiplication solely, but also envisioning transition in people's awareness and mindset and institutional adaptation. This is possible by working towards scaling pathways together with the local actors, thus avoiding reproducing negative impacts of former scaling paths.

1.5 Objectives of the thesis

The overall objective of this thesis is to explore the functioning of European food systems using UCs. The concept of functioning is defined as *"the fact of working or operating, or the way that something operates"* (Cambridge Dictionary, 2025). This thesis thus aims to understand *how* these food systems "work" or "operate". Food systems in this thesis encompass farms, value chains and communities in specific contexts. In order to explore how European food systems using UCs work, this thesis focuses on the values UCs create, the motivations of the actors involved, how these actors build the resilience of their food system in the face of risks, and on pathways that can be envisaged to scale these food systems. The specific sub-objectives (SO) are the following, substantiated through analyses across multiple chapters (in brackets):

SO1: *To assess the economic performance of UC farms and value chains. (Chapters 2, 3 and 4)*

SO2: *To explore UC farmers and other value chain actors' motivations for using UCs. (Chapters 3, 4)*

SO3: *To analyze the resilience of UC farms and value chains. (Chapters 3 and 4)*

SO4: *To investigate scaling pathways for UCs. (Chapters 2, 3, 4 and 5)*

1.6 Scientific contributions

This thesis has four scientific contributions. First, while the economic literature on UCs in Europe is sparse and largely focused on yields, this thesis consolidates the currently scattered economic information on UC farms, value chains and communities across the scientific literature. It systematically gathers economic information dispersed in both economic and non-economic journals to bring it to the knowledge of economists. It explores how actors managing UCs create monetary value, such as farm profit, as well as indirect monetary value, such as local food, social ties, economic activities and tourism in rural areas.

Second, by investigating the motivations of UC farmers and processors, this research contributes to a better understanding of the multiple motivations of actors in UC systems. While some advantages of UCs for farmers are highlighted in the literature as potential motivations for farmers to use UCs, this thesis uncovers actual motivations of UC farmers

and other actors along the value chain for growing, but also for processing UCs. These motivations include contributions to local food autonomy, biodiversity conservation, cultural heritage, but also well-being and social life.

Third, while the information on UCs highlights the adaptability of UCs as a contribution to risk reduction, the mechanisms of how UCs may contribute to the resilience of farms and food systems (e.g. anticipation of and response to a wide set of disruptions and stresses) are not yet studied. This thesis contributes to covering this gap by investigating how UC farms and value chains build resilience in the face of challenges through combinations of strategies, including the use of UCs. Additionally, the thesis reports how UC value chains act with regard to reuse and circularity of resources, which also contribute to robustness and adaptability of food chains.

Past examples of scaling UCs have shown drawbacks when expanding without a plan and focusing on expansion only. This thesis proposes an up-front reflection of the decided scaling for UCs in a concrete case and from the field actors' perspective. Instead of looking at the expansion of UCs only, it conceptualizes the desired scaling, including how it should be developed institutionally and within mindsets (change of paradigm) to avoid drawbacks.

1.7 Conceptual framework

To understand the functioning of UC systems, this thesis uses the transition management and integrated thinking (TMIT) framework from Schoenmaker & Schramade (2019). The TMIT framework gives guidance on how to move away from the traditional economic risk–return thinking towards a more sustainable and integrated management regime. The framework encompasses enterprises, governments, and households. It is built on the premise that sustainable management needs to integrate economic, environmental and social aspects, while considering long-term risks. The framework also points out that transition paths to more sustainable management require personal, i.e. individual, change. Inspired by the TMIT framework, the first sub-objective (SO1) of this thesis investigates how UCs create economic value, thereby also considering indirect (non-monetary) benefits. As a summary, the TMIT is based on three main pillars: (i) accounting for an integrated value encompassing social and environmental dimensions in addition to the direct economic one, (ii) building up on personal motivations rather

than on economic incentives solely, (iii) long-term planning, such as taking into account long-term risks. The TMIT pillar on personal change inspires SO2 regarding personal motivations of farmers and processors to start with - and to keep on using – UCs, despite a series of challenges. As explained in the TMIT framework, understanding mindsets and motivations is needed to contribute to long-lasting, successful, sustainable transitions. The TMIT pillar on the need to account for long-term risks feeds into SO3 on the resilience of UC farms and beyond farm stages. The fourth pillar of the TMIT framework, i.e. the relevance of exploring transition scenarios and envisaging accompanying pathways, inspires SO4 of this thesis on scaling pathways for UCs from an integrated thinking perspective, thereby also considering the need for paradigm shifts and institutional change. The links between the TMIT framework and this thesis are visualized in Figure 1.1.

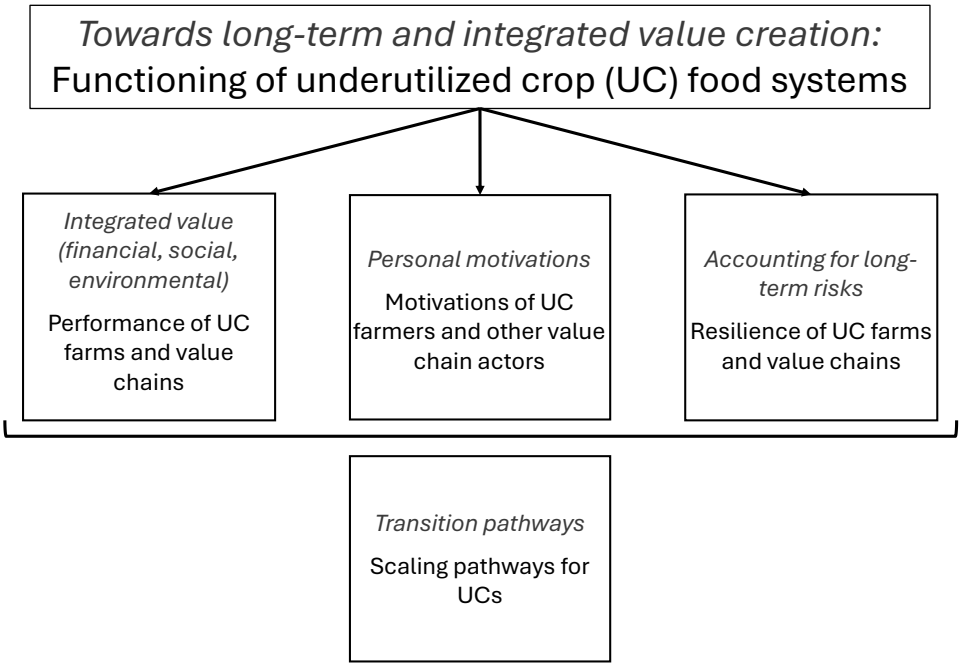


Figure 1.1 Conceptual framework of this thesis, adapted from the Transition Management and Integrated Thinking Framework (Schoenmaker & Schramade, 2019). Text in italic refers to the TMIT framework, text below shows focus of the sub-objectives (SO) of the thesis: SO1: to assess the economic performance of UC farms and value chains, SO2: to explore UC farmers and other value chain actors' motivations for using UCs, SO3: to analyze the resilience of UC farms and value chains, SO4: to investigate scaling pathways for UCs).

1.8 Outline

This thesis comprises six chapters, including this general introduction (Chapter 1), four research chapters (Chapters 2-5) addressing the sub-objectives, and a general discussion (Chapter 6). Table 1.1 shows a schematic overview of the thesis chapters, the methodology in each chapter, and the links between chapters and sub-objectives.

Table 1.1 Chapters in thesis, methodology per chapter, and accompanying sub-objectives (SOs).

Chapter	Data collection	Data analysis	Geographic focus	Actors involved	UC types	SOs[1]
Chapter 2 (scoping review)	Systematic scoping review	Categorization of literature: - Three levels: farms, value chains, communities - Five economic indicators: yield, costs, prices, profit, risks[2] - Challenges and opportunities	Europe		Arable crops, vegetables, and fruit trees	1, 4
Chapter 3 (farm management)	In-person interviews (n=17) in three regions	Structured assessment (with comparison to FADN dataset) of: - Farm structure - Farm economic performance - Farmers' goals - Farmers' strategies - Farmers' perceived resilience	France	Farmers	Field crops, Vegetables	1, 2, 3, 4
Chapter 4 (resilience of value chains)	In-person interviews (n=7) in three value chains	Structured assessment of: - Context - ABCD resilience attributes[3] - Resilience capacities	France, the Netherlands, Scotland	Farmers, processors	Cereals, processed food from cereals (e.g. flour, bread, beer, biscuits)	1, 2, 3, 4
Chapter 5 (scaling pathways)	Workshops (n=2)	Scaling pathways analysis through: - Context investigation - SWOT analysis - Desired future scenario making	The Netherlands	Farmers, processors, breeders, sellers, local policy makers, NGOs	Field crops, vegetables, and fruit trees	4

[1] SO1 assesses the economic performance of UC farms and value chains, SO2 explores UC farmers and other value chain actors' motivations for UCs, SO3 analyses the resilience of UC farms and value chains, SO4 investigates scaling pathways for UCs.
[2] Only at farm level.
[3] ABCD refers to the four following resilience attributes: agency, buffer, connectivity, and diversity (De Steenhuijsen Piters et al., 2022).

Chapter 2 reviews and describes the scientific literature on the economic aspects of UCs in Europe systematically, following the PRISMA method (Moher et al., 2009). The review categorizes the literature into three levels, i.e. the farm, value chain, and community levels. At farm level, more detailed are provided regarding the yields, costs, prices, profitability and the risks. At value chain and community level, economic aspects are sorted into challenges and opportunities. Additionally, to integrate this knowledge into a broader context, social and institutional challenges and opportunities connected to economic aspects are also reported.

Chapter 3 assesses the farm management of UC farms, encompassing UC farmers' motivations (goals) and strategies, UC farms' structure and economic performance, and UC farmers' perceived challenges and perceived resilience. Where possible, data for UC farms are compared with the literature and the open-source aggregated FADN dataset.

Chapter 4 investigates the resilience of UC value chains (farmers and processors) through three cereal UC value chain case studies in Scotland, the Netherlands and France. The chapter assesses the relevant context, resilience attributes (agency, buffers, connectivity, diversity), and resilience capacities of the case studies.

Chapter 5 explores scaling pathways for UCs in the case of the Netherlands, and from the perspective of the local actors involved in producing, processing, managing or selling UCs. Through desk research, context investigation, and workshops with diverse types of local actors involved in using UCs, this chapter assesses the scaling of UCs, building on the three scaling paths of Valencia et al. (2022), i.e. the institutional policies (scaling up), beliefs and knowledge about UCs (scaling deep), and aspects of producing and selling UCs (scaling out). Additionally, the desired future scaling situation for UCs in 10 years is assessed.


2

Chapter 2
The Economics of Underutilized Crops in Europe: a Scoping Literature Review

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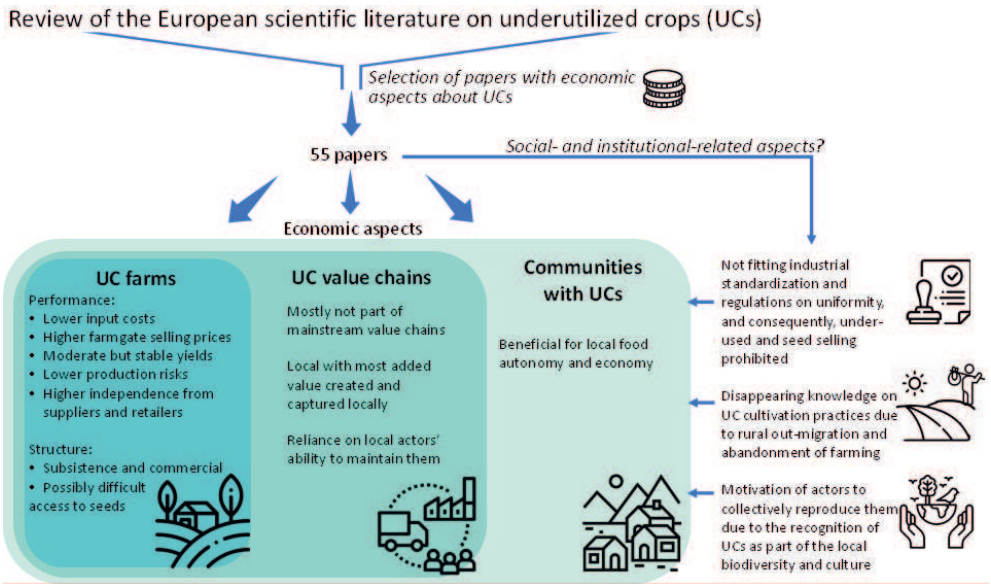
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Abstract

Underutilized crops (UCs) represent a considerable number of crop varieties. Acknowledged as a source of biodiversity and food security in the global south, they could also contribute to crop diversity in Europe. This chapter aims to review the scientific literature on the economic aspects of UCs at farm, value chain and community levels in Europe. We find 55 papers. The literature gives only partial evidence on these economic aspects scattered across disciplines. Yet, combined, these insights help understand their potential. UCs mostly relate to specific farm types, i.e. moderate-scale farms and home gardens, with agroecological or low-input practices, and mostly involve local selling or self-consumption. When they are commercialized, positive characteristics emerge: lower input costs, moderate but stable yields, low production risks, sometimes relatively high selling prices and higher market independence. However, the literature also reports challenges: farmers face difficulties in accessing UC seeds and UCs are mostly commercialized outside of mainstream food systems due to incompatibility with crop registration rules and standardization requirements. To stimulate wider adoption, releasing UCs from their informal status appears essential. Supporting bottom-up initiatives of producing UCs could also widen their use and eventually contribute to development paths towards more sustainable and resilient food systems.

Keywords: Underutilized crops, landrace, forgotten crops, farm, value chain

Graphical abstract



2.1 Introduction

An increasingly globalized food system and rapid expansion of industrial agriculture have led to a decline of cultivated biodiversity worldwide (Jones et al., 2021) and in Europe (De Ron et al., 2018; Negri, 2005). This may have several adverse consequences in the near future. For instance, the decline of crop genetic diversity in currently used varieties makes agroecosystems more vulnerable to biophysical changes, such as climatic events or diseases. This potentially decreases farm and farming system resilience (FAO, 2010; Traoré et al., 2020) and poses a threat on food and nutrition security (Vijayalakshmi et al., 2023b) on every continent, with an increase of chronic diseases connected to dietary habits (André et al., 2024). Further, the lack of cultivated biodiversity negatively impacts ecosystems where crops are grown (Camacho-Henriquez et al., 2016; FAO, 2010; Galmés et al., 2011). Thus, restoring or maintaining biodiversity is high on the policy agenda. For instance, as part of the 2019 EU Green Deal, the "Biodiversity strategy for 2030" puts forward a plan to bolster Europe's overall biodiversity, and the "Farm-to-Fork Strategy" aims at accelerating the transition towards sustainable and resilient food systems. This will require alternative farm production and food systems that preserve natural resources from depletion (Padulosi, et al., 1999). One promising opportunity to increase cultivated biodiversity lies in the growing of so-called underutilized crops (UCs) (Camacho-Henriquez et al., 2016; Pinto et al., 2023; Traoré et al., 2020).

There is no consensus on one precise definition of UCs in the literature. Here, we use the FAO definition of UCs: landraces, varieties or cultivars that (1) were either anciently used but later abandoned or originated from an outer region, and (2) have limited current use in the region but are locally well-adapted to a given geographic, social and economic context (adapted from FAO, 2018). Some examples are the Marano and Spongio corn landraces used by some farmers in the Veneto region (Italy) (Fenzi & Couix, 2022), the Bere barley landrace used in Orkney (Scotland) (Mahon et al., 2016), or the red onion landraces 'de Buzău' and 'de Turda' (Romania) (Antofie & Sava Sand, 2017). UCs present a genetic base that enables farms to adapt to heterogeneous and changing environments such as climatic conditions (Karanikolas et al., 2018), thereby also contributing to farm resilience (Meuwissen et al., 2019b). Last, in the face of climate change and uncertainties, such as those seen with COVID-19, the Ukrainian war or financial crises, diversified

agriculture, e.g., through using more diverse locally adapted crops like UCs, could increase food security of European populations (Loi et al., 2024).

While UCs have received attention from various disciplines in a development context (e.g. see (Padulosi, et al., 2002; McMullin et al., 2021) and are commonly recommended by international institutions, there is a lack of published cases where UC cultivation is promoted in the European Union (Bjarklev et al., 2019). The European knowledge base on UCs so far mostly exists as technical information at lab and field levels, including information on genetic composition (Dez et al., 2011; Dubois et al., 2018), molecular, morphological and agronomical traits (e.g. yield) (Ahokas & Poukkula, 1999; Arteaga et al., 2019; Bacchi et al., 2010; Desheva, 2014; Falcinelli et al., 1994; Lucchin et al, 2003), and chemical compositions for nutritional, storage (Berni et al., 2019; Dosi et al., 2013; Siracusa et al., 2013), or organoleptic characteristics (Renna et al., 2018). A limited number of sociological and anthropological studies have also focused on UCs (e.g. Acosta-Naranjo & Rodríguez, 2014; Scartazza et al., 2020). However, understanding the factors determining whether and how farms, value chain actors and community members can produce, process and commercialize UCs in Europe, necessitates insight into the functioning and economic performance of their businesses (NIAB, 2022). While farmers are key actors for UC production, they can be connected to downstream value chain actors for processing and commercialization. Actions from other community members, such as representatives or local environmental associations, may also support UC businesses. Moreover, the functioning and the economic performance of UC farms and value chains are themselves affected by social and institutional issues. As social and institutional contexts condition the possibilities to grow and generate profit from UCs, they may influence motivations of farmers and other community members to produce UCs and lift them from their underutilized status.

Literature on the economic aspects of UCs in Europe is highly dispersed across disciplines and often presented only as a topic for further research. For instance, Ahokas and Poukkula (1999) perform a molecular and agronomic analysis, and then also discuss the yield and European regulation regarding the commercialization of the variety analyzed. Piergiovanni and Laghetti (1999), in the field of genetic conservation, explain the interesting role of EU quality trademarks such as PGI for on-farm conservation of landraces. The Chapter concludes that conserving genetic resources on farms cannot be

performed only for conservation and thus, the economic dimension (i.e. local farmers' costs and benefits, involved areas' development, market opportunities) needs to be considered. Siracusa et al. (2013) study the morphological and productive traits and polyphenol contents of UC varieties of onions and tomatoes, and highlight in the conclusion that the maintenance of these UCs is relevant for the socio-economic aspects of marginal local communities in Europe. The scattered evidence on the economics of UCs, spanning across various disciplines, leads to a partial rather than holistic understanding, limiting our ability to fully comprehend their true potential and impact in Europe. Additionally, the lack of visibility and knowledge on the economic aspects of UCs may make UCs little considered by local policymakers, while they could be an interesting solution for a more resilient agriculture.

We start from the observations of environmental and nutritional science fields, which identified a lack of cultivated biodiversity in European agriculture. This lack of cultivated biodiversity threatens ecosystems and our environment, as well as our food security and our ability to offer diverse diets to people. From these points of view, using more UCs is needed, but are systems using UCs economically viable? The objective of this chapter is to systematically review the scientific evidence on the economic aspects of UCs at farm, value chain and community levels. We define economic aspects from a *micro*-economic perspective, i.e., we are interested in how individuals, households, or companies producing, processing, or selling UCs make decisions, in factors that influence these decisions, and in how these decisions affect others (Tubaro, 2015). At farm level, examples are farm profitability, risks, and issues regarding access to markets. At value chain level, examples are the creation of added value for UCs, processing, selling, demand and coordination in the chain. At community level, also aspects that do not have a direct monetary value are considered, such as informal exchanges of food and seeds (Spataro & Negri, 2013), and community attractiveness (Biscotti et al., 2022). Incorporating non-monetary micro-economic aspects provides a more complete story on the economics of UCs. To be as exhaustive as possible in retrieving economic aspects of UCs in the literature and to reach a more complete picture of the economic aspects of UCs, we also report social and institutional aspects influencing the economic aspects.

The scientific contribution of the review is twofold. First, we bring together the scattered scientific economic knowledge on UC production from a European perspective.

Second, we present a holistic picture by discussing the economic knowledge across the farm, value chain, and community levels. We retrieved and selected papers systematically following the PRISMA-ScR method. In the results, we first describe the characteristics of the papers retrieved (Section 3.1), and the configuration of UC farms and value chains (Section 3.2). The evidence found on the economic aspects of European UC production and processing at farm, value chain and community level is presented in Sections 3.3, 3.4 and 3.5 respectively. The findings on social and institutional aspects are summarized in Sections 3.6 and 3.7. Finally, we discuss the findings and knowledge gaps that emerge from this analysis and identify areas for further research.

2.2 Methodology

2.2.1 Literature search scope

As we aim to collect evidence on economic aspects of UCs in Europe as exhaustively as possible we performed a scoping review. Scoping reviews follow a systematic review process to retrieve evidence in broad bodies of literature (Tricco et al., 2018). Systematic reviewing methods are used for mapping and synthesizing perspectives described in the literature (Gough et al., 2017; Pickering & Byrne, 2014). By using a systematic, replicable, and transparent way to review and summarize the literature, systematic reviewing reduces the risk of biases compared to an unstructured literature search (Petticrew & Roberts, 2006; Rousseau et al., 2008; Tranfield et al., 2003).

For the present topic, i.e. economic aspects of UCs, we do not focus on one precise economic feature e.g. only farm level costs, price, or profit solely. This is because UCs are often used in home gardens (Feyisa et al., 2022), informal exchanges in terms of seeds and food (Padulosi et al., 2013), and as they contribute to the territory's heritage and its attractiveness (Martin, Russell, et al., 2023). Hence, focusing on one precise aspect would lead to overlooking an important part of the story on the economic aspects of UCs, which is what we aim to reconstruct by reviewing the literature. Therefore, we also report these more "loose" economic aspects, making our framework also more complex, i.e. focusing on three levels instead of on direct farm economic aspects only. By scoping large bodies of literature instead of a precise one, we follow a scoping review process, i.e. the PRISMA-ScR procedure (Tricco et al., 2018), rather than a PRISMA systematic literature review.

Scoping reviews focus on identifying knowledge gaps, scoping large bodies of literature, and clarifying concepts (Munn et al., 2018). Scoping reviews, in contrast with systematic reviews, extract evidence rather than data, and chart evidence rather than assessing quality (Mellor, 2021). Furthermore, scoping reviews aim to present and summarize the evidence retrieved (Peters et al., 2015), to estimate where evidence is located, and the sort of studies they are from (Petticrew & Roberts, 2006), and to give an estimate of the existing volume of literature and how dispersed it is (Petticrew & Roberts, 2006). Here, we aim to extract and report evidence exhaustively across the literature, and to clarify what 'economic aspects' mean in the context of UCs. Hence, we scope a large body of literature encompassing agricultural sciences as well as genetics and conservation, food science and nutrition, or ethnobotanical fields, to not overlook aspects disseminated in different fields of the scientific literature. However, we do not aim to analyze the quality and potential biases in the selected papers.

We systematically review the literature up to the end of 2024. For more exhaustiveness, two different scientific databases were used, namely Web of Science and Scopus, because they are comprehensive databases in the field of agriculture and food systems (Enthoven & Van den Broeck, 2021; Komarek, De Pinto, & Smith, 2020; Muflikh, Smith, & Aziz, 2021; Pinto et al., 2023; Totin et al., 2018; van Ewijk & Ros-Tonen, 2021) and allow complex search strings across various disciplines.

2.2.2 Search strategy

To perform the systematic search of papers, we created a search query code for Scopus, and then adapted it to Web of Science. It encompasses three main parts (**Error! Reference source not found.**): UC synonyms, economic lexicon and geographical focus. In this way, we aim at collecting all papers that contain economic information on UCs in Europe. The first part of the code is a list of synonyms of UCs. In order to get to an exhaustive list of synonyms, we first listed all the synonyms found in the literature. Second, we shared the list with all project partners of the European project RADIANT[3] which focuses on UCs, and we asked our partners to brainstorm and add any missing synonyms of UCs they may think of in order to complete this list. After obtaining this list of synonyms, we then made all the possible word combinations. For instance, "forgotten

[3] Realizing dynamic value chains for underutilized crops (www.radiantproject.eu).

crops" or "old varieties" may also appear in the literature as "forgotten varieties" or old crops".

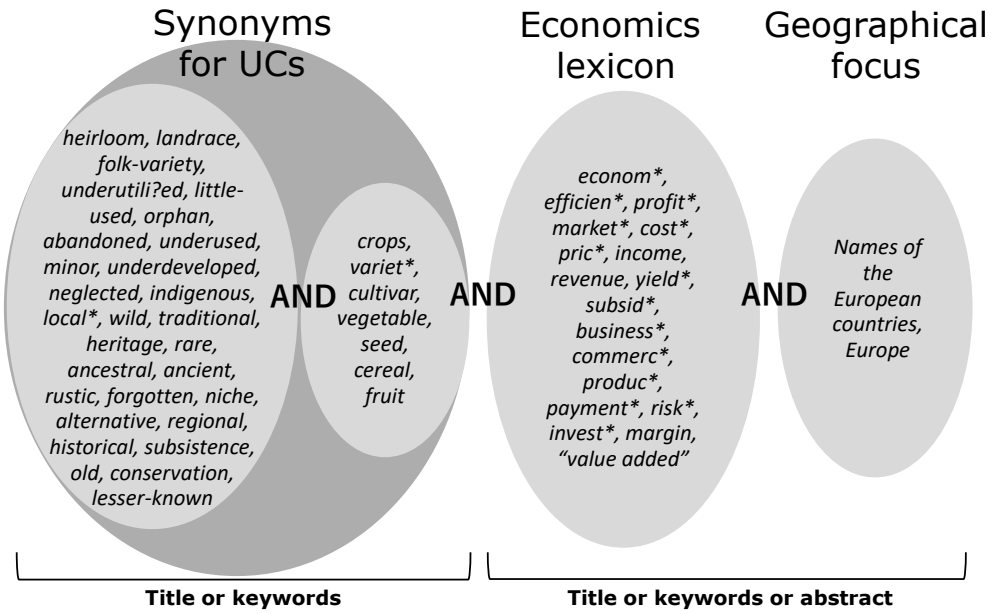


Figure 2.1 Three parts of the code capturing economic aspects of underutilized crops (UCs) in Europe.

The second part of the code encompasses economic terms enlisted by the authors. The third part of the code lists all European countries, including all EU countries, Norway, Switzerland, Scotland, United Kingdom, Wales, England, Serbia, Moldavia, Ukraine and finally the word Europe.

As UCs should be the main focus of the papers, we look for at least one combination of terms referring to UCs in the title or the keywords. Concerning economic aspects and geographical focus, we are less restrictive, and we search for at least one term from the list of economic terms and countries in the title, the keywords or in the abstract of the papers.

Because we want to gather all papers reporting on economic aspects of UCs, also papers that have been published in non-economic journals, such as in social or agricultural sciences, were included. We searched for papers in the following disciplines,

i.e. for Scopus: agricultural sciences, economy and social sciences, and for Web of Science: agricultural economics and policy, agronomy, economics, social sciences, interdisciplinary, agronomy or agriculture, and multidisciplinary. For both Scopus and Web of Science, we selected only document types that are original articles (see Supplementary Material 2.1 for the exact codes used). The code was run in July 2022. The results obtained from the two databases were merged, and after removing duplicate entries, a single list was compiled with the program EndNote 21 (The EndNote Team, 2013).

2.2.3 Selection process

The papers obtained through the code were screened and only included in the final database for analysis according to four inclusion criteria. The papers should (1) have a full text in English, (2) focus on a study located in Europe, (3) present original case studies (e.g. not a review of former case studies only), and (4) report at least one economic-related aspect of UCs in their findings. The screening was done by reading the title, keywords and abstract. Then, for the remaining papers, the entire text was read during the eligibility step. Here, papers were discarded if they either (1) do not fulfill one of the four previous criteria, or (2) do not have a sufficient level of transparency in the methodology applied. Yield by itself, was not considered as a sufficient economic aspect for selecting a paper. Figure 2.2 displays the flow chart of the selection process for obtaining the final database of papers that were fully analyzed.

We retrieved 454 articles from Scopus and 453 from Web of Science. After removing 153 duplicates, we obtain 754 papers (see Supplementary Material 2.2 for the list of selected papers). According to the inclusion criteria detailed above, 55 articles were finally selected. Among them, 48 gave information at farm level, 45 at value chain level and 31 at community level (Figure 2.2). All selected papers have a detailed methods section.

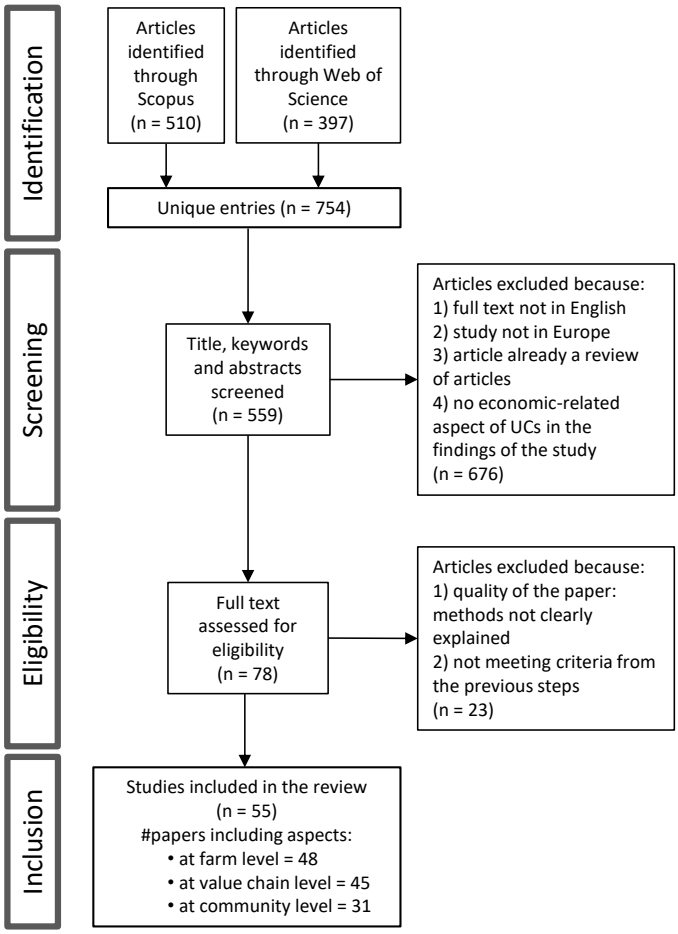


Figure 2.2 Overview of the selection process.

2.2.4 Assessment of the literature

The full-text of the 55 selected papers was analyzed to capture information across the three levels addressed (farm, value chain, community) and to assess whether the paper focused only on economic aspects or also on social or institutional aspects. While screening each of the selected papers, all economic aspects (and related social and institutional aspects) found were reported in a five-box table sorting the results into purely economic aspects (split into farm, value chain, and community levels), and social, and institutional aspects. Multiple papers included more than one level. All evidence was first recorded by the first author with its source. In a second step, each box of the table

was analyzed by the three researchers together to create the five summary tables presented in the results. During this second phase, some aspects were moved from one box to another for a better fit.

At farm level, we focus on aspects related to farm business and production issues. Aspects going beyond the farm, such as sales, processing, demand, coordination, and organization in the value chain are classified as value chain aspects. The community level includes even broader aspects, such as regarding informal food exchange, home consumption, and indirect economic aspects such as tourism and local economy.

Due to the wide variety of details and depth of the papers, and because several only provide qualitative information, we summarize them in the following qualitative manner. For the economic aspects at farm level, we use “+” and “–” indicators to indicate whether UCs were found to perform relatively well or poorly, respectively. A “≈” sign is used if performance was judged as "satisfactory". As literature does not always provide a precise comparison between UCs and other varieties when discussing performance (e.g. mainstream crops in the same area, or UCs elsewhere), any connotation pointing at a relatively good performance, such as “high”, “higher” or “well”, is attributed a “+” score. Likewise, any negative connotation, such as “low” or “modest”, is allotted a “–” score. Information found on UC value chains was mostly not specific to precise stages of the value chain, but rather qualitative aspects for the value chain as a whole. Thus, at value chain level, economic aspects are summarized as “challenges” and “opportunities”. The same holds for the community. Last, we present social and institutional aspects influencing the economics of UCs: for social aspects (37 papers), both challenges and opportunities were identified. With regard to institutional aspects (24 papers), findings from the literature are summarized as “hindering” and “supporting” factors.

2.3 Results

2.3.1 Characteristics of the selected papers

A large proportion of the selected papers has been published fairly recently, i.e. after 2012 (Figure 2.3a). An increase in the number of relevant papers for this review seems to be visible for the year 2024, which might be an outcome of the EU Horizon projects on

UCs that have been running during the last four years. Focusing on diversity in crop types studied, no clear pattern emerges: while cereals and vegetables are studied most (26.5% and 21.7% respectively), there is also research on pulses (18.1%) and fruits (15.7%) (Figure 2.3b).

Most of the papers reporting economic aspects regarding UCs are not from economic journals. Most frequent fields are agriculture and horticulture (19), genetics and conservation (14), multidisciplinary journals such as "Diversity" or "Sustainability" (11), and socio-economics (nine). Two papers are from food science and nutrition (Figure 2.3c). This shows that economic evidence regarding UCs is scattered among different non-economic disciplines.

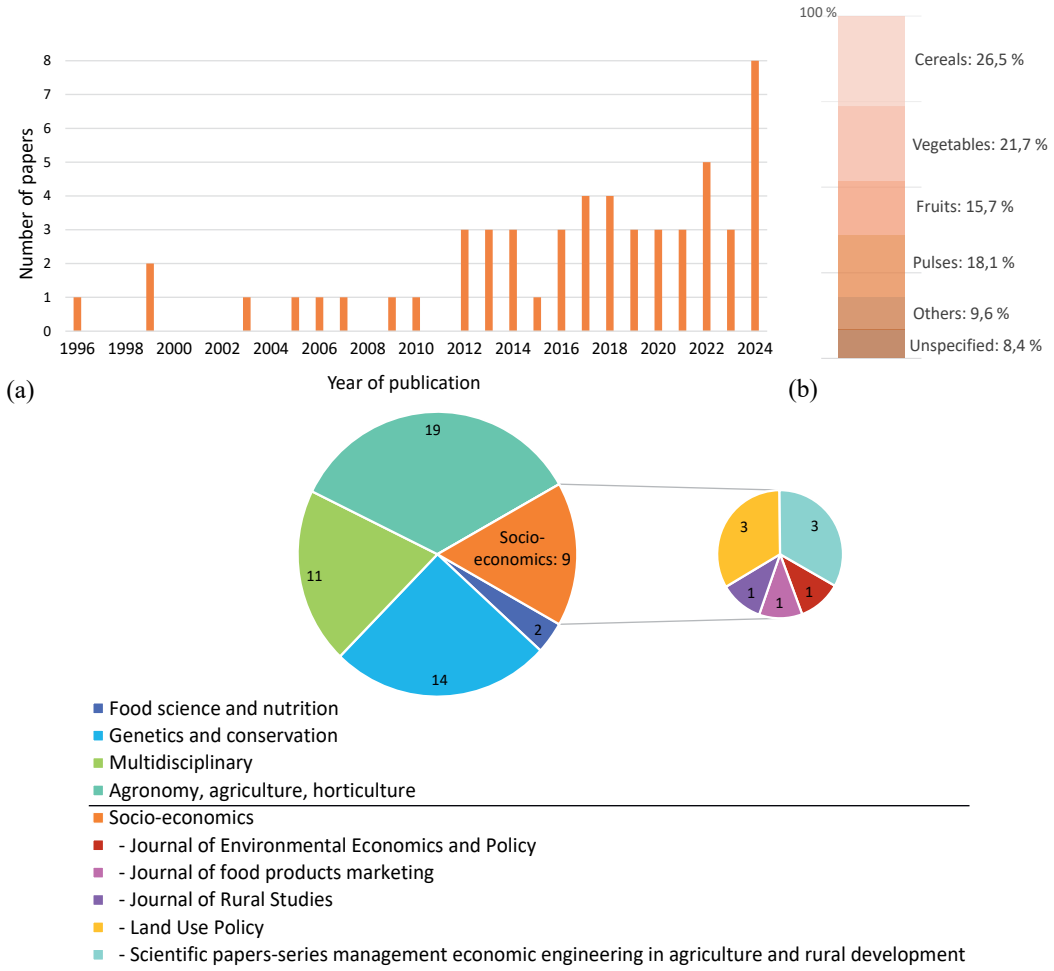


Figure 2.3 (a) Distribution of the 55 selected papers per year of publication, (b) Proportion of crop types studied (note: one paper may include more than one crop type), and (c) Distribution of the 55 selected papers per journal discipline with details of the socio-economic discipline (see Supplementary Material 2.3 for a detailed classification of the journals into disciplines).

Among the 55 selected papers, several report more than one case study, and two papers analyze the European Union as a whole. Figure 2.4 presents a heat map that displays the number of case studies conducted in each country. A large share of papers about UCs relate to Southern European countries, especially Italy (with in total 22 papers), followed by Spain (10), Greece (nine) and Romania (five). The multitude of papers in Southern Europe might relate to a more challenging geo-physical context; several papers explain that when climate is harsh, such as in mountainous or dry areas,

only locally well-adapted UCs could still provide acceptable yields (Petrovic & Dimitrijevic, 2012; Riu-Bosoms et al., 2014; Thanopoulos et al., 2021; Thanopoulos et al., 2024).

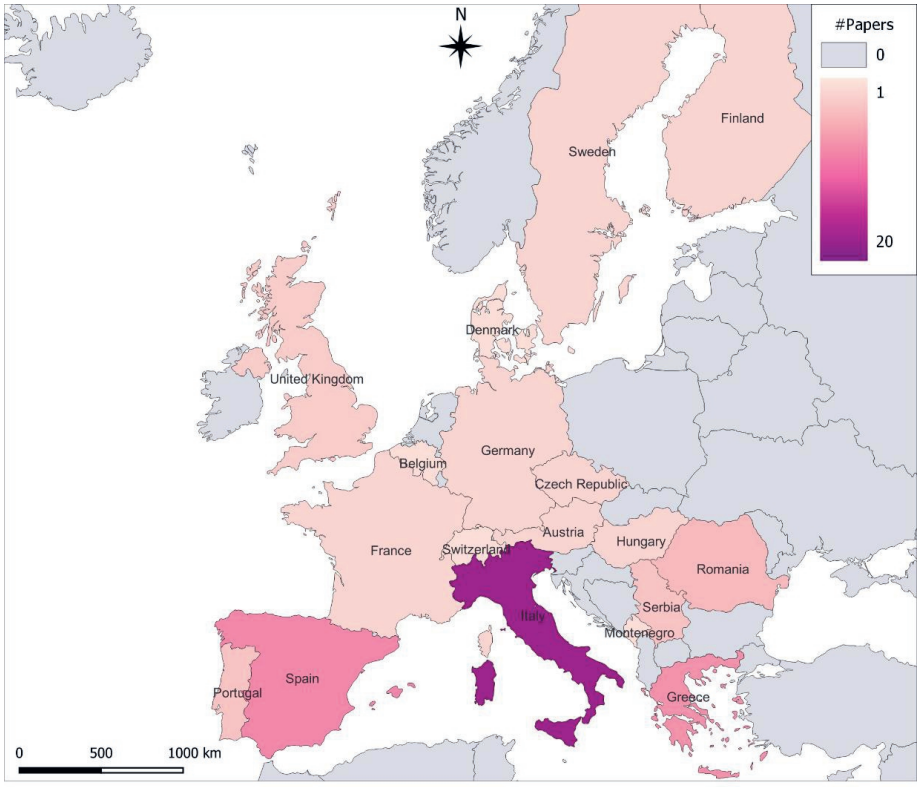


Figure 2.4 Number of papers on UCs conducted by country in Europe.

2.3.2 Configuration of UC farms and value chains

Farms producing UCs are described in the literature with some recurrent characteristics. First, UCs are repeatedly found in home gardens (21 papers[4]) (Červenski et al., 2013; Conversa et al., 2020; Douma et al., 2016; Thanopoulos et al., 2024), small farms (Conversa et al., 2020; Douma et al., 2016; Sardaro et al., 2016; Timpanaro et al.,

[4] The words "home gardens", "family gardens", and "small gardens for self-consumption" are included in this counting. Other words, such as "amateurs", "smallholdings with self-consumption", or "small-scale subsistence farms" are not included in this counting.

2022) and sometimes middle-size farms (Bela et al., 2006). Still, Ortman et al. (2023) specify that farms growing UCs were not especially small, which is also confirmed by Brémaud et al. (2025). Second, UC farms are also associated with various farming practices (Fenzi & Couix, 2022), such as organic farming (Bela et al., 2006; Fenzi & Couix, 2022; Giupponi et al., 2018; Ortman et al., 2023), mixed cropping (Bela et al., 2006; Fenzi & Couix, 2022; Sardaro et al., 2016), multicropping (Douma et al., 2016; Goufa et al., 2024) or intercropping (Bela et al., 2006; Gomes et al., 2024; Ortman et al., 2023; Thanopoulos et al., 2024). Third, UCs are not only cultivated for commercialization such as presented by Pieroni et al. (2005), Elia and Santamaria (2013) and Karanikolas et al. (2018), but also for self-consumption by farm families (Biscotti et al., 2022; Conversa et al., 2020; De Ron et al., 2018; Giupponi et al., 2018; Gomes et al., 2024; Negri, 2003; Thanopoulos et al., 2024).

When UCs are commercialized, niche markets and local markets are primary drivers of UC production beyond farms (Brugarolas et al., 2009; Douma et al., 2016; Karanikolas et al., 2018; Thanopoulos et al., 2024) ensuring UC farmers' profits (Fenzi & Couix, 2022). Value chains are recurrently specified as "local" (Douma et al., 2016; Negri, 2003; Pieroni et al., 2005), which is in line with the fact that UCs, by definition, are grown in a specific local context.

2.3.3 Economic aspects of UCs at farm level

Table 2.1 presents an overview of the economic aspects of UCs at farm level. Ten papers mention higher selling prices for UCs. The yields are found to be lower than in a conventional context in seven papers (André et al., 2024; Korpetis et al., 2023), satisfactory in six papers, and good in five papers. Among the papers with positive statements about UC yields, it was specified that UC yields were especially good in low-input and organic systems (Korpetis et al., 2023; Timpanaro et al., 2022), in adverse environments, with harsh climates and soil conditions (Goufa et al., 2024; Martin et al., 2023; Ortman et al., 2023; Petrovic & Dimitrijevic, 2012; Riu-Bosoms et al., 2014a; Thanopoulos et al., 2021a, 2024) and in terms of resistance to pests and diseases (Goufa et al., 2024). In general, the literature mentions UC farms as low-input farms with relatively low production costs: production costs as a whole are reported as low in 10 papers (Antofie & Sava, 2020; Goufa et al., 2024; Karanikolas et al., 2018; Korpetis et al., 2023; Mahon et al., 2016; Martin, et al., 2023; Ortman et al., 2023; Sardaro et al., 2016,

2017; Timpanaro et al., 2022). In one paper, production costs are mentioned as lower or similar to conventional, depending on the crop (André et al., 2024). None of the papers considers production costs as high. More precisely, while the costs for water, fertilizers or pesticides are indicated as low (Goufa et al., 2024; Martin et al., 2023; Sardaro et al., 2017; Timpanaro et al., 2022), papers differed regarding the costs for plant materials, adapted machines, and labor. Some papers also note the relatively high costs for some quality plant materials (e.g. Sardaro et al., 2017). In contrast, other papers report that seeds are selected, saved, and distributed by farmers (and sometimes local nurseries), offering more autonomy to farmers and suppressing seed costs, as farmers do not buy any seeds (Fenzi & Couix, 2022; Gomes et al., 2024; Goufa et al., 2024; Ortman et al., 2023; Timpanaro et al., 2022).

Labor requirements for UCs are mentioned in 13 papers: six specify that, in general more labor is required (Bela et al., 2006; Negri, 2003; Riu-Bosoms et al., 2014). In contrast, seven papers report fewer field interventions due to low-input requirements and good competitiveness against weeds of UCs (André et al., 2024; Martin et al., 2023). Two papers specify that the largest part of the workforce is family labor (Fenzi & Couix, 2022; Karanikolas et al., 2018), and two highlight the specific need for manual labor (Stillitano et al., 2017; Thanopoulos et al., 2021). Four papers also point out difficulties to access seeds (Elia & Santamaria, 2013; Martin et al., 2023; Riu-Bosoms et al., 2014; Thanopoulos et al., 2021) and three papers difficulties to access appropriate machinery (Antofie & Sava, 2020; Douma et al., 2016; Fenzi & Couix, 2022). Yet, compared to other farms with more conventional crops, UC farms can have a low level of mechanization (Goufa et al., 2024; Martin et al., 2023) and lower machinery costs (Martin et al., 2023; Sardaro et al., 2016). When profitability is analyzed, most papers report profitable businesses, in some cases even without subsidies (Sardaro et al., 2017; Stillitano et al., 2017), yet negative profits are also reported (Karanikolas et al., 2018). More recent papers also report on the substantial financial contribution of UCs to the household or farm income, such as Martin et al. (2023), Ortman et al. (2023) and Timpanaro et al. (2022).

In terms of risks, production risk is most frequently discussed. The yield for UCs is reported as more stable than for conventional crops in 14 papers (implying lower production risk). This was mostly attributed to the intrinsic genetic diversity of the crops, which enables them to adapt to local conditions (Ortman et al., 2023). No paper indicating

the opposite was found. The risk-reducing effect is also attributed to the "multi-usage" potential of some UCs, e.g. as a food commodity, feedstock (Goufa et al., 2024; Martin et al., 2023; Thanopoulos et al., 2024), or for animal grazing, depending on the yearly climate conditions (Attene et al., 1996a). Financial risk was cited as relatively low due to lower needs for investments (Petrovic & Dimitrijevic, 2012; Sardaro et al., 2016) and lower production costs (Karanikolas et al., 2018; Sardaro et al., 2017). Market risks are mostly linked to the absence (Fenzi & Couix, 2022; Goufa et al., 2024; Sardaro et al., 2017) or difficult access to markets (Antofie & Sava Sand, 2017), or considered as relatively low due to partnerships between farmers. Such partnerships mostly consist of small cooperatives and consortia that manage the process from harvest to sale, ensuring minimum prices for all farmers (Fenzi & Couix, 2022). Minimum and stable prices are also secured thanks to branding (Varia et al., 2021), direct selling or short chains (Ortman et al., 2023), or labelling (Expósito-Goás et al., 2024; Karanikolas et al., 2018; Stillitano et al., 2017). Farmers actively create stable market demand by informing consumers about the qualities of UCs (Ortman et al., 2023). Pooling production is also found to reduce market risk as it enables farmers to negotiate a more stable price, as shown by Karanikolas et al. (2018) for olive oil made from local varieties of olive trees. Lastly, processed products with a long shelf life, such as olive oil, can be sold when prices are higher, which helps to ensure a minimum price, reducing market risk (Karanikolas et al., 2018).

Table 2.1 Economic aspects of UCs at farm level found in 29 papers and summarized through qualitative indicators with + and − indicating a relatively high or low performance, respectively, while the ≈ sign indicates levels perceived as sufficient, and inversely for the costs and risks.

Authors, Year	Country	Crop[1]	Performance				
			Price & markets[2]	Yield[3]	Costs & access to inputs[4]	Profitability[5]	Risks[6]
Attene et al. 1996	Italy	C	IND^{+}				P^{-}
Negri 2003	Italy	A, C, F, PL	IND^{+}		CL^{+}		P^{-}
Bela et al. 2006	Hungary	U			CL^{+}, CC^{-}		
Polegri and Negri 2010	Italy	PL				FI$^{+/\approx}$	
Petrovic and Dimitrijevic 2012	Montenegro, Serbia	C		Y^{-}	CINV^{-}		F^{-}
Montesano et al. 2012	Italy	A, H, PL	P^{+}				P^{-}
Elia and Santamaria 2013	Italy	A	P^{+}		AS^{-}		I^{+}
Knezevic-Jaric et al. 2014	Serbia	C		Y^{-}			P^{-}

Authors, Year	Country	Crop[1]	Performance				
			Price & markets[2]	Yield[3]	Costs & access to inputs[4]	Profitability[5]	Risks[6]
Riu-Bosoms et al. 2014	Spain	A, C, H, PL	IND^{+}	Y$^{\approx}$	CL^{+}, AS^{-}		P^{-}
Biasi et al. 2015	Italy	PN		Y$^{\approx}$	CI^{-}		P^{-}
Douma et al. 2016	Greece	A, C, PL, PN			AM^{-}, CI^{-}		
Mahon et al. 2016	Scotland	C	DEM^{+}		CI^{-}		P^{-}, M^{-}
Sardaro et al. 2016	Italy	PN	DEM^{-}	Y^{-}	CM^{-}, AC^{-}, CP^{-}, CW^{-}, CE^{-}		M^{+}
Sardaro et al. 2017	Italy	PN	P^{+}	Y^{-}	CL^{-}, CE^{-}, CF^{-}, CW^{-}, CP^{-}, CPL^{+}, CI^{-}	NPV^{+*}, IRR^{+*}, IRR^{+*}, DBCR^{+*}	F^{-}
Stillitano et al. 2017	Italy	PN			CmhL^{+}	NPV^{+*}, B/C^{+*}, IRR^{+*}	
Karanikolas et al. 2018	Greece	PN	P^{+}	Y$^{\approx}$	CI^{-}, ChL^{-}	NFI^{+*}	M^{-}
		PN	P^{+}	Y^{+}	CI^{-}, ChL^{-}	NFI^{+*}	
		PN	P^{-}	Y^{+}	ChL^{-}, CI^{-}	NFI^{-}	
		PL	P^{+}		CL^{-}, CI^{-}	NFI^{+*}	M^{-}
Antofie and Sava Sand 2017	Romania	A, C, F					I^{+}
Antofie and Sava Sand 2020	Romania	A, C			AM^{-}, CM^{+}		P^{-}
Raggi et al. 2021	Europe	U			CI^{-}		
Thanopoulos et al. 2021	Greece	A, C, F, H, PL, PN		Y^{+}	AS^{-}, CmL^{+}		P^{-}
Varia et al. 2021	Greece, Italy	C	P^{+}	Y^{-}	CS^{+}	OM^{+}	M^{-}, P^{-}
Fenzi and Couix 2022	Italy, France	C	IND^{+}	Y^{-}	CS^{-}, AM^{-}, CM^{+}, CL^{+}		
Petrescu-Mag et al. 2022	Romania	A, C, F, H, PL					P^{-}
Timpanaro et al. 2022	Italy	A		Y^{+}	CP^{-}, CF^{-}, CPL^{-}		
Korpetis et al. 2023	Greece	C		Y$^{\approx}$	CC^{-}, CF^{-}		P^{-}
Martin et al. 2023	Scotland	C	DEM$^{\approx}$, P^{+}	Y$^{\approx}$	CF^{-}, CL^{-}, AS^{-}, CM^{-}	FI^{+}	P^{-}, M$^{\approx}$
Ortman et al. 2023	Sweden	C	P^{+}, IND^{+}, DEM^{+}	Y$^{\approx}$	AS^{+}, CF^{-}	FI^{+}	M^{-}, P^{-}
André et al. 2024	France	C, PL		Y^{-}	CM$^{\approx}$, CL^{-}, CC^{-}, CF^{-}		
Goufa et al. 2024	Greece	PL	DEM^{+}	Y^{+}	CC^{-}, CF^{-}		
Expósito-Goás et al. 2024	Spain	PL	P^{+}		CS^{-}, CmL^{+}		
Sums for the main performance indicators:			IND: 5^{+}, 0^{-} P: 10^{+}, 1^{-} DEM: 3^{+}, 1$^{\approx}$, 1^{-}	Y: 5^{+}, 4$^{\approx}$, 7^{-}	CL: 6^{+}, 7^{-} CS: 0^{+}, 3^{-} CC: 0^{+}, 5^{-} CF: 0^{+}, 7^{-} CM: 2^{+}, 1$^{\approx}$, 2^{-}	FI: 2^{+}, 1$^{\approx}$, 0^{-}	P: 0^{+}, 13^{-} F: 0^{+}, 2^{-} I: 2^{+}, 0^{-} M: 1^{+}, 1$^{\approx}$, 5^{-}

[1] A: annuals (and biennial vegetables and fruits), C: cereals, F: forage crops, H: herbs (aromatic and medicinal), PL: pulses, PN: perennials such as trees, U: undefined multiple crops.
[2] DEM: market demand, IND: increased independence with regard to selling prices, P: selling prices at farm gate.
[3] Y: Yields (sometimes higher than conventional e.g. due to resistance to cold or some diseases).
[4] CE: costs of energy, CL (CmL: manual labor (sometimes increased e.g. due to terrace fields), CmhL: manual hired labor, ChL: hired labor): costs of labor, CS: costs of seeds (sometimes reduced e.g. due to seed saving), CP: cost or

amount of pesticides, AS: access to seeds (sometimes reduced e.g. because seeds only saved by some farmers), AC: access to credit, AM: access to machines, CI: costs or amounts of inputs for production in general, CM: costs of machines, CW: costs or amount of water, CC: costs of chemicals, CF: costs of fertilizers, CPL: costs of plant material, CINV: costs of investments.
[5] FI: farm income, NPV: net present value, IRR: internal rate of return, DBCR: discounted benefit-cost rate, B/C: benefits and costs ratio, GR: gross revenue, NFI: net farm income, OM: operating margin. Asterisks (*) indicate that the profitability indicator remains positive or high even without subsidies.
[6] P, F, I, M: production, financial, institutional and market risks.

Looking across economic performance parameters, several trade-offs appear. First, 14 papers stress that, although yields are generally at a moderate level or somewhat lower, they are more stable. Especially, under very harsh climate conditions, well-adapted UCs were the only crops still succeeding (Goufa et al., 2024; Martin et al., 2023; Ortman et al., 2023; Petrovic & Dimitrijevic, 2012; Riu-Bosoms et al., 2014; Thanopoulos et al., 2021). Additionally, intercropping systems mixing cereals and pulses were found to give higher yields than conventional varieties (Ortman et al., 2023). André et al. (2024) also highlight that yields were lower in grain volumes but represented higher fiber and nutrition intake for the same area of production. In addition, longer straws from cereal landraces were described as valuable by-products (Martin et al., 2023; Ortman et al., 2023). The second trade-off concerns the inputs of seeds and labor. The increase in labor needs for seed management (selecting, drying, and storing) was compensated for through more independence from commercial seed markets (Riu-Bosoms et al., 2014). Riu-Bosoms et al. (2014) and André et al. (2024) found that some UCs had rather lower yields, but were still interesting because they required fewer field interventions. Sometimes, no weeding was needed due to the higher competitiveness of the crops. On the contrary, Riu-Bosoms et al. (2014) also found UCs with relatively high yields, but also requiring some extra work. The third trade-off is about the production costs. Four papers concluded that the yield was sometimes fairly modest, but production costs (Karanikolas et al., 2018; Sardaro et al., 2017) and investments (André et al., 2024; Petrovic & Dimitrijevic, 2012) were relatively low as well.

In short, the literature can be summarized as follows. Prices are often higher with specific markets providing more independence to producers. Costs are often reduced with some exceptions regarding labor costs (especially manual labor) and machinery costs for some UCs. Yields are, in general, lower but still satisfactory, and more importantly, they are more stable, especially in low-input or harsh environmental conditions. As a consequence, production risks and market risks are usually lower, but the informal status

of UCs is described as an institutional risk. Note that all these results are general trends in the literature, but vary according to specific crop and context.

2.3.4 Economic aspects of UCs for the value chains

The success of UC value chains seems to mostly rely on the ability of actors to organize themselves and work collectively (Fenzi & Couix, 2022; Polegri & Negri, 2010; Raggi et al., 2021). Table 2.2 presents a summary of the challenges and opportunities of UC value chains. It illustrates how actors, through both informal networks (Gomes et al., 2024) and formal organizations, create economic opportunities for UC products. Although several examples of UC value chains are found in the literature (Expósito-Goás et al., 2024; Fenzi & Couix, 2022; Martin et al., 2023; Ortman et al., 2023; Varia et al., 2021), there are also cases where UCs are not produced for commercialization but for self-consumption (Douma et al., 2016; Gomes et al., 2024; Knezevic-Jaric et al., 2014; Pieroni et al., 2005).

Table 2.2 Economic challenges and opportunities at value chain level and explaining factors (44 papers).

Challenges
Mismatch with standardization and organization of mainstream value chains
➢ Many UCs do not fulfill the requirements from commercial markets[13], such as uniformity[17,39] for processing[17] and convenience for glasshouse cultivation[39], simultaneity for harvest[39] or shelf-life during transportation[7] which led to the abandonment of many UCs[7] ➢ UCs mostly do not fit the mechanized, capital-intensive and standardized organization of mainstream value chains[7,17,24,40] ➢ Supermarkets quickly replace products that do not sell enough to keep the most highly sold products[31]
Lack of information and coordination between actors
➢ Lack of information, knowledge[24] and organization[7,11] lead to, among others, difficulties of obtaining labels, such as PGI[24], no fair sharing of profits[7], possible spread of seed-borne diseases through exchange[31] leading to reduced yields[18] ➢ Cooperation between farmers and value chain actors has proven beneficial[20,28] for boosting UC production through indications, brands[19,35,36,43], price setting[19,35], decreased costs, increased productivity[19], collective seed conservation[42], mass selection[42], multiplication[17,42] and distribution[15,42] and by widening markets[23,36], but is still difficult to implement[4] ➢ Technical services have been useful to coordinate tasks among farmers, such as seed exchange and crop improvement trials[19] and creating brands[43], but they are rarely available
Fragmented and underdeveloped market
➢ UC products are not sufficiently recognizable to prevent competition with equivalent products of lower quality[16,17,23] which complicates market development ➢ Lack of market infrastructure[3,27,32,28], farmers' cooperatives[24], labels[8], origin indications[11] and missing promotion activities to advertise on nutrition[31], climate change mitigation and income contribution of UCs[8,5,28,44] hinder the potential to create added value for UC products[27,36] and to raise the demand[5,26]
UCs belong mainly to the informal seed sector

Challenges

- Limitations imposed by the formal seed regulation system with regard to volume and location restrict value chain development[39]
- UCs are mainly locally produced and exchanged between farmers[18,42], which is considered illegal by officials, thereby hampering value chain development[12,14]

Opportunities

Growing demand for UCs and related products

- There is a positive feeling[26] and a growing demand from consumers for traditional varieties, local, seasonal agricultural products[42] and traditional foods[12,13,18,20,21,31,41], as well as for typical and better quality products[8,16,18,21,22,23,30,37] including from specific sectors such as the hospitality industry, e.g. agri- and culinary tourism[4,28,41], food trotters, haute cuisine and gastronomy[7]
- Although UCs are often used for self-consumption, they are also made available for the value chain[2,7,18,28,31]

Suitability of UCs for commercialization

- UCs can be marketed as unique and high-quality products[18,22,25,42,31,38], and are suitable for collective catering, not requiring more workload for cooks[2]

Demand for non-uniform varieties

- There is increasing demand for non-uniform varieties from organic and local niche sectors[31,39]

Added value is created and captured locally (in some cases also beyond)

- UCs are mostly sold at local scale[9–13,16,25,29,33,34,36,41] without intermediaries[23,25,31] capturing added value for the farmers and local businesses (local markets, local restaurants, bakeries, mills, farmers' shop and cooperatives)[9,16,20,28,31,34,41]
- The informal nature of UCs can more easily be overcome at local level due to connectedness[9,16,31]
- The traditional and local character of UCs provide extra marketing opportunities[9,19,23,28,31], such as through brand creation[23], niche markets[41] or indications like protected geographical indication (PGI)[11,18,23,33], protected designation of origin (PDO)[30], traditional specialities guaranteed (TSG)[13], special labels certifying a zero-km concept[6] or transparency in origin, quality[20] and processing[6,28] of the products
- Opportunities exist for sales outside the region[7,12,14,28,30] albeit sometimes leading to unfair prices for farmers[7]

[1] Ahokas & Poukkula, 1999; [2] André et al., 2024; [3] Antofie & Sand, 2017; [4] Antofie, 2019; [5] Bayudan et al., 2024; [6] Berni et al., 2019; [7] Biscotti et al., 2022; [8] Botelho et al., 2018; [9] Brugarolas et al., 2009; [10] Cebolla-Cornejo et al., 2007; [11] Červenski et al., 2013; [12] Conversa et al., 2020; [13] De Ron et al., 2018; [14] Didonna et al., 2024;[15] Döring et al., 2012; [16] Douma et al., 2016; [17] Elia & Santamaria, 2013; [18] Expósito-Goás et al., 2024; [19] Fenzi & Couix, 2022; [20] Giupponi et al., 2018; [21] Gomes et al., 2024; [22] Goufa et al., 2024; [23] Karanikolas et al., 2018; [24] Karelakis & Tsantopoulos, 2017; [25] Knezevic-Jaric et al., 2014; [26] Lauterbach & Bantle, 2022; [27] Mahon et al., 2016; [28] Martin et al., 2023; [29] Montesano et al., 2012; [30] Negri, 2003; [31] Ortman et al., 2023; [32] Petrescu-Mag et al., 2022; [33] Piergiovanni & Laghetti, 1999; [34] Pieroni et al., 2005; [35] Polegri & Negri, 2010; [36] Raggi et al., 2021; [37] Sardaro et al., 2016; [38] Scartazza et al., 2020; [39] Spataro & Negri, 2013; [40] Thanopoulos et al., 2021; [41] Thanopoulos et al., 2024; [42] Timpanaro et al., 2022; [43] Varia et al., 2021; [44] Wang et al., 2024.

In many cases, value chains for UCs seem better suitable for local scales than for national or international ones. Indeed, part of the sustained demand is local: from local consumers (Brugarolas et al., 2009), local processors and restaurants (Fenzi & Couix, 2022; Martin et al., 2023; Riu-Bosoms et al., 2014), niche or local markets (Brugarolas et al., 2009; Cebolla-Cornejo et al., 2007; Karanikolas et al., 2018; Mahon et al., 2016; Piergiovanni & Laghetti, 1999; Pieroni et al., 2005; Raggi et al., 2021; Riu-Bosoms et al., 2014; Sardaro et al., 2016) or tourism (Antofie, 2019; Biscotti et al., 2022). Growers, and

sometimes local nurseries, organize themselves to produce, select and distribute the seeds independently (Timpanaro et al., 2022). This is reinforced by the mismatch between the characteristics of UCs, such as diversity within varieties and the restrictive standards of the agricultural processing industry, demanding standardized varieties (Thanopoulos et al., 2021). Moreover, the commercial markets require specific crop characteristics, such as a long shelf-life for handling and transport, for which UCs are often less suitable (Ahokas & Poukkula, 1999; Biscotti et al., 2022; Elia & Santamaria, 2013). The informal character of UCs (Döring et al., 2012) also favors locally organized value chains rather than international markets.

In order to boost UC value chains where profit is equally shared between the local value chain actors, a key requirement is the ability of the actors to coordinate efforts and collaborate in these remote places (Biscotti et al., 2022; Červenski et al., 2013; Martin et al., 2023; Ortman et al., 2023). As a whole, enhanced social connections and cooperation between actors (e.g. through networks, partnerships and group organizations) appear to be essential for effective UC value chain creation (Douma et al., 2016; Fenzi & Couix, 2022; Giupponi et al., 2018; Polegri & Negri, 2010; Raggi et al., 2021; Varia et al., 2021). Cooperation between actors also boosts the development of processing facilities such as local dryers, mills, and malting equipment (Martin et al., 2023).

Demand for high-quality, local and traditional products with transparent origins is an opportunity for UC value chains (Expósito-Goás et al., 2024b; Lauterbach & Bantle, 2022). Yet more communication on UCs is still necessary as customers positively value UCs for their taste, naturalness and health-promoting characteristics, but are less informed about other aspects related to farmers' income contribution, and UCs' environmental adaptability (Lauterbach & Bantle, 2022). The organic and niche markets are also in need of more UC varieties. Lastly, the local organization of UC value chains favors local businesses and the economic development of rural areas by creating and capturing the value added locally in restaurants and open markets (Brugarolas et al., 2009; Giupponi et al., 2018; Martin et al., 2023).

2.3.5 Economic aspects of UCs for communities

At community level, the literature only reports opportunities. Indeed, challenges found refer to the dispersion of local actors and their difficulties in cooperating and

implementing value chains, which have already been captured and discussed at value chain level (see section 3.4). The two recurring aspects are (1) that UC products represent an opportunity for boosting the local economy and (2) increased food autonomy (Table 2.3).

Table 2.3 Economic opportunities of UCs at community level and explaining factors (19 papers)

Opportunities
UCs help to boost or restore the local economy in rural areas
➢ The economic opportunities of UCs benefit and revitalize the local economy[3,4,7,9,11,15,16,18,19], among others, through gastronomic agro-tourism and fairs[17,11,18], in turn stimulating UC production[2,5,17]
➢ The local character of UCs creates opportunities[5,11,19] for new companies and activities, such as cooperatives[8] for processing and marketing[7,8,10,15]
➢ UCs contribute to local employment and conservation of biodiversity thereby increasing the attractiveness of the area and reducing migration to urban areas[13]
UCs are relevant for local food provision
➢ UC production provides food for the local population[1,3–6,14] thereby increasing autonomy[4,6,11,14,18]
➢ UCs are often shared within informal networks[1,12,15], such as kinships, friendships and neighborhoods[15], thereby also boosting autonomy[1,12,15,18]
➢ In villages isolated due to harsh climate conditions, UCs are essential for food provision as they are often the only crops adapted to the local conditions[11,14,18]

[1] Acosta-Naranjo & Rodríguez Franco, 2014; [2] Antofie, 2019; [3] Berni et al., 2019; [4] Biscotti et al., 2022; [5] Conversa et al., 2020; [6] Döring et al., 2012; [7] Douma et al., 2016; [8] Fenzi & Couix, 2022; [9] Giupponi et al., 2018; [10] Karelakis & Tsantopoulos, 2017; [11] Martin et al., 2023; [12] Ortman et al., 2023; [13] Pérez y Pérez, 2019; [14] Petrovic & Dimitrijevic, 2012; [15] Pieroni et al., 2005; [16] Stillitano et al., 2017; [17] Thanopoulos et al., 2021; [18] Thanopoulos et al., 2024; [19] Wang et al. 2024.

2.3.6 Social challenges and opportunities for UC farms, value chains and communities

Motivations to grow UCs are often not economic in kind, even though profit may be generated. The main factors at play are social, as farmers and other community actors are often driven by the will to conserve the local cultural heritage (Gomes et al., 2024; Martin et al., 2023), or by the possibility to connect with each other, e.g. getting involved into a seed exchange network (Fenzi & Couix, 2022) or a local non-profit association (Varia et al., 2021). For the whole community, the consequence of UC growing can be the increase of social connections between members and the reconstitution of a distinct identity using UCs as a local symbol (Acosta-Naranjo & Rodríguez, 2014; Fenzi & Couix, 2022; Gomes et al., 2024; Martin et al., 2023; Timpanaro et al., 2022), which supports the well-being of the local actors (Scartazza et al., 2020). Social challenges and opportunities for UCs are presented in Table 2.4.

Table 2.4 Social challenges and opportunities of UCs and explaining factors (37 papers).

Challenges
UCs are mostly grown in isolated places with little resources thereby limiting promotion
➢ UCs are produced in remote, rural[15,22,25,26] and isolated areas[5,7,8,9,21,29] making the communities relatively marginalized[15] and fragile[14] ➢ UCs are grown in mountains[28.37] with high elevation[15], slopes and fragmented land[26] or on remote islands with harsh soil and climate conditions[22] and thus with low mechanization and no irrigation[22,32] impeding the agricultural production compared to low-land areas
Limited farm succession and limited transmission of practices and knowledge
➢ Knowledge on UC practices[2,19] has not been transmitted[9,22] and is now lost due to (1) changing consumption and living practices[6,11,16,26,27], (2) youth migration to cities[9,16,19,20,36] and depopulation[15,16] of rural areas, and (3) the retirement of farmers[5,7,9,14,15,21] without succession[15]
Opportunities
Attachment to identity, culture and traditions
➢ UCs and their associated knowledge are maintained through commitments of farmers, local people and/or tourists attached to typical traditions and dishes related to UCs[11,12,14,16,20,22,24,30,31,34,35,37,45,67] and local cultural aspects[8,16,35] ➢ UCs are largely associated with small-scale cultivation[22,35], i.e. they are mostly grown in family[7], small size[8,9,11,15,22,32,35,37], and hobby[9] farms or home gardens[7,8,9,11,34,37], and sometimes in mid-sized farms[5] which tightly links them to local traditions[16,22] ➢ UCs contribute to provide an identity to isolated communities who look for identity and symbols[1,16] attached to their history and origin[14,16,18]
Appreciation for UC characteristics
➢ Farmers and other community members appreciate the quality[7,23,35], and the organoleptic [1,4,8,9,11,13,14,16,19,31,37], nutritional, and health-related[12,35] benefits of UCs ➢ UCs are grown for entertainment[15], pleasure and interest[1]
UCs promote social activities, connectedness and well-being
➢ The conservation of local culture and traditions related to UCs[8] stimulates community members to engage in collective actions[36] and join networks[14,22,31] ➢ Informal and extensive UC seed exchanges among farmers and gardeners[9,16,25], on local markets, and through self-propagation[10,25] enhance social networks ➢ UCs provide opportunities for social well-being activities, tourism[22] and promotion of the local culture (through gastronomy[14], fairs, festivals)[18,22,36] thereby improving well-being and health[27,35] ➢ UC production triggers economic activities which help to avoid rural migration[24]
Quest for autonomy
➢ Some farmers aspire to be less dependent on suppliers (e.g. for seeds, chemicals, technology-advanced machinery), which is enabled by UCs[14,17,22,25,35]
Willingness to preserve local biodiversity
➢ As UCs are part of cultivated biodiversity, they contribute to preserving the environment[25,30,32] and the biodiversity[18,24,25,35,37] ➢ UCs are largely grown with old[8] and traditional practices[1,5,11] and low mechanization[3,22] which preserves the local traditions and environment
Moral responsibility toward UCs' conservation
➢ Some farmers and gardeners feel the responsibility for cultural heritage and nature[16,19,23] and have the ideological conviction to support agroecological practices[25,31] and the conservation of UCs[14]

[1] Acosta-Naranjo & Rodríguez, 2014; [2] André et al., 2024; [3] Antofie, 2019; [4] Antofie & Sava, 2020; [5] Bela et al., 2006; [6] Biscotti et al., 2022; [7] Červenski et al., 2013; [8] Conversa et al., 2020; [9] De Ron et al., 2018; [10] Döring et al., 2012; [11] Douma et al., 2016; [12] Elia & Santamaria, 2013; [13] Expósito-Goás et al., 2024; [14] Fenzi & Couix, 2022; [15] Giupponi et al., 2018; [16] Gomes et al., 2024; [17] Goufa et al., 2024; [18] Karanikolas et al., 2018; [19] Karelakis & Tsantopoulos, 2017; [20] Knezevic-Jaric et al., 2014; [21] Mahon et al., 2016; [22] Martin et al., 2023; [23] Montesano et al., 2012; [24] Negri, 2003; [25] Ortman et al., 2023; [26] Pérez y Pérez et al., 2019; [27] Petrescu-Mag et

al., 2022; [28] Petrovic & Dimitrijevic, 2012; [29] Pieroni et al., 2005; [30] Raggi et al., 2021; [31] Riu-Bosoms et al., 2014; [32] Sardaro et al., 2016; [33] Scartazza et al., 2020; [34] Spataro & Negri, 2013; [35] Thanopoulos et al., 2021; [36] Thanopoulos et al., 2024; [37] Timpanaro et al., 2022.

While those social motives can enhance the use of UCs by farmers and communities, some social aspects, in contrast, hinder their production, such as the lack of coordination between isolated and marginalized farms and communities (Bela et al., 2006; Červenski et al., 2013; Conversa et al., 2020; Montesano et al., 2012; Raggi et al., 2021), or the abandonment of rural areas by youth (Gomes et al., 2024; Knezevic-Jaric et al., 2014), preventing knowledge and farm transmission (De Ron et al., 2018). The development of jobs in different sectors, such as tourism instead of agriculture, also diminishes the number of UC producers (Thanopoulos et al., 2021). In this context, knowledge on adequate agricultural practices for UCs is now often unavailable (Douma et al., 2016; Petrescu-Mag et al., 2022; Pieroni et al., 2005).

2.3.7 Institutional factors influencing UC farms and value chains

The institutional arguments in the literature impacting UC production and value chains can be divided into hindering and supporting factors (Table 2.5). Several policies at national and EU levels have been hindering UC production, such as the fact that crops should fulfill uniformity to be registered, i.e. to have an official existence, which is not possible for most UCs (Didonna et al., 2024; Spataro & Negri, 2013), and that seed exchange between farmers is not legal (Döring et al., 2012) or in handful proportions (Didonna et al., 2024). These restrictions lead to difficult access to UCs seeds (Didonna et al., 2024), and extensive illegal UC seed exchanges between farmers. A further example in the literature is the regulation on “conservation varieties” (European Commission, 2009). While intended to stimulate the conservation and commercialization of UCs through registration, it restricts the seed production in terms of area and quantity (Didonna et al., 2024; Spataro & Negri, 2013), and it is still a rather ‘static’ definition of UCs, not taking into account the evolution of UCs in farmers' fields to adapt to specific local environmental conditions (Didonna et al., 2024). Hence, it led to a very small number of UC registrations (Didonna et al., 2024). On this last point, the more recent regulation on Organic Heterogenous Material (European Commission, 2021)—only mentioned by Ortman et al.

(2023) in the literature reviewed here—may partially tackle this issue[5]. Registering UCs as official crops causes a contradiction: on the one hand, registration helps prevent fraud with similar products (Karanikolas et al., 2018; Varia et al., 2021), while on the other hand, to fulfill registration criteria, the heterogeneity of UCs needs to be reduced (Douma et al., 2016). Reducing UCs' heterogeneity means reducing their genetic diversity which confers them adaptability. Several papers claim that as long as UCs are not legally recognized, developing businesses using them is difficult (De Ron et al., 2018; Douma et al., 2016; Elia & Santamaria, 2013; Spataro & Negri, 2013), one reason being that plant materials often remain unavailable to farmers (Douma et al., 2016; Elia & Santamaria, 2013).

Table 2.5 Institutional aspects hindering or supporting UC farms and value chains and explaining factors (24 papers).

Hindering
UCs remain informal and cannot be registered due to non-compliance to UPOV*
➢ The UPOV* regulation specifying distinctiveness, uniformity, and stability makes registration impossible for most UC varieties because of their intrinsic diversity[7,8,11,19,22]. This in turn results into accessibility issues for UC seeds[10], as: (i) most UCs are not registered[8-11,19], and (ii) seeds are only stored by UC farmers[11] (The regulations on "conservation varieties"** (European Commission, 2009), aiming at enabling the marketing of these excluded varieties[8], did not solve this problem[8,10,22]) ➢ Seed exchange between farmers is illegal, or tolerated in handful proportions[8] which leads to extensive informal exchanges of UC seeds between farmers[9,24]
EU trade regulations do not accommodate for UC diversity
➢ EU regulations, such as with regard to the minimum acceptable size of cereal grains for trade[2], have pushed farmers to switch to conventional varieties to keep selling through commercial EU channels[2]
Lack of support from governments
➢ In rural territories, the lack of support to access official local markets[4] or to create new geographic origin indications[6] undermines the possibilities for selling and valorizing UCs
Unsuitable agri-environmental policies
➢ Too strict regulations of some agri-environmental schemes regarding field intervention periods are not fit for some UCs showing earliness or lateness[18]
Supporting
Supporting rural development projects, funds and other programs
➢ EU rural development programs[5], such as Local action groups using LEADER funds, support farmers' access to UC seeds[1] and local communities to preserve UC cultivation[5] ➢ Support for a group of UC producers through the rural development program 2014/20 helps farmers to organize access to seeds and production of UCs[16] ➢ Non-profit associations[13,24] help farmers to cooperate, e.g. through creating official networks for crop preservation[3] or seed exchange[10], consortia[13] or cooperatives[15,17] ➢ Support from research centers[13,14] and local institutions, such as municipalities[14], helps farmers to access, use[13,14,17,12,15] and register UCs[14]

[5] The EU regulation on diverse organic seed is much wider, but this scoping review centering on economic aspects does not capture it.

- In some countries, specific agri-environmental schemes (from the Common Agricultural Policy for 2023-2027 for EU countries) provide financial support to growers using adapted varieties, such as UCs[15,18]

EU regulations acknowledge non-uniform varieties

- The 2008/10 EU regulation on "conservation varieties"** (European Commission, 2009) enables less uniform varieties to be registered[10,16,21,22] which (1) ensures official propagation of seeds including for the organic sector (but only in a limited quantity[10,16,17,18]), (2) enhances acknowledgment of the uniqueness of products thereby facilitating valorization[16,22], and (3) prevents fraud in supply chains[24]

Introduction of quality labels and trademarks

- Official labels and trademarks[7,16,20,23] certify the quality and provenance of UC products[6,14], thereby increasing market opportunities[6,7,16], added-value[7,23] and income[20] for farmers and UC value chain actors[16]
- Local labels and unofficial trademarks enhance market opportunities[4,12]

* UPOV: International Union for the Protection of New Varieties of Plants.

** The "conservation varieties" regulations (European Commission, 2008, 2009) demonstrate that the European Commission acknowledges the need for growing and conserving UCs[17]. Yet, registration is accorded upon strict morphological uniformity[17], the administrative load is heavy, and the regulations restrict the volume and area of production[17].

[1]Acosta-Naranjo & Rodríguez, 2014; [2] Ahokas & Poukkula, 1999; [3]Antofie & Sand, 2017; [4] Antofie, 2019; [5] Biscotti et al., 2022; [6]Červenski et al., 2013; [7] De Ron et al., 2018; [8] Didonna et al., 2024; [9]Döring et al., 2012; [10] Douma et al., 2016; [11] Elia & Santamaria, 2013;[12] Expósito-Goás et al., 2024; [13] Fenzi & Couix, 2022; [14] Giupponi etal., 2018; [15] Goufa et al., 2024; [16] Karanikolas et al., 2018; [17]Karelakis & Tsantopoulos, 2017; [18] Martin et al., 2023; [19] Ortman etal., 2023; [20] Piergiovanni & Laghetti, 1999; [21] Raggi et al., 2021;[22] Spataro & Negri, 2013; [23] Thanopoulos et al., 2021; [24] Varia etal., 2021.

The EU regulations on crop trade also pushed farmers to switch to conventional varieties, for example by regulating the minimum grain size (European Commission, 2008): non-compliant varieties cannot be traded across the EU, causing local varieties to disappear (Ahokas & Poukkula, 1999). Lastly, the lack of support from local governments to access local markets (Antofie & Sava Sand, 2017) or develop trademarks (Červenski et al., 2013) undermines the valorization of UCs.

Within the reviewed literature, EU and national policies that enhance UC development were also identified. Examples include the EU trademarks requested by territories to valorize their niche production (De Ron et al., 2018; Karanikolas et al., 2018; Piergiovanni & Laghetti, 1999; Thanopoulos et al., 2021), and the European fund for rural development projects implemented by local governments or organizations, which was stated to positively enhance UC development through Local Action Groups (Acosta-Naranjo & Rodríguez, 2014).

2.4 Discussion

2.4.1 Knowledge gaps

This review shows that the knowledge on the economics of UCs in Europe is currently limited. At farm and value chain levels, information is mostly disseminated in qualitative terms across non-economic papers. The scientific evidence on UC economic aspects has increased in recent years, but still represents a relatively small number of papers, not published in economic journals, but from different journal types (e.g. genetics, agronomy, food consumption). As economists are known not to read much outside of their own field (Fourcade et al., 2015), it is likely that they will therefore miss part of the UC story regarding UC economic aspects. This is a concern as economic incentives and market opportunities are also mentioned as prerequisites for UCs cultivation by farmers (Ortman et al., 2023). At farm level, we find lower input costs, lower production risks and more independence from markets, while the labor needs can be higher, and the access to seeds and adapted machinery difficult. However, technical and economic analyses of different types of UC farm businesses are missing. For example, the literature often cites lower levels of inputs without defining nor quantifying these inputs. There is also no data on the implications of lower inputs for farm profit stability, while fewer inputs may improve the stability of profit (Harkness et al., 2021). Although UC farms are diverse, analyzing several typical types could capture most of their diversity and give a picture of their most common characteristics. Assessments of the different and the most common types of UC farm businesses would enhance our understanding of underlying economic mechanisms.

At value chain level, we find that the lack of coordination between local actors, the mismatch between UC characteristics and the standards of the mainstream food system, as well as the informal character of UC seeds impede UC value chain development. Nevertheless, the reviewed papers also highlight that UC value chains create and capture added value locally, and that there is a growing demand for UC products. Yet, almost no economic information was found regarding the organization and functioning of UC value chains, e.g. information on the variation of quality and volumes, the profit distribution and the sharing of risks between the actors. We found not a single economic analysis of the different businesses of the UC value chains, such as processors, shops, or restaurants.

Technical and economic benchmarks of the most typical businesses that constitute UC value chains are needed to make these businesses better known and understood.

At community level, although papers report the importance of UC production for the local economy and food provision, the exact processes and impacts of UC businesses on the economy and food autonomy of local communities have not been precisely documented, e.g. in terms of employment created, economic attractivity, or degree of reliance of inhabitants on UC food produced locally. Only by uncovering the exact processes of how UC production brings economic benefits to local communities, can local governments replicate and improve successful initiatives.

UCs are numerous and diverse, which can explain the difficulties in identifying general good practices and prototypes of UC farms and UC value chain businesses. Yet, more precise information on how UC businesses operate would help future entrepreneurs willing to grow or process UCs to make good management choices. We argue that such in-depth assessments would help to obtain more relevant insights into how growing and processing UCs can be economically feasible to support the local economy and boost its resilience. Sketching out such conditions would help to formulate more precise and adapted recommendations on the best ways to develop UC production across Europe in order to restore and boost biodiversity, as intended by the EU Biodiversity Strategy for 2030 (European Commission, 2020).

As we find an important role for social and institutional aspects to increase the feasibility of UC production, future research should favor multi- and interdisciplinary approaches that also take into account these two dimensions.

2.4.2 Potential biases and generalizability

Even though we performed a systematic review of the literature in order to present a holistic picture, we cannot rule out literature availability bias (Hardaker et al., 2004). Financially successful cases may be more widely studied than those that were not, either because researchers may prefer studying successful case studies over failing ones, or because unsuccessful initiatives of producing UCs may remain more often unknown. Yet, several papers do point out the difficulties farmers face in producing UCs (e.g. access to seeds and markets), and ask for more support for actors who contribute to crop diversity preservation. One solution to rule out availability bias could be for future research to

review the grey literature to complement the scientific literature, as several UC production initiatives may not have been reported in scientific journals. To explore the scientific literature further, additional search engines could be used, and reviews of studies could be investigated to find potential other articles.

Another issue that may play when analyzing the economic aspects of UCs is an oversimplification of the situation by focusing on traditional economic indicators only, such as profitability. Additionally, several trade-offs appear, such as between costs and yields, between volumes and stability or quality of the crop production. In addition, a number of economic aspects are not directly monetary, such as self-consumption or seed saving, and also not always at the farm business level, such as through processing and tourism. Simplification of this complex reality may lead to wrong conclusions regarding the economic aspects of UCs.

In this review, we do not compare studies but rather try to display all the evidence regarding the economic aspects of UCs and try to point at main communalities. For example, among the UC characteristics most often mentioned are the stability of yields, especially in harsh environmental conditions (Goufa et al., 2024; Martin et al., 2023; Ortman et al., 2023; Petrovic & Dimitrijevic, 2012; Riu-Bosoms et al., 2014; Thanopoulos et al., 2021, 2024), explained by the large intrinsic genetic diversity of UCs (Ortman et al., 2023). No studies were found indicating the opposite. Yet, as UCs represent a huge amount of species and varieties (Camacho-Henriquez et al., 2016), and as Europe encompasses very diverse economic and environmental contexts, exceptions possibly exist.

2.4.3 Recommendations for policymakers

UCs represent genetic reservoirs that enable the creation of new varieties better adapted to withstand diseases, pests or difficult climates. The fact that most UCs have no legal existence and that seed exchange between farmers is considered illegal threatens their conservation, and thereby the possibility of finding resistant varieties in the future. Hence, a contradiction exists. On the one hand, the EU strives to use more UCs and eventually boost European farms' diversification through the Biodiversity Strategy for 2030. On the other hand, its legislation requiring stability and uniformity for varieties to be legally traded, which has constrained their use and the economic benefits they could

provide. As an attempt to solve this issue, the regulation on "conservation varieties" was created in 2008. However, it is still too strict for some UCs to be registered and excludes farmers located outside the designated areas (Spataro & Negri, 2013). More recently, the EU regulation on Organic Heterogenous Material (European Commission, 2021) proposes a new legal frame for UCs, but its implications were little discussed in the reviewed literature here. Only Ortman et al. (2023) mentioned that this legal development was seen positively by several farmers of the study. As UCs are often exchanged locally and rarely commercialized through official channels, legalizing the sale and exchange of unregistered seeds between farmers would ease their access to seeds and eventually boost European farms' diversification in line with the Biodiversity strategy for 2030 (European Commission, 2020).

Small European farms, i.e. those of less than five hectares, are mostly subsistence or semi-subsistence farms producing food to feed the farm's family, while some are family-run businesses (Eurostat, 2022). In 2020, they still accounted for almost two-thirds of the EU farms (Eurostat, 2022). As we find that, due to their characteristics, it is most likely small farms that produce UCs in the future, preserving small farms closely relates to preserving the diversity of UCs. Hence, to support UCs and crop diversity, it would be worth changing the structure of financial support from the first pillar of the Common Agricultural Policy from hectare-based criteria to other criteria such as the amount of employment generated or farm-level environmental measures, as previously proposed by Lécole et al. (2021).

As UCs are often grown in remote areas where the social networks of communities have been fragilized by rural outmigration and actors struggle to coordinate their efforts to revitalize the local economy, local organizations and governments have a crucial role in supporting networks and cooperations between actors interested in developing UCs. Reinforcing such local networks and cooperation between farmers is also pointed out as promising in the context of incentivizing diversified farming systems, including agroecological systems (Aguilera et al., 2020) and mixed farming and agroforestry systems (Low et al., 2023). Enhancing viable farms and value chains and local businesses is also part of the Biodiversity Strategy 2030's goals. In order to stimulate coordination between local actors, the capacity for action of local organizations and governments supporting UC actors should be increased. These local bodies could be financially

supported through national and international funds, e.g. the European Agricultural Fund for Rural Development in the frame of the second pillar of the CAP.

In order to become a global player in the use of UCs, and thus reintroduce a larger agrobiodiversity in farms, Europe should abandon current international seed treaties that legally forbid the use of non-registered seeds. In fact, international rules on crop registration require stable crops over generations, which is impossible for adaptable (thus unstable over generations) crops like UCs. A second way to promote UCs efficiently is the promotion of their main selling channels: short food chains and local food systems, which also enable a lower degree of standardization. Third, awareness raising regarding what UCs are and what agrobiodiversity is among society may help consumers to make more conscious expenditure choices. In case a UC starts to be grown industrially through a few highly selected varieties and traded globally, it will become a new monoculture crop, along with its usual environmental challenges. This is the path followed by quinoa in Andean regions; quinoa is no longer a UC but a new monoculture (Andreotti et al., 2022). However, succeeding in producing diverse locally adapted UCs across Europe would not only mean more agrobiodiversity and dietary improvements in Europe; it would likely also increase food autonomy for European populations, especially in the face of global issues disturbing international trade, such as the COVID-19 pandemic, the Ukraine war, or possible financial crises.

2.5 Conclusions

We reviewed the scientific literature on the economic aspects of European UC farms, value chains and communities. A large share of studies were conducted in Southern (e.g. Italy, Greece, Spain) and Eastern Europe (e.g. Romania, Hungary, Serbia), which could be explained by the harsher climates, lower levels of farm industrialization or more mountainous production circumstances compared to Northern and Western European regions. Additionally, a large proportion of the papers were not from the field of economics. Our final set of 55 papers was from related or multidisciplinary fields such as agriculture, conservation or genetics, and often gave qualitative and partial economic information rather than a full economic analysis.

Although we cannot generalize our findings to all UCs as they are by definition very diverse types of crops grown in different economic and environmental contexts, several

aspects hold across the studies retrieved. The following insights emerged: UCs are mostly discussed in the context of specific farm types, i.e. often small-scale farms and home gardens, with agroecological or low-input practices, and mostly focusing on direct selling or self-consumption. When UCs are grown for commercialization, UC farms show recurrent positive characteristics such as lower input costs, moderate but stable yields, low production risks, sometimes relatively high selling prices, and a higher market independence. These insights make them promising solutions for diversified and resilient food systems. Yet, the literature also reports challenges: labor needs of UC farms can be higher per farm, and farmers often face difficulties in accessing UC seeds. They are also mostly commercialized outside of the mainstream food system due to their incompatibility with crop registration rules and standardization requirements. UC value chains are thus displayed mostly at the local level, where they create and capture added value, and contribute to local communities' food autonomy. To conclude, we have found evidence that growing UCs can be profitable. However, profits do not seem to be the only economic aspect UCs can provide to farmers, processors, and communities. More importantly than profit, UCs often seem to provide food to farmers and local communities, hence increasing food autonomy (self- and local consumption). Also, they support farm resilience through more stable and satisfactory yields, and decrease production risks through reduced input needs. In addition, their shorter chains lead to more stable markets. Furthermore, their embeddedness in local economic settings and their often high added values contribute to communities' local economy and attractiveness. In summary, our review finds that the full economic value of UCs goes well beyond mere profits and the farm level, and that the evidence could have been stronger if the literature on the economic aspects of UC was not scattered across various disciplines.

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Supplementary materials

The three supplementary materials, i.e. (2.1) the code to search the literature, (2.2) the list of selected papers, and (2.3) the detailed classification of the journals into disciplines, are available at:

https://www.tandfonline.com/doi/suppl/10.1080/21683565.2026.2626312?scroll=top.


3

Chapter 3
Uneconomic hobby or pursuit of autonomy? Exploring the farm management of underutilized crop farms

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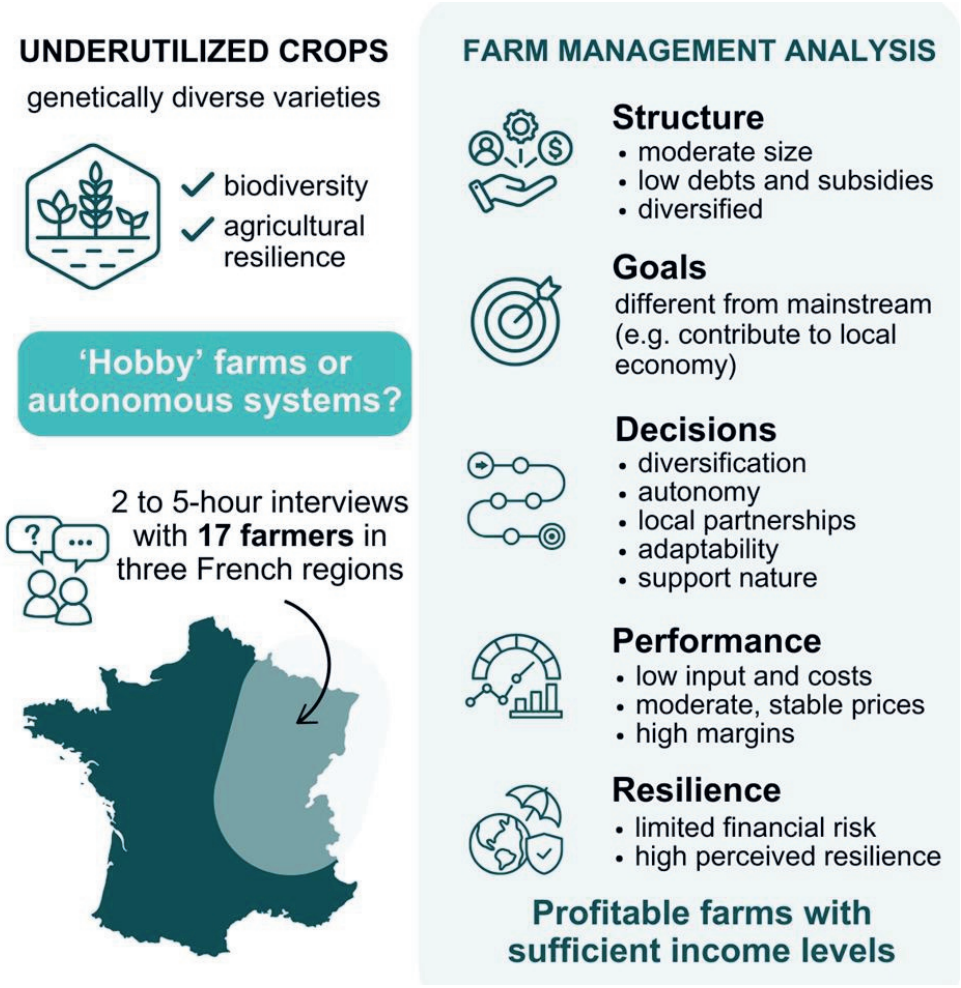
Marie-Fleur E Nguyen Brémaud, Yann de Mey, Miranda P M Meuwissen, Uneconomic hobby or pursuit of autonomy? Exploring the farm management of underutilized crop farms, Q Open, Volume 5, Issue 2, 2025, qoaf031, https://doi.org/10.1093/qopen/qoaf031

Abstract

To improve food security and adaptation to climate change, EU policies promote agricultural diversification with the cultivation of more genetically diverse crops, including underutilized crops (UCs). However, little is known about how UC farms operate and perform in Europe. This chapter aims to explore the farm management of UC farms. We interview 17 cereal and vegetable UC farmers in France and address multiple farm management aspects: farm structure, farmers' goals and decision-making, farm performance, and farmers' perceived resilience and challenges. We also compare UC farms with reference values from FADN farms where possible. Interviewed UC farmers operate in a specific way, often having a moderate asset base. Also, their goals are different, e.g. they want to contribute to the local economy and food autonomy. Decision-making focuses on boosting farm autonomy through seed saving, using little inputs, and on-farm processing. The interviewed UC farmers are profitable with low levels of debt (i.e. on average 32 per cent and 11 per cent of total fixed assets for cereal and vegetable farms, respectively), and farmers consider their income sufficient to support their households. Their levels of subsidies are low (i.e. on average 18.3 per cent and 1.5 per cent of total income for cereal and vegetable farms, respectively). Outputs are valorised through direct sales and short chains. Overall, interviewed UC farmers deem their farms resilient but still face challenges, such as limited know-how, and limited access to seeds when starting with new UCs. More effort is needed to integrate UCs effectively into EU policy frameworks such as the Farm-to-Fork strategy.

Keywords: resilience, local, autonomy, direct selling, diversification

Graphical abstract



3.1 Introduction

The world has over 50,000 edible plants (FAO, 1995), but only three of them—rice, maize, and wheat—provide 60% of the world's food energy intake (FAO, 1995; IPES-Food, 2016). Today, people across the globe consume approximately 255 different crop species, still only a fraction of all edible options (Khoury, et al., 2023). Even within this limited range, genetically diverse varieties have been abandoned, undermining both biodiversity and farm resilience. Monocultures of genetically uniform crops are more vulnerable to pests, diseases, or sudden changes in climatic conditions (Elouafi, 2024), a weakness that threatens our food security (ARC, 2023; Elouafi, 2024).

Underutilized crops (UCs) are genetically diverse crop varieties that have been cultivated in the past, but were later on abandoned, and that are currently rarely cultivated, even in regions where they are locally well-adapted (FAO, 2010, 2018a). They hold promises to increase cultivated biodiversity and contribute to building resilient agricultural systems, especially in the context of the challenges that climate change pose (FAO, 2010; Pinto et al., 2023b). In practice, this means that UCs are fertile varieties that can be resown and reproduced, and that can evolve and adapt to local conditions across generations. In Europe, the European Commission therefore also focuses on UCs as a viable solution to diversify agriculture and improve food security and adaptation to climate change (Communication from the Commission to The European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, EU Biodiversity Strategy for 2030, Bringing Nature Back into Our Lives., 2020). There are several reasons why crop diversity has declined: mechanization and standardization (Thanopoulos et al., 2021), the switch from local varieties to commercial ones (Fenzi & Couix, 2022b), intensification of agricultural systems, and the rural exodus entailing a loss of workforce (Knezevic-Jaric et al., 2014) and know-how to cultivate UCs (Pieroni et al., 2005). Yet, several UCs have demonstrated large adaptability (Negri, 2003), low-input requirements (Mahon et al., 2016), and high nutrient contents (Pieroni et al., 2005; Vijayalakshmi et al., 2023). In the context of increasingly harsh climatic conditions and tightening input markets, some UCs seem promising to revive. Their capacity to adapt to local conditions (Altieri, 1992; Baldermann et al., 2016; Burgess, 1994; Galmés et al., 2011; Karunaratne et al., 2015; Mabhaudhi et al., 2013) may reduce production costs

(Sardaro et al., 2017) and better ensure farm economic sustainability (Karanikolas et al., 2018; Stillitano et al., 2017).

Yet, farmers face several difficulties when cultivating UCs, including access to seed material when they decide to start using new UCs (Douma et al., 2016; Elia & Santamaria, 2013) and the appropriate tools for screening seeds and harvesting (Antofie, 2019; Douma et al., 2016), as well as a lack of expertise on appropriate cultivation practices (Fenzi & Couix, 2022b). Reduced yields (Petrovic & Dimitrijevic, 2012; Sardaro et al., 2016) and more challenging valorization, as UC products deviate from conventional standards, further complicate their reintroduction (Sardaro et al., 2016). The international and European regulations on the marketing of seeds remain complex (Döring et al., 2012) and strict (Newton et al., 2010). They ensure that only registered seeds can be marketed –or exchanged—(Council Directive of 14 June 1966 on the Marketing of Fodder Plant Seed (66/401/EEC), 2022) and by the breeder only (UPOV, 1961), thus prohibiting seed exchange between farmers and consequently restricting farmers' possibilities to access UCs, as they are mostly non-registered varieties (Newton et al., 2010). Saving and reusing seeds from non-registered varieties is still allowed. Additionally, in France, selling seeds of non-registered varieties to non-professional users is also allowed (Code Rural et Maritime, Art.10, 2020).

While UCs and their reintroduction have been studied in Asia, Africa, and South America (Camacho-Henriquez et al., 2016; Feyisa et al., 2022; Vijayalakshmi et al., 2023), less is known about UCs in Europe. In addition, as UCs are diverse and have been studied from different angles in a range of disciplines, economic insights into UCs are particularly sparse (Brémaud et al., 2025). Farm management is an important force in shaping the sustainability of farm operations and, hence, agricultural systems. To better understand what role UCs can play in European farms and food systems, evidence is needed on the structure of UC farms, their overall functioning in terms of management (goals and decisions), income generation (performance) in both the short and long run, and how they deal with shocks and changes (resilience).

As UCs inherently display a broad level of diversity across Europe, a large-scale quantitative survey approach would be unfeasible to approach this topic. We, therefore, perform a detailed case study analysis with descriptive numerical summary tables on how UC farmers operate in France, a country known for its tradition of safeguarding its food

heritage and which consequently still conserves several UCs in farm fields. The objective of this chapter is to investigate how French UC farmers operate and how their farms perform. More specifically, we aim to assess five main farm management concepts, which represent the five sub-objectives of the Chapter: (1) What is the farm economic structure of UC farms? (2) What are UC farmers' goals? (3) What are key decisions of UC farmers to achieve these goals? (4) How do UC farms perform? (5) How resilient are UC farms towards the challenges they face? As farms differ according to their crop types, we focus here on farms producing two common crop types: mixed-vegetable and cereal farms. We perform a detailed farm management analysis through investigating UC farms' structure, goals and decision-making, economic performance, and perceived resilience and comparing our results to reference data[6] and literature for 'usual' non-UC farms when available. Based on these insights, we first discuss that, while sometimes perceived as "hobby" farmers, i.e. performing an activity that is not one's occupation, nor is it done for money (Daily, 2018), interviewed UC farmers should not be considered "hobby" farmers. Second, we discuss the potential of growing UCs in a European context and whether UCs are fated to be niche products only. Third, we discuss whether specific farm(er)s are more suited to UCs and vice versa, and conclude on the specific fit between UCs' characteristics and interviewed UC farmers' specific farm management. We end by making policy recommendations to support small-scale and diversified farms, as they are the ones that diversify agriculture and landscapes, and support the rural economy through the local selling of UC products.

3.2 Methods

In this section, we present the conceptual framework and its operationalization (section 2.1), which we use to design semi-structured interviews (section 2.2) for our sample of French case study farms (section 2.3). We further detail the descriptive methods we choose to explore the interview data (section 2.4).

[6] We use the open-source aggregated Farm Sustainability Data Network (FADN) dataset for the same year and crop types.

3.2.1 Conceptual framework and its operationalization

As farm management plays a crucial role in ensuring the efficiency and sustainability of agricultural operations, we use it as an overall umbrella for our conceptual framework to gain a deeper understanding of how UC farms operate. We focus on the five core elements of farm management (Kay et al., 2016): farm structure, goals, decision-making, performance, and risk management (here: resilience) – see Figure 3.1 (upper part). We use the concept of resilience instead of risk management, as resilience is a more holistic concept that captures the farm's ability to overcome challenges (Meuwissen et al., 2019; OECD, 2020), whereas risk management focuses on short-term and known risks (Spiegel et al., 2020). More generally, risk management is a classic and static concept, while resilience is more contemporary and dynamic, looking at how farmers deal with changes and challenges over time (OECD, 2020; Spiegel et al., 2020). Below, we discuss each of the five core elements of farm management and how we operationalize their measurement in semi-structured interviews.

Farm *structure* is characterized by three resource types that have to be available for farmers to achieve their goals (Kay et al., 2016): physical resources, human resources, and financial resources. We collect indicators on these resource types and add the proportion of cultivated land with UCs as a specific indicator (lower part of Figure 3.1).

Farmers' *goals* influence decision-making, farm structure, and performance. Yield and farm income maximization are often assumed as major farmers' goals in the literature (Gasson, 1973; Paut et al., 2018), yet Kay et al. (2016) distinguish 11 diverse goals: (1) stay in business, (2) maximize profit, (3) keep or raise living standards for the family, (4) own land or accumulate assets, (5) reduce or write off debts, (6) avoid years of low profit; stabilize income, (7) ensure the farm take-over by the next generation, (8) increase free time, (9) increase farm size, (10) maintain or improve the soil, water, and air quality, (11) be one's own boss. Gasson (1973) divides farmers' goals or "motivations" into four groups: instrumental (farming is a mean, for example to obtain an income), social (where farming provide inter-personal work relationships such as being part of the farming community), expressive (farming is a mean for expression and self-fulfilment), and intrinsic (performing farming provides satisfaction in itself). The latter is also found by Hill and Bradley (2024). In the same vein, Darnhofer & Walder (2014) conclude that when looking at farmers' "fundamental aspirations", three groups of farmers can be

distinguished based on the emphasis given to the family income: "hobby" or "lifestyle" farmers whose primary goal is to perform a recreational activity, "subsistence" farmers whose main goal is to produce food for their family, and last, farmers who farm primarily for the source of income it provides. In the case of UC farmers, goals are little known and unclear in the literature: Karanikolas et al. (2018) and Sardaro et al. (2017) study cases of UCs grown for commercial interest generating a source of income, while Conversa et al. (2020) and Douma et al. (2016) analyse farms where UCs are mainly used for the family. In addition, we hypothesize that UC farmers likely have different or additional types of goals, such as having their own seeds that can be resown instead of hybrids, or the possibility of offering consumers a unique product (Fenzi & Couix, 2022b). In the operationalization, we ask an open question about farmers' goals in order to avoid influencing answers.

Decision-making refers to farm management actions implemented to achieve farmers' goals, e.g. an investment or a cultivation practice. However, farmers' decisions are not fully correlated to their goals (Willock et al., 1999). Indeed, decisions are also influenced by several other factors, such as farmers' aversion to taking risk, knowledge, access to information (Kpienbaareh et al., 2020; van Zonneveld et al., 2020), farmers' prior values and beliefs (Vignola et al., 2010), farmers' social networks (Burli et al., 2021), farm business characteristics (Edwards-Jones, 2006; Keshavarz et al., 2010), or farmers' past experiences (Hansson & Ferguson, 2011). Decisions are generally grouped as operational, tactical, or strategic (Kay et al., 2016; Koliba et al., 2022; Muñoz et al., 2012), depending on the timeline of their impact. Operational decisions refer to day-to-day actions with short-term outcomes, tactical ones target medium-term outcomes within a year, while strategic ones relate to outcomes a year or more into the future. In the operationalization (lower part of Figure 3.1), we want to understand how UC farmers reach their goals, thus we ask them to explain concrete decision examples, such as regarding their agricultural practices and organization of sales, and the motivations behind them, with follow-up questions throughout the interview. We also asked several indicators to illustrate (and verify) the decision-making described by the farmers (e.g. distances between the farm and their selling points).

For farm *performance*, generally three aspects can be distinguished: economic, social and environmental (Slingerland et al., 2003; Vrolijk, 2016). We focus on economic

performance and variables (e.g. revenue, costs, farm income, yield and price) (Kay et al., 2016), as well as reliance on subsidies (Kumbhakar et al., 2023).

The *resilience* of farms is determined by their resilience attributes, such as buffers, connectivity, and diversity (De Steenhuijsen Piters et al., 2022; Meuwissen et al., 2022; Resilience Alliance, 2010). Such attributes enable systems to cope, adapt, or transform in response to challenges (Meuwissen et al., 2021; Meuwissen et al., 2019). We assess the UC farmers' perceived resilience (Meuwissen et al., 2019) using the statements developed by Slijper et al. (2020) for three resilience capacities. 'Robustness' is the capacity to withstand shocks and stresses. 'Adaptability' represents the capacity to respond to shocks and stresses by modifying the composition of inputs, production, marketing, and risk management while keeping the main structure of the farm. Last, 'Transformability' is the capacity to integrally change the farm structure to overcome shocks and stresses (Meuwissen et al., 2019). We also look at the *challenges* UC farmers strive to be resilient to. Challenges are commonly divided into five main agricultural risk categories, i.e. production, price or market, financial, and institutional risks (Hardaker et al., 2015; Komarek et al., 2020). However, to avoid influencing answers, we elicit the challenges faced by UC farmers with an open question.

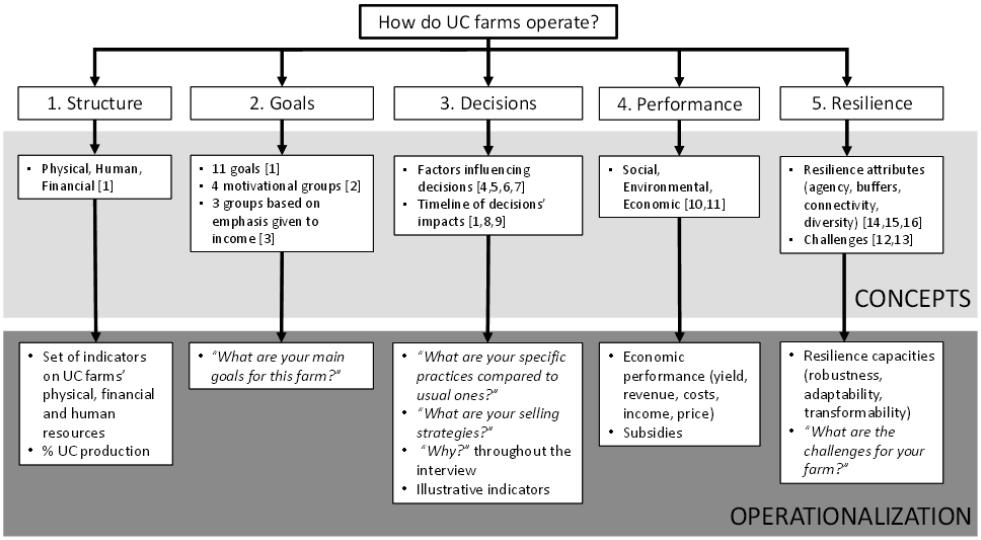


Figure 3.1 Conceptual framework assessing how farms using underutilized crops (UCs) operate, rooted in concepts from farm management literature (top), and operationalization of these

concepts in semi-structured interviews (bottom). Main literature used: [1] Kay et al. (2016); [2] Gasson (1973); [3] Darnhofer & Walder (2014); [4] Kpienbaareh et al. (2020); [5] van Zonneveld et al. (2020); [6] Vignola et al. (2010); [7] Hansson & Ferguson (2011); [8] Koliba et al. (2022); [9] Muñoz et al. (2012); [10] Slingerland et al. (2003); [11] Vrolijk (2016); [12] Hardaker et al. (2015); [13] Winsen et al. (2013); [14] De Steenhuijsen Piters et al. (2022); [15] Meuwissen et al. (2022); [16] Resilience Alliance (2010).

3.2.2 Semi-structured interviews

Seventeen farmers were interviewed between March and June 2023: eight growing vegetables, six growing cereals, and three growing both. Identifying UC farms was not straightforward, as there are no farm records about UC farms. We thus perform convenience sampling; based on contacting farmers from the first author's network already known to focus on growing UCs (one farmer), as well as farmers who were found through the internet (six farmers), and follow-up snowball sampling (the remaining 10). The interviews were conducted in French by the first author. Two interviews were performed by phone, one due to the distance and one for the convenience of the farmer. The other interviews were conducted in person at the farm. In addition to manual notes, interviews were recorded to document all conversations. All interviews lasted between two and five hours, and 10 were followed by a farm and field visit with the farmer(s). During the interviews, farmers were regularly encouraged to give more details and explanations regarding their farm management decisions. Follow-up questions by phone and email allowed probing for more details on some specific points.

The interview questionnaire comprised seven structured sections (see Supplementary Material (SM) 3.1 for the full questionnaire). Section 1 aimed at introducing the research project and the objectives of the Chapter, with the type of information to be collected, as well as the consent form. Section 2 relates to the farm business as a whole, such as its history, production type, and the main goals of the farmers. Section 3 zoomed in on household(s)' characteristics. Section 4 collected economic information such as revenues, costs, and subsidies. Section 5 probed the socio-economic context of the farm, including different aspects of decisions regarding sales (e.g. type of selling points, on-farm processing, isolated or well-connected to urban centres, type of clientele, awareness of local people regarding agriculture and nature). Section 6 assessed the farmer(s)' perceived resilience and challenges. With regard to the challenges, we also asked farmers about the most likely and most impactful challenge they may face (in line with Gerba,

2019). The last section was a concluding part where contacts of other farmers could be retrieved, and any remaining specific comments could be addressed.

3.2.3 Case study of UC farms in France

The interviews with UC farmers were performed in three regions in France: Auvergne Rhône-Alpes, Bourgogne Franche-Comté, and Grand Est (see Figure 3.2). We do not display the farms' exact locations to ensure their anonymity. The area of the case study is inland with semi-continental or mountainous weather, with often hot summers and cold winters (Météo France, 2024). All farms are located in rural areas, some very isolated in mountainous places, and others slightly closer to a small town. None are neighbouring a significant urban centre. The most remote farm is a mixed vegetable farm located at 1100 meters elevation where the growing season for crops is relatively short, i.e. it stops end of October. Although we did not look for organic farms specifically, all the farms in this Chapter happen to be certified organic.

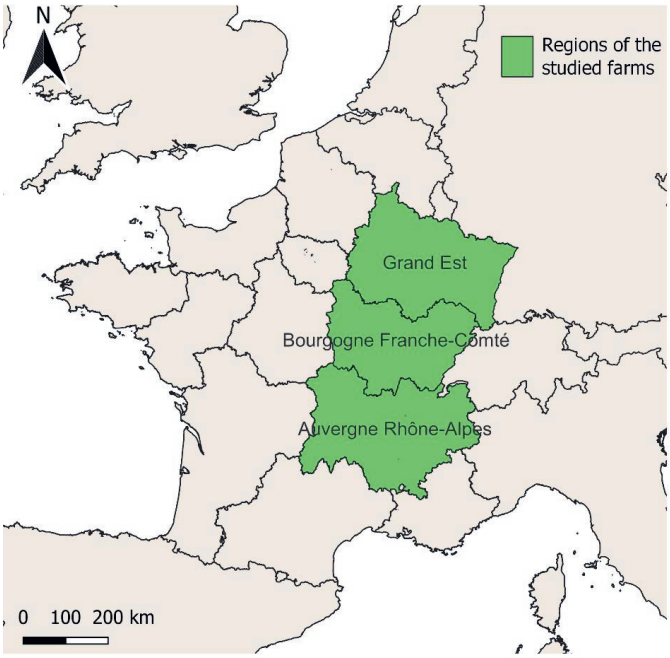


Figure 3.2 Case-study area (source: Geofabrik).

Crops grown by the interviewed UC farmers in the case study are mixes of landraces, old cultivars, and varieties obtained through exchanges between farmers, purchased from small organic seed companies, and created on-farm by crossing or mass selection processes. When starting the farm, the cereal farmers obtained seeds from other farmers in small quantities, except for two farmers who went through a seed bank and a local NGO. The farmers multiplied seeds on-farm for several years until they had enough to commercialize the cereals. All the farms use only fertile varieties, i.e. varieties that can be resown and evolve from generation to generation, and are free-of-right (no fees apply to reuse them). Only one vegetable farmer still uses hybrids as well, i.e. non-reproducible, hence non-adaptable varieties.

Interviewed UC farmers save their seeds to reuse varieties from one year to another. As such, the cereal farmers are fully autonomous in seeds, except one who purchases additional seeds for some crops in the rotation (e.g. alfalfa, lentils). The vegetable farmers save, exchange, and purchase seeds to complete their yearly seed pool. Five vegetable growers have some revenues from seed production, sold to non-professional growers or through a contract with a small organic seed company.

With a plot dedicated to trials and multiplication, some cereal farmers create specific mixes of varieties with specific characteristics, such as resistance to lodging or drought, suiting the micro-climate and soil type. One cereal farmer also reproduces part of his varieties in other farms to boost their adaptability capacity for atypical climatic conditions.

The farms producing cereals process their grains on-farm into flour or bread. The vegetable farms commercialize their vegetables directly, and some process a minor part into finished products such as sauces or soups. Two of the vegetable farms have chickens as a source of fertilizer and for self-consumption. The products are sold directly to consumers or through short local value chains.

Three farms produce both cereals and vegetables and have some additional activities. One also has livestock (i.e. three lambs, three pigs, three cows, poultry and bees) and processes all crops into meals at their farm-restaurant. A second farm also has 250 chickens for egg production. The third farm sells its vegetables to a semi-large retailer, unlike all the other UC vegetable farmers in this case study, who sell directly to consumers or through short local value chains.

3.2.4 Data analysis

Alongside our analysis, we present summary tables of numerical indicators that describe our sample of UC farms. The 17 farms in our sample were divided by types of crops produced: cereals (six farms), vegetables (eight farms), and both cereals and vegetables (three farms). For each indicator, we computed the average and standard deviation for each of the three mentioned groups of UC farms. We display the standard deviation to indicate the variability between farms. Where possible, we compared numerical indicators of UC farms with FADN farms as represented in the openly available aggregated FADN data[7]. For the present study area (Grand Est, Bourgogne Franche-Comté and Auvergne Rhône-Alpes), the 2022 FADN sample is based on 100 to 200 representative cereal farms, and 15 to 40 representative vegetable farms. Only averages and no standard deviations are reported in this aggregated FADN data. For three indicators unavailable in the aggregated FADN data, i.e. farmers' age, debt ratio, and wheat yield variability, we found data originating from the French database for agriculture Agreste for comparison (Agreste, 2023a, 2023b). Note that while comparing our interviewed farms with FADN farms provides valuable regional context for our results, this comparison is not aimed at generating causal insights into the effects of using UCs versus conventional crops.

Assessment of UC farms' structure

Physical resources were captured with six indicators (Table 3.1). Regarding human resources, the indicator of cultivated land per worker was computed by dividing the total workforce by the cultivated land in hectares. The total farm workforce corresponds to the sum of the farmers' labour, the unpaid family support, and the (seasonal and permanent) hired labour. Even though some farmers reported working more than one AWU, these additional hours were not taken into account in the total farm workforce.

For the age of the farm, we listed the year of farm takeover by the current generation (in the case it has been running for several generations) or the year of establishment (in the case the farm has been founded by the current farmer). Financial resources were

[7] FADN website: https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html#. FADN defines French farms as holdings with a minimum of € 25,000 standard output, i.e. average monetary value of the agricultural output at the farm-gate price (European Commission, DG Agriculture and Rural development, 2021).

represented by the debt-to-assets ratio, i.e. the proportion of total fixed assets that are financed with debt. The last indicator for farm structure is the proportion of cultivated land dedicated to UCs.

Assessment of UC farmers' goals

We asked UC farmers to explain their main goals for their farms (see SM3.2). When compiling an overview of UC farmers' goals, we used triangulation within the research team to reduce potential subjectivity bias. Each of the three researchers individually compared the list of goals retrieved with the list of farmers' goals for farms given by Kay et al. (2016). Each researcher matched the interviewed UC farmers' goals with the goals proposed by Kay et al. (2016). When a goal given by the interviewed UC farmers did not match any of these goals, the researcher had to formulate an additional goal (see SM 3.2 for classifications and interpretations per researcher). Subsequently, the three researchers pooled their results. When two or three researchers agreed on one goal, this one was chosen as the final categorization. When the three researchers gave a different interpretation to a goal given by the interviewed UC farmers, they discussed the results together. Finally, using the long list of "other" goals, they agreed on a final list representing the main categories of goals of UC farmers of the sample.

Assessment of UC farmers' decision-making

We grouped the decisions expressed by interviewed UC farmers (SM 3.3) into three categories: operational (short-term), tactical (within a year), and strategic (more than a year) (Kay et al., 2016; Koliba et al., 2022; Muñoz et al., 2012). This categorization was also performed through triangulation in the research team similar to the goals. During the group discussion phase, also five overarching decision-making themes were discerned by the three researchers, as being the main themes repeatedly mentioned across the long list of decisions retrieved.

Assessment of UC farms' performance

Economic performance was assessed by looking into its components: revenue, costs (operational and other), profitability, and subsidies. Revenue corresponds to the money made over one year from selling products and services and does not comprise subsidies. For cereal farms, the yield and the yield variability of wheat were recorded, while vegetable farmers did not know precisely the yield of their different crops, so no yield

could be recorded. The yield variability of wheat (in ton per hectare of cultivated land) was retrieved by asking for yield "in a bad year" (a), the "most likely" yield (b), and yield "in a good year" (c). Yield variability was then calculated assuming a triangular distribution following Kissell & Poserina (2017):

$$Yield\ variability = \frac{(a^2+b^2+c^2-ab-ac-bc)}{18}. \quad (3.1)$$

The operational costs represent all costs of the following inputs: energy, fertilizer, seed, pesticide, and "other" input costs (e.g. packaging costs). All the other (non-operational) costs include the hired salaries, maintenance costs, taxes, certification, and memberships. Note that other costs comprise only hired salaries but no family farmer[8] salaries that are part of the farm income.

Profitability was assessed by calculating the operational gross margin and the farm income after annual debt repayment. The operational gross margin is the proportion of revenue (without subsidies) remaining after paying the operational costs:

$$Operational\ gross\ margin\ = \frac{(Revenue-Operational\ costs)}{Revenue} \times 100 \quad (3.2)$$

and represents the relative profitability of the farm from its core operating activities.

The farm income after annual debt repayments represents the amount of money left for the family farmers after repaying all costs and servicing annual debt repayments. It is computed both with subsidies (3.3) and without (3.4):

$$FI_{with\ subsidies} = Revenue + Subsidies - All\ costs - Annual\ repayments \quad (3.3)$$

$$FI_{without\ subsidies} = Revenue - All\ costs - Annual\ repayments \quad (3.4)$$

Subsidies were recorded as the sum of all sources of institutional financial support: payments from the Common Agricultural Policy (CAP), support for organic agriculture through the "crédit d'impôt" at the national level, and any regional support for replacing materials or paying the organic certification. In the results section, we make an explicit distinction between European CAP (both coupled and decoupled) subsidies and other national and local types of subsidies.

[8] Family farmers of one farm may be from different households.

To represent the capital structure of the farm, total debts and net worth were recorded. Net worth signals the financial health of the farm indicating what remains after all debts are paid off:

$$Net\ worth\ = Total\ fixed\ assets - Total\ debts \quad (3.5)$$

with total fixed assets comprising the values of land, buildings, machinery and equipment, and total debts—the total amount of money that farmers borrow from any external party.

To understand whether UC farms can yield economic returns on the invested capital, we compute return on equity (Petersen & Schoeman, 2008):

$$Return\ on\ equity\ = \frac{FI_{with\ subsidies}}{Net\ worth} \quad (3.6)$$

Assessment of UC farmers' resilience and challenges

Perceived resilience was assessed through twelve statements following Slijper et al. (2020) (see SM 3.4). Note that three of the resilience statements (2, 8, and 10) are framed negatively and their scores, therefore, were reversed (e.g. 6 becomes 2). For each farmer, the three resilience capacity scores were calculated as the average of the scores across four statements within each capacity.

We recorded all challenges mentioned, including which ones the farmers perceived as most impactful or most likely (see SM 3.5). We then sorted the challenges into the five main agricultural risk categories, i.e. production, price or market, financial, personal, and institutional risks (Hardaker et al., 2015). We also used triangulation for this sorting, reaching consensus by calculating averages across the three researchers.

3.3 Results

3.3.1 UC farms' structure

Indicators on the physical resources show that UC farms are, on average, rather small, i.e. cultivated land size of 39 ha for cereal farms and 0.84 ha for vegetable farms. For UC cereal farms, the total fixed assets (on average 227 kEuro) are fairly similar to FADN cereal farms (211 kEuro). The total fixed assets of UC vegetable farms (75 kEuro) are on average lower than for FADN farms (157 kEuro). The value of the machinery and

equipment is lower than average for UC farms, except for the three farms producing both cereals *and* vegetables, which might be because they need equipment for several activities (Table 3.1).

As for human resources, the workforce can be seen as relatively large, i.e. 19.1 ha of cultivated land per worker unit for cereal farms and 0.5 ha for vegetable farms. One explanation could be the labour involved in direct selling and on-farm processing. The farmers' backgrounds are as follows: nine master's university degrees (six in agriculture-related fields), seven technical or bachelor's degrees (six related to agriculture), and one had no degree. Farmers were also relatively young as the average age was respectively 43 and 44 years old for cereal and vegetable farms, and the farm creation or takeover was around 10 years ago on average for cereal farms and 18 years ago for vegetable farms (Table 3.1).

The financial resources, assessed through the share of debt in total fixed assets, show low dependency on banks, at 31.8% for cereal farms and 10.9% for vegetable farms. This difference can partly be explained by the need for larger machinery for cereal production and by the recent takeover of some cereal farms in our sample for which the investments made at the start are not yet repaid (Table 3.1).

Table 3.1 Structural characteristics of interviewed UC farms (n=17) and similar characteristics of FADN farms with these crops.

	UC farms			FADN farms	
	Cereals (n=6) Mean (SD)	Vegetables (n=8) Mean (SD)	Cereals and vegetables (n=3) Mean (SD)	Cereals Mean[a]	Vegetables Mean[a]
Physical resources (1000 €)					
Total fixed assets	227 (73.7)	75 (67.5)	350 (185.8)	211	157
- Land	69 (56.9)	17 (12.2)	118 (66.2)	58	12
- Machinery and equipment	81 (35.8)	37 (15.9)	131 (63.8)	115	51
- Buildings	76 (60.0)	30 (69.7)	101 (72.1)	38	94
Total farmland (ha)	38.9 (28.3)	2.3 (3.1)	89 (64.1)	136.5	11.9
Cultivated land (ha)	38.9 (28.3)	0.8 (0.8)	69 (47.5)	127.0	8.9
Human resources					
Total labor (AWU)[b]	2.17 (1.2)	1.82 (0.7)	2 (0.5)	1.50	3.74
Hired labor (AWU)	0 (0)	0.21 (0.3)	0.42 (0.5)	0.3	2.3
- Permanent	0 (0)	0.13 (0.4)	0.33 (0.6)	NA	NA
- Seasonal	0 (0)	0.09 (0.1)	0.08 (0.14)	NA	NA
# fulltime family farmers (AWU)[c]	2.17 (1.17)	1.63 (0.52)	1.33 (0.58)	NA	NA
Cultivated land per worker (ha/AWU)	19.1 (9.6)	0.5 (0.5)	39.9 (32.8)	NA	NA

Year farm takeover or creation	2014 (7.9)	2015 (4.5)	2005 (7.1)	NA	NA
Average family farmer age	44 (9.7)	43 (3.9)	50 (5.1)	52.2[d]	52.2[d]
Financial resources					
Debts/Total fixed assets (%)	31.8 (42.4)	11.0 (20.4)	13.3 (13.7)	34[e]	46[e]
Proportion UCs (%)[f]	91.7 (9.8)	96.9 (8.8)	93.3 (11.5)	NA	NA

Note: Data that were not available are indicated as NA.
[a] Data are from FADN for the same year (2022) and the same regions. Only Family farmers' age and Debts/Total fixed assets are from Agreste and refer to year 2020 (Agreste, 2023a, 2023b).
[b] Annual Work Unit. Value includes unpaid family support estimated by farmers.
[c] All family farmers worked full-time on the farm and had no other employment.
[d] 54% of cereal farms and 40% of vegetable farms have at least one farmer aged 55 years or older, and farmers' age is on average 52.2 in France in 2020 .
[e] Median values: around 34% for cereal and oleaginous farms, and 46% for vegetable farms in 2020 in France. The average in France in 2020 for all types of farms is 41.1% (Agreste, 2023a).
[f] Number of cultivated hectares with UCs over the total # hectares cultivated.

3.3.2 UC farmer goals

Our UC farmers state 3.5 goals on average. Among the goals listed by Kay et al. (2016), five are similar to those of UC farmers interviewed (left-hand side of Table 3.2). The other UC farmers' goals found are different from the ones in Kay et al. (2016) (right-hand side of Table 3.2). Regarding these additional goals, we highlight that additional goal 6—"Provide an alternative to supermarkets"—has three dimensions: providing "quality", "local", and "affordable" food. Indeed, farmers interviewed sell an important part of their production directly, operate organically, and try to keep prices affordable for their customers, who often have limited financial resources in rural areas. The general goal is to provide an alternative type of food compared to the standard supermarket offer. Additional goal 11—"Be autonomous"—also goes beyond the goal from Kay of 'owning and managing my own business', as interviewed UC farmers refer here to self-sufficiency in food, and independence from banks, suppliers and retailers, in addition to making one's own technical choices.

The additional goals listed in Table 3.2 show that interviewed UC farmers aim for a positive economic, social, and environmental impact on the local territory. For example, interviewed UC farmers see their job as a means to advocate for social change: *"We make our own identity beer, it is more a militant act"* and *"I want to show that we can make a living from a small farm".* This is also illustrated by the following statement of one of the farmers: *"My job is a way to be part of a societal change, to get engaged, not only outside*

my job, but during my job". Gasson (1973) does mentions "social" motivations for farming but defines them as a mean to get inter-personal work relationships such as being part of the farming community", which aims to benefit the farmers themselves. The goals expressed here by interviewed UC farmers seems closer to Gasson (1973)'s category called "expressive" defined as a mean for expression and self-fulfilment, although it seems that expressive motivation is also more self-directed than altruistic. The large emphasis on social and environmental contributions expressed by the interviewed UC farmers' goals, is not fully reflected by the categorization from Darnhofer & Walder (2014) who distinguished farmers' goals for their farm between lifestyle, subsistence and income.

The farmers also explain that their farms do not need to grow in size, but rather, they want to collaborate further with colleagues or improve crop cultivation practices or valorization. They favour their autonomy and the farm viability over yield or profit optimization. This can be illustrated by additional goal 9—"Be a small farm, make a decent living from small-scale farming" and goal 11 "Be autonomous".

Interviewed UC farmers are looking for meaningful jobs, e.g. that improve nature, the local economy, and people's health, as illustrated by additional goal 1—"Do a meaningful job, a job that makes sense to me"—and with a diversity of tasks such as cultivation practices, processing or sharing knowledge, and dimensions such as creativity and social connections, as reported by additional goal 7—"Find pleasure at work, create something beautiful". These goals seem comparable to the intrinsic goals from Gasson (1973). Yet, in the latter reference, these goals seem self-directed, i.e. focused on what farming directly brings to the farmers themselves, while for the interviewed UC farmers, they seem more altruistic, such as in "Contribute to alternative farming systems, knowledge-sharing, and a societal transformation" (goal 4).

Table 3.2 Interviewed UC farmers' goals list, composed of goals overlapping with *Kay et al. (2016)* (left side), and additional goals (right side). Each farmer gave on average 3.5 goals. Goals are listed in no particular order.

Goals overlapping with literature[a]	Additional goals
1. Survive, stay in business, do not go broke, avoid foreclosure	1. Do a meaningful job, a job that makes sense to me[b] 2. Restore the nobility of the profession, honor legacy, maintain old varieties

2. Maintain or increase standard of living, attain a desirable family income 3. Increase leisure and free time 4. Maintain or improve the quality of soil, water, and air resources 5. Own and manage my own business	3. Contribute to the economy and food autonomy of the local territory 4. Contribute to alternative farming systems, knowledge-sharing, and a societal transformation 5. Increase the diversity of local crops and food 6. Provide an alternative to supermarkets[c] 7. Find pleasure at work, create something beautiful[d] 8. Live close to nature, in a rural area 9. Be a small farm, make a decent living from small-scale farming 10. Adapt to the place, use the local resource only 11. Be autonomous

[a] We here refer to the goals in the work of Kay et al. (2016).
[b] This goal comprises different aspects mentioned by UC farmers: (1) feeding the people around me in a healthy way, (2) doing the whole process from seed production to the social connections with customers, and (3) working with the living.
[c] This goal refers to three aspects: provide (1) quality, (2) affordable, and (3) local food to people.
[d] This goal differs from "increase leisure and free time" from Kay et al. (2016) as it aims at finding pleasure during work, not outside it.

3.3 UC farmers' decision-making

Regarding the categorization of decisions based on the timeline of their impacts (Koliba et al., 2022; Muñoz et al., 2012), interviewed UC farmers' decisions refer almost invariably to the middle (tactical) and long-term (strategic) vision of the farm (see SM 3.3). UC farmers' decisions can be summarized into five overarching themes: diversification, autonomy, local partnerships, adaptability, and supporting the natural environment (Table 3.3), each of which is elaborated below.

Interviewed UC farmers aim to remain diversified in various ways: varieties, species, finished products, networks and partnerships, sales channels, and customer types. Crop diversity secures and smooths the total farm production, as explained by one farmer: "*If you do not have wheat, you will eat rye, but you will always have something to eat, that is the peasant philosophy*", and consequently, it also smooths the revenue. Diversification is illustrated by the number of species (on average 6.7 for cereal farms and 51.3 for vegetable farms), and varieties grown (on average 88.4 for cereal farms and 146.9 for vegetable farms). The number of selling points (on average 9.8 for cereal farms and 13.4 for vegetable farms) or the number of finished products (on average 12 for cereal farms and 150 for vegetable farms) further illustrate diversification. Diversified tasks from cultivation to selling to people were also seen as a source of meaningfulness and

motivation at work. Finally, diversification of products provides a large food autonomy to the farmers' families.

Interviewed UC farmers also aim for autonomy at all levels: buying fewer external inputs through seed saving, doing their own compost, using green manure instead of buying fertilizers, slow investments not requiring debt or subsidies, performing repairs or doing accounting themselves, and processing on-farm and selling directly to customers. This autonomy helps farmers disconnect from price fluctuations and powerful suppliers and retailers, and enables them to decide what to produce, how to produce it, and to whom to sell it: *"I chose this job to be free, it's not every farmer who can say that. I decide how I work and to whom I sell my products".* This freedom to make one's own decisions was seen both as financial security as well as a source of happiness and motivation to run the farm. Farmers' autonomy can be illustrated by expenditures on external inputs per hectare of cultivated land. UC farmers do not use pesticides at all (0 €/ha) except for one farm buying 333 €/ha of organic pesticide. As they buy little to no seeds, they spend on average only 12 €/ha for cereal and 1,017 €/ha for vegetable farms on seeds. Water costs are also marginal, i.e. on average 3.3 €/ha for cereal and 744.1 €/ha for vegetable farms. UC farmers limit fertilizer costs (on average 0 €/ha for cereal and 2,227 €/ha for vegetable farms) by making compost on-farm and planting green manure. Energy input is slightly higher (224 €/ha for cereal and 3,460 €/ha for vegetable farms on average) as it includes the processing activities carried out on-farm, such as grinding or baking. While the literature points out that farm business characteristics influence farmers' decision-making (Edwards-Jones, 2006; Keshavarz et al., 2010), it seems the other way around for the UC farmers interviewed. For them, it seems that the farm business is more shaped by the UC farmers' decisions, such as the choice in investing with parsimony to maintain the farm autonomy, and the choice to keep diversification levels high even if it negatively impacts the workforce.

On-farm processing, selling directly to customers, and forming local partnerships help increase profits by adding and keeping value on-farm: "*There is an injunction from big companies: 'Each to his own job', so farmers only grow crops and do not get added value for their products anymore, while originally, farmers are also seed savers, sellers, and produce diverse finished products*". Autonomy to sell also helps to stabilize prices independently from global markets and create stronger local partnerships. This strategy of adding value

is illustrated by a larger revenue per hectare of cultivated land: 3 k€/ha for cereal and 108 k€/ha for vegetable farms. Illustrating autonomy from financial support, the debt shares in total fixed assets in Table 3.1 (31.8% for cereal farms and 11% for vegetable farms) shows limited reliance on debts and thus financial independence from banks. The proportion of CAP subsidies in total income (18.3% for cereal and 1.5% for vegetable farms), also underscores the limited level of financial support received (note that only two vegetable farms receive CAP subsidies). While subsidies appear decent when expressed on a per-hectare basis (600 €/ha for UC cereal and 300 €/ha for vegetable farms), they are much lower when expressed per working unit (10.1 k€/AWU for cereal and 400 €/AWU for vegetable farms), which is surprising as these subsidies also support employment in rural areas.

Interviewed UC farmers enhance local partnerships by selling their products on local markets or via local partners rather than through large value chains. This strategy saves energy and time and enhances collaboration with other farmers and social connections with customers. This strategy can be observed through the share of revenue from direct selling on markets, at the farm, and through AMAPs[9] (73.3% for cereal and 82.3% for vegetable farms). Direct connections between farmers and customers (e.g. through fairs or open markets) raise awareness for food production issues in society. Another indicator of local organization is the average distance of the selling points from the farms, respectively only 20 km for cereal and 10 km for vegetable farms. Partnerships are also strengthened by fixing selling prices within a year and sometimes over the years, which helps long-term planning, secures local businesses (e.g. bakeries, breweries), and enhances long-lasting partnerships. Through local partnerships, farmers support each other (e.g. mutualize material, work, delivery, machinery, buildings, exchange of straw, manure and seeds, help each other for selling surplus, and settle selling prices through concertation). Local collaboration is also materialized by participation in local producers' associations, NGOs, syndicates, shared producers' businesses (e.g. shops, local mill cooperatives), or seed houses. Interviewed UC farmers take part in collective projects (e.g.

[9] Association for Maintaining Peasant Agriculture: partnership between a group of customers and a farm, based on a distribution system of farm products. Customers pay in advance for a period, guaranteeing revenue for the farmers. It is a direct selling system where customers and farmers meet weekly (https://amap-aura.org/).

a shared malthouse creation) and assist aspiring farmers by providing trainings and integrating them into their professional networks.

Interviewed UC farmers display adaptability in various ways. Farmers who have settled for several years do not want to increase production volumes or farm size, but rather try to remain polyvalent. This strategy facilitates an exhaustive view of the farm (i.e. embedded within a natural ecosystem) and decreases financial risk through fewer investments. It is achieved through keeping mechanization low with easily repairable or mutualized equipment, avoiding debt, limiting input usage, doing specific interventions to save energy, time, and costs, and producing to meet the demand only, avoiding surplus. Adaptability, therefore, is enhanced through prudence with regard to investments, i.e. leaving sufficient margin and not having too much debt. Interviewed UC cereal farms had a 31.8% debt share in total fixed assets and vegetable farms 11.0%, which is lower than the debt share reference data from Agreste (2023a) (Table 3.1). Adaptability is also exemplified through the use of rustic varieties and variety mixes to better resist harsh climates or diseases, boosting varieties' adaptability by growing them in different conditions, and regularly trying new techniques such as no-tillage (implemented by three farms, under experimentation by one farm, and four other farms reported doing shallow stubble ploughing only), and different varieties. Kpienbaareh et al. (2020) and Vignola et al. (2010) found that knowledge, beliefs, and access to information are important factors influencing farmers' decision-making in general. In the case of the interviewed UC farmers, these factors seem particularly relevant in supporting their level of adaptability. For instance, they reported to be involved in several professional and social networks regarding knowledge and information sharing, and to follow examples from other farms. Moreover, some interviewed UC farmers specifically mentioned not to believe blindly in technical advisors from the private sector to prevent following mainstream trends regarding investments. The outspoken importance of these factors might relate to the high level of education (nine farmers have a master's degree).

Interviewed UC farmers aim to support the natural environment as they indicate this strategy increases the farm's resilience in the face of harsh weather events. They do so by farming organically, planting hedges (e.g. for humidity, organic matter), or sowing flowers (e.g. for pollinators), which helps them to control pests and diseases and increases soil health and water retention. To boost soil fertility, UC farmers plan long rotations (e.g. 6 to

10 years with a major cereal no more than 2 years) with green manure, and give straws back to the soil. UC farmers never leave the ground bare (e.g. inter-cultures), avoid using heavy machinery, and practice no-tillage cultivation in order not to disturb soil life functioning.

Table 3.3 Indicators illustrating decisions of interviewed UC farmers (n=17).

	Cereals (n=6) Mean (SD)	Vegetables (n=8) Mean (SD)	Cereals and vegetables (n=3) Mean (SD)
Diversification			
Minimum # species	6.7 (1.2)	51.3 (15.5)	31.7 (24.7)
Minimum # varieties	88.4 (59.3)	146.9 (58.5)	71.7 (69.0)
Maximum revenue (€)/ # varieties	1,846 (1,686)	374 (152)	4,040 (4,677)
# selling points	9.8 (7.2)	13.4 (21.1)	5 (1.7)
# finished products	12 (4.5)	150 (101)	84 (57.4)
Autonomy			
Water (€/ha)	3.3 (3.1)	744.1 (622.7)	2.9 (5.1)
Energy (€/ha)	224 (104.4)	3,460 (3,241)	127 (72.2)
Fertilizers (€/ha)	0 (0)	2,227 (2,949)	17 (28.9)
Pesticides (€/ha)	0 (0)	41.7 (35.4)	0 (0)
Seeds (€/ha)	12 (30.1)	1,017 (1,029)	16 (14.8)
Revenue (€/ha)	2,982 (1,811)	108,478 (92,820)	1,735 (362)
CAP subsidies/total income[a] (%)	18.3 (10.4)	1.5 (3.8)	13.0 (2.9)
CAP subsidies (€/ha)	619 (421.4)	329 (817)	279 (138.4)
CAP subsidies (1000 €/AWU)	10.1 (4.8)	0.4 (1.23)	9.7 (6.8)
Local partnerships			
Direct selling (%)	73.3 (12.9)	82.3 (26.8)	66.7 (38.2)
Max. # intermediaries	1.2 (0.4)	0.8 (0.5)	1.3 (1.2)
Av. distance to selling points (km)	22.1 (10.1)	15.8 (13.6)	8.3 (5.8)
Selling price variability[b]	0 (0)	0 (0)	NA
Adaptability			
Machinery and equipment (1000 €/ha)	2.6 (1.4)	64.6 (41.1)[c]	2.4 (1.9)
Machinery and equipment (1000 €/AWU)	43.6 (21.1)	22.8 (14.3)	67.8 (35.3)
Total costs (1000 €/ha)	0.8 (0.3)	49.9 (80.8)[c]	0.9 (0.5)

Notes: Non-available data are denoted NA.
[a] The total income represents the revenue and subsidies.
[b] All farmers reported not changing their prices within the year (2022), except one vegetable farmer who reported a price adjustment due to a weather event (hail).
[c] One vegetable farm produced alcohol, increasing its costs greatly due to high taxes: without this outlier, total costs for vegetable farms are 22.1 k€/ha. This farm also had more debts and assets.

3.4 UC farm performance

Interviewed UC cereal farm yields are twice as low as those of FADN farms in 2022 (Table 3.4), which likely stems from their organic production practices, avoiding the use of pesticides and fertilizers. Farmers did mention that UC wheat varieties have longer straws than conventional varieties (up to 1.80 meters), which they valorise or restitute to the soil. Costs are low for the farmers we interviewed: between five and 10 times lower than those of FADN farms (Table 3.4). The low operational costs can be explained by using no pesticides and limited (organic) fertilizer, little purchase of seeds, and relatively low energy costs, taking into account that several farms process their products. They also have few repairing and hiring costs. The low costs reflect the general strategy of interviewed UC farmers to remain autonomous from suppliers and banks and to limit investments: "*The more machines are beautiful, the more they are expensive and the more you need to work later to repay them*. *Nowadays, a tractor costs 100 kEuros; this represents a lot of working hours before you actually start making a profit with it*".

CAP subsidies for studied UC farms are lower than for FADN farms (i.e. 22,700 € for UC cereal and 500 € for vegetable farms, versus respectively 37,000 € and 3,800 € for FADN farms). Land areas of UC vegetable farms were small compared to FADN farms, explaining the lower subsidies per farm. For UC cereal farms, three farms currently receive CAP support for installation, which boosts the CAP subsidy value of our sample. Studied UC farms' debts were also much lower compared to FADN values, with 78.4 k€ for UC cereal and 19.3 k€ for UC vegetable farms, while debts are respectively 183.6 k€ and 142.3 k€ for FADN farms. Eight farms in our sample are debt-free, among which five are vegetable farms.

The selling price of bread is around 4 to 5 €/kg, and for tomatoes 4.5 €/kg. Note that these prices are relatively low compared to similar organic products on the market, but high compared to usual farm gate selling prices of raw products to retailers. For organic wheat grains for example, farm gate prices are only around 200 €/tonne in 2022 in France (DRAAF, 2024) [10]. Several interviewed UC farmers explained that they keep prices relatively low compared to the market prices for similar organic products and do not follow market corrections because their products should remain accessible to their local

[10] One kilogram of bread requires approximately one kilogram of grains due to a loss of matter during grain cleaning then water added for bread making.

customers, who often have moderate incomes. One farmer also refuses to sell his products to star restaurants.

As a result of low costs, low debts, and good selling prices (ensured by processing and direct selling), studied UC farms' profitability is high with an operational gross margin of around 90% of the revenue. This does not mean that farmers have high incomes, however, as these UC farms' volumes are limited compared to FADN ones, yet it shows that a large share of the revenue is truly for the farmers rather than for repaying costs or debts. Although the UC farmers interviewed perceived their income as "satisfactory", there were differences between individual farmers: one farmer mentioned that subsidies were welcome to finance the household's holidays each year, while another farm offered a thirteen-month salary to every farmer. Last, several vegetable farm households were almost fully self-sufficient in food, also reducing household expenditures.

While we did not record revenue variability over the past years, it largely depends on the variability of prices and yields. The price variability per year is zero (Table 3.3), as interviewed UC farmers explained not changing their prices within a year. For yield variability, we were unfortunately unable to find a comparison against which the yield smoothing decisions of UC farmers (choosing genetically diversified varieties and cultivating mixes of varieties and species) could be verified. The interviewed UC farmers did note that the large diversity of crop species grown (long rotations with various cereals, forage crops, oilseeds, and pulses, and multiple species and varieties for vegetable farmers) ensures an overall stable farm revenue every year: "*It's impossible for everything to fail at the same time: one year might be good for the carrots and the next for the cabbages*".

Table 3.4 Economic performance of interviewed UC farms (n=17), and FADN farms with these crops .

	UC farms			FADN farms	
	Cereals (n=6)	Vegetables (n=8)	Cereals and vegetables (n=3)	Cereals	Vegetables
	Mean (SD)	Mean (SD)	Mean (SD)	Mean[a]	Mean[a]
Revenue					
Revenue (€/year)	98,192 (55,248)	58,350 (44,801)	111,867 (77,521)	282,638	293,803
Wheat yield (T/ha/year)	2.36 (0.35)	NA[b]	2.35 (0.92)	6.93	-
Yield variability (T^2/ha^2)	0.064 (0.040)	NA	0.098 (0.097)	NA	-
Selling price[c] (€/kg)	4.73 (1.93)[d]	4.46 (0.10)	1.50 (1.41)	NA	NA
Operational costs (€/year)					

	UC farms			FADN farms	
	Cereals (n=6)	Vegetables (n=8)	Cereals and vegetables (n=3)	Cereals	Vegetables
	Mean (SD)	Mean (SD)	Mean (SD)	Mean[a]	Mean[a]
Energy	7,537 (4,376)	2,057 (1,506)	9,100 (7,650)	17,279	18,469
Fertilizers	0 (0)	876 (1,037)	1,833 (3,175)	38,760	14,955
Seeds	1,167 (2,858)	825 (1,029)	833 (1,041)	16,288	42,439
Pesticides	0 (0)	13 (35)	0 (0)	19,219	3,839
Other[e]	2,125 (4,176)	1,611 (3,444)	17 (28,9)	3,543	16,572
Total (1000 €)	10.83 (9.01)	5.38 (4.55)	11.78 (8.43)	95.09	96.27
Other costs (1000 €/year)					
Hired labor	0 (0)	5.86 (8.35)	15.03 (21.45)	7.44	59.78
Maintenance	5.52 (4.26)	1.58 (1.80)	5.67 (3.79)	22.02	19.97
Other[f]	10.45 (5.08)	16.40 (31.10)[g]	21.58 (16.04)	58.45	40.35
- including water	0.13 (0.16)	0.35 (0.27)	0.05 (0.9)	NA	NA
Total	15.97 (8.49)	23.84 (36.01)[g]	42.28 (41.28)	87.91	120.10
Profitability					
Operational gross margin (%)	89.26 (5.10)	90.77 (2.79)	90.16 (3.59)	NA	NA
Farm income with subsidies (1000 €)[h]	86.5 (55.9)	31.9 (14.9)	71.9 (43.9)	NA	NA
Farm income without subsidies (1000 €)[h]	57.9 (41.1)	26.5 (28.4)	47.5 (14,4)	NA	NA
Subsidies (1000 €/year)					
CAP	22.7 (15.6)	0.5 (1.2)	19.6 (15.7)	37.0	3.8
Other	6.0 (7.9)	4.9 (2.7)	4.9 (6.3)	NA	NA
Total	28.7 (20.1)	5.3 (2.7)	24.4 (15.8)	37.0[i]	3.8[i]
Capital structure (1000 €)					
Total debts	78.4 (114.0)	19.3 (44.72)[g]	63.3 (77.7)	183.6	142.3
Annual repayment	13.5 (17.5)	2.6 (4.6)[g]	10.3 (9.3)	NA	NA
Net worth	148.2 (117.1)	55.9 (26.7)	286.7 (110.2)	324.3	162.5
Return on equity (%)	-45.7 (274.7)[j]	83.6 (71.1)	23.7 (11.8)	NA	NA

Note: Non-available data are denoted NA, non-applicable data are denoted with "-".
[a] Reference data from openly available FADN for 2022 and the same region.
[b] Yield was not retrievable for vegetable farmers.
[c] Selling price at farm gate (as bread for cereal farms, and a kilogram of tomatoes for vegetable farms).
[d] Average over 5 farms (one farm sells flour but not bread).
[e] Other operational costs include expenditures e.g. packaging, manure, ingredients for making finished products.
[f] Includes e.g. insurance, phone subscription, accounting costs (water costs are also other costs to follow FADN computation).
[g] One vegetable farm had high taxes due to alcohol production increasing other costs, and had also more debts (without this outlier: Total other costs = 10,485 €, Total debts = 3,250 €).
[h] After annual debt repayments.
[i] FADN records only CAP subsidies, there might be other financial supports at lower levels.
[j] One cereal farm was taken over by young farmers in 2021; thus, at the time of the data collection (2022) the new farmers had more debts (287,500 €) than assets (275,000 €). Without it, return on equity for UC cereal farms is 63.8 (66.7)%.

3.5 UC farmers' resilience and challenges

As illustrated by the resilience scores in Table 3.5, interviewed UC farmers perceive themselves as relatively resilient: all resilience capacities score above 4, which is the neutral score. Scores are also higher than the ones found for a sample of Dutch farmers by Slijper et al. (2020). Cereal farms and farms with both cereals and vegetables have the highest scores in terms of adaptive capacity, while vegetable farms score highest for transformative capacity.

Table 3.5 Perceived resilience capacities of interviewed UC farms measured on a 7-point Likert scale from 1 (totally disagree) to 7 (totally agree).

	Cereals (n=6) Mean (SD)	**Vegetables (n=8)** Mean (SD)	**Cereals and vegetables (n=3)** Mean (SD)
Robustness	4.21 (1.8)	4.17 (2.1)	4.63 (1.9)
Adaptability	4.75 (1.8)	4.92 (2.2)	4.78 (2.1)
Transformability	4.58 (1.6)	5.25 (1.9)	4.47 (1.3)
Average	4.51	4.78	4.63

Although the UC farmers expressed not facing a lot of challenges when asked during the interview, they subsequently still reported some. The challenge mentioned as the most likely (and sometimes most impactful) by most of the UC farmers is climate change, bringing more hails (two farms) and stronger winds (one farm), and periods with drastic lack of water (all farms). Some UC farmers fear that their efforts to be as adaptable as possible may not be sufficient in the future if climate change happens too fast and strongly: *"What if climate change comes too fast, and varieties do not have time to adapt?"* or *"Our varieties can survive with very little water, but what if there is no water at all?"*.

The institutional risks mentioned are the possible change in the legislation about (1) the right to use old varieties, and (2) the use of Genetically Modified Organisms (GMOs) that could threaten organic farming by polluting old varieties with GMO varieties. Some farmers also face issues regarding unsecured land or difficult access to land. Some fear the possible reduction of the organic label's quality standards that could allow unfair competition for organic products, and some point out that sanitary regulations are adapted to large-scale businesses only. A recurrent issue is the acquisition and exchange of UC seeds, as only small amounts of seeds are allowed to be exchanged between farmers.

This situation threatened UC vegetable growers who need to work in networks to manage a diversity of open-pollinated varieties in isolation from each other. It also impacts UC cereal farmers because they have to start farming with a handful of seeds and multiply these on-farm for several years before having enough volume to commercialize the grains.

Price and market-related risks reported by farmers are the competition with supermarkets or increased prices, e.g. to buy equipment. Finally, UC farmers mentioned human and personal risks, such as the risk of disagreement between family farmers, accidents, or burnout. Financial risks were hardly mentioned, yet some farmers reported that their business types, e.g. farmer-baker, are little known by bankers, hindering access to credit at the startup phase.

3.4 Discussion

3.4.1 The potential of UC farms

Our findings help to explore the potential of UC farms in relation to three cross-cutting discussion questions: whether or not (1) UC farmers are 'hobby farmers', (2) UC products are fated to be niche products only, and (3) there are specific characteristics that define a good match between the farms and the UCs.

As mentioned in the introduction, a 'hobby' activity is a type of serious leisure that is not one's occupation, nor is it done for money (Daily, 2018). All farmers interviewed farm in a full-time professional capacity and need this income to feed their households. Farm revenues were perceived as sufficient to sustain their households. Even more, they materialized this with relatively little financial support from the CAP, i.e. on average 22,700 €/year for cereal farms and 500 €/year for vegetable farms, while farms from FADN receive respectively 37,000 and 3,800 €/year. The UC farms in our samples could therefore clearly not be considered hobby farms.

Even though UCs are underutilized by definition, that does not make them niche products only. By pursuing niche product strategies, companies target a small market to benefit from higher prices and less competition (Schaefers, 2014). Conversely, the UC farms in our study strive to keep stable and affordable prices for a large number of customers, i.e. on average 4.73 €/kg for bread and 4.5 €/kg for tomatoes, fixed over 2022.

UCs might intrinsically be better adapted to smaller-scale production and local markets. Their genetic diversity, while important for e.g. climate adaptation, may at the same time make them less adapted to standardization, long storage, transportation, or mechanization (Ahokas & Poukkula, 1999; Biscotti et al., 2022; Elia & Santamaria, 2013; Spataro & Negri, 2013), and better suited for local selling and small-scale agriculture than large-scale markets. Thus, although prices are affordable to many, UC cultivation and selling seem to suit multiple local and small-scale channels better.

Given their special characteristics, it is likely that UCs are mostly suited for a specific type of farm(er). UCs are genetically diverse varieties, so they are adaptable and resistant crops (Bela et al., 2006; Karanikolas et al., 2018) that allow cultivation under low-input conditions (Antofie & Sava, 2020; Mahon et al., 2016; Sardaro et al., 2017). We find that the farmers in our sample look for adaptability (e.g. to climate change) and try to keep input levels low, which makes UCs interesting crops to fulfil their goals. In addition, UCs are mostly non-registered crops, i.e., free to use as no breeder rights apply (UPOV, 1961), which enables seed saving and thus autonomy by avoiding seed purchases. Enhancing autonomy is also a priority in interviewed UC farmers' decision-making to limit risks (e.g. in case of a change in market prices). Last, as UCs are adapted to organic production, they are quality products that fit a direct selling strategy well. Due to these aspects, UCs suit especially well the goals and decisions of the studied UC farms. The genetic diversity of UCs does make them less standardized, which makes them little adapted to mechanized practices (Karelakis & Tsantopoulos, 2017; Thanopoulos et al., 2021). As seen in this Chapter, interviewed UC farmers keep the mechanization level moderate and sell the products locally, avoiding transportation at the maximum. This way of functioning again makes UCs well-suited to interviewed UC farms' practices and vice-versa.

Most of the UC farmers interviewed in this study are young and highly educated, suggesting that they may be part of a new generation of farmers, oriented more towards smaller scale, and increased diversity and flexibility, perhaps pushing towards less land and capital-intensive farming, that may be more resilient to future market and climatic shocks, as well as transmission issues, as suggested by Pitson et al. (2020).

Interviews lasted between two and five hours, including a visit of the farm. Some of the interviewed UC farmers partly kept working while answering questions (two were making bread, for example). There may be several reasons why the farmers were willing

to sit for such a long time with the interviewer and share such an abundant amount of information. First, interviewed UC farmers may consider sharing information about their farm's functioning and practices as part of their job duties. This is in line with the results regarding their goals and decision-making: interviewed UC farmers were involved in professional and high school farming trainings and learning exchange networks. Thus, they seem to highly value education and knowledge sharing. A second aspect might be the feeling of being little understood and known by the rest of society, and little taken into account by policy-makers, and their wish for more visibility. A third possible reason is that several farmers were reached by snowball sampling, implying that we could refer to a colleague. This might increase trust and incentivize one's engagement (Sadler et al., 2010).

3.4.2 Limitations and further research perspective

Even though our sample is relatively small, with 17 farms interviewed, this limitation is balanced by the depth of our analysis. While all these farms are located in France, the study area covers a broad area across three regions. Given the diversity of European contexts, such as climatic conditions, land prices, customer preferences, and farmers' experiences, we likely did not capture the full range of UC farm diversity. Nevertheless, our study focuses on providing a first detailed exploration of how UC farms operate, rather than looking for representativeness across a larger sample.

While farms were partly found through snowball sampling, most of them are from different networks. Additionally, they are from distant locations spread over three regions. Despite this social and geographical spread, the lists of goals and decisions are remarkably similar across the sample. Due to this observed homogeneity, we consider the interviewed UC farms representative of UC farms in the case study areas; yet, studies in other areas could help to further generalize our findings.

From a temporal perspective, our Chapter focused on cross-sectional performance in 2022. By not explicitly recording inter-year variability (except for expected yields), potential fluctuations in interviewed UC farm performance are not fully captured, nor compared with FADN farms. Nevertheless, three findings suggest that our UC farms had stable performance over the years. First, interviewed UC farmers grow a large diversity of crops, which smooths the total output as crop failures are unlikely to arise at

the same time for various crops. Second, they keep their prices very stable thanks to local long-term partnerships. Third, although revenue values for the preceding years to 2022 have not been recorded, several established farmers explained that the preceding years were similar. Hence, we hypothesize that revenue may be more stable over the years for UC farms than for specialized farms. Future research could look deeper into the economic stability of UC farms over time, making an empirical comparison to more 'usual' farms.

In order to compare our results with the larger population of farms, we compare our findings with the literature, and we give a reference value next to the indicator values where possible. Yet, some reference values could not be found or computed with the openly available FADN dataset. In future studies, using micro-FADN data could enable placing a more precise reference value for each of the indicators for the same period and crop types. Still, this comparison would have limitations as it is not possible to identify UC farms in the FADN data set as it lacks information on varieties grown. Even though the new FSDN dataset promises to extend the scope of data collection from a primarily economic towards a more general farm sustainability focus (European Parliament and Council of the European Union, 2023), a more thorough comparison with non-UC farms would be to interview non-UC farms neighbouring UC farms.

Last, while farm performance can also be analysed from a social and environmental perspective (Slingerland et al., 2003), we focus here on an economic perspective only. While we argue that we examine economic performance in-depth as it is a core necessity for farm viability, looking into the social and environmental performance of UC farms and how they relate to economic performance would give interesting further insights.

3.5 Conclusions

This Chapter provides a first documentation of farms that use crops that are underutilized and thus no longer mainstream. It explores how a sample of underutilized crop (UC) farms located in France operate using a farm management framework focusing on structure, performance, goals, decision-making and resilience. Based on in-depth interviews and a comparison with the farm management literature and FADN farm dataset, we draw the following overall conclusions. First, interviewed UC farms are characterized by relatively little equipment, on average smaller land size, and higher

labour (mostly for vegetable farms). Second, UC farmers focus on achieving long-term resilience for their farm and territory and on making a positive social, economic, and environmental impact locally. They do not focus on increasing profit, yield, or farm size. Third, interviewed UC farmers take decisions focused on diversification, autonomy, local partnerships, adaptability, and supporting the natural environment. Fourth, the UC farm performance is characterized by lower input levels and wheat yields. Farmers perceive their farm income as sufficient to sustain their families. They valorise several by-products, keep costs low, and attain high added value through on-farm processing and direct selling. All these factors result in a sustainable farm income, with little reliance on subsidies or debts. Fifth, interviewed UC farmers consider their system and themselves as relatively resilient to deal with shocks and stresses. Regarding the latter, the main perceived challenges are production challenges due to climate change, price and market challenges such as difficulties in reaching customers, and personal challenges including disagreement between family farmers or health issues.

To integrate UCs effectively into policy frameworks (e.g., the Farm-to-Fork strategy or measures aimed at enhancing biodiversity), we formulate the following policy recommendations. First, for policymakers at the EU and national levels, we highlight that exchanging seeds between farmers should be recognized as a necessary right for farmers to access UC seeds when they decide to start using new UCs, know-how, and knowledge to grow UCs. Second, for local policymakers, we recommend developing market infrastructures such as collective catering and open markets for local production systems to support UC farmers in reaching customers and creating strong local markets. Further, collective projects with processors within local networks could be better supported to create stronger markets for UC products (e.g. shared producer shops or delivery systems) and boost the sharing of knowledge, inputs, and materials. In addition to enhancing collaboration between professionals, connecting with society, e.g. through social events, would also help UC farmers to be understood by customers. Finally, as supporting coordination between farmers requires local workers, and collaborative projects require funds, we recommend that EU policymakers prioritize funds for rural development. Beyond support for farm establishment, UC farmers seem to mostly need support to facilitate cooperation, such as setting up short-value chains for their products. Taking these recommendations into account could stimulate (new) farmers to grow UCs and

ultimately boost crop diversification, which in turn improves food security and adaptation to climate change.

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Supplementary materials

The supplementary materials with the questionnaire (SM 3.1), the detailed data on goals (SM 3.2), decision making (SM 3.3), perceived resilience (SM 3.4) and challenges of UC farmers (SM 3.5) are available here: https://academic.oup.com/qopen/article/5/2/qoaf031/8314063#supplementary-data.


4

Chapter 4
Resilience of three European value chains processing underutilized crops

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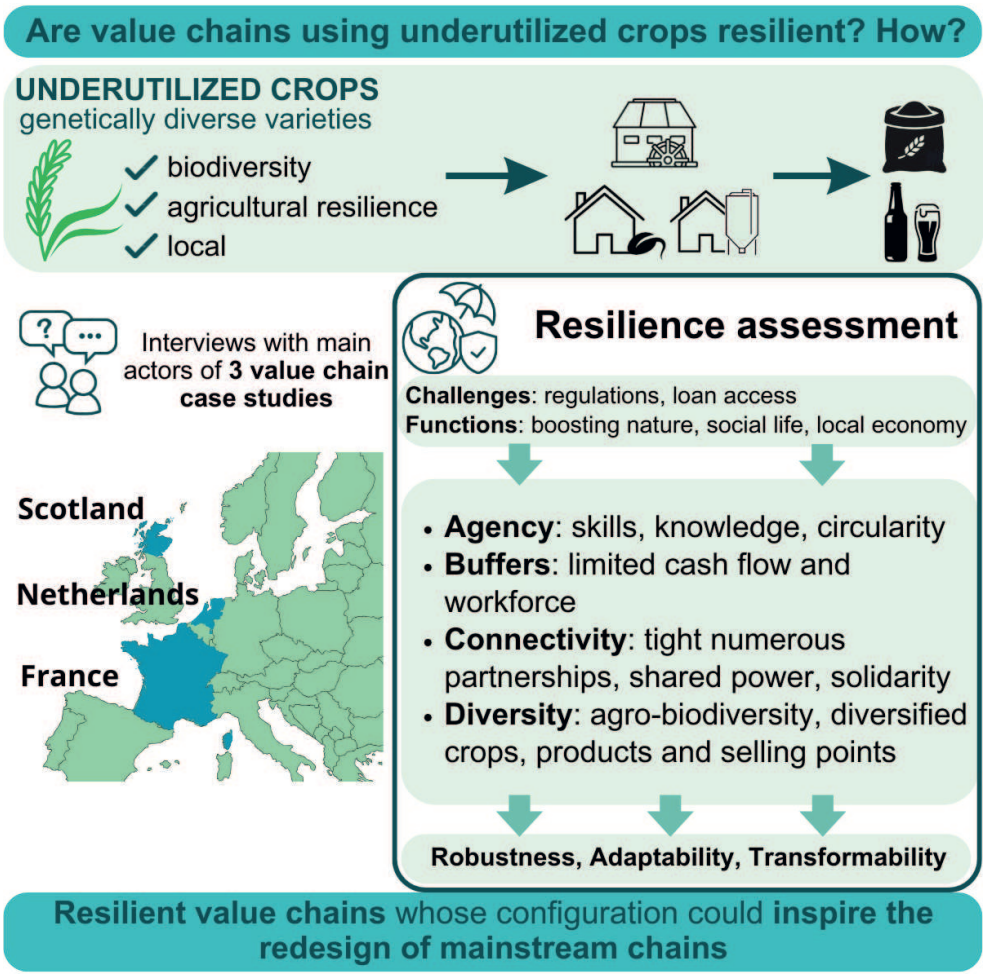
Nguyen Brémaud, M-F.E., de Mey, Y. & Meuwissen, M.P.M. Resilience of three European value chains processing underutilized crops

Abstract

Underutilized crops (UCs), as genetically diverse varieties, have the potential to increase resilience of farms. But are post-farm stages of UC value chains also resilient and, if yes, how? These questions remain barely explored, while the answers are fundamental for developing UCs. This Chapter analyzes the resilience of three European UC value chains processing cereals into flour (Scotland) or beer (France and the Netherlands). Via semi-structured in-depth interviews (n=7) with the main chain actors we explore the chains' resilience as informed by the ABCD resilience attributes, i.e. *Agency*, *Buffers*, *Connectivity* and *Diversity*. We first investigate each chain's context by mapping them and analyzing their challenges and functions. We then assess their resilience. Results show a strong *Agency,* observed through actors' knowledge and skills to save natural resources and implement circularity. *Buffers* are limited, e.g., regarding workforce or cash flow. *Connectivity* materializes through tight partnerships to jointly manage transportation, price setting or quality and quantity variations in harvest. *Diversity* is observed through enhancing farm-level agrobiodiversity, cultivating several crops next to cereals, saving different UC varieties per cereal species and developing different finished products sold in multiple places. We thus conclude that both farm and post-farm stages of UC chains are configured based on principles of resilience. These chains provide practical examples for configuring resilient value chains and may inspire the redesign of mainstream chains.

Keywords: Forgotten crops, food system, value chain, local, cereal

Graphical abstract



4.1 Introduction

Underutilized crops (UCs) are genetically diverse varieties that were used historically but later abandoned. They currently have limited use in regions where they are locally adapted (FAO, 2018a; Pinto et al., 2023b). UCs can, however, foster local genetic diversity and varietal options (Mahon et al., 2016), and therefore have the potential to improve the resilience of farms (Brémaud et al., 2025b; de Roest et al., 2018). In this context, resilience refers to the ability of farms and food systems to absorb shocks, adapt to changes and continue to function effectively over time (Folke et al., 2010). However, realizing the full potential of UCs requires not only agronomic or genetic attention, but also the development of resilient UC value chains that can support their cultivation, processing and marketing in the face of shocks and challenges.

UCs have primarily been studied in Africa or South America (Andreotti et al., 2022; Feyisa et al., 2022). The literature regarding their use in the European context is limited (Bjarklev et al., 2019). Studies focused on the resilience of UC value chains in Europe has primarily focused on the farm production aspects. The need to consider their embedding in the wider food system is often only touched on in the discussion or conclusions, such as the need to add value to the products (Negri, 2003b), develop local value chains (Varia et al., 2021; Zaharieva et al., 2010) and food systems (Karelakis & Tsantopoulos, 2017; Spataro & Negri, 2013b) or suggestions on how to better valorize and market UCs (Montesano et al., 2012; Raggi et al., 2021; Riu-Bosoms et al., 2014). Papers focusing on UC processing and selling in a European context are rare (Brémaud et al., 2025a). Existing literature deals primarily with UCs used for self-consumption, such as in home gardens (Douma et al., 2016; Knezevic-Jaric et al., 2014; Pieroni et al., 2005). Niche and local markets play an important role in sales (Brugarolas et al., 2009; Douma et al., 2016; Fenzi & Couix, 2022; Karanikolas et al., 2018), while intermediaries play a limited role (Brugarolas et al., 2009; Douma et al., 2016; Fenzi & Couix, 2022; Pieroni et al., 2005). These studies provide some insights into the factors contributing to the resilience of specific parts of UC value chains, but there is a lack of understanding when it comes to the resilience of UC value chains as a whole. This chapter aims to fill this gap.

We focus on three UC chains all cultivating and processing UC cereals but in different configurations and with different outputs, that is, beer in France (henceforth *Beer FR*), flour in Scotland (*Flour SC*), and beer in the Netherlands (*Beer NL*). Our findings contribute to the literature in four ways. First, the assessment covers two stages of the value chain, i.e., the farm and processing stages up to the finished products. Previous literature operationalizes and assesses resilience attributes at the farm level (Prat-Benhamou et al., 2025), household level (Nguyen et al., 2025) or community level (Asresehegn et al., 2025). Insights from actors across the value chain inform how resilience attributes (*Agency*, *Buffers*, *Connectivity* and *Diversity*) operate beyond the single business level. Second, we substantiate the perceived performance scores of the attributes with factual indicators. Third, we explore how resilience attributes relate to capacities of robustness, adaptability or transformability, in practice when risks arise. Previous literature addressed this relationship conceptually (Feindt et al., 2022; Mathijs & Wauters, 2020) and case studies so far addressed it hypothetically (Paas et al., 2021), or by revealing a perceived contribution (Paas et al., 2021), but without investigating the relations between the attributes and the resilience capacities in practice. Fourth, we investigate how resilience is built for three case studies through a list of detailed statements. These detailed analyses of how resilience is built up in concrete case studies contribute to substantiating resilience assessments and are still lacking in the literature, as explained by Barrett and Constas (2014). Analyzing how UC value chains operate and how their actors build their resilience, helps us understand how UCs thrive in local food systems. In doing so, we advance the knowledge on how these diverse and adaptable crops can be integrated into agri-food value chains. Our results offer practical guidance to support UCs through targeted policy, investment, and grassroots initiatives aimed at strengthening cultivated biodiversity in Europe.

4.2 Methods

4.2.1 Conceptual framework

The resilience of a farming system can be defined as "its ability to ensure the provision of the system functions in the face of increasingly complex and accumulating economic, social, environmental and institutional shocks and stresses, through capacities of

robustness, adaptability and transformability" (Meuwissen et al., 2019). In this Chapter, we investigate the characteristics, i.e. the resilience attributes, of our case studies to understand how the resilience of these systems is built by their actors. Resilience attributes are the individual and collective competences within food systems and their enabling (or constraining) environments that enhance one or more resilience capacities (robustness, adaptability, transformability), and, more broadly, as such contribute to general resilience (Meuwissen et al., 2019). They have been recognized as core in the resilience literature (FAO, 2016). In contrast, a large number of studies focus on measuring resilience outcomes (Low et al., 2025; Slijper et al., 2021) rather than understanding how the resilience of a system is built.

Resilience attributes have different names in the literature, but all aim at decrypting the factors or characteristics of a system that contribute to—or deteriorate—its resilience (Resilience Alliance, 2010). This chapter builds on the four ABCD resilience attributes from De Steenhuijsen Piters et al. (2022). The attributes are defined as follows: (i) *Agency* is the ability of people to decide what to do and execute appropriate actions to adapt and learn, but also to anticipate and prevent shocks or stressors. (ii) *Buffering* represents anticipatory actions to face a shock or stressor, for example, by setting up stocks or savings accounts. (iii) *Connectivity* represents the type and strength of interactions, such as through physical infrastructure and communication networks (e.g. internet access), and the social, economic and political relationships between actors. (iv) *Diversity* represents the variety of elements within the food system, mitigating the impact of shocks or stressors because one resource will compensate for another one. It encompasses not only biodiversity, but also diversity in production and distribution (De Steenhuijsen Piters et al., 2022).

Resilience attributes operate differently depending on the context (Feindt et al., 2022; Meuwissen et al., 2019), which is why it is important to describe a system's configuration, challenges and functions (Figure 4.1). Finally, the functioning of the resilience attributes can be assessed by observing how they shape the capacities of robustness, adaptability and transformability (Meuwissen et al., 2019).

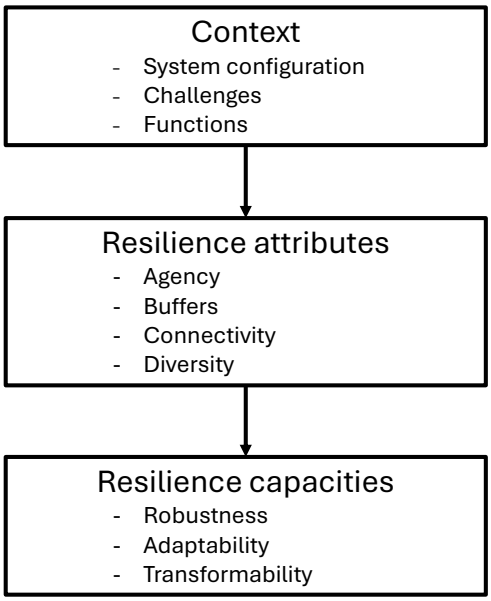


Figure 4.1 Conceptual framework to assess the resilience of value chains using underutilized crops (UCs), adapted from Meuwissen et al. (2019).

4.2.2 Interviews

Semi-structured interviews were carried out with the main actors of the UC value chains. The interviews were conducted in person and combined with a company visit for the *Beer FR* and *Beer NL* value chains. For *Flour SC*, a scoping visit was carried out with the processor, after which interviews were performed online. All meetings took place between June 2023 and November 2024. In total, seven actors were interviewed. Each interview began with an introduction of the broader research project, the objective of the Chapter, and the type of information to collect. Participants also signed a consent form. Each interview lasted between two and four hours. Follow-up emails (8), phone calls (2), additional online meetings (4) and one in-person meeting provided missing information to complete our understanding of the value chains. Following the conceptual framework, each interview consisted of three sections: Section 1 related to the presentation of the business and its context (see Supplementary Material 4.1), Section 2 addressed resilience attributes (see Supplementary Material 4.2) and Section 3 investigated resilience capacities (see Supplementary Material 4.3).

4.2.3 Description of the context

System configuration of the case studies

The three UC value chains process local cereal varieties into flour or beer. We focus on the businesses that constitute the value chains from UC seeds to final products, i.e., farmers and processors. Figure 4.2 shows the configuration of these value chains and displays their UC-related activities. Non-UC cereal activities (e.g. lentils and oils also produced by farmers) are not shown. The figure also indicates which businesses were actually interviewed, those that were studied but not interviewed, and actors that are part of the chain but not assessed (e.g. customers).

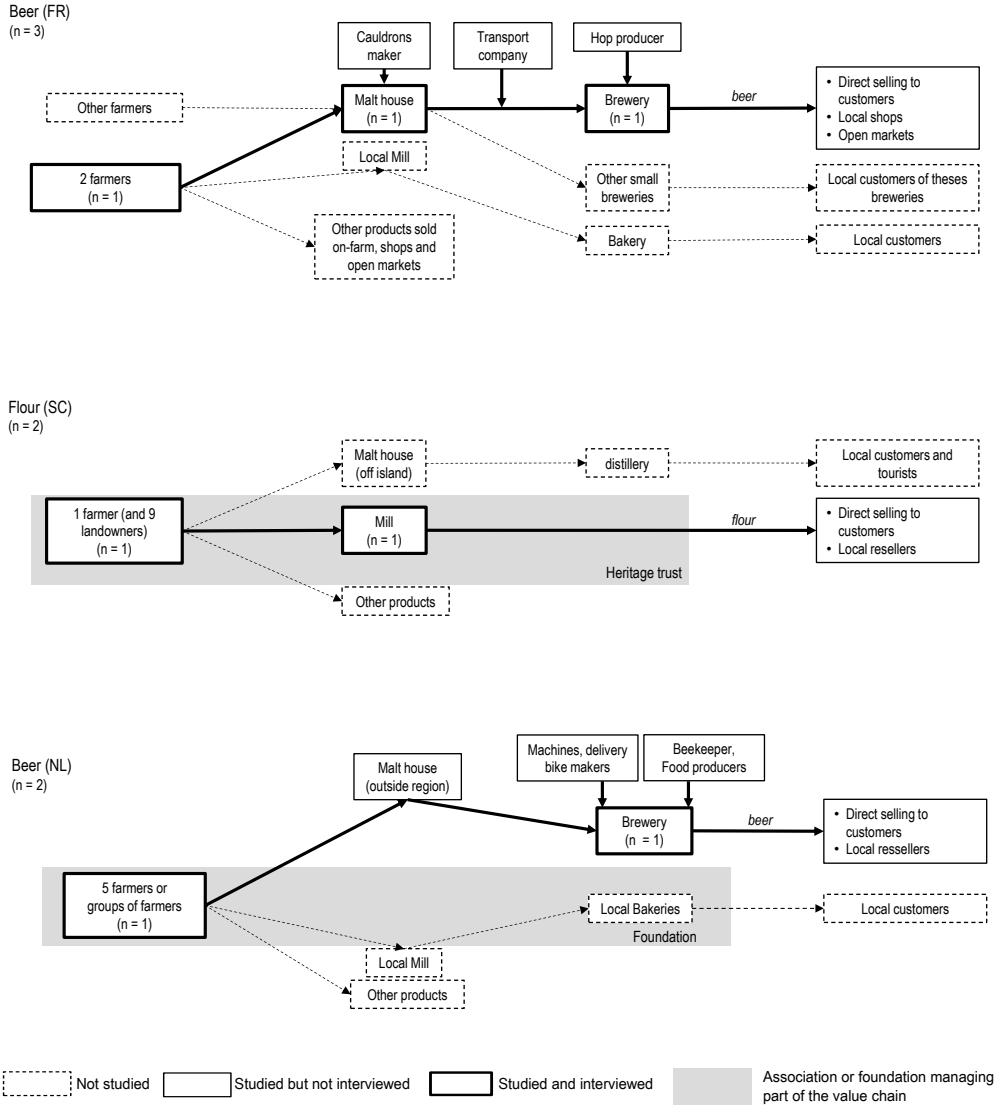


Figure 4.2 Mapping of the local businesses that constitute the three UC value chain case studies. The businesses interviewed are in bold (n = 7).

Understanding the configuration of the respective chains sets the scene by addressing the first context question of the conceptual framework, i.e., 'Resilience of what?'. *Beer FR* is a value chain in Auvergne, France, which grows and processes different local varieties (e.g. *Milanais de Limagne*, *Trésor du Velay*) of barley as well as some other cereals into

beer. When the brewery was launched in 2009, local barley varieties and malthouses had disappeared from the region. Since the 1980s, malt had been imported from abroad. Farmers started to grow old barley varieties again, and in 2017, a new local malthouse was created, capable of handling small batches adapted to the value chain production scale. The farmers deliver the grains directly to the malthouse, where they are malted and transported to the brewery. The UC beer is sold directly at the brewery, on open markets and in nearby shops. Hops are not specifically UC varieties and come from a nearby farm. All actors are certified organic or 'Nature et Progrès', which is stricter. The brewery processes approximately 12 tons of grain per year (Table 4.1). Three businesses took part in the interviews: one farm, the malthouse and the brewery (Figure 4.2).

Flour SC in Orkney, Scotland, processes an old local barley landrace variety (Bere barley) into flour, while part of the grain is sold to make whisky (Mahon, et al., 2016). Bere barley was almost extinct on the Orkney Islands in 2002, and has been restored to 73 hectares by 2020. Since 2023, the value chain has grown Bere barley over 52 hectares, of which 18 tons are ground in the mill (Table 4.1), and the rest is sold for malting. The chain is managed by the local community through a heritage trust, a non-profit organization that contracts one farmer and several landowners to produce grains and run the mill (Martin et al., 2023). The Bere seeds belong to the Trust. The farmer grows, harvests, dries, sorts and delivers the 18 tons of grain to the mill, the rest is sold to a malthouse on the mainland (no more malthouses are present in Orkney) before part of it is resold to a local distillery. We study the chain through its two main actors: the farm and the mill. Finished products are sold directly at the mill shop, online via a webshop, to wholesalers mostly in Orkney, to restaurants and food shops and in lesser proportion, shipped to the rest of the United Kingdom.

Beer NL, in Gelderland, the Netherlands, comprises a local brewery launched in 2013 and the five local farm(group)s it works with. One group of farmers is supported by a foundation, i.e., a non-profit organization, that contracts the farms to grow local grains, provides them with seeds and also owns 20 hectares of land. Farmers grow several old varieties of cereals (e.g., Aalter Troshaver, Grijs Brabants Zandboekweit, Veluws Kruiprogge) for local bakeries and the local brewery. We focus on the beer value chain. The brewer sends the grains for malting to a malthouse in Antwerp (Belgium), the closest location that can malt small batches, before brewing. A project to recreate a local

malthouse is ongoing. We study the value chain through its main actors: one farmer and the brewery. The beer is sold directly at the brewery, through a web shop and other local selling points

Table 4.1 Description of the three UC value chain case studies.

	Beer FR	Flour SC	Beer NL
Cultivated area per year (ha/year)	6 ha among 2 farms	52 ha (16 ha owned, 34 ha rented)	15 ha among multiple farmers
Cereals processed (tonnes/year)	Malted: 10 to 12; crude: 2	18 (the rest is sold for malting)	30
Finished product per kg of grain	4.4 liters of beer	1.0 kg of flour	4.0 liters of beer
# Full-time employees per business surveyed	Farm: 1 Malthouse: 2 Brewery: 3 (and one part-time trainee)	Farm: 6 (and 2 part-time employees) Mill: 1.5 (and 3 interns in summer)	Farm: 1 Brewery: 5 (and several students employed for some hours)

Challenges and functions

To understand the potential challenges faced by the value chain actors, we asked the actors the open question: "What are your challenges for running this business and the value chain in general?". The functions of the UC value chains were assessed by asking an open question about the goals of the actors: "What are your goals for your business and for the value chain as a whole?". See Supplementary Material 4.1 for the full list of interview questions related to the UC value chains' context.

4.2.5 Operationalization of the assessment of resilience attributes

For each of the four ABCD resilience attributes, indicators are shown in Table 4.2. We adapt the indicators proposed by Meuwissen et al. (2022) and Prat-Benhamou et al. (2025) to the context of our cases, i.e. UC production and processing, and remove those that are not relevant. The list contains 16 indicators that are similar for farmers and processors, plus one additional one for farmers only. Each indicator is assessed through a number of sub-indicators (49 for farmers and 38 for processors), which in turn are assessed through a number of statements (68 for farmers, 49 for processors) graded on a 5-point Likert scale ranging from totally disagree (1) to totally agree (5). For some statements, factual indicators are also retrieved to numerically illustrate the scores of the statements. For instance, the local setting of a value chain is illustrated by the distance in kilometers between the businesses. These factual indicators (21 for farmers and 17 for

processors) support the interpretation of the respective statements. Factual indicators are simple indicators that can be quickly filled in during the interview without requiring long calculations or document checks. The hypotheses related to each statement are listed in Supplementary Materials 4.2.

Table 4.2 Resilience attributes (4), indicators (17 for farmers, noted ***(F)*** for farmers only, and 16 for processors, noted ***(P)*** for processors only), sub-indicators (49 for farmers and 38 for processors), statements (68 for farmers and 49 for processors), factual indicators (16 for farmers and 16 for processors) and underlying sources.

Attributes	Indicators	Sub-indicators	Statements	Factual indicators	Source[1]
Agency					
	1. Exposure to disturbance	1.1. Level of experience with shocks (e.g., weather, family, health)	F, P: You have experienced and overcome several shocks over the years, which makes you more confident in handling future ones.		M
	2. Organizational feedback	2.1. Traceability of the inputs	F, P: You know well where the raw products come from and where the final products are sold.		PB, O
		2.2. Full transparency of the process up to finished products	F, P: You can explain with full transparency the whole process from raw products to finished products.		
		2.3. Level of trust in the other VC actors	F, P: You fully trust the value chain actors involved in the processing of your products.		
		2.4. Level of trust in the institutions (e.g., NGO, syndicates) you belong to	F, P: You fully trust the institutions you belong to (NGOs, syndicates...).		
		2.5. Level of usefulness of the institutions you belong to	F, P: The institutions you belong to are very useful (e.g., information, connections, etc.).		
	3. Production coupled with local and natural capital	3.1. Level of care about soil fertility, water resources	F, P: You care about and maintain as much as possible natural resources (such as soil fertility, pollinators, or water resources).		M
		3.2. Level of care about maintaining and enhancing nature	F: You strive to maintain and enhance nature (e.g. maintain plant cover). F: You provide habitat for wildlife and align production with local ecological parameters.		
		3.3. Level of integration of the farm production in the local territory	F, P: You reused or exchanged by-products with neighbors.	F, P: Circularity (reuse or recycling)	
	4. Legislation coupled with local and natural capital	4.1. Level of alignment of the norms, legislation and regulatory frameworks with the local conditions.	F, P: Norms, legislation and regulatory frameworks are well adapted to the local conditions.		M, PB

Attributes	Indicators	Sub-indicators	Statements	Factual indicators	Source[1]
Agency					
	5. Autonomy	5.1. Level of reliance on external inputs (e.g., artificial fertilizer, seeds from non-local seed companies, water from the network, energy from the network, pesticide use)	F: You do not rely on seed supply coming from non-local seed companies. F, P: You are little reliant on energy (i.e., auto-production and self-consumption of energy). F: You do not need pesticides as external inputs for your farm. F: You do not need artificial fertilizers as external inputs for your farm. F: You do not need water coming from the network for your farm.	F: % seed saving	M, PB
		5.2. Level of on-farm processing or through local short chains	F, P: You process the production through short local value chains (or directly on-farm).		
		5.3. Level of production sold independently from global markets	F, P: You sell the production independently from the global markets.	P: % local selling	
		5.4. level of reliance of the workers' wages on subsidies	F,P: Your income and your workers' wages do not depend on subsidies.	F: % subsidies/total farm income P: Presence of subsidies)	
	6. Honored legacy	6.1. Maintenance of cultural heritage, such as old varieties and their practices	F: You use old varieties and adapted cultivation practices for their conservation.		M, PB
		6.2. incorporation of traditional cultivation techniques with modern knowledge.	F, P: You combine traditional cultivation knowledge and modern techniques.		
Buffering					
	7. Plurality of options to finance investments	7.1. Level of reliance on loans	F, P: You have enough cash flow when you need to invest in new equipment.		PB, O
		7.2. Level of choice when making an investment	F, P: If you need to make a new loan for new equipment or a machine, you have the choice between a set of banks and contracts.	F: % loan/total assets P: Presence of loans	

Attributes	Indicators	Sub-indicators	Statements	Factual indicators	Source[1]
Buffering					
	8. Level of reliance on resources, level of safe access, OR plurality of options to access resources	8.1. Low need, safe access, and plurality of options to have land	F: Your land is large enough for the farm's needs, and secured, if necessary, you would find realistic options to find more land.		M, PB, O
		8.2. Low need, safe access, and plurality of options to have water	F, P: You do not rely much on water input and /or have secured and/or diversified water sources (e.g., water tank, enough rain, spring on-farm, access to network ensured even in periods of drought).	F, P: Water cost per year	
		8.3. Low need, safe access and plurality of options to have seeds	F: You have safe and diverse options to always have enough seeds (seed saving, exchanges, purchase from companies, etc.).	F: Seeds cost per year	
		8.4. Low need, safe access and plurality of options to have adapted machinery	F, P: You can easily find the adapted machinery and equipment for producing and processing your crops (price, distance, possibility to repair yourself).		
		8.5. Low need, safe access and plurality of options to have fertilizers	F: You do not need much and/or can get your fertilizers from different secure sources.	F: Fertilizers cost per year	
		8.6. Low need, safe access and plurality of options to have pesticides	F: You do not need much and/or can get your pesticides from different secure sources.	F: Pesticides cost per year	
		8.7. Low need, safe access and plurality of options to have energy sources	F, P: You do not rely much on energy input and/or have secured and diversified energy sources.	F, P: Energy cost per year	
	9. Human capital	9.1. Support for social events in farming communities	F, P: There are enough social events in the farming community.		M, PB
		9.2. Programs for the preservation of the local knowledge	F, P: There are enough initiatives for the preservation of the local knowledge.		
		9.3. Possibility to learn skills from predecessors or colleagues	F, P: You have/had the opportunity to learn from colleagues or predecessors.		
		9.4. Level of reflectivity	F, P: You have a good vision of the farm/business system as a whole (e.g., accounting, fields, processing part, market, etc.); F, P: You have good knowledge about the state of the agroecosystem.		

Attributes	Indicators	Sub-indicators	Statements	Factual indicators	Source[1]
Buffering					
	10. Spatial and temporal modularity	10.1. Level of land diversity on the farm and across the landscape	F: You have different ecosystems, such as forests and meadows on your farm or around it.		M, PB, O
		10.2. Level of diversity in crop rotations	F: You have long and diversified rotations.		
		10.3. Redundancy of labour	F, P: When a worker is missing, you feel at risk because his/her tasks cannot easily be taken over by another worker.[3]		
		10.4. Redundancy of production in space (multiple field locations)	F: You have different locations of fields, which ensure that not everything is impacted by a weather event.		
		10.5. Redundancy of production in time (different batch processed)	F, P: You process the crops on a daily/weekly basis, which results in a small impact in case of an issue with one batch.		
	11. Work and life quality	11.1. Level of satisfaction with workload	F, P: You are satisfied with the workload of your job.		M, PB, O
		11.2. Level of satisfaction with motivation, meaningfulness, and self-realization at work	F, P: You are satisfied with the level of meaningfulness, motivation, and self-realization of the work.		
		11.3. Level of shared learning	F, P: You are efficiently supported by advisory services such as local NGOs to receive technical advice or to implement a collaborative project with your colleagues. F, P: You collaborate with universities or research centers every time you have the opportunity. F, P: There is enough cooperation and knowledge sharing between professionals (farmers and other value chain actors).		

Attributes	Indicators	Sub-indicators	Statements	Factual indicators	Source[1]
Connectivity					
	12. Local inter-connectivity/ Social self-organization	12.1. Level of independence from external markets	F, P: You rely on local resources rather than on large and distant input suppliers.		M, PB
		12.2. Level of self-organization between farmers and other local actors	F, P: There is a close relationship between you and the consumers.	P: % direct selling P: Selling price	
			F, P: You share material and/or by-products with other colleagues.		
			F, P: You can easily reach out to policymakers.		
			F, P: You are often in touch with the other value chain actors (in person, by phone, through chat groups).	F, P: Distances processors-farmers (km)	
			F, P: You collaborate closely with your colleagues and other partners of the value chain.	F, P: Price paid by processors to farmers	
			F, P: In case of an issue, you can rely on your professional network to find a solution together.		
			F, P: Your professional network is organized into formal associations or cooperatives.		
		12.3. Level of access to information through value chain actors	F, P: You can easily get the information you need through the other value chain actors.		
	13. Infrastructures of the living area	13.1. Level of development of infrastructures supporting rural life nearby	F, P: Rural life is supported by enough facilities in the nearby area (e.g., school, hospital, businesses in the town).	F, P: Distances to high school & hospital (km)	M, PB
		13.2. Level of connection of the area to the rest of the region	F, P: Internet and phone signals are sufficient in your area.		
			F, P: There are public transport facilities nearby (e.g., bus or train).		

Attributes	Indicators	Sub-indicators	Statements	Factual indicators	Source[1]
Connectivity					
	14. Social support	14.1. Level of support from the community	F, P: You are integrated into and supported by the local community.	F, P: # permanent jobs created locally	M, O
		14.2. Level of involvement in community life	F, P: You take part in a local cooperative, local association and/or NGO.		
Diversity					
	15. Agro-biodiversity	15.1. Level of agro-biodiversity maintained on-farm	F: You plant multiple crops and multiple varieties per crop.	F: # varieties F: # species	M
			F: You have access to the necessary equipment to handle various crop production.		
			F: You favor varieties with large genetic diversity rather than highly selected ones or hybrids.		
	16. Upstream value chain diversity	16.1. Level of diversity of suppliers and independence from suppliers	F, P: You are free to choose your suppliers and can easily switch if you want to.		M, PB
	17. Downstream value chain diversity	17.2. Level of diversity of income sources and markets	F: You ensure a diversity of activities for your business.		
			F, P: You ensure a diversity of selling points and customers.	P: # selling channels	
		17.3. Level of legal obligations or market monopoly that prevents switching buyers	F, P: You are free to choose your buyers and can easily switch if you want to.		

[1] Meuwissen et al. (2022) (M), Prat-Benhamou et al. (2025) (PB), and own addition (O).

[2] Score reversed for this statement.

4.2.6 Operationalization of the assessment of resilience capacities

We assess resilience capacities through 12 standardized resilience capacity statements (four per capacity) developed by Slijper et al. (2020). Respondents are asked to score statements on a 7-point Likert scale from totally disagree (1) to totally agree (7), with (4) being neutral. Resilience capacity statements are listed in Supplementary Material 4.3. The answers to the different statements informed the interviews allowing elaboration on the resilience capacities.

4.2.7 Data analysis and interpretation

Data are analyzed in a descriptive manner. To assess resilience scores of each attribute, we first inverted the score of the negative statement (sub-indicator 4.3 in Table 4.2) to get positive statements only. Second, average scores are computed per attribute and per individual, comparable to Prat-Benhamou et al. (2025). Third, radar charts are created for each case study and for farmers and processors separately.

To assess the scores of the resilience capacities, we first inverted the scores of the negative statements (statements 2, 8 and 10 in Supplementary Material 4.3). Second, average scores are computed per capacity and presented per case study and for farmers and processors separately.

For both the resilience attributes and resilience capacities, we explain our results by first looking at commonalities between the three case studies, and second by analyzing the main findings case by case.

4.3 Results

4.3.1 Challenges and functions

The actors of *Beer FR* all face the same challenges: they have to keep prices low enough so that end products remain affordable for local customers who often have limited buying power in rural areas (see Supplementary Material 4.4 for the table on challenges). In addition, they are all at the mercy of uncertain climatic events and production variations in quality and volume. The farmers express that creating UC value chains is hindered by skepticism from bankers and technical advisors about the ability of unconventional business models to make it through, and lobbying by the large farmers' syndicate. For the

processors, costs (e.g., energy) and inspections (e.g., regarding equipment and facility safety regulations) are challenging, as well as finding lenders willing to support the startup phase. The actors of *Flour SC* report fewer challenges. With strong support from the Heritage Trust association and the municipality council, the Bere barley variety benefits from strong recognition among the local population. Still, the farmer points to the harsh weather as a constraint factor, and the mill indicates having a limited workforce. In *Beer NL*, both the farmer and the brewer mention challenges related to the lack of local processors (malthouse for brewers, local channels for the farmers), too many inspections, and the fact that small producers and processors need to comply with industrial-scale regulations. For the farmer, restoring soil health and accessing adapted machines is also difficult. Additionally, the society-agriculture disconnect makes it challenging to explain to consumers how their work and products differ from those produced at industrial scale. For the brewers, the lack of professional support in the microbrewery sector, the high costs (energy, workers, rent) and the competition in the beer sector are highlighted.

Regarding the functions, all value chain actors in the case studies want to have a positive environmental impact, as illustrated by F^{4}, F^{5}, F^{8}, F^{9}, F^{10}, F^{13}, P^{4}, P^{14} in Table 4.3. For example, in *Beer FR* and *Beer NL*, they call on local businesses to minimize their carbon footprint (P4, P14), and farmers in the three case studies adopt organic or environmentally friendly cultivation practices with complex crops (F^{5}, F^{8}, F^{10}, F^{13}). Actors of the three case studies are largely motivated by public goods-related purposes, e.g., preservation of the environment and the local economy (F^{2}, F^{11}, F^{12}, P^{8}, P^{10}, P^{13}). Actors across the three cases also share common purposes. For example, processors want to create and sell their products locally, i.e., from local ingredients and locally built equipment, and sold locally without intermediaries (P^{3}, P^{5}, P^{10}, P^{13}, P^{14}). Moreover, actors of the same value chain share similar purposes: in *Beer FR*, all actors want to ensure a decent livelihood for each actor in the chain (F^{3}, P^{2}, P^{3}, P^{5}) and make the territory lively again, by recreating activities in deserted, rural places (F^{2}, P^{7}, P^{8}). In *Flour SC,* all actors want to preserve the Bere barley as cultural heritage (F^{8}, P^{9}). There were also differences across cases. For *Flour SC*, the farmer wishes to keep growing the farm (F^{6}, F^{7}), while farmers from *Beer FR* and *Beer NL* do not (F^{3}, F^{9}). Instead, they insist on the importance of finding a model of agriculture that synergizes with nature (F^{3}, F^{9}), and want to showcase to society that other types of agriculture are possible (F^{3}, F^{9}).

Table 4.3 Functions of each UC value chain reported by farmers (F) and processors (P).

Farmers	Processors
Beer (FR)	
F[1]: Restore the nobility of the profession. F[2]: Revive the local economy by supporting rural businesses to stop the decline of the countryside. F[3]: Earn a decent living and show that small farms can be viable without expansion. F[4]: Reintroduce diversity in crops grown and self-processed products. F[5]: Produce quality food products, e.g., organic.	P[1]: Contribute to the creation of a farm product. P[2]: Earn a living for two people without expanding. P[3]: Work directly with farmers and brewers, without intermediaries, to adapt to their needs. P[4]: Produce high-quality, environmentally friendly food products. P[5]: Keep the production and supply local, i.e., direct selling with involvement in markets and fairs. P[6]: Show others that it is possible to start and run a local business. P[7]: Revitalize village life by initiating a new local open market, attracting tourists and enhancing village prestige. P[8]: Boost the local economy by creating jobs, and thus, bringing households consuming in the village and children to the village school, and by calling on local businesses, e.g., farmers, carriers, equipment makers, rather than distant companies.
Flour (SC)	
F[6]: Continue farm progress and expansion. F[7]: Ensure farm succession to future generations. F[8]: Keep on producing Bere barley and improve farming practices, such as trying green manure.	P[9]: Preserve the cultural heritage of Bere barley by promoting Bere as a local grain and food and maintain the old water mill as a working business, which requires some value chain profits to support preservation efforts. P[10]: Boost the local economy by diversifying income sources for farmers, offering mill tours and selling Bere products in local businesses (e.g., bakeries, restaurants), attracting tourists. P[11]: Enhance community life on the island by participating in local fairs, open days and public shows.
Beer (NL)	
F[9]: Demonstrate that agriculture can support biodiversity and beauty, e.g., field excursions, bakery workshops and brewery tours trigger interest in alternative farming systems, raise awareness and attract tourists. F[10]: Promote biodiversity and diverse species and varieties. F[11]: Boost social cohesion between farmers with meetings and a WhatsApp group. F[12]: Produce food locally, through local channels. F[13]**:** Increase crop diversity e.g., with rotations including sunflower, flax and radish.	P[12]: Enable people to consume locally produced food and connect with the land. P[13]: Make craft-quality beers using local ingredients and equipment, despite higher costs. P[14]: Sell beers locally without long travel. P[15]: Adapt to small farmers' needs. P[16]: Increase social cohesion at the brewery and the connection between society and farmers.

4.3.2 Resilience attributes

In this section, we describe the resilience attributes of the sampled UC value chains. Figure 4.3 summarizes our findings in radar charts with the main indicators for each

ABCD attribute. In addition, factual indicators covered by each attribute are displayed in Table 4.4.

Agency:

Both farmers and processors of the three case studies consider full transparency, traceability and trust between them important (as illustrated by the second indicator in Figure 4.3). Little external needs are enabled by implementing different strategies, such as circularity. For example, in *Flour SC*, the husks are burnt to dry grains before grinding, which avoids large energy needs. Cow manure is used to fertilize crops on-farm and straw and malt waste are used as feed for cattle. Barrels and glassware are washed and reused instead of using disposable ones (Figure 4.3, Indicator 3, and illustrated in Table 4.4, with (3) Circularity). *Agency* is also expressed by the autonomy of businesses with little external inputs, both for farmers and processors (see Indicator 5 in Figure 4.3), minimizing the impact of input market price changes. As UCs are low-input crops managed through seed saving (Table 4.4, Factual indicator (5) Percentage of seed saving), they eventually also promote farm autonomy (Figure 4.3, Indicator 5). Local selling also illustrates *Agency* as a strategy of the value chains to stabilize the market prices and increase autonomy. In addition, organizing the chain locally limits transportation energy needs (Figure 4.3, Indicator 5). In all cases, a large proportion of products is sold in direct selling, and the rest locally, with few intermediaries (Table 4.4, Factual indicator (5) Percentage of direct and local selling). All farmers and processors are also financially autonomous (Figure 4.3, Indicator 5). In terms of financial support, only the brewers in *Beer FR* benefit from the social security tax exemption for low-salary employees (for hiring one trainee), and the mill in *Flour SC* receives a grant from the Council (enabling the hiring of three part-time interns in the summer) (Table 4.4, Factual indicator (5) Reliance on subsidies). Still, some *Agency* aspects scored lower, such as the level of trust in the institutions for *Beer FR* and *Beer NL*, as well as legislation, seen by several actors as unsuitable to promote the local and natural capital. They claim legislation is often designed with large businesses in mind, hampering smaller companies aiming to develop their local economy or implement more circularity strategies (Figure 4.3, Indicator 2).

Buffering:

Buffers appear to be more limited than the three other resilience attributes (Figure 4.3). For instance, in terms of financial buffers, although running autonomously, some processors reported having limited cash flow (Figure 4.3, Indicator 7). In *Beer FR*, processors had multiple options to invest, while the brewery in *Beer NL* did not, and the mill in *Flour SC* would rather apply for public funds than obtain a bank loan if an investment had to be made. In the same vein, the human capital is competent, i.e. actors explained having a holistic vision of the business and chain and a workforce that is polyvalent (Figure 4.3, Indicator 9) but often limited in quantity due to the small size of the businesses (Figure 4.3, Indicator 10). Processors in *Flour SC* and *Beer NL* see the absence of even a single worker as disruptive. In *Beer FR*, the brewers have developed the polyvalence of each worker to address this issue. Still, in terms of human capital, some actors in *Beer FR* and *Beer NL* consider the number of initiatives to preserve local knowledge insufficient, and the number of social events organized in the farming community still too sparse, while these could strengthen the human capital of the value chains (Figure 4.3, Indicator 9). Regarding quality of work and life, as one aspect of strengthening buffers, answers diverged (Figure 4.3, Indicator 11). On the one hand, all actors are fully satisfied with the level of self-realization and meaningfulness of their job, yet on the other hand, the brewers in *Beer FR* and *Beer NL* find the workload too high. In addition, some actors consider receiving little (*Beer FR*) or inefficient (*Beer NL*) support from advisory services. They also indicate a lack of opportunities to learn from colleagues or predecessors. In *Beer NL*, brewers feel isolated and lonely in improving their knowledge and experience as craft brewers. In general, instead of ensuring large buffers (e.g., cash flow, workforce, or stocks), actors tend to have limited needs for buffers by relying less on external inputs (see Table 4.4, Factual indicator (8) Use of seeds, fertilizers, pesticides, water, energy on farms), or by relying on multiple sources (e.g., several energy sources) (Figure 4.3, Indicator 8). As an example of energy saving, in *Flour SC*, the mill uses solely a water wheel as its power source (as observed in Table 4.4, Factual indicator (8) Water and energy used by processors). Despite strategies to increase autonomy, some actors still rely on external energy sources (e.g. in *Flour SC*, the farm largely relies on fuel, and processors in *Beer FR* and *Beer NL* on electricity) (Table 4.4, (8) Water and energy used by processors). To address their dependence on electricity, the brewers in *Beer FR* diversify their energy sources with wood and gas. Safe access to raw materials is also secured by

strong, long-term reciprocal partnerships (see *Connectivity*) rather than distant suppliers. Yet, access to some resources is seen as difficult, such as adapted machinery for the farmer in *Beer NL* (Figure 4.3, Indicator 8). Regarding spatial and temporal modularity, farmers have different field locations, ecosystem types, and diversified long rotations (see *Diversity*), which help to buffer potential losses, and processors work with batches, although this does not always prevent issues (Figure 4.3, Indicator 10).

Connectivity:

The value chain actors report extensive interconnectivity and self-organization with close relationships between each other and their customers (Figure 4.3, Indicator 12). Both farmers and processors say they are often in touch, collaborate closely, and are able to get information through colleagues or solve an issue together. This collaboration is also concretized by setting prices through consensus rather than top-down decisions (as substantiated in Table 4.4, (12) Selling price paid to farmers). In *Flour SC*, the farmer lists his production costs each year and is paid accordingly by the Trust. In *Beer FR* and *Beer NL*, the farmers and the brewers also agree on a grain price, allowing both to make a profit while keeping the beer affordable to customers. For example, in *Beer FR*, a 33cl bottle of beer costs €2.00, including €0.48 of tax and €0.10 refund if customers bring the bottle back for reuse (as reported in Table 4.4, (12) Selling price paid to customers). Due to their autonomy, largely disconnected from wider markets, this price was kept relatively fixed over the years, enabling actors to plan and secure their business. For *Beer NL*, the brewer is willing to pay high prices for barley grains to farmers, in order to brew quality local beers. This solidarity between value chain actors contrasts with mainstream objectives to maximize profits per business. Indeed, in the three case studies, the common objective of all actors is to create an affordable food product from local crops. For this, they need to ensure that every actor stays in business. The strong connectivity between actors is also evident from their close proximity (32 km for *Beer FR*, 10 km for *Flour SC*, and 45 km for *Beer NL*, including all farmers; Table 4.4, (12) Distance between actors). The social connectivity between actors and their community is described as well developed (Figure 4.3, Indicators 12 and 14). The businesses of the value chains create permanent jobs and offer additional crop production, thus an income source, to farmers (see Table 4.4, (14) Number of jobs created in the region). They also support other local businesses by calling on their services (e.g., construction, equipment, delivery, repairs, restaurants) and by

offering by-products (e.g., malt residuals) to local farms. Additionally, all processors point out their attractiveness to tourists, contributing to the prestige of their village or town. For *Beer FR*, this involvement in the local economy is perceived as substantial because the creation of economic activities in the countryside counters the shrinking rural communities. Indeed, the actors explained that jobs created through the activities of the value chains bring additional households to the village, consuming locally and sending more children to the local schools, which were previously at risk of closure. The presence of these households in the area restrains the disappearance of social services, including schools and public transport (Figure 4.3, Indicator 13; Table 4.4, (13) Distances to hospital and high school). Finally, social connectivity also appears in the involvement of value chain actors in local fairs, open markets and other social events (Figure 4.3, Indicator 14). Still, some connectivity aspects were unsatisfactory. The farmers in all three case studies state that they are not sufficiently organized into formal associations or cooperatives (Figure 4.3, Indicator 12). Instead, they all sell their products individually. Furthermore, for *Beer FR* and *Beer NL*, actors feel that they have few possibilities to reach out to policymakers, including local ones (Figure 4.3, Indicator 12). In addition, the connectivity in the area is perceived as insufficient due to the lack of public transport for *Beer FR* and *Flour SC,* and of local businesses for *Beer NL* (Figure 4.3, Indicator 13).

Diversity:

Agro-biodiversity is considered crucial by farmers (Figure 4.3, Indicator 15). They indicate that they maintain biodiversity through favoring different species, multiple varieties per species and crops with high genetic diversity (Table 4.4, (15) Number of varieties, Number of species). Regarding the *diversity* of suppliers, all actors feel that they can choose or change suppliers (Figure 4.3, Indicator 16). However, the brewer in *Beer FR* explains that partnerships with local farmers are long-term collaborations. For the end part of the chains, a diversity of finished products and selling points is ensured, i.e., at least 25 beers for *Beer FR* and *Beer NL*, and more than eight finished products made of Bere flour in *Flour SC* (Figure 4.3, Indicator 17; Table 4.4, (17) Number of end products, Number of selling points). Yet, some actors cannot switch buyers easily, such as the farmer in *Beer NL*, who has little choice if he wants to sell his different products locally, as the number of local businesses that can process or sell his products is very low. In *Beer FR*, the customers of the malthouse and the brewery are respectively microbreweries and people living in

the nearby rural area. It is not possible to switch to other customers, which implies that they have to adapt to them. The mill in *Flour SC*, working with several local shops and restaurants of the island, and the brewery in *Beer NL*, located in a town, were rather satisfied with the diversity of potential buyers available (Figure 4.3, Indicator 17).

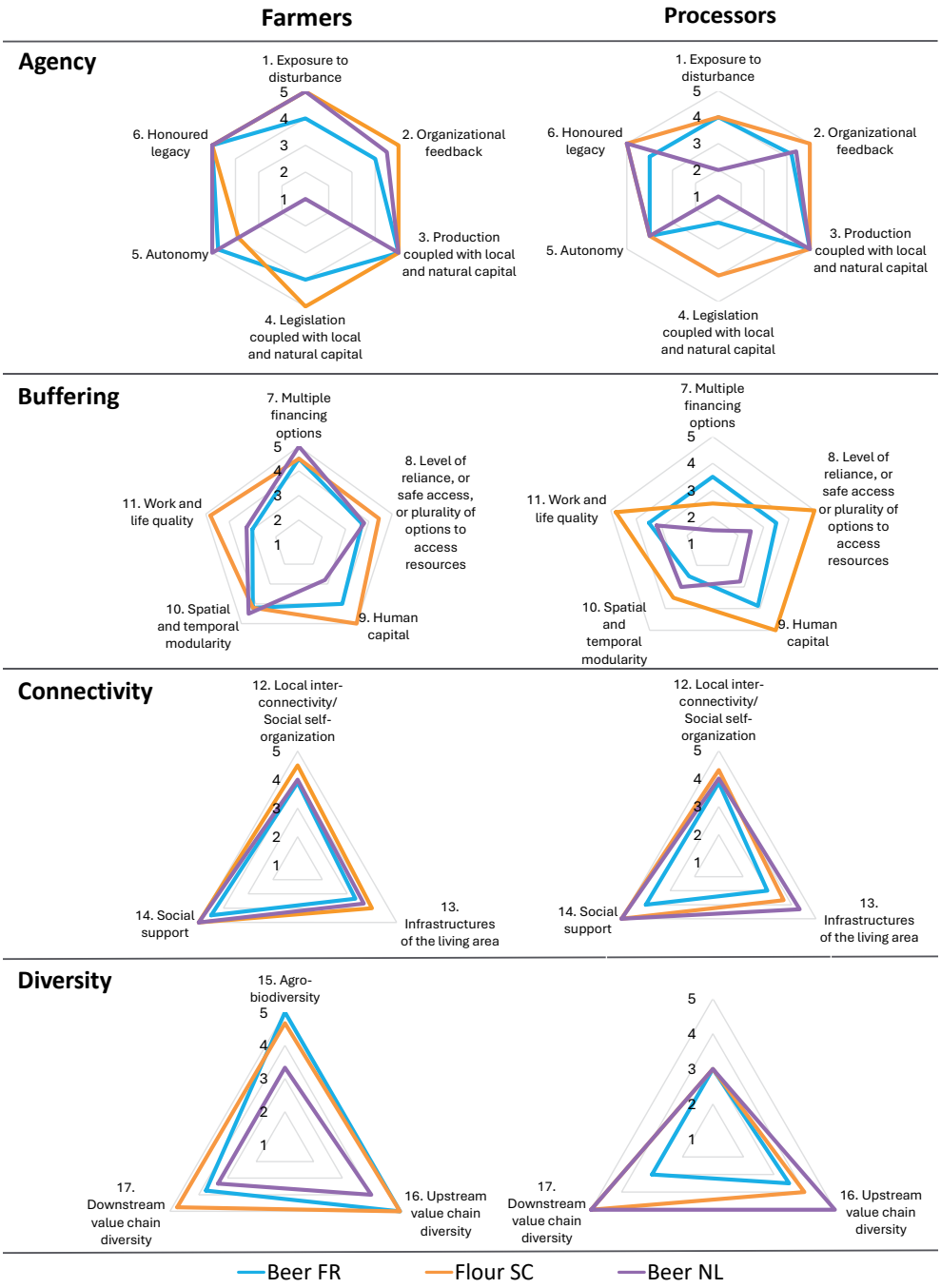


Figure 4.3: Agency, buffering, connectivity and diversity attributes for farmers (left) and processors (right) in three UC value chains. Score 5 (totally agree) refers to the highest level of the resilience attribute, while 1 (totally disagree) refers to the lowest level. Score 3 signifies a neutral position.

Table 4.4 Factual indicators per attribute. Numbers between brackets refer to the numbering of indicators in Table 4.2.

	Beer FR	**Flour SC**	**Beer NL**
Agency			
• Circularity (3)	Straw sold as mulch or insulator for eco-construction; malt residuals sold to pig farms; project to recycle water for irrigation; soaked cereals offered to cow and chicken farms replacing soy meal; yeast and hop composted; alcohol from distillation and hops maceration valorized as liquors, beer jam, beer vinegar; glassware washed and reused.	Straws used for landowners' livestock; small seeds given to calves; manure used as cereal fertilizer; husks used for the fire to dry grains before grinding.	Straws exchanged with manure at local sheep farms; husks given to a cow farm; residues from brewing used in some breads; reusable barrels.
• % seed saving (5)	100%	100%	100%
• % direct sales (5)	50%	22.5%	75 to 80%
• % local selling (5)	100% (within 80 km)	65.8 to 75% (in Orkney)	100% (in Gelderland)
• Reliance on subsidies (5)	Farm: 36% of farm income; malthouse: small regional support; brewery: lowest salaries exempt from social security contribution enabling hiring a trainee	Farm: 3% of farm income; mill: Council grants enabling hiring interns in summer	Farm: no subsidies (hobby); brewery: one subsidy this year for the first time.
Buffering			
• Presence of loans (7)	Farmers: no; malthouse and brewer: NA	Farmers: 5% total assets; mill: no.	Farmer: no; brewer: NA
• Use of seeds, fertilizers, pesticides, water, energy on farms (€/Tonne) (8)	0 (saved on farm), 0 (green manure only), 0 (no pesticides), 0 (no water use), 82 (fuel, solar panels)	0 (saved on-farm), 46 (1/3 from livestock), 0 (no pesticides), 0 (no water use), 226 (fuel, electricity)	0 (saved on farm), Very little manure, organic calcium: NA, 0 (no pesticides), 0 (no water use), NA energy
• Water and energy use by processors (€/Tonne) (8)	Malthouse: 350 (5 to 9 m^3) 350 (electricity) Brewery: 71 (from the river) 1188 (wood, electricity, gas, fuel)	Mill: 0 (no water) 0 (river stream, fire from husks for drying)	Brewery: Negligible water cost 1300 (electricity)
Connectivity			
• Distance between actors (12)	<32 km	<10 km	<45 km (excluding the malthouse)[1]
• Selling price paid to customers (12)	2 €/33cl including 0.48 € tax and 0.10 € deposit per glass bottle	3.90 GBP/kg of flour.	10 €/75cl including 2 € tax.
• Selling price paid to farmers (12)	450 €/Tonne	482 €/Tonne	400 to 600 €/Tonne
• Distance to hospital (13)	15 km	20 mile	10 km
• Distance to high school (13)	15 km	5.5 mile	10 km
• #jobs created in the region (14)	3 FTE (permanent), 1 trainee, one more crop for the farms, one more channel for the malthouse	1.5 FTE (permanent), 3 interns in summer, one more crop for the farms	3 FTE (permanent), 5 part-time (2 FTE), one more crop for the farms
Diversity			
• #varieties (15)	53	13	>10
• #species (15)	>8	>8	>10

	Beer FR	Flour SC	Beer NL
• **#end products (17)**	22 in different volumes	8 flour-based products in various volumes; malting	25 in different volumes
• **#selling points (17)**	3, and occasional fairs	>10	20

[1] The closest malthouse that can malt small batches of grains is 149 km away. A project to create a local one is ongoing.

4.3.3 Resilience capacities

Actors in the sampled UC value chains perceive themselves as relatively resilient (Table 4.5). Self-perceived *robustness* is higher for farmers—and their farms—than for processors. All brewers explain that bouncing back to normal profitability after an issue is possible, but requires intensive efforts. The *robustness* of the chain is boosted by the *agency* attribute. Indeed, circularity, recycling, reusage and the level of experience of workers with shocks reduce the impact of external and sudden changes on the chains. For example, a sudden increase in glass bottle prices did not affect the French brewery much, as they had already implemented bottle washing and reuse. Additionally, high willingness to help each other (good *connectivity*) also contributes to the *robustness* of the chain because an issue faced by one actor will actually be faced by the different value chain actors together. The same is true for *diversity*, which acts as a buffer, for example, when one crop does not perform well in a given year, total production is buffered by other crops that may perform better. Hence, *diversity* also contributes to the robustness of the chain.

Adaptability is perceived as relatively high for all actors (always scores above 5, Table 4.5). Farmers indicate that diversification ensures adaptability. In *Beer FR* and *Beer NL*, processors explain being flexible and able to make decisions fast to adapt to situations, also thanks to the small size of their business and to their close connections to the other local actors and the community (*connectivity*). They explained that, when one value chain actor has an issue, the other actors are willing to adapt and find a solution together rather than switching partners. *Diversity* also increases *adaptability*, as the plurality of crops, finished products or selling points gives flexibility to adjust production, processing and selling according to circumstances.

Transformability is relatively good (scores mostly above 4, Table 4.5) for all actors. The brewer in *Beer FR* explains that big changes cannot happen instantaneously, as cereals are grown and processed over a whole year period. Strong *connectivity* increases the *transformability* capacity. For example, to implement a new business or reorganize the

chain, actors know how to communicate and work together, making larger changes more feasible. However, in *Flour SC*, functioning with the Trust is perceived as an advantage for *robustness*, but also hampers somewhat the *transformability*, as changes need the consensus of all trustees. Based on the relatively high scores obtained for the resilience capacities and for the resilience attributes, we conclude an overall satisfactory level of resilience for the three UC value chain cases.

Table 4.5 Perceived resilience capacities measured on a 7-point Likert scale from 1 (totally disagree) to 7 (totally agree). Red indicates a score below 4, yellow a score of 4 and green a score above 4.

	Robustness	Adaptability	Transformability	Overall[a]
Beer FR				
Farmer	6.00	5.25	3.75	5.00
Processors[b]	3.00	5.125	4.375	4.17
Flour SC				
Farmer	5.75	6.00	6.00	5.92
Processor	5.38	5.75	5.25	5.46
Beer NL				
Farmer	5.88	6.13	6.50	6.17
Processor	4.00	5.75	4.38	4.71

[a] Average of the three capacities.
[b] Average scores of the malter and brewer.

4.4 Discussion

We discuss our results through three cross-cutting aspects. First, we observe context-independent factors that matter for the existence and configuration of UC value chains, as well as what triggered the start of the UC chains. Second, we reflect upon the differences between UC and 'mainstream' value chains. Third, we recap the contributions of UCs in building resilience in UC value chains. We end by reflecting on our methods.

1. *Context-independent factors that triggered the start of the UC value chains and matter for their existence and configuration*

A common factor that may have triggered the start of the UC value chains is the common vision of these actors. Although they come from both outside and inside the farming sector, the value chain actors all share the will to contribute environmentally and

socio-economically to their local area. They are all sensitive to the environmental and socio-economic impacts of our current way of farming and food system, and foresee a similar alternative to it.

A second factor that may trigger UC value chains is a similarly challenging situation for all actors (e.g., isolated in their endeavour, little supported by policies). Facing the same challenging situation seems to have somehow strengthened networks and collaboration. The value chain actors are all "pioneers" because the type of business they run, at this small scale, is rare, little known and understood, and barely—or not at all—taken into account by policies (e.g., malting, craft brewing). As a consequence, several regulations are misaligned or even entirely out of scope, and lenders are sceptical and reluctant.

2. Differences between UC value chains and mainstream chains

The "value chain" concept used in this Chapter was helpful to focus on one product type, such as flour or beer, but it was not well adapted to describe the dense networks in which the businesses we studied are embedded. Indeed, we observe that UC value chains differ substantially from mainstream chains. First, the term "value chain" is generally linked to a just-in-time linear mainstream chain (Chopra & Meindl, 2013), while the resilience of UC chain actors is grounded in complex and intertwined social networks, enabling diverse exchanges and offering possibilities to continuously adapt to each other. Second, some value chain actors clearly expressed their desire to differentiate themselves from the mainstream food processing industry. They do not want to reproduce its patterns within their own business, but try to take an alternative approach. For instance, glass bottles and barrels are washed and reused, while the common trend is to use disposable ones. Third, the value chain actors take each other into account in their price-setting decision-making process. This contrasts with the mainstream objective of maximizing the profit of individual businesses at the possible expense of other actors in the chain. Here, a relationship of solidarity instead of competition connects the actors. Fourth, the shared purpose of being connected to their customers and developing the local economy and social cohesion in their area are different from the mainstream. These findings align with Feenstra (2002)'s findings on the prominent role of partnerships, involvement of the different community members, and commitment to social, economic, and environmental justice principles in sustainable food and agricultural systems.

3. Contribution of UCs in UC value chains

The configuration of UC value chains, which suggests a relatively strong resilience, is not solely the result of using UCs. However, UCs suit and support the specific value chain configuration—local and small-scale—found across our three case studies. First, UCs are often managed through seed saving (as is the case in our three value chains), which supports farmer autonomy rather than depending on external input resources. It contributes to stabilizing prices in the chains, and thus eases tight partnerships and planning between the local partners. Second, because UCs are resown every year, they adapt to the local conditions (Altieri, 1992; Baldermann et al., 2016; Burgess, 1994; Galmés et al., 2011; Karunaratne et al., 2015; Mabhaudhi et al., 2013), which supports the use of low-input (Mahon et al., 2016b) environment-friendly farming practices and the purpose of local actors to have a positive environmental impact in their place. Third, UCs' standardization is limited, which, in contrast to mainstream chains, is not necessarily an issue in the context of these value chains. Processors are willing to adapt to the differences in harvest and are looking for a special local product, not replicating standard products already available on the market. Fourth, UCs are often known to have not been selected to maximize yield, but rather to ensure a certain genetic diversity, enabling them to survive an environmental change. This aspect also aligns with the mindset of the small value chain actors encountered, who do not look for profit maximization, but rather aim at making their value chains run smoothly over time.

4. Reflection on our methods

Although we study only three cases with a limited number of actors and cannot claim representativeness of the diversity of European UC value chains, similarities appear between our three cases. While they are in different countries, we find overlap in terms of goals, challenges and configuration (i.e., local setting, strong connectivity, numerous exchanges, including with the local community). These similarities support the idea that our case studies are useful and insightful examples of UC value chains in Europe. As the value chains studied in this article were launched several years ago, the actors involved have already faced several shocks, such as droughts, crop diseases and the COVID-19 pandemic, and have been confronted with several stressors, such as unfit legislation or limited access to loans that compromise the settlement of their businesses. Therefore, this

Chapter assesses the concrete and practical materialization of resilience rather than looking for representativeness.

With regard to the four resilience attributes proposed by De Steenhuijsen Piters et al. (2022), we found, similar to Eakin et al. (2017), that boundaries between attributes can be porous and certain aspects may overlap across several attributes. For instance, some aspects of *buffers* overlap with those of *agency* as well. Still, the ABCD attribute system enabled us to think as exhaustively as possible about the various aspects at play in building resilience. Especially the combination of statements with factual indicators has been useful. Although statements may be rated more or less strongly according to respondents' perception and way of expression, factual values contribute to a more exact understanding. For example, the factual indicator 'distance between actors' gives concrete evidence of what 'local setting' and 'strong connectivity' mean. None of the factual indicators was found to contradict the ratings.

4.5 Conclusion

In this Chapter, we assessed the resilience of three European underutilized crop (UC) value chains processing cereals through a system's resilience attributes, by first investigating their context (configuration, challenges, functions), second, by reflecting on core resilience attributes, i.e. *agency*, *buffers*, *connectivity* and *diversity*, and third, by reflecting on the chains' perceived resilience capacities. Overall, we conclude that the sampled UC chains often have few *buffers*, such as limited human capital and cash flow, but they manage to compensate this with strong *agency* (e.g., developing circularity, reusage), *connectivity* (developing strong partnerships and solidarity in the chain and the local area) and *diversity* (multiplying crop varieties, species, finished products and partnerships). These characteristics enable UC chain actors to ensure good adaptability, for example, with respect to the specific needs of the different chain partners, and provide the robustness of chains to shocks. We thus conclude that the sampled UC value chains are relatively resilient, not only at the farm level—through using crops with a large genetic diversity—but also at post-farm stages through developing the different attributes of resilience, especially *agency*, *connectivity* and *diversity*.

We compared small-scale case studies to mainstream value chains. We argue that, despite large differences between these value chain models, UC value chains can still give

inspiration to mainstream chain actors to rethink their configuration, not to focus on efficiency, individual margin maximization and just-in-time supply patterns. This could be in terms of revised market power balances, with fair price-setting processes in short food supply chains as also explained by Reina-Usuga et al. (2020). Alternatively, the focus could be on stronger cooperation between actors, also potentially improving risk management in European agricultural systems (Bertolozzi-Caredio et al., 2021).

We highlight that all the processors in the three UC value chain case studies are profitable businesses that operate without relying on subsidies for their survival. At least three of them (i.e., the two breweries and the malthouse) faced large issues in accessing loans to start their businesses as their activities were very little known to lenders. We advise lenders to get more acquainted with existing local food-processing businesses—such as the ones in this study—to make more informed decisions in the future. In addition, in the Netherlands and France, regulations (e.g., regarding food processing, building construction) barely take into account small-scale processors. This often leads to extensive costs, cumbersome administrative procedures, or numerous inspections for these businesses. To boost the development of these business models, policies should more systematically treat their cases separately from industrial-scale food processing business models. Further research on (1) business model analysis of local food processing businesses and (2) the exact impact of regulations on their value chains could guide both lenders and policymakers in adapting to these types of food systems. Financial and policy challenges could then be reduced significantly, which would boost the development of local food systems using local and adaptable crops, i.e., UCs, and eventually support the cultivated biodiversity they maintain.

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Supplementary materials

The supplementary materials with the questionnaire Section 1 (SM4.1), Section 2 (SM4.2), and Section 3 (SM4.3) are available here:

https://doi.org/10.5281/zenodo.18730495

Supplementary Material 4.4 Table on challenges reported by farmers (left) and processors (right) for each UC value chain. Results are summarized in Section 4.3.1 of the chapter.

	Farmers	Processors
Beer FR	• Local demand for quality food exceeds farm capacity. • Climate change impacts quality and volumes. • Reduced consumer buying power. • Producers are influenced by systemic beliefs that the existing food system is the only viable one. • Advocacy from FNSEA[1] for large-scale producers' interests.	• Vanished barley cultivation and malthouses in the region forced brewers to purchase foreign malt until local barley cultivation revived and a local malthouse was recreated. • Starting a micro-brewery or malthouse is difficult due to lender scepticism regarding these little-known business types. • Climate variability impacting crop quality and volume for processors. • High water needs for malting. • Rising energy costs while end-products have to remain affordable for locals. • Costly industrial-level controls (e.g. safety, electricity). • Uncertain customer demand for beer tied to social trends.
Flour SC	• Harsh weather conditions require resilient crops. • Absence of local abattoirs forcing off-island cattle transport (triggering plans for a new local facility).	• The Covid pandemic required a grant for recovering. • A crop disease (e.g. fungal Ergot) impeded fulfilling the contract with the malthouse for a season. • A limited workforce slows down key projects like marketing and local distillery creation.
Beer NL	• Restoring soil health takes years due to high phosphate and nitrogen levels. • Restrictive national policies hinder unconventional farming practices. • Cereal small farms face burdensome regulations and paperwork. • Limited access to affordable machinery (i.e. too large-scale or rare). • Scarce local processing businesses obstructing sustainable cereal cultivation and value chain development. • Climate-adapted crop varieties are difficult to access. • A cultural disconnect of society reduces appreciation for traditional agriculture and foods.	• Lack of bakeries may lead to the use of cereals as cattle feed. • Small breweries face substantial labor, rent and energy costs. • Competition with large players like Heineken. • Lack of professional support. • Absence of local small-scale malthouses. • Regulatory burdens, e.g. with regard to costly compliance with noise and fume rules, constrain processors' profitability. • Regulations originally designed for large industries are applied to small-scale processors, while they are unsuitable for small-scale operations. For instance, regulations prevent them from operating downtown - while they rely on customers' proximity and appreciation.

[1] National Federation of Agricultural Holders' Unions.


5

Chapter 5
From Seeds to Sales and Grains to Glass: Scaling Pathways for Underutilized Crops in the Netherlands

This chapter is submitted for publication as:

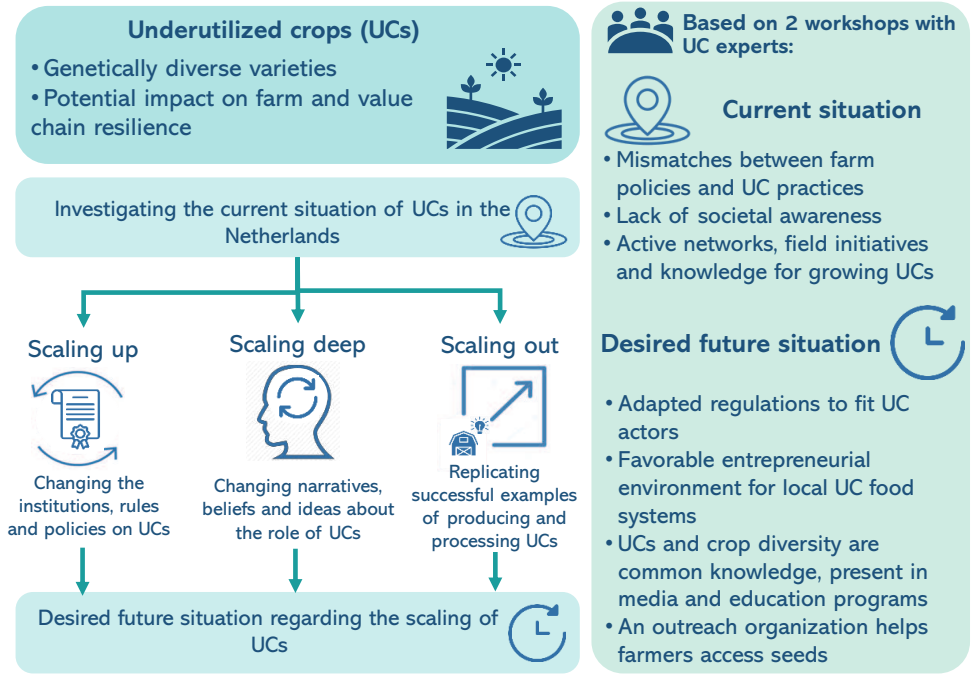
Nguyen Brémaud, M-F.E., de Mey, Y. & Meuwissen, M.P.M. From Seeds to Sales and Grains to Glass: Scaling Pathways for Underutilized Crops in the Netherlands

Abstract

Underutilized crops (UCs), as genetically diverse varieties, may increase the farm and value chain resilience. However, former UC scaling paths have rather led to new monocultures with negative socio-economic and environmental impacts. The literature on scaling UCs mostly reports on global South contexts and on cases of UC expansion rather than investigating desirable scaling ex-ante. We investigated the current situation and a desirable future situation after scaling for UCs in the Netherlands. Through two workshops with UC experts, we explored three pathways of UC scaling: policies impacting UCs (scaling up), knowledge and beliefs regarding UCs (scaling deep), and initiatives for producing UCs (scaling out). Results show mismatches between farm and food policies and UC production and processing, and a lack of societal awareness. However, active networks and field initiatives demonstrate that knowledge for producing and processing UCs still exists. The desired future situation for UCs unveils three aspects. First, regulations are specifically adapted to fit UC farms and processors, creating a favorable entrepreneurial environment for local food systems using UCs to develop alongside the global one. Second, UCs become societal knowledge: society understands the differences between open-pollinated varieties and F1-hybrids, the media spotlight UCs, and crop diversity and seed saving are taught at multiple educational levels. Third, an outreach organization helps farmers learn about seed saving, and farmers access seeds through shared facilities, paying with seeds they have produced. Shortly, this future situation shows that UCs can only develop if 'a space' in mindsets and policies is created for them.

Keywords: Pathways, crop diversity, scaling, forgotten crops, workshops, local actors

Graphical abstract



5.1 Introduction

Our globalized food system is facing a decline in cultivated biodiversity (Jones et al., 2021; Negri, 2005). More specifically, the decline of crop genetic diversity in current varieties makes agroecosystems more vulnerable to biophysical changes such as climatic events or diseases (Camacho-Henriquez et al., 2016; Khoury et al., 2022). Potential consequences are a decrease in farm and farming systems' resilience (FAO, 2010; Khoury et al., 2022) and in food and nutrition security (André et al., 2024; Vijayalakshmi et al., 2023). Underutilized crops (UCs) are genetically diverse varieties that were anciently used but later on abandoned and currently have limited use in regions where they are locally adapted (FAO, 2018a; Williams & Haq, 2002). Although underutilized, UCs represent the broad majority of all known crops (Camacho-Henriquez et al., 2016). Reintroducing them will return biodiversity to farms, ensure food security (Bela, et al., 2006; Fenzi, et al., 2022) and offer customers a greater food diversity (Berni et al., 2019; Pinto et al., 2023a). Yet, scaling underutilized species has not always led to positive outcomes. For instance, scaling quinoa and teff led to a single "new major crop" that failed to deliver on their promises, especially in terms of increasing agro-biodiversity and supporting local food systems (Andreotti et al., 2022).

UCs are genetically rich varieties and therefore are adaptable and heterogeneous (Berni et al., 2019; Karanikolas, et al., 2018; Negri, 2005). They can be grown with limited or no external inputs, and can be reproduced by farmers (Altieri & Merrick, 1987; Brémaud, et al., 2025c; Sardaro et al., 2016). Typical characteristics are their good adaptation to diseases, pests (Newton et al., 2010; Sardaro, et al., 2017), and climate change (Petrović & Dimitrijević, 2012; Riu-Bosoms, et al., 2014; Thanopoulos, et al., 2021). They also enable farmers to be autonomous with respect to the seed supply (Brémaud, et al., 2025c; Fenzi & Couix, 2022), and they can reduce dependence on production means such as fertilizers, pesticides or irrigation water (Attene, et al., 1996; Brémaud, et al., 2025b; Sardaro et al., 2016). UCs also benefit agrobiodiversity and environmental sustainability (Camacho-Henriquez et al., 2016; Galmés, et al., 2011). Their origins are rooted in local cultural heritages and their adaptability to specific locations encourages the development of cultural heritage pride among local actors (Attene, et al., 1996; Brémaud, et al., 2025b; Mahon, et al., 2016; Martin et al., 2023) as well as the

development of local value chains for their finished products, thereby supporting local food systems (Berni et al., 2019; Brémaud, et al., 2025a; Stillitano et al., 2017).

Despite these positive features, past experiences with scaling underutilized species out of their "underutilized" status has not led to the above-mentioned positive characteristics. An example is quinoa; it entered international markets in a few decades and jumped from a local subsistence to a global staple crop (Bazile et al., 2021). The international boom in consumption led to market prices rising, pushing more farmers to start cultivating the crop, thereby abandoning their usual crop varieties (UCs) and farming and water management practices in order to fit global standards and agroindustry requirements. These changes negatively affected agrobiodiversity and ecosystems, provoked a rapid land use change, and affected local natural smallholder system resources, eventually threatening local farming system sustainability (Andreotti et al., 2022; Andreotti, et al., 2023; McDonell, 2015). In addition, after intensification, market prices dropped (Andreotti et al., 2022), and most quinoa landraces faced genetic erosion (Andreotti, et al., 2023). With the adoption of this intensive type of cultivation, Andean farmers had become dependent on international exports and COVID-19 revealed their vulnerability to economic shocks (Bazile et al., 2021).

The European Commission finances research projects to stimulate the use of more diverse crops such as UCs in farms and value chains (European Commission, 2018). The European Biodiversity Strategy, as part of the Green Deal Framework, also acknowledges that "the decline of genetic diversity must be reversed, including by facilitating the use of traditional varieties of crops and breeds" (European Commission, 2020). In the Netherlands, to conserve crop genetic diversity (UCs), the Dutch National Gene Bank (CGN) was created in 1985. It conserves old Dutch plant varieties systematically. Furthermore, in 2016, after 10 years of collaboration between De Oerakker Foundation and the CGN, the Oranje lijst was created, which lists 6638 varieties grown in the Netherlands from 1850 to the Second World War (Kik et al., 2019). However, despite these conservation efforts, no past or current policy has yet promoted the reintroduction and use of this crop biodiversity in the field. In fact, it seems that little consideration has been given to the cultivation of UCs in industrialized regions such as Western Europe, and little is known about how to scale UCs in these regions. Therefore, the objective of our chapter is to explore scaling pathways for UCs in the Netherlands. The contributions of

the chapter are twofold. First, we assess the scaling of UCs in a country in which intensive agriculture is mainstream. This context makes agrobiodiversity, and especially UCs, highly relevant for diversification and the environment, but also more challenging to reintroduce and preserve. Second, we disentangle three levels of scaling pathways: changing institutions, policies and rules (scaling up); changing narratives, beliefs and ideas (scaling deep); and replicating successful solutions (scaling out). This dissociation of pathways enables us not only to focus on UC replication but also to investigate the role of the enabling environment and human behavior and mindset.

Our research is conducted in the Netherlands, an industrialized European country with a globally leading seed (International Seed Federation, 2022) and food processing sectors. Moreover, farm margins are low, giving farmers little room for experimentation (fi-compass, 2020; Meuwissen et al., 2019; Wojtynia, et al., 2023), pushing them to increase the scale of production to reduce costs (fi-compass, 2020). The organic sector is still underdeveloped, with less than 5% of the total utilized agricultural area of the country being organic, placing the Netherlands 23rd among the 27 EU countries in 2022 (Eurostat, 2025). Potential measures to change the logic of the Dutch farming and food system challenge vested interests and threaten the freedom of powerful private sector parties (Aarts & Leeuwis, 2023). Existing mindsets with a focus on maintaining the status quo also block changes, such as the adoption of more crop diversity (Meuwissen et al., 2020). Wojtynia et al. (2023) report that agricultural education in the Netherlands is primarily focused on targeting optimization with economic and efficiency logic and loans and investments rather than cost reduction. In addition, alternative farming practices are sometimes regarded as 'outdated'. Hence, the country faces many challenges with respect to loss of agrobiodiversity (Kik et al., 2019) and other environmental problems (Lamkowsky et al., 2024). While numerous active networks and initiatives for preserving crop diversity exist, they are still scattered and only slowly becoming organized, hence with only little or moderate outreach to society or national policies (Kik et al., 2019; Paas, Coopmans, et al., 2021).

Through participatory workshops with experts, we first studied the current situation of UCs in the Netherlands in terms of scaling. Second, we designed the future desired situation regarding the UC scaling. Lastly, we developed recommendations for

policymakers, local practitioners and researchers to unlock the potential of UCs, i.e. how to achieve a desirable situation of UC scaling.

5.2 Methods

5.2.1 Theoretical framework

The potential scaling of farming systems that succeed in growing and selling UCs (disruptive farming systems) can be understood through the three scaling pathways described by Valencia et al. (2022). They distinguish *scaling up*, i.e. farming systems can be redesigned by changing institutions, rules, and policies. This can be achieved by influencing policy-making or working on major funding schemes. They then discuss the pathway of *scaling deep*, i.e. changing narratives, beliefs and ideas, such as promoting a change by creating completely new narratives. Lastly, they introduce *scaling out,* which involves replicating successful models and tools across different contexts or regions. Scaling UCs may require scaling through all three paths. We investigated scaling pathways of UCs in the current situation and the desired future scaling (Figure 5.1).

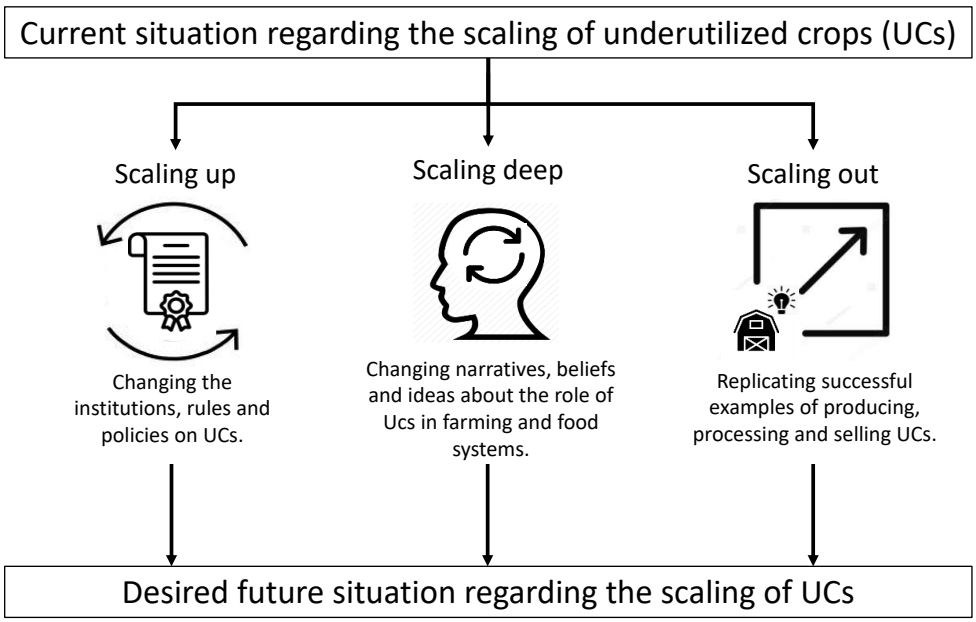


Figure 5.1 Theoretical framework of scaling underutilized crops up, deep and out (adapted from Valencia et al. (2022)).

5.2.2 Workshops: present situation and desirable future situation

Preparation of the workshops

We organized six informal meetings (one in-person and five online) with experts to investigate the current situation of UCs in the Netherlands with regard to policy, existing networks, and initiatives. Moreover, we conducted a literature search in both grey and scientific literature to investigate European and Dutch legislation, and the history and current initiatives regarding UCs in the Netherlands. Based on this initial information, we then organized two workshops with different scopes: 'from seeds to sales' (workshop A), and 'from grains to glass' (workshop B).

Creation of the expert groups

We invited different expert groups to the workshops (Table 5.1). Workshop A included three farmers (two community-supported agriculture (CSA) farms and one mixed vegetable farm), one founder of an NGO working on developing farmers' access to free-of-right open-pollinated seed varieties, and one breeder, an expert in old varieties working on recreating *in-situ* crop diversity. Workshop B included one farmer growing UC cereals, a brewer turning these into beer, one local alcohol seller selling the UC beer product, one local policymaker specialized in developing sustainable agriculture and supporting the brewery's subsidy acquisition, and one local catering company being a potential future seller of the beer product. Experts in Workshop A are more related to seed and crop production aspects, while experts in Workshop B are more focused on crop processing and marketing issues.

Table 5.1 Experts per workshop.

	Workshop A (From seeds to sales)	Workshop B (From grains to glass)
Focus	From seed production to selling Both vegetable and cereal farming	From crop production to selling Cereal farming
Experts	• A CSA[1] farm partially producing its seeds • A CSA farm interested in UCs • A mixed vegetable organic farm interested in UCs • A breeder expert in old varieties • An NGO working on developing farmers' access to UC seeds	• A farmer growing UC cereals • The brewer processing UC cereals • A local policymaker in charge of agricultural issues • A local alcohol (including local beer) seller • A local catering company, i.e. a potential future seller of UC beers

[1] Community-supported Agriculture: an alternative food network connecting farmers and consumers in a local non-commercial partnership to share costs and outputs of agricultural production (Glinska-Newes, et al., 2025).

Outline of workshops

We divided our workshop into two main exercises: a SWOT analysis of the current situation of UCs in the Netherlands, and second, a description of the most desirable and plausible situation of UCs after scaling in the Netherlands in 10 years. The workshops' agenda is detailed in Table 5.2. It is divided into seven parts, with parts four and six being the two main exercises. The workshops took place in February and April 2025, each lasting two hours.

Table 5.2 Detailed content of the workshop agenda (the two main exercises, parts 4 and 6, are highlighted in grey).

Agenda	Content details	Time (2 hours)
1. Context presentation	General introduction, definition of UCs, research objective, consent forms.	5'
2. Round table	Experts introduce themselves and their relation to UCs.	5'
3. Background information	Brief recap on European and Dutch regulations, Dutch history of UCs, and current situation for UCs in the Netherlands.	10'
4. SWOT analysis of the current situation for UCs	Brainstorming of the Strengths, Weaknesses, Opportunities, and Threats (SWOT) characterizing the current situation of UCs in the Netherlands regarding the three scaling pathways: up, deep and out.	45'
5. Five-minute break	Coffee break.	5'

6. Description of the desirable situation for UCs in 10 years	Formulating concrete characteristics describing the scaling of UCs in the most desirable and still plausible situation in the Netherlands in 10 years.	45’
7. Wrap-up	Acknowledgements, use of the workshop results, gifts, drinks and bites.	5’ and more

A SWOT analysis is a strategic planning framework used to evaluate the situation of an organization, a plan or a project. The SWOT method aims to identify both organizational factors through an internal analysis i.e. weaknesses and strengths of the project, and external factors through an external analysis i.e. threats and opportunities (Gürel & Tat, 2017). We applied the SWOT analysis as the first exercise in the workshops to understand the present situation of UC scaling in the Netherlands. We defined as ‘internal’ all actors already involved in scaling UCs, e.g. gardeners, farmers, researchers, NGOs, networks; and as ‘external’, all actors not (yet) involved, e.g. the rest of the society, and non-UC farmers.

To evaluate the current UC scaling situation, we decomposed our SWOT analysis exercise into the three scaling pathways, i.e. up (institutions, rules, policy changes situation), deep (current beliefs, narratives, ideas, values changes regarding UCs), and out (i.e. development of actions, initiatives for UCs). This was achieved by jointly completing a table on a large piece of paper divided into strengths, weaknesses, opportunities, and threats as rows, and up, deep, and out-scaling of UCs as columns.

When classifying the characteristics of the situation of scaling UCs in the Netherlands, we noted that some aspects can belong to more than one box in the SWOT, e.g. some aspects that can be seen as both a threat and triggering new opportunities, depending on how actors deal with them. In the same vein, determining between up, deep and out was sometimes challenging, e.g. a lack in education regarding biodiversity in schools was formulated by some respondents as a need for an educational program change (scaling up) and by others as a need for awareness raising (scaling deep). The final classification was therefore left to the researchers’ discretion, as the primary aim was to analyze the situation systematically and exhaustively rather than a meticulous classification of the UC scaling situations.

The second exercise aimed to conceive a concrete, locally adapted, desirable, and still plausible situation for UCs after scaling, 10 years in the future. This was achieved by

formulating the different characteristics of the most desirable and plausible situation for UCs 10 years from now.

5.2.3 Data analysis and interpretation

We analyzed the current situation of UCs in the Netherlands per workshop by summarizing all points mentioned by experts during the SWOT analysis. We looked separately into the aspects of up, deep and out scaling of UCs for each workshop (i.e. each column separately) and then summarized the strengths, weaknesses, opportunities and threats per system.

We then analyzed the desired future situation for UCs in the Netherlands in 10 years by constructing a descriptive list of all the points mentioned about the desired situation for each workshop. Through triangulation between the three authors, we divided these again into up, deep, and out-scaling characteristics.

5.3 Results

5.3.1 SWOT results of the current scaling situation of UCs

Scaling up

The analysis of the current up-scaling situation of UCs is presented in Figure 5.2 for workshops A ('From seeds to sales') and B ('From grains to glass'). Experts underscore more external factors, i.e. opportunities (O) and threats (T), than internal ones, i.e. strengths (S) and weaknesses (S). Identified strengths (S) are the operational presence of UC seeds (S_2A) and of local businesses selling UCs (S_3B) in the Netherlands. However, perceived weaknesses (W) are the scarcity of local food businesses (W_2B) and the scattered character of the food sovereignty networks (W_1A), giving them little power to influence policy. Perceived opportunities (O) are the presence of policies recognizing the importance of crop diversity and food sovereignty in Europe, such as the Farm-to-Fork strategy of the Green Deal (O_1A) and specific subsidies such as the "Subsidy to learn about sustainable agriculture" [11] (O_3A). Despite these polices, experts also outline several threats (T). For instance, some policies largely restrict farmers' and small processors'

[11] Subsidy from the Dutch government: 'Subsidie om te leren over duurzame landbouw' (SABE).

possibilities to use UCs. Examples at farm level include complex and restrictive regulations, such as volume restrictions and numerous requirement specifications for farmers to produce non-registered varieties (T_1A), as well as specific rules unsuitable for certain agroecology practices to grow UCs (T_2A). At the processing level, experts indicate that "*policies have long forgotten to consider local products and small-scale processing activities such as craft beers as they only focus on industrial food sectors"* and that brewing is classified as an industrial activity only (T_5B), and it is forbidden for local ware markets to sell alcohol (T_6B).

Overall, the experts' explanations suggest tensions between industrial and artisanal, often smaller-scale, operations. High taxes (T_{10}B), absence of subsidies (T_{11}B), and settlement location regulations (T_5B) are mentioned as all adapted to industrial scale only, hardly leaving room for local food processors to exist, and creating an unbalanced competition between them and industrial sectors with more financial resources to comply with regulations. As an example of unfair competition between small local processors of UC products and the large-scale food sector, experts note that local markets no longer sell only local products; they are used by industrial companies to sell their cheaper products alongside local businesses (T_{12}B). Lastly, experts stress that terms such as "local", "regional" (T_4B) and "bakery" (T_{13}B) are used by industries for marketing, creating confusion among customers regarding which products are 'truly' locally made and those which are not, eventually creating competition between locally-made ones and industrial non-local ones.

STRENGTHS	**WEAKNESSES**
S_1 (A) The numerous active agroecology, food, and seed sovereignty networks in the Netherlands can influence institutions, raise awareness of UCs among policymakers, obtain subsidies, and drive policy changes. **S_2 (A)** The Oranje Lijst[1] managed by the Center of Genetic Resources gives official recognition to 380 Dutch heirloom varieties. **S_3 (B)** At least, local varieties still exist (in seed banks, open-pollinated seed companies, farms).	**W_1 (A)** The networks are scattered, resulting in a lower power to speak up at national or European level. **W_2 (B)** Creating and improving local markets is challenging, as local processors are currently rare.
OPPORTUNITIES	**THREATS**
O_1 (A) European policies (e.g., Farm-to-Fork strategy and the Green Deal) support agrobiodiversity and smallholder farmers.	**T_1 (A)** Complex, strict seed laws and heavy bureaucracy (e.g., restrictions on selling seeds) limit farmers' rights and discourage farmers from saving seed. **T_2 (A)** Hygiene regulations, for example, are designed for large greenhouses and applied uniformly to all farms

O_2 (A) EU policymakers recognize Europe's lack of food sovereignty as a risk, which favors scaling UCs. **O_3 (A)** Existing subsidies for agrobiodiversity (like SABE[2]) can be used, though some experts are reluctant to rely on subsidies. **O_4 (A)** It is legally allowed to reproduce heirlooms as they are free-of-rights varieties. **O_5 (B)** There is financial support from the province. **O_6 (B)** As farmers need to scale down livestock activities, opportunities for new (crop) production arise. **O_7 (B)**"PDO and PGI" (Protected Designation of Origin and Protected Geographical Indication) and/or regional labels can be used to communicate the products' story to customers.	and crops, but are non-adapted to small farms and agroecological practices used to grow UCs. **T_3 (A)** A small number of powerful seed companies dominate the market and influence regulations (towards more restrictions on the use of UCs). **T_4 (B)** It is hard to show customers the difference between local foods and other products, as terms such as 'local' and 'regional' are used by all sectors for marketing. For example, Heineken bought Texels beer and still markets it as 'local', while this is no longer true: this is unfair regarding 'real' local brewers. **T_5 (B)** Brewing facilities can only be set up in industrial areas, as brewing is classified as an industrial sector. **T_6 (B)** Alcohol sales are now banned at local markets ('warenmarkt'), including local craft beers. **T_7 (B)** The "blurring law" bans combining different industries (e.g., wine at a hairdresser), preventing alcohol sellers from both selling and offering tastings, and thus, limiting the promotion of local quality products. **T_8 (B)** Frequent regulatory changes create uncertainty, delaying actions like farm transformations. **T_9 (B)** Seed companies and supermarkets form cartels and lobby for policies favoring industry over small local businesses. **T_{10} (B)** The high taxes on alcohol are poorly adapted to small local processors like craft breweries. **T_{11} (B)** "Hidden" state support is prohibited, restricting access to project-specific subsidies and funds, which impedes local food systems development. **T_{12} (B)** Local markets ('warenmarkt') are no longer predominantly local; no policies favor local producers over industrial food, causing direct competition. **T_{13} (B)** Terms such as "bakery" are unregulated, unlike in France, where it is reserved for on-site bread production, creating unfair competition between local bakers and industrial bread sellers.

[1] Initiative that identified and listed 'old' Dutch varieties i.e. those existing before the Second World War (Kik et al., 2019).
[2] Subsidy from the Dutch government: 'Subsidie om te leren over duurzame landbouw'.

Figure 5.2 SWOT analysis regarding the current up-scaling situation of UCs in the Netherlands. A and B refer to workshops A ('From seeds to sales') and B ('From grains to glass') respectively.

Scaling deep

The analysis of the deep scaling situation of UCs is presented in Figure 5.3. Strengths (S) highlighted are the compelling narratives that can be drawn for UCs and local foods,

backed up by the local history, which explains what was traditionally produced in each specific location. These narratives could help raise societal awareness about UCs and agrobiodiversity, and boost pride in cultural heritage (S_1A). Strengths also lie in people's current interest in local food (S_5B) and in the knowledge about these crops, which still exists, for instance, in NGOs (S_4A). Yet, weaknesses (W) are that farmers often fear that UCs are less productive, uniform and reliable than more 'conventional' seeds (W_2A). In addition, using UCs is often associated with seed saving, perceived by farmers as being more demanding in terms of labor, organization, and practical knowledge (W_3A). Moreover, explaining the differences between open-pollinated crop varieties able to locally adapt and non-adaptable commercial varieties is noted as being difficult, both towards society in general and other professionals (W_4A). According to experts, raising awareness among customers regarding local foods and their benefits also takes time and effort that small farmers and processors lack (W_6B).

Opportunities (O) foreseen during the workshops are gaining support from the slow food movement (O_2A) or Community-Supported Agriculture (CSA) farms (O_3A), both of which are in direct contact with customers, and taking inspiration from other countries (e.g., Italy) (O_1A). The nitrogen and climate change crises are also noted as arguments and opportunities to experience UCs (O_4A), and the lack of market development regarding organic seedlings could make farmers interested in producing their own seedlings, providing opportunities to introduce UCs (O_5A). Research on the nutritional value of UCs was highlighted as being sparse, while it could stimulate interest in their production and consumption (O_6A). Another opportunity anticipated during workshop B lies in sharing knowledge with processors (e.g., brewers, bakers) and more systematically showcasing to them how to work with local farmers and local crops (O_7B). This could then enable replicating successful cases of UC production and processing in different locations.

Perceived threats (T) include a lack of awareness about crop diversity among both customers and sometimes farmers (T_1A). Moreover, genetic diversity is often overlooked and little understood (T_2A). Education about crop genetic diversity and its role for farming and food systems' resilience is noted as being either absent or minimal in high schools and professional schools (T_3A). Another threat is that farmers also see "clean" uniform fields as "better", undervaluing the benefits of diversity (T_4A). In addition, it is explained that the abundance of seeds on the market tends to make farmers feel little need for more

genetic diversity in crops (T_6A). With regards to beer, it was stated that beer is assumed to be a cheap product by customers (T_7B). While direct selling is becoming more popular, customers still look for the cheapest food (T_9B), and the large disconnect between customers and producers prevents customers from understanding differences between products and how they are made (T_{11}B). On the farmers' side, a distrust in the government (T_8B), low self-esteem, and large past investments were stated as undermining potential farm changes, such as a switch from corn to grains (T_{12}B).

STRENGTHS	WEAKNESSES
S_1 (A) Raising awareness about crop genetic diversity is a powerful lever, especially through narratives that raise pride in our heritage varieties. **S_2 (A)** Exploring the history of the land (what used to be grown here) helps raise awareness. **S_3 (A)** UCs have a positive image within agroecological networks for their benefits in supporting food sovereignty and genetic biodiversity. **S_4 (A)** Knowledge is available, such as through the course offered by the NGO Zaadgoed. **S_5 (B)** More demand for local beers is observed in local alcohol shops: customers focus on independent brewers (local or regional), but this requires more effort for sellers to explain the differences between beers. **S_6 (B)** Local foods have a great story to tell about the land and cultural history and nature and environment preservation.	**W_1 (A)** Farmers aware of crop genetic diversity often lack practical knowledge to save, select, and sort UC seeds. **W_2 (A)** UCs are perceived as less productive, uniform, and reliable than commercial seeds. **W_3 (A)** UCs and seed saving have a negative image among farmers; they are seen as costly, impractical, and demanding in terms of land, labor, and organization. **W_4 (A)** The complexity of F1-hybrids[1] and genetics is difficult to communicate clearly. **W_5 (A)** Knowledge dissemination often stays within a small, educated, 'left-leaning' group and does not reach wider society. **W_6 (B)** More marketing is needed to sell the story; even locals do not all know about the local brewery in their city, but this takes time and effort for small businesses. **W_7 (B)** Customers have the final choice; if they prefer non-local, cheaper products, these must be provided.
OPPORTUNITIES	**THREATS**
O_1 (A) Taking examples of other places e.g. Italy, could help build strong narratives and raise awareness. **O_2 (A)** Raising awareness can be supported by the Slow Food education movement and the multicultural society. **O_3 (A)** Raising awareness can be done partly through CSAs[2] as they sell directly to customers (although not all CSAs are interested in UCs). **O_4 (A)** The current climate and nitrogen crises are arguments to scale UCs. **O_5 (A)** While the organic seed market is relatively well developed (so farmers do not see the need for more seed varieties), the choice in organic seedlings is still very limited[3]: this can trigger initiatives such as creating "shared nurseries" for farmers to make their own seedlings where UCs can be used.	**T_1 (A)** Consumers and many farmers lack awareness about crop diversity, ignore the large existing crop diversity, and some customers cannot recognize special varieties (e.g. yellow or round zucchinis). **T_2 (A)** Society and many farmers often overlook genetic diversity, and understand sparsely the difference between open-pollinated varieties and F1-hybrids. **T_3 (A)** Education on crop genetic diversity and its role in farms and food systems' resilience is minimal or absent in various educational levels (e.g. high schools, applied and technical schools). **T_4 (A)** Farmers often believe that uniform "clean" fields are better, undervaluing diversity. **T_5 (A)** Changing beliefs requires time and communication, but no marketing is performed to highlight the benefits (e.g. nutrition, environment) of UCs. **T_6 (A)** The abundance of commercial seeds makes farmers feel little need for more diversity, as they do not have

O_6 (A) Future research support could help strengthen and promote the nutritional value of UCs, currently under-documented. **O_7 (B)** More showcasing to fellow brewers and bakers that local beers and breads are possible is crucial, although this requires craftsmen's shops (different from industrial). **O_8 (B)** Many people are proud of local food. **O_9 (B)** There are huge unexplored territories regarding local businesses and products.	explanations on the differences between varieties (genetically diverse or not). **T_7 (B)** Beer is perceived as cheap, less valuable than wine. **T_8 (B)** Farmers distrust the government, despite sharing similar goals i.e. less maize, more grains. **T_9 (B)** Direct selling is becoming more popular, but sustaining this trend and shifting consumers away from buying the cheapest food is challenging. **T_{10} (B)** Craft skills are disappearing, as everyone goes for technical schools or university, making it hard to find the knowledge for local and craft food production. **T_{11} (B)** The large disconnect between consumers and producers prevents customers from understanding how their food is made. **T_{12} (B)** Many farmers have low self-esteem and large past investments, thus feel unable to change production or practices.

[1] First filial generation of two different inbred lines. This type of hybrid is not able to produce seeds as productive as their parents (Tripp, 1996). Thus, farmers must repurchase new seeds for the next sowing season.
[2] Community-supported agriculture is a type of agricultural enterprise where consumers buy shares in the farm and receive a portion of what is available each week of the growing season (Brown & Miller, 2008; Sharpe et al., 2022).
[3] At the time of writing, Plantenkwekerij Jongerius, the only organic seedling provider in the country, suddenly shut down, threatening the largest part of the small vegetable growers throughout the Netherlands.

Figure 5.3 SWOT analysis for the deep-scaling situation of UCs in the Netherlands. A and B refer to workshops A ('From seeds to sales') and B ('From grains to glass') respectively.

Scaling out

The analysis of the out-scaling situation of UCs is presented in Figure 5.4. A perceived strength (S) is the existence of successful and inspiring examples, such as a small seed company selling open-pollinated varieties (De Zaderij) (S_2A) or an association working with farmers to produce old cereal and process them into bread, pasta and beer (Graangeluk) (S_7B). In addition, the NGO Het Kiemcollectief helps farmers to produce and reshare their open-pollinated seeds with each other (S_1A), and a farmer preserves 530 old Dutch cereal varieties in fields (S_6B). These initiatives, as well as those from neighboring countries (S_4A), are seen by experts as inspiring examples that can support future ones. Regarding UC cereal processing, strengths described by the experts are tight collaboration and circularity implemented between the farmers and processors involved (S_8B).

However, the scattered character of the networks and the small proportion of professional members weakens (W) their capacity for action (W_1A). In addition, farmers

foresee economic and practical issues in using more UCs, such as the lack of time or knowledge (W_3A). As seed costs are relatively small compared to land rent and employees' salaries, changing the seed management of the farms is not a priority for farmers (W_4B). Initiatives of processing UC cereals into local food products are typically smaller-scale and thus less profitable due to lower volumes with a larger share of labor costs for the businesses (W_5B). However, expanding the production volumes requires large investments and devalues the local character of the products, which encompasses aspects such as circularity, less transportation, strong collaboration between actors, and real connections with customers (W_7B). Thus, to maintain a local character, a business can only expand to a certain level.

A perceived opportunity lies in the fact that the main organic seed companies have become large multinationals, selling seeds mostly not well adapted to Dutch conditions. This can motivate farmers to look for other sources of better-adapted seeds, providing opportunities for farmers to reintroduce UCs (O_3A). According to experts, encouraging retailers to sell UCs (O_1A), better adapted policies to leverage costs of small food businesses (O_4B), and the creation of more cooperatives, open markets for local products, honesty shops (O_7B), and shared farmers' shops, can boost opportunities to reach customers and to market and sell more UC products (O_5B).

A reported threat (T) is the risk of "seed grabbing", i.e., privatization of natural traits by seed companies through property rights (T_3A). In addition, it is highlighted that seed companies look for specific traits rather than conserving the genetic diversity of crops (T_2A), and farmers willing to grow their own –genetically diverse— crops face an absence of logistic infrastructure to produce and reuse or reshare their seeds (T_1A). Farmers also face high land prices, which pushes them to produce large volumes to overcome the rent rather than to experiment with different crops or farming practices (T_4A). With regards to processing, the large market power of supermarkets is highlighted; it results in smaller businesses having difficulties competing with them, and collaboration with supermarkets is also difficult due to their focus on the lowest-priced products (T_5B). A perceived threat related to catering companies is that these generally like to order all at once rather than receiving different products from different small producers (T_7B). Moreover, it is mentioned that end-consumers are price-sensitive and, unless they can recognize local

products and their added value, they usually look for the cheapest products (T_6B). Lastly, it is pointed out that craft breweries have to pay high taxes, making competition with industrial beer companies unfair, as the latter pay less taxes (T_8B).

STRENGTHS	WEAKNESSES
S_1 (A) An NGO (e.g. Het Kiemcollectief) can help farmers collaborate, each reproducing a few seed varieties, then resharing them between each other. **S_2 (A)** Existing businesses like Odin (organic supermarket chain with its own farms) and De Zaderij (small seed company) offer business model examples. **S_3 (A)** Valuable knowledge exists among farmers reproducing adapted varieties and at De Zaderij, with experts available to teach seed selection. **S_4 (A)** Seed companies like Bingenheimer (Germany) offer open-pollinated varieties suited to Dutch conditions and can serve as seed sources and examples. **S_5 (B)** In the Gelderland region, several people focus on supporting local initiatives. **S_6 (B)** A farmer is preserving 530 old cereal varieties: his knowledge and the genetic resources he conserves in the fields are a great resource. **S_7 (B)** The Graangeluk[1] association is a success story and an inspiring example; they have won many awards. **S_8 (B)** The value chain of craft beer is strengthened by focusing on circularity and collaboration. **S_9 (B)** It is somehow "easy" to grow grains, and 1 kilo of grains represents 4 liters of beer, which makes it a great economic opportunity for entrepreneurs.	**W_1 (A)** Networks for seeds are numerous but scattered and mostly cater to hobby gardeners; professional networks are limited, (yet slowly organizing themselves). **W_2 (A)** The organized sector for open-pollinated seeds is small and even smaller for seedlings. **W_3 (A)** Farmers foresee economic and practical barriers to seed saving; lack of time, workforce, knowledge, and land availability discourage them from trying. **W_4 (B)** Because seeds are relatively cheap compared to land rent and labor costs, changing the seed management of the farm is not a priority for farmers. **W_5 (B)** Local food production is typically small-scale, so less profitable due to low volumes, meaning that labor costs take a larger share. **W_6 (B)** The brewery was awarded a gold medal and could sell worldwide, but the harvest was tiny. **W_7 (B)** Scaling production is expensive and devalues the local character of products. **W_8 (B)** Even specialty supermarkets consider local beers too costly. **W_9 (B)** Many local brewers went bankrupt as intermediaries absorbed too much margin. **W_{10} (B)** Running a small business selling local food (e.g. brewing) is time-intensive. **W_{11} (B)** Extensive negotiation with the food chain is required to set up local supply infrastructure (e.g. a maltery). **W_{12} (B)** Profit margins in hospitality (a potential selling channel) are shrinking.
OPPORTUNITIES	**THREATS**
O_1 (A) Retailers might sell more UC products in the future, boosting UC production. **O_2 (A)** Future subsidies could support farmers growing and multiplying UCs and researchers assisting them. **O_3 (A)** Many organic seeds are produced abroad and poorly adapted to Dutch conditions (organic seed companies have now become multinationals)—this supports using locally adapted UC seeds. **O_4 (B)** Finding solutions to reduce the costs of local businesses (e.g. tax exemption, adapted policies to small-scale businesses) is crucial. **O_5 (B)** More cooperatives, farmers' markets, and shared farmers' shops could be created. **O_6 (B)** The university nearby has a bar that allows alcohol to be sold. **O_7 (B)** Honesty shops (where you pay and serve yourself alone) could be further developed to make local products available.	**T_1 (A)** The seed logistic infrastructure focuses on F1-hybrids[2]; a UC seed logistic system has yet to be created. **T_2 (A)** Most seed companies (also organic ones) are looking for specific traits and proposing F1-hybrids, rather than keeping the existing genetic diversity and proposing open-pollinated varieties. **T_3 (A)** "seed grabbing" risks –privatization of natural traits by seed companies through property rights— exist. **T_4 (A)** The high land prices push farmers to achieve a high productivity per hectare rather than giving them room to experiment with new practices or varieties. **T_5 (B)** Supermarkets have a large market power, making it hard for small businesses to compete. Moreover, they focus on low-cost products only, making it hard to sell local products through them. **T_6 (B)** Customers are price sensitive (tension with housing costs) and spend little on food and drinks: if they do not know local products' specificities, they do not buy them. **T_7 (B)** It is easier for catering companies to order all at once, rather than from different producers. **T_8 (B)** The competition between small brewers and large beer companies like Heineken is unfair as the latter pay less tax.

[1] Association of farmers and bakeries producing and processing UC cereals into breads, pasta and beers.

[2] First filial generation of two different inbred lines. This type of hybrid is unable to produce seeds as productive as its parents (Tripp, 1996). Consequently, farmers have to repurchase new seeds for the next sowing season.

Figure 5.4 SWOT analysis of the current out-scaling situation of UCs in the Netherlands. A and B refer to workshops A ('From seeds to sales') and B ('From grains to glass'), respectively.

5.3.2 Desired and still plausible situation for the scaling of UCs

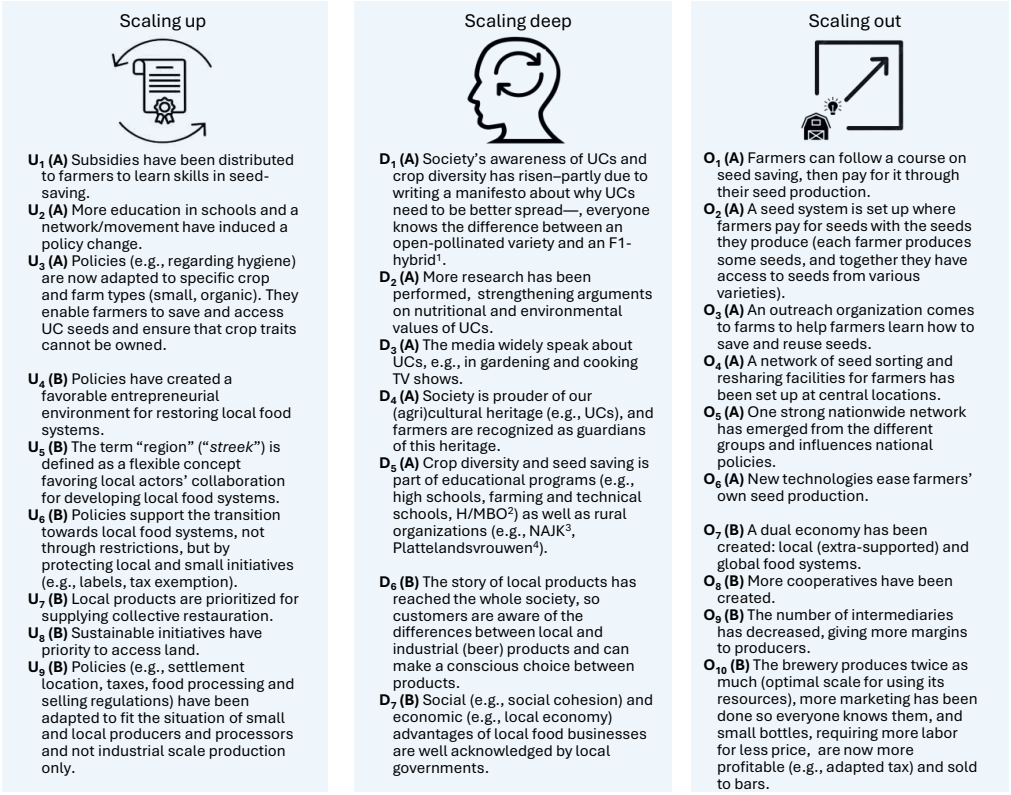
The future desired situation after scaling described during workshops A and B is presented in Figure 5. The ideal situation in 10 years regarding scaling up (U) UCs can be summarized as a space to be created for local seed and food systems using UCs alongside the global market. Concretely, the regulations on seed exchange are relaxed, and seed saving for UC farmers is allowed (U_3A). There is a favorable entrepreneurial environment for more small farmers and food processors (U_4B). This is achieved through (1) regulations, e.g. regarding taxes (U_6B), security, hygiene (U_2A), settlement license (U_9B), adapted to local businesses' socio-economic situation, and through (2) adapted definitions of terms such as "local", "regional" or "local markets" so that local producers and processors are protected from competition with larger companies (U_5B, U_6B). In addition, policies prioritize UC products in collective restoration schemes (U_7B) and prioritize sustainable farming initiatives for access to land (U_8B).

The desired situation for scaling deep (D) UCs is a much greater societal awareness and understanding of crop diversity (D_1A) as well as larger pride in UC farming and food heritage, i.e. old varieties and their benefits. Farmers gain societal recognition as protectors of crop diversity (D_4A). UCs are in the spotlight and crop diversity promoted in media such as in gardening and cooking TV shows (D_3A), and in educational programs at high and middle technical schools, and high schools (D_5A). UCs are also under focus in scientific research, for example, regarding their nutritional value (D_2A).

The desired future on the scaling out (O) for UCs is a nationwide network of seed actors able to influence national policy (O_5A), a nationwide seed network with facilities in central locations to sort (O_4A), store and reshare seeds, and an outreach organization (able to come to farms) to help farmers gain knowledge on seed saving (O_3A). New technologies ease farmers' own seed production (O_6A). A dual economy is in place: an extra-protected local economy alongside the global food system (O_7B). Hence,

cooperatives and shops selling UC products are in place, with fewer intermediaries in the chains, ensuring better margins for producers and processors (O_9B). As noted in workshop B, scaling out UC products can remove the 'local' specificity. Hence, the brewer wishes to increase volumes only up to an optimal scale (i.e. 70 000 liters per year) to be able to fully monetize the brewery facilities and achieve a sufficient income, yet not to reproduce industrial beer processes and products (O_{10}B).

Finally, experts express the need for a "bigger plan" that integrates the different aspects of the desired situation together. In this plan, communication and education programs target different actors: (i) policymakers through a manifesto explaining biodiversity and food system resilience aspects (D_1A), (ii) retailers and supermarkets through a marketing narrative regarding special and ancient foods with specific taste, color, and appearance (D_6B), (iii) students through educational programs explaining crop diversity (D_5A), etc. In parallel, scattered networks in the Netherlands organize themselves better to obtain the attention of policymakers (O_5A). These lead to subsidies and technical support to farmers for growing UCs (U_1A), as well as changes in regulations to better adapt them to growing UCs (U_3A). It is also highlighted that local food systems, which are the ones processing and selling UCs, have not been taken into account by policies for decades, as they have become barely nonexistent. This situation requires the creation of 'a space' to enable them to exist again (D_7B). This means rethinking policies designed for the industrial sector and no longer fitting smaller-scale local businesses (scaling-up) (U_9B) as well as explaining the struggles and specificities of these local systems to society (e.g. regarding nature and health). These later explanations to society can enable customers to make conscious choices in their food and drink purchases (scaling-deep) (D_6B).



[1] First filial generation of two different inbred lines. This type of hybrid is unable to produce seeds as productive as its parents (Tripp, 1996). Consequently, farmers have to repurchase new seeds for the next sowing season.
[2] Hoger/Middelbaar Beroepsonderwijs: Higher/Middle-level professional education.
[3] Nederlands Agrarisch Jongeren Kontakt: Dutch young farmer network.
[4] Plattenlandsvrouwen: Dutch Association of Rural Women.

Figure 5.5 System characteristics describing the desired and plausible situation of the scaling of UCs 10 years in the future for workshops A ('From seeds to sales') and B ('From grains to glass') respectively.

5.4 Discussion

We first reflect on our findings by first summarizing our main conclusions. Second, we discuss the generalizability of our findings. Third, we address the need for adapting UC initiatives rather than 'simply replicating' them. Finally, we discuss three "principles" for scaling emerging from the workshop discussions.

5.4.1 Main conclusions

To explore the scaling pathways for UCs, we investigated both the current scaling and the desired future scaling of UCs. Our investigation of the current scaling of UCs revealed several barriers, including restrictive policies (scaling up) and a lack of knowledge and awareness (scaling deep). However, several evolving initiatives are supporting current UC scaling. These (e.g. the Oranje Lijst, existing networks) represent opportunities to spread knowledge in wider society and raise awareness, but also to influence national policy decisions. The desired future scaling of UCs is foreseen with well-maintained crop genetic diversity and local specificities in food products, and not reproducing existing industries or past examples of 'super food'.

To achieve the desired scaling of UCs, pathways require the creation of a nationwide network for UC seeds that organizes and supports a large crop diversity. This consolidated network could better spread societal knowledge and raise awareness, as well as influence national policy decisions. Up-scaling pathways also include modifications to two main sets of policies: seed policies and food processing policies. First, seed policies should be modified to enable access to UC seeds for farmers through the possibility to exchange, resow, and make a profit from UCs. Second, food processing policies should be modified to consider both mainstream food processing industries and the business models of smaller local processors. Additionally, to make crop diversity and UCs well-known and understood by farmers and society, deep-scaling pathways encompass training and educational programs and media visibility. These needs resonate with results from Berthet et al. (2025) who report on major issues for collective actions to manage crop diversity in fields: facilitating a collective management of seeds, raising awareness of a wider public, and sharing knowledge between practitioners (Berthet et al., 2025).

In short, to support the desired scaling of UCs, these up and deep-scaling pathways together create favorable conditions for local food systems to develop (out-scaling), with more small processors and sellers handling UCs as necessary selling channels for UC farmers. For the future desired scaling of UCs to be concretized, these three pathways create a space for UC producers and processors to exist, i.e., for the local economy to develop alongside the global food market. The creation of this space requires revised

policies that take into account local and smaller-scale businesses, and not only the mainstream large-scale food system. The revised policies concern a wide range of policies regarding farming and food processing. The necessity to create a space for the existence of local food systems correlates with findings by Feenstra (2002), that four kinds of space need to be created and protected for alternative and sustainable food systems to exist: social, political, intellectual, and economic space.

5.4.2 Generalizability of our findings; differences and similarities between the two workshops

We performed two workshops with different types of experts. In the workshop ''from seed to sales', experts were small vegetable farmers, an NGO and a breeder working on seed availability to farmers, while in the workshop 'from grains to glass', cereal farmers, local cereal processors and sellers, as well as a local policymaker, were present. This led to different focuses during the discussions. While the first workshop focused more on the availability of seeds (scaling up) and knowledge for farmers to be able to grow UCs (scaling deep), the second focused more on adapting policies that would enable local processors and sellers to process, sell and market UC products (scaling up) and increase societal awareness on where food comes from and how it is produced (scaling deep).

Overall, we can conclude that a similar perspective on how to scale UCs is shared by all the experts. They all noted the need for supportive policies regarding small stakeholders striving to maintain crop diversity (scaling up). Non-adapted policies (regarding seeds and production, and for processing and selling) were discussed in both workshops (scaling up), as were the lack of societal understanding and connection with farming and how food is produced (scaling deep).

Despite the two workshops having slightly different focuses and a diversified expert composition, a coherent vision of the current scaling of UCs and the desired future situation emerges without contradictions appearing between the information collected. Hence, we feel confident that our results provide an informative overview of the current situation of scaling UCs and of the desired future situation of scaling UCs in the Netherlands. Future research should explore UC developments and policies in other European countries. Yet, some up scaling issues mentioned by our experts arise from

international regulations (e.g. rules on selling seeds) and thus impact countries in a similar way. National and local policies may temper or enhance these issues in some specific European regions. For example, the food-selling policies mentioned in the workshops are specific to the Netherlands and may be less of an issue in other countries. Yet, complaints regarding national policies that do not support small-scale processors and farmers have also been noted in other European countries, such as France (Brémaud et al., 2025b). Regarding scaling deep, in line with the literature (Khoury et al., 2022), experts raised issues such as a societal lack of understanding of crop diversity, and the need for raising knowledge and awareness e.g. through education. Although education and raising awareness towards crop diversity may be better tackled in some other regions, this situation is not exclusive to the Netherlands. Consequently, our analysis of UCs in the Netherlands likely mirrors the situation elsewhere in Europe.

5.4.3 Adapting rather than replicating

Some initiatives to produce UCs may need to be expanded, such as the brewery, which could perform better economically by doubling its production volume to 70,000 liters to make full use of its facilities. However, the experts mostly highlight that when replicating existing initiatives of producing and selling UCs to alternative locations, the new initiatives should be adapted to the unique context of these specific locations. Expanding a underutilized species without limit would lead to creating another major monoculture, thereby losing its 'local' specificities and not strengthening the nutritional, environmental or farming system resilience aspects that UCs promise. Hence, in the context of UCs, scaling out pathways should be understood as "replicating while adapting to specific contexts" rather than simply "copy-pasting" initiatives.

The need for new tailor-made initiatives rather than replicating existing cases is not advocated in the case of producing and processing UCs alone; it is also recommended for implementing regenerative agriculture (Schreefel, de Boer, et al., 2022; Schreefel, van Zanten, et al., 2022). These types of agriculture are based on different levels of complex knowledge, such as a detailed understanding of ecology, farm management, and socio-economic context. Similarly, UC scaling pathways were highlighted during the workshops as requiring complex knowledge to find the crops, practices and selling channels adapted to specific local (farming) contexts.

To achieve tailor-made initiatives for growing UCs, we recommend future research to study the perspective of local actors striving for sustainable farming and preserving the available crop diversity. This would avoid repeating similar pathways to monocultures, where only the most high-yielding varieties are used, leading to environmental and socio-economic drawbacks for the local actors, as described by Andreotti et al. (2022) for the case of quinoa in the Andean region.

5.4.4 While 'simply replicating' is undesirable, key UC principles lend themselves to scaling

Across the explanations given by the experts regarding UC scaling pathways and crop diversity, three more general principles emerged. These can serve as guiding threads for future projects on preserving crop diversity. First, while expanding underutilized species is not advocated, expanding some 'principles' attached to UCs may be beneficial. One principle reflected in our findings is experts' clear will to expand the existing crop diversity in the fields and to expand the efforts allocated to the preservation of this crop diversity. Expanding a single underutilized species is undesirable, but more support should be given to local farmers and processors to use and preserve crop (genetic) diversity as a whole.

Second, following our findings, local food systems based on crop diversity can only develop if policies on crop production and food processing give them a space to exist, i.e. take them into account; scaling up can unlock scaling out. Nicholls & Altieri (2018) also advocate not focusing on farming alone, but on local food systems as a whole –as they constitute the necessary selling channels for UCs. In Brazil, policies related to the food systems were found to be among the most beneficial for boosting agrobiodiversity. For example, favoring small farmers' products in school cantinas was one of the most effective policies promoting agroecology (Nicholls & Altieri, 2018).

Third, our results suggest a substantial need to raise societal awareness, as well as that of farmers, regarding what crop diversity and subsequent local products mean. This can be achieved in various ways, among which are (free) farm-based training programs for farmers, more education on crop diversity in schools at different levels and how to maintain it, the introduction of labels for customers to distinguish between different finished products, and the protection of "local" or "regional" terms in marketing food

products. Furthermore, societal awareness about UCs could be supported by the general ongoing movement towards more local and regional products and food systems, which gained a boost during the COVID-19 period (Nemes et al., 2021). These suggestions may help ensure local product differentiation and thus market share for small actors involved in maintaining crop diversity.

5.5 Conclusions

In this Chapter, we explored the scaling pathways for underutilized crops (UCs) in the Netherlands. We held two workshops with Dutch UC experts. We first investigated the current situation of UCs regarding policies and regulations (scaling up), knowledge and awareness (scaling deep), and actions and initiatives concerning UCs (scaling out). Second, we explored the desirable scaling for UCs regarding these three pathways. Workshop discussions confirmed the necessity not to focus on scaling out crops, but rather scaling out 'principles' inherent to crop diversity preservation: this requires further studying scaling up (e.g. adapting some policies related to farming, food processing and selling) and scaling deep (e.g. working towards more societal knowledge and awareness of crops' genetic diversity and the food system). Additionally, as scaling up and deep are needed to achieve a desirable "out-scaling" for UCs, it is essential to jointly tackle issues of the three scaling aspects, e.g. through an integrated plan, rather than separately.

To boost knowledge sharing among professionals and awareness raising among both agri-professionals and broader society regarding crop diversity and how to use UCs in value chains in the Netherlands, we recommend supporting existing initiatives such as networks, training programs for gardeners and farmers, or social events, by connecting and aligning them. This would enable the set-up of a national unified level of organization. This would then also enable broadcasting a common message that would eventually boost the impact of isolated initiatives. Moreover, local products, among which those made from UCs, could be prioritized in collective catering.

For scaling crop diversity in the Netherlands and more broadly in European contexts, we recommend that policymakers spend extra effort to talk to and listen to local food system actors (e.g. small farmers, processors, and sellers) who strive for more diversified agriculture. These stakeholders can highlight where policies conflict with their practices

and socio-economic situation, as well as propose potential solutions for scaling crop diversity.

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6

Chapter 6
General Discussion

6.1 Background

This thesis aimed at investigating the functioning of European food systems using underutilized crops (UCs), more precisely, at exploring the motivations, performance, resilience, and scaling pathways of UC farms, value chains and communities in European contexts. I assessed the performance of UC farms through a farm management analysis with main components consisting of farm structure and economic performance, farmers' goals, decision-making and perceived resilience. At value chain level, I mapped UC value chains and looked at structural indicators (SO1). I explored the motivations of UC actors through interviews with farmers and other value chain actors about their goals for their business, value chain and community (SO2). Resilience of UC farms and value chains was investigated through the resilience attributes and the perceived resilience capacities of farmers and processors of the UC value chains, backed up by factual indicators (SO3). Scaling pathways for UCs were analyzed in two ways: through a systematic literature review that reports economic challenges and opportunities related to UCs, and through SWOT analyses conducted during workshops with UC experts and envisioning future scaling for UCs (SO4).

This chapter synthesizes the key findings of this thesis for each of the four sub-objectives and recapitulates in what sense UC food systems are 'meaningful'. Limitations in the methodology are then discussed. Recommendations for policymakers and for business owners are given next. Lastly, areas for future research are listed, followed by the main conclusions of this thesis.

6.2 Synthesis of the thesis

6.2.1 Economic performance of UC food systems

The performance of a system consists of multiple domains: environmental, social and economic (Schoenmaker & Schramade, 2019). In this section, I focus on the economic performance of UC food systems. I first discuss the economic performance at farm level, then at the value chain level, and finally, at community level.

At farm level, UC cereal yields are often reported to be lower or similar to non-UC varieties (Chapters 2 and 3). Yet, these results depend on practices, soil and climatic conditions, and are variety-dependent as well. The most repeated aspect in the literature

is that UCs perform better than conventional crops under bad conditions, such as in too dry or too wet, too cold or too warm climate (Karanikolas et al., 2018; Thanopoulos et al., 2021). This is corroborated by the results of Chapter 3, where interviewed farmers also explain using UCs for their adaptability to different environmental conditions, such as droughts. The explanation for these characteristics of UCs is their large genetic diversity within varieties, enabling them to adapt to different environmental conditions, as explained by the interviewed farmers (Chapters 2 and 3) as well as by De Ron et al. (2004), Elia & Santamaria (2013), Karanikolas et al. (2018) and Spataro & Negri (2013).

Chapter 3 points out that these crop characteristics can have several advantages for the farm business. A good crop adaptability, when used with adapted cultivation practices and knowledge, supports the reduction of production costs (fewer inputs) and risks. This is mentioned in recent literature on UCs such as Ortman et al. (2023) who explain how Finnish UC farms make a living from UC cultivation through limited costs and higher prices compared to conventional crops. Low prices of farm products have been a major issue in European countries (Vermunt et al., 2022). Prices at the farmgate directly impact farm profitability (Kalinowska & Bórawski, 2024). UC farms use different strategies for ensuring higher prices: certification and higher quality standards, fewer intermediates, and strong partnerships between farmers, and with processors and customers (Chapters 3 and 4), as also reported by recent studies such as Fenzi & Couix (2022), Karanikolas et al. (2018), Ortman et al. (2023) and Varia et al. (2021). No or little external inputs brought to the crops contribute to the environmental value of the crops, and favor organic or low-input cultivation practices, which can be translated into economic value as well, such as through the possibility to obtain an organic certification, as also reported by recent work on UCs by Fenzi & Couix (2022) and Ortman et al. (2023). UC farms obtain good margins, while not trying to optimize production volume or increase farm size (Chapter 3). Profits are reported to be sufficient to support the household(s) involved (Chapter 3). This is in line with results from Ortman et al. (2023), who report that farmers would not be willing to grow UCs if they could not make a living from it.

Efforts for implementing environmental measures are often seen as financially costly but also in terms of time or management for farmers (Scherfranz et al., 2025). Yet, in Chapter 3, supporting the natural environment of the UC farms (e.g. through organic practices, favoring soil life, water and hedges) is seen as a strategy to strengthen the

business in the long-run, because strong natural features hosting healthy ecosystems in and around the farms are seen as eventually supporting a reduction of input costs (e.g. fertilizers), and reducing risks (e.g. biotic or abiotic stresses). Ortman et al. (2023) report that longer and more complex crop rotations and intercropping were not only seen as ways for diversifying farm products, but also helped to control weeds. They also report that biodiversity, including the intrinsic UC diversity, also helps in resisting pests and diseases, which is in the end positive for the farm business. Karanikolas et al. (2018) also conclude on positive outcomes for both local agrobiodiversity and farm profitability.

While profitable, farm businesses studied in Chapters 3 and 4 also face large challenges, among which are not fitting seed regulations (e.g. low availability of UC seeds partly due to restricted seed exchange), as also highlighted by Didonna et al. (2024). Similarly, in line with the results of this thesis, Fenzi & Couix (2022) also explain that when retrieved from a seedbank, many UCs have no name, and their morphological characteristics are largely unknown; farmers need to try them out, select the one suitable for them, and learn how to grow them. Knowledge to grow UCs as a prerequisite is also pointed out by Varia et al. (2021) and André et al. (2024). UC farmers' interviews (Chapter 3) also revealed farmers' difficulty in explaining to customers the differences between their products and mainstream products. UC farmers also often reported the lack of societal awareness regarding different ways of farming and the intrinsic quality differences between food products (e.g. lack of societal knowledge and understanding regarding farming and nature). The latter challenge has only been briefly described in the literature, although Fenzi & Couix (2022) explain that farmers had to create a "counternarrative" marking the difference with the dominant industrial model.

At value chain level, case studies of UC chains are rare in the literature, enabling little comparison with the three case studies of Chapter 4. Indeed, several studies report cases of UCs supported by certifications such as protected designation of origin (PDO) or Protected geographical indication (PGI), but these cases focus on the economic situation of farmers and do not study the post-farm stage of the chains, i.e. the processors (Karanikolas et al., 2018; Stillitano et al., 2017; Thanopoulos et al., 2024; Varia et al., 2021). Chapter 4 concludes on the economic viability of UC processors, with businesses being usually relatively small-scale businesses compared to mainstream value chains, striving for minimizing external inputs (e.g. energy), and more local partnerships and

circularity among the businesses (e.g. exchanges of by-products, and reusage). These characteristics resemble those of the UC farms and are in line with the results from Mahon et al. (2016) and Martin et al. (2023), who also studied the same value chain case study in Scotland; they also emphasized the low needs of external inputs and the reliance of these businesses on local partnerships. Fenzi and Couix (2022) report two case studies in Italy and France where partnerships between farmers were largely supported by local NGOs, which enabled the creation and organization of the cooperation between farmers crop processing. Additionally, in the Italian case, a cooperative was created to process (drying and milling) the (corn) grains collectively and mills were used for the grinding. Although these cases explain the chains' functioning, the performance of the businesses is not studied. Both in the Scottish case and the Italian case reported by Fenzi and Couix (2022), municipalities are involved in the consortium (in Italy) and in the management of the heritage mill in Scotland. In contrast, in the French and Dutch value chains studied in Chapter 4, the municipality is not officially taking part in the organization of the chain. However, in the Dutch case study, some municipality-level actions to support the brewery are observed, such as through the authorization for settling in the city center.

As seen in Chapters 3 and 4, UC farmers and processors target high standards in terms of social and environmental benefits of their products, such as regarding human health (Ortman et al., 2023) and biodiversity (Varia et al., 2021). This increases the economic value of UCs and UC products, and thus supports the profitability of the value chain businesses (Chapter 4).

Still, findings of Chapter 2 show unsuitable regulations regarding UCs' processing and selling that hold back the economic performance of UC value chains. While unsuitable regulations regarding seed management were documented in the literature (Didonna et al., 2024; Spataro & Negri, 2013a), unfit regulations impeding the processing and selling of UCs were not found. This issue might not be specific to UCs only, but belongs to the broader topic of small and medium enterprises that cannot always comply with policy and industrial regulations (Šūmane et al., 2021). In Chapter 4, regulations on building construction safety, food safety, and high taxes were pointed out as impeding local processing businesses. Connected to this issue, UC processors in Chapter 4 faced difficulties obtaining loans when they started, because their business models were little-known by bankers. In the same vein, these UC businesses operate with little economic support, as few subsidies apply to them (Chapter 4). This is corroborated by Karanikolas et al. (2018) who suggest that more

measures supporting short supply chains are needed, for instance, to better support the commercial valorization of UC products.

At community level, the literature repeatedly mentions the presence of UCs in home gardens, mostly meant for feeding the household and for food exchange with the neighborhood (Conversa et al., 2020; De Ron et al., 2018; Douma et al., 2016; Timpanaro et al., 2022). These functions of UCs were not addressed in this thesis, as only commercial farms were studied. Yet several professional UC farmers explained that the food consumption of their households was largely supported by the farm (Chapter 3). This local food production can contribute to the food autonomy of European territories and, as such, is part of the economy. Aside from this impact on the economy of communities, UCs also often originate from specific local sites. As a consequence, UCs represent a heritage and cultural value, also translated into economic value through tourism with, for example, the development of restaurants, shops, and other touristic attractions and activities (e.g. events, fairs) (Chapter 4). This impact of UCs on communities is also found in the literature (Karanikolas et al., 2018; Martin, Russell, et al., 2023; Thanopoulos et al., 2024). UC actors further explained that UCs, or the UC finished products, attracted visitors to their remote place. Tourists were considered a benefit to the whole city or village, as they typically consume in different local businesses (Chapter 4). Additionally, UC growing, processing, and selling provides jobs in these rural places. For instance, workers establish with their family, contributing to the village life (e.g. school, consumption) while often the local population was decreasing and ageing (Chapter 4). Similar explanations regarding economic dynamism of remote and less favored areas are given by Martin et al. (2023) regarding the Scottish value chain. Ortman et al. (2023) point out that UCs can potentially generate livelihood opportunities in rural areas with marginal agricultural land where no human food would be grown otherwise, and Karanikolas et al. (2018) report that the exploitation of local genetic material through the commercialization of unique UC products can be an employment prospect for young people and farmers. Last, beyond their business activity, UC actors create and participate in fairs, open markets, and social events (Chapter 4). In general, both the literature available on UC value chains and the present results (Chapter 4) highlight that UC value chains participate in boosting the local economy and social dynamism of their communities (Magnani, 2016).

6.2.2 Motivations of UC actors

In this thesis, UC actors' motivations to use UCs were explored through the literature (Chapter 2) and interviews (Chapters 3 and 4). According to the transition management and

integrated thinking (TMIT) framework, personal motivations are important for transitions to really take place because economic incentives, although triggering behavioral changes, do not ensure the continuity of these changes in the long term (Schoenmaker & Schramade, 2019). UC actors' motivations are peculiar because, instead of focusing on the business itself, they are often related to the social and environmental contributions of the business to the local community and area. Economic profitability of the business, instead of being a goal, is more seen as a requirement to keep on running rather than as an objective in itself. Several UC actors' motivations are disseminated mainly across four papers, i.e. by Mahon et al. (2016), Ortman et al. (2023), Martin et al. (2023), and Fenzi & Couix (2022), who look at UC farmers' motivations for growing UCs in the core of the studies, while Goufa et al. (2024) make a SWOT analysis of the use of a specific UC. Similarly to UC farmers interviewed for this research, Swedish UC farmers interviewed by Ortman et al. (2023) also explained that they need to make a profit from UCs, and would not grow UCs solely for the sake of agrobiodiversity conservation. Still, the literature also reports that UC actors have several motivations beyond profit for growing UCs.

First, farmers give agronomic reasons for favoring UCs. UC farmers in this thesis, mostly based in France (Chapter 3), greatly appreciated the agronomic characteristics of UCs, their adaptability and resistance. Similarly, Martin et al. (2023) report that the most consistent replies when asking Scottish UC farmers about their motivation were the adaptation of the UCs to local soil conditions. Other important motivations repeated in the literature were the low management requirements, disease resistance, tolerance to extreme temperatures (Goufa et al., 2024; Mahon et al., 2016; Martin et al., 2023), and to a lesser extent, market demand (Martin et al., 2023). Mahon et al. (2016) also report the adaptation of UCs to environmental conditions as farmers' motivation for UCs. Ortman et al. (2023) also point out several agronomic advantages motivating Swedish UC farmers to grow UCs: low demands on nutrient availability, large straw production, good weed competition, good for diverse crop rotations and intercropping, good tolerance to pests and diseases and extreme weather events, and the ability to adapt to local conditions. Lower yields were mentioned by UC farmers in Chapter 3. This was also mentioned in the literature (Chapter 2). This was not seen as a major drawback, as it was also explained by the low-input and organic practices that UC farmers choose.

Second, beyond the agronomic reasons for growing UCs, the UC farmers (Chapter 3) and the literature also mention economic reasons, such as market demand, but these

appear less important for farmers, according to Mahon et al. (2016) and Martin et al. (2023). Ortman et al. (2023) report economic incentives and markets for landrace cereals and an increasing market for landrace products. More importantly, both UC farmers of Chapter 3 and Ortman et al. (2023) pointed out that an important motivation was the possibility to sell directly to customers through short value chains, which ensured premium prices. In Chapter 3, UC farmers also explained striving to recover a maximum of autonomy and saw on-farm processing and short value chains for which UCs are well-adapted, as a good means to increase their freedom. Similar to UC farmers of Chapter 3, Ortman et al. (2023) also report the will of Swedish farmers to 'be free' and 'independent of large multinational companies' and classify these in the category 'ideals of sustainable farming'. Thus, growing UCs was seen as a means to reduce external inputs dependence and to increase circularity (for nutrient supply) (Ortman et al., 2023). Fenzi & Couix (2022) also report the farmers' wish for more autonomy from seed companies specifically, and classify it in the 'political and cultural' reasons for growing UCs. Food autonomy was given as a proper motivation in the interviews with farmers in this research. Although the literature repeatedly mentions UCs' contribution to food autonomy, it is not directly mentioned by farmers as a 'motivation' in the literature (Fenzi & Couix, 2022; Martin et al., 2023; Ortman et al., 2023). Yet, Goufa et al. (2024) report that Greek farmers considered food autonomy as a strength to grow grasspea. Indeed, according to Chapter 3, this argument seems to be more valued by vegetable growers than cereal ones, possibly due to the larger diversity of crop species the former grow, which can significantly contribute to the family diet.

Third, interviewed UC actors appreciate the social ties that growing UCs enables (Chapter 3). This is also the case in the literature; farmers were motivated by the networking opportunity that growing UCs provided them through being part of a consortium (Fenzi & Couix, 2022a), or through seed exchange and alternative food networks (Ortman et al., 2023). UC farmers also appreciated the well-being their way of farming provided to themselves and to their families by living in the countryside and close to nature (Chapter 3). This specific point was not explicitly found in the literature, maybe due to the fact that it corresponds more to the choice to be a farmer in general, than to the choice of crops used.

Fourth, several motivations could be called 'altruistic' or 'social', i.e., aiming at the well-being of not only themselves but also of the society, especially, of their local community, and at boosting the local economy of their place (Chapter 3). UC actors, both from this research and in the literature, are seeking to create local, high-quality, healthy food products (Fenzi &

Couix, 2022; Karanikolas et al., 2018; Martin et al., 2023; Ortman et al., 2023; Stillitano et al., 2017), in a less 'unethical' way than the conventional ways (Ortman et al., 2023), or in an environmentally-friendly way (Karanikolas et al., 2018; Ortman et al., 2023). By 'high-quality', the literature refers to taste, nutritional value, and healthiness (e.g. certified organic) (Karanikolas et al., 2018; Ortman et al., 2023). Regarding their 'social' motivations, UC actors interviewed in Chapter 3 also explain striving to support their community through creating employment in rural areas, boosting the local economy through new open markets and businesses, and organizing social events. Although mentioned as a benefit of UCs in the literature, this argument was not found as a farmer's 'motivation' to grow UCs. Still, as a 'social motivation' for growing UCs, some farmers in Chapter 3 want to restore the nobility of farming as a profession, as it is sometimes seen negatively by society: UC farmers want to show that farming does not necessarily pollute the environment, and the food produced can be of good quality. They look for recognition from society and want to create products that they can be proud of, recognized by their customers as tasty and healthy. This motivation of restoring pride in farming has not been found explicitly in the literature. However, the high standards of UC farmers for quality and taste for their products are repeated in the literature (Fenzi & Couix, 2022; Karanikolas et al., 2018; Mahon et al., 2016; Martin et al., 2023; Ortman et al., 2023). In addition, the sense of pride in growing UCs is also a strong motivation to grow UCs, as some UCs are attached to local territories and are anciently grown. In some places, UC farmers see their work as an important contribution to the preservation of the heritage in terms of crops, practices and sometimes features such as old mills (Fenzi & Couix, 2022; Mahon et al., 2016; Martin et al., 2023). The will to increase territorial autonomy was largely explained by UC actors in Chapters 3 and 4. They explained trying to keep prices low enough to feed the local people and not create expensive products inaccessible to the locals. The same explanation is given by the farmers interviewed in the study by Varia et al. (2021). They also explained that they want to 'make people eat well and at fair price' (page 8).

Fifth, several motivations of UC actors in Chapters 3 and 4 are about improving the natural environment for future generations, such as growing crops with environmentally-friendly practices, through boosting the biodiversity, and landscape resilience (e.g. planting trees, hedges, recreating ponds, performing no-till or superficial soil work, implementing intercropping, diversified and complex rotations, renouncing to chemicals use), but also processing with little energy needs and recycling, reusing material and by-products as much as possible. UC farmers in the studies of Fenzi & Couix (2022) and Ortman et al. (2023) also explained their willingness to cultivate through more environmentally-friendly practices. UC

varieties were seen as well-adapted to organic practices and low-input systems (Fenzi & Couix, 2022a; Ortman et al., 2023). Lastly, conservation and development of local landraces and more generally of agrobiodiversity were cited both by UC farmers in this thesis (Chapter 3) and in the literature as a motivation to grow UCs (Fenzi & Couix, 2022; Mahon et al., 2016; Martin et al., 2023; Ortman et al., 2023; Varia et al., 2021).

Eventually, UC actors' motivations also have the specificity of being long-term targets and not one-year-long objectives. These motivations also influence the structure and functioning of UC farms and value chains. In fact, it seems that UC actors seek to optimize resilience (long-term profitability) rather than current profits. This leads them to a specific way to valorize crops. Their long-term motivations focus on their business and value chains, but also on society and the preservation of natural resources. In general, it is striking to see the similarities of arguments given by UC actors from different countries for using UCs.

6.2.3 Resilience of UC food systems

In this section, I discuss how UC actors build the resilience of their food system by focusing on their businesses and value chains' resilience. Resilience of UC farms and value chains was analyzed through their attributes and capacities (Chapters 3 and 4) and relates to the need to think of long-term risks in the TMIT framework (Schoenmaker & Schramade, 2019). Relatively good levels of the perceived resilience capacities were found, both at farm and processing levels, especially regarding the adaptability capacities. Exploration of the attributes, together with additional factual indicators, shows how resilience is built in the UC value chains. This approach was not encountered in the literature on UCs, yet arguments regarding resilience attributes, such as diversity (e.g. biodiversity) or connectivity (e.g. strong partnerships) are present.

Value chain actors often strive to maximize their autonomy from distant and external resources (e.g. in food, in energy) or services (Chapter 4). They also experiment with new techniques, practices, and crops. Workers show polyvalence to undertake various tasks. These agency characteristics support adaptability and transformability capacities in the face of potential shocks (Chapter 4). On that point, Martin et al. (2023) explain that the isolation of the Orkney Islands has pushed towards self-sufficiency strategies, which is one of the reasons why Bere barley, well-adapted to the environmental conditions, was still grown while most landraces on the main island have been abandoned. Additionally, Acosta-Naranjo &

Rodríguez Franco (2014) point out the role of UCs in self- and local-food consumption, and the ability of communities growing UCs to keep a larger control on their food sovereignty.

Although overall good perceived resilience levels are found for UC farms and value chains that were studied, buffers, as an attribute of resilience, were limited (Chapter 4). Some businesses operate with relatively little cash flow, moderate stocks and a limited amount of workforce. This may be partially solved by good levels of agency, diversity and connectivity to face potential issues. Instead of competing for a larger margin share within the chain, value chain actors maintain close connections with each other and support each other, for example, through knowledge exchange, exchange of by-products and services, and mutual aid (Chapter 4). These characteristics of UC value chains were repeated across several studies (Douma et al., 2016; Fenzi & Couix, 2022; Polegri & Negri, 2010; Raggi, et al., 2021; Varia et al., 2021). The strong connectivity between actors supports the robustness capacity of the chain, as issues are shared by different actors together (Chapter 4).

Diversity is also a main focus at all levels: in the fields, diversity in crop varieties, in farm practices (complex rotations, crop mixture), farm activities, finished products, partnerships, and selling channels. Diversity is also visible in the polyvalence of the workers, also acquired through knowledge sharing. Diversity supports the robustness capacity as well, as not all activities or crops fail at the same time (Chapter 4). The literature reports mostly about the agrobiodiversity, which includes UCs (Raggi et al., 2021; Sardaro et al., 2016), but little information at value chain level is found.

6.2.4 Scaling pathways for UCs

In this section, I first recap on the current situation of UCs in terms of challenges and opportunities encountered by UC actors because they constitute the baseline situation for scaling UCs. Second, I report on the scaling pathways for UCs to transform the current situation into a more desired one according to UC actors. Scaling pathways relate to the 'transition pathways' of the TMIT framework, and deal with the changes that need to take place for a transition to happen (Schoenmaker & Schramade, 2019).

This thesis reports the main challenges encountered by actors in UC chains: unfit regulations (seed and industrial norms), unavailable seeds, lack of technical knowledge and machinery, a lack of actors to cooperate with, hardship to convince banks and to raise awareness of customers and colleagues, and last, fighting against the belief that the desired

changes are actually impossible to implement (Chapters 2, 3, 4, 5). Subsidies are still rare, and the issue of crop diversity still has too little visibility in society (Chapter 5). The unsuitability of seed regulations was documented (Didonna et al., 2024; Elia & Santamaria, 2013a), as well as the lack of seeds (Douma et al., 2016), machinery (M.-M. Antofie & Sava, 2020) and knowledge (Karelakis & Tsantopoulos, 2017).

Main opportunities are that UC knowledge still exists, as well as networks of farmers and gardeners, and numerous initiatives can be observed, such as associations, small nurseries, seed selling companies, and some processors are willing to use local ingredients and are interested in trying UCs (Chapter 5). The literature also reports several associations created to grow and process UCs (Fenzi & Couix, 2022; Karanikolas et al., 2018; Martin et al., 2023).

Discussions regarding scaling pathways for UCs in Chapter 5 show that UC farms and value chains can operate, but they still face numerous challenges, potentially preventing more initiatives from appearing. Solutions exist and are implemented by UC actors, but are often unknown or overlooked by society, policymakers, other farmers and entrepreneurs. Eventually, for more initiatives to succeed, we need to create space for UCs in mindsets and policies (Chapter 5). Policy recommendations are given in sub-section 6.4. Here, I reflect on the space to be created for UCs in mindsets.

Throughout the research work for this thesis, I heard several prejudices that represent challenges to UC scaling. Some of these prejudices are challenges experienced by UC actors to explain to society what they do and why. These prejudices relate to society's mindsets, sometimes including scientists, as pointed out by UC actors. Among others, the following prejudices can be listed: (1) UCs are 'underutilized' likely because they are not good crops (comment during conference), (2) UCs probably cannot work at a large scale (comment from several scientists), (3) we need to produce more to feed everyone and these crops have lower yields (comment during conference), (4) there is, or seems to be, already a large crop diversity (UC farmers' challenges to explain what UCs are to customers, Chapter 3). Last, (5) we like to see the world through human-made categories, such as species (Darwin et al., 1859; Turnhout & Purvis, 2020), which might prevent us from understanding how biodiversity truly works. In what follows, I discuss these assumptions or ways of thinking that may contribute to holding back UC scaling.

(1) Many modern cultivars are highly selected crops to fulfil uniformity and stability requirements for crop registration (*UPOV Lex*, 1961), hence, they are less adaptable to various environments and ensuring good yields often requires external inputs (e.g. synthetic chemical

fertilizers, fungicides, pesticides) (Korpetis et al., 2023). UCs bring other advantages: as low-input and adaptable crops (Korpetis et al., 2023; Negri, 2005), they may become more interesting in the context of external input shortage or increased input prices, climate change, and other uncertainties. Hence, if UCs have become underused in a logic of yield optimization without input shortage, they may still be useful for feeding people.

(2) UCs, as less standardized crops, are likely not the most suited crops for highly mechanized bulk production and export. Additionally, producing a UC at industrial scale would mean a loss of its local specificities. However, by supporting local initiatives, various UCs could be grown and processed in various locations. Today, several policies are not fit for growing and processing UCs (e.g. in terms of access to seeds, facilities to process, selling channels). This is a barrier for actors to run and start a UC-based business. However, solutions emerge from Chapters 3 and 4, such as recreating local channels with fewer intermediaries and modifying policies to take into account SMEs. These would help to grow, process and sell locally-adapted UCs in various locations. This would also boost the food autonomy of territories across Europe.

(3) Papers characterize UCs by modest yields with less inputs, and especially still good enough —more stable— yields in difficult contexts (Goufa et al., 2024; Karanikolas et al., 2018; Martin et al., 2023; Ortman et al., 2023; Petrovic & Dimitrijevic, 2012; Riu-Bosoms, Calvet-Mir, & Reyes-García, 2014; Thanopoulos et al., 2021, 2024). In addition, yields are usually computed "per ton" of the main product (e.g. grain for the cereals). However, it does not include by-products such as straw yield, while they can be significant for farm businesses and support diversification of revenues. In the case of UC cereals, much larger straw yields are common (Martin et al., 2023; Ortman et al., 2023). Moreover, grain yield does not reflect the yield of protein, nutrients, and fibers. Nutrition arguments are still growing in research interest, and for several UCs, they look promising (Biasi et al., 2015). For these reasons, we need to shift our mindset from quantity (grain yield) to farm resilience (diverse and stable revenues), and from quantity (grain yield) to quality (diverse nutrients, fibers, and other elements crops may contain) (André et al., 2024). This may bring us to value UCs differently. Last, the objective to produce more food to feed everyone may be challenged in itself, as other dimensions (e.g. food waste, food distribution) are more and more put into question regarding food security (Schlein, 2021).

(4 & 5) Crop diversity is huge (Massawe et al., 2016; Negri, 2005; Spataro & Negri, 2013), but already partly lost, and raising societal awareness about it is needed (Khoury et al., 2022).

Species and varieties are human-made categorizations (Darwin et al., 1859; Turnhout & Purvis, 2020). Crop varieties registration rules, "distinct, uniform, stable" (DUS), tend to fix crops' genotypes and phenotypes over time (*UPOV Lex*, 1961). Categorization of crops into well-defined species and varieties makes us see biodiversity as 'static', while biodiversity is constantly evolving (evolution towards new varieties and species). While categorizing is a way to simplify and understand our environment, it changes our representation of it and decreases our understanding of what biodiversity is (Darwin, et al., 1859; Turnhout & Purvis, 2020). Raising societal awareness about the evolving character of biodiversity would stir the design and implementation of regulations to be more adapted to the biodiversity concept. This requires a process of knowledge sharing and education, and possibly multidisciplinary approaches.

6.2.5 Using UCs: towards meaningful food systems

The word "meaningful" is defined as an adjective of something "intended to show meaning" or something "useful, serious, important, or valuable" (Cambridge Dictionary, 2026). During this research, actors using UCs said that they wanted "to do something that made sense". Some examples used by the UC actors to explain what made sense to them were "working with the living, such as soil and plants", "feeding healthy other people", "taking care of nature", or "making their area a beautiful place". In this section, I discuss in more detail "what made sense" to UC actors in UC food systems, i.e. what was important or valuable to them.

UC actors look for performance (i.e. yield and profitability), but not at all costs. For them, individual profit is necessary, but if the business pollutes or brings social concerns to the people, it does not make sense. UC actors believe their businesses need to bring something to nature and/or society, and should not harm either of them. Several of the actors interviewed had done other jobs before farming or running a food processing company. They decided to create their business with the objectives of supporting their society and the natural environment, or at least not harming them. They materialize this through producing a maximum volume under several constraints, such as preserving nature (environmental constraint) and supporting people with a lively social community and by offering them healthy products (social constraint). Environmentally, UC actors look for preserving nature and minimizing their environmental impact, for instance by avoiding unnecessary transportation, and not throwing away packaging when it can be reused. These processing methods make more sense to them. Socially, UC brewers were aware that their businesses

were also places of social exchange and well-being. The mill managers were also aware in Scotland that the mill was a symbol of identity and pride for the community (Mahon et al., 2016; Martin et al., 2023). UC actors actively participate in fairs, open markets and other social events and are even initiators of some. Eventually, initiatives of growing UCs are meant to imply social connections and partnerships and boost social ties (Fenzi & Couix, 2022; Martin et al., 2023; Riu-Bosoms et al., 2014; Thanopoulos et al., 2021).

Working with nearby companies so they can meet their partners in person, feeding people in their community with whom they can have direct contact, rather than distant people that they cannot meet or get to know, are also choices that make more sense to UC actors. Related to this point, both Fenzi & Couix (2022) and Ortman et al. (2023) highlight that farmers largely value networking opportunities and possibilities to create real social relationships. Creating healthy finished products with good quality ingredients from partners they know, with more transparency and traceability, was also a point mentioned by Varia et al. (2021). In the same vein, UC actors find the possibility of knowing and connecting with their customers more meaningful. They want to ensure that their product is appreciated by customers, that customers have access to the information regarding the product (e.g. how the product is made and where). Eventually, they wish customers to know, and if possible, value and support their effort as also reported by Fenzi & Couix, (2022) and Ortman et al. (2023). Lastly, UC actors explain that making a unique product, with a unique taste (characterized by a specific soil, climate, varieties, practices, recipes) makes more sense to them than producing crops for bulk production, that would be exported somewhere unknown, mixed with other crops from elsewhere, maybe of less good quality, to be processed in bulk into an unknown industrial product which would have no geographic identity, as it is the same everywhere. On this point, Fenzi & Couix (2022) and Martin et al. (2023) report the pride of farmers in making a unique product.

By striving to give sense to what they do, UC actors' objectives and strategies are largely long-term and not yearly objectives, as seen in Chapter 3 for UC farmers. For example, farmers plant hedges to strengthen their farm's ecosystem and resistance to droughts and wind. Hedges are made of shrubs and trees, and need years to fully play their role. Yet, once grown, they can be maintained for centuries. This way, because UC actors want to do something that makes sense, they also have long-term targets and strategies. This, in turn, has consequences for their decision-making and for the structure and economic performance of their businesses and value chains, which are more related to resilience than maximizing yearly profit. These

results are in line with findings from Ortman et al. (2023), who explain that UCs fit well with the farmers' ideals on sustainable farming (e.g. possibility to cultivate on marginal agricultural land, with less intensive weed control, with new intercropping methods, and possibility to use the cereals for baking).

Finally, UC actors express their need to feel proud of what they do, to know why they do what they do, to feel that what they do is right, and to align with their opinion. UC actors try every day to contribute as little as possible to global warming, to find alternative solutions for this, and to support nature and their community members. By doing something that makes sense to them, UC actors can feel proud of what they do, which helps them grow their self-esteem. Low self-esteem among farmers was also mentioned as a barrier to transition in Chapter 5.

6.3 Reflection on using the term "underutilized crops"

As mentioned in the General introduction, the term "underutilized crops" can mean both underutilized species and underutilized varieties. While the underutilized species focus is most commonly adopted in the field of agronomy, in this thesis, I defined it as underutilized varieties, i.e. as both varieties of underutilized species and underutilized varieties of major species, as long as they are adapted and adaptable (i.e. genetically diverse) to farmers' needs. The advantage of not focusing on the species level, but investigating the intra-specific level (also of major species), is that my research shows a more exhaustive overview of how cultivated biodiversity may impact farms. My thesis does not avoid underutilized species, but aims to bring to the economic field the potential impacts of cultivated biodiversity, especially the intra-specific diversity. The latter is investigated much less compared to the economic perspective of crop species diversity. In Chapter 3 for example, farmers have both a large number of species and numerous underutilized varieties per species. Looking only at species here would have led to overlooking part of the explanation of how UC farmers practice crop diversification: largely operating at the variety level. For instance, UC cereal farmers use both levels of diversification; they mix species (e.g., legumes and cereals) in intercropping, but also mix varieties or "populations" of a cereal together.

The disadvantage of having a broad term such as "underutilized crops" is that it creates fuzziness. Indeed, while many economic issues concern both interpretations (e.g. lack of adapted machinery, lack of market to sell them), some apply specifically at variety level only

(e.g. genetic diversity within the field that can help buffer yield in bad climatic conditions) or at species level only (e.g. a variety of products to sell).

In Chapter 2 (Scoping review), I retrieved papers containing keywords of varieties and the keyword "crops". The reason for having "or" between keywords in the search code and not "and" is that I look exhaustively for retrieving all possible studies that may deal with underutilized varieties. Some studies may mention only UCs in their title, abstract and keywords, then investigate landraces in the body of the text. Yet, the definition of UCs in the introduction of Chapter 2 clears the doubt regarding what is considered as UCs in the study; not underutilized species but underutilized varieties. Hence, once studies were retrieved, studies dealing with introducing an underutilized species, not discussing the variety level, were not included. In order to look at species only, the code should include the word "species" and replace "or" with "and". Then, keywords designating intraspecific level of diversity, such as "variety" and "cultivar" would not be necessary anymore and could be removed from the code to focus on the species level. Looking at underutilized species instead of underutilized varieties would have overlooked all the underutilized varieties of major species. "Species" is not used in the search code, only "crop" (as well as variety, cultivar, seed, cereal, fruit, and vegetable). This is because some studies may frame their research as "underutilized crops" in their title, then later discuss adapted varieties or cultivars in the core of the text, and I did not want to miss these. Inversely, removing "crop" from the keyword list could have suppressed some studies presenting underutilized crops and their different varieties, but not mentioning explicitly "varieties" in the title, abstract, and keywords.

In future economic research, I advise using terms such as "neglected cultivated biodiversity" or "neglected genetic resources". These terms prevent that we overlook one part of the impact of cultivated biodiversity by focusing on species, and remove the fuzziness of the generic word "underutilized crop" or even "underutilized varieties" which can still be subject to interpretation. In addition, the word "neglected" seems more precise than "underutilized" as it suggests that this pool of crop genetic resources was actively abandoned at a certain point in time. By contrast, "underutilized" emphasizes current potential and overlooks historical aspects of cultivated biodiversity, which was once in use but was later on left behind.

6.4 Limitations

In this section, I critically discuss the most important limitations of this thesis. The systematic literature review (Chapter 2) was only based on published scientific literature. However, as UCs are often little known and locally grown, it is likely that cases of using UCs may not have been known and reported by scientists. The grey literature, such as reports from local associations, local governments, and technical advisory services, could have been informative in finding additional concrete cases. Despite this shortcoming, the review of scientific papers demonstrates that there is a past lack of academic interest in UCs in the European context from an economic perspective, with a growing interest in the very recent years.

Different definitions of UCs exist in the literature (Camacho-Henriquez et al., 2016; Padulosi et al., 2002). There is a continuum between wild plants, landraces, old cultivars, and the most modern varieties. Hence, there is also no strict distinction between UCs and non-UCs. In addition, farmers can use a mix of older (rarer) and more recently bred (and common) varieties. Consequently, defining UCs, what a UC farm is, and estimating how many UC farms exist in Europe is an impossible endeavor that requires deciding arbitrary thresholds between what we consider as UCs and UC farms and what we do not. This difficulty in clearly defining the subject may have contributed to difficulties in reporting on UCs, explaining them to scientists outside the genetic and agronomic field, and eventually overlooking them and their potential contribution to the agricultural landscape (e.g. biodiversity) and agricultural economy (e.g. food autonomy of territories, rural economy). In this research, explaining UCs and what is at stake was also challenging, and I took an open stance on this definition in order to bridge the gap between fields of study. As a result, this work brings to light the connections between (crop) genetic diversity (i.e. UCs) and business economics, which has been little studied so far (Bjarklev et al., 2019).

The third limitation relates to the absence of records reporting which UC is currently growing where. UCs can be from any species, growing in any location. Yet, no database exists to indicate which UCs grow where, which is in line with the fact that UCs are often left behind in agriculture. To the best of my knowledge, there are only lists made by ethnographic scientists in specific areas (Biscotti et al., 2022; Pieroni et al., 2005; Riu-Bosoms et al., 2014). As a consequence of the absence of records, primary data collection

was necessary for this research. Hence, I chose qualitative and detailed assessment approaches, making use of quantitative indicators. As all data had to be collected in a limited amount of time, sample sizes are small (low number of farms, limited number of countries and UC chains represented). However, focusing in depth on specific cases enables understanding the connection between UCs and the context in which they are grown. Although limited sample sizes may restrict the generalizability of the findings, a large number of specific characteristics were shared between case studies of different areas and tend to the same overall objectives (e.g. diversification and autonomy of farms). These results consolidate the hypothesis that there is a common paradigm regarding agricultural production behind the use of UCs, and this thesis proposes a detailed understanding of how this materializes into specific cases.

UCs are often grown in relatively small quantities (for example, a few tons for cereals, or on one or two-hectare vegetable farms), and also contribute to households and neighborhoods' food consumption. UCs are also often grown in a context of tight social networks involving informal services and food or by-product exchanges. These numerous informal flows of services and agricultural matters developed social networks that mix friendships with professional partnerships. Overlooking these informal ties, hides part of the explanation why and how well UC farms and processors perform. However, taking into account all of these exchanges is difficult as they are little recorded and quantifiable. This thesis uses a mix of numerical and descriptive indicators to describe in detail the different aspects at play and strives to be as exhaustive as possible in explaining how specific UC value chain case studies operate.

A smart use of diversification strategies (e.g. in terms of species, varieties, but also activities such as processing or tourism, and finished products) supports the resilience of the farm business. Indeed, diversity is a core attribute of resilience (De Steenhuijsen Piters et al., 2022). Genetic diversity is only part of the diversification strategy: using UCs, mixing them, mixing species in intercropping, and diversifying rotations are all part of the same attempt to buffer potential loss. Farmers implement most of the time these practices simultaneously. More research on the impacts of each and their interactions would be useful.

This research presents in two ways how well these highly diversified farms succeed: (i) farmers' perception that their system is strong in the face of shocks and stressors, such

as climate change (i.e. perceived resilience), and (ii) the eventual profitability of the farm business. . However, it is clear that these are overall indicators resulting from multiple practices. Profitability is a result of many practices and decision-making (e.g. also social networks) among which the use of a large amount of adapted species and varieties may have a minor contribution, or a major one. Still, the thesis shows that some farmers, in certain contexts, achieve sufficient economic results by growing UCs. By supporting diversification, UCs can support the resilience of a food system. However, using UCs is never the only cause of resilience: multiple strategies are simultaneously implemented by the actors of a food system and build on each other to create the resilience of the food system. Among others, the creation of partnerships (i.e. connectivity), or the implementation of new cultivation practices, such as superficial tilling or intercropping, are also strategies that are combined with the use of more UCs. As a consequence, the contribution of UCs to the resilience of a system cannot be assessed in isolation from farming practices or business and value chain management strategies. For this reason, instead of attempting to quantify the exact contribution of UCs in a food system, this thesis showcases how actors create resilience for their business, value chain and community through various integrated strategies, including the use of UCs.

As this thesis looks successively at the farm, then value chain level and finally at how to scale UCs, the impression might arise that genetic diversity and its benefits can be easily scaled from field to farm to farming system. This, of course, does not universally hold, as genetic diversity is one factor among many in the functioning of farms, and even more farming systems. Instead, looking at different scales enables to understand how farmers and other local actors manage to use UCs in a way that is beneficial for them economically and sometimes personally and socially (e.g. for community building, rural development). Focusing on variety genetic diversity is not sufficient because even with very well-adapted varieties at field level, low prices or lack of market opportunities for the product may still make the crop little helpful for the farm business. Focusing on farm level only does not enable us to fully understand how some UC farmers achieve a good level of perceived resilience because several factors go beyond the farm gate: networks, collaborations, connections with customers, by-product exchange, support and integration in their local community. As previously mentioned, the use of genetic diversity is one practice that farmers use in combination with several others to, in the end, build a

farm business that meets their goals towards their communities and themselves (e.g. well-being, social ties, financial needs).

The sample sizes in this thesis are limited. In Chapter 3, I perform a deep analysis of a small number of farmers (17) located in different regions in France. In Chapter 4, I study three local value chains through their (7) main actors. Interviews in both cases were long (several hours), in-person, and with a visit to the place. Interviews were then completed through email and phone calls for checks and missing details. For the two workshops with each five participants held in Chapter 5, several meetings were organized with different participants prior to the workshops. This enabled framing the workshops in the most suitable way regarding the background and interests of the participants.

For Chapters 3 and 4, the reason for choosing detailed analysis over sample size is that I am interested in understanding the fine functioning of these farms (and subsequent local value chains). I do not aim nor claim representativeness, but rather hope to bring a deeper understanding of how (some of) these farms and value chains can work, as they are innovative and could present interesting solutions for more farmers and food processors. For Chapter 5, the reason for not holding more and larger workshops is primarily to enable space for listening to the perspective of each participant and their personal perspective, as the topic of the workshop directly affects participants in their professional activities. Preparing the workshops in relation to their interests and situation requires learning about local situations, individual perspectives, and wishes and subsequent fine-tuning of the workshop content, format and outline. Welcoming a large number of participants at once may be less welcoming or respectful, as time and means to listen to each participant's perspective are then decreased.

Although sample sizes are small, some conclusions can be drawn beyond the detailed analysis of the cases. In Chapter 3, although farmers are spread over a large area in France, they share stunning similarities (aside from using a large amount of rare open-pollinated varieties and saving their seeds for most of their crops). They share similar goals, decision-making (and practices), and they are all professional farmers, all making sufficient income for their households, and all perceiving a relatively high level of resilience. I detail their (similar) goals and decision-making in Chapter 3. The fact that, although distant and although not using the same varieties, they show large similarities

in farm management characteristics is, in itself, a result. More studies in France and in other European countries could ascertain or moderate our results regarding the functioning of these types of farms. The study from Ortman et al. (2023) in Sweden on farmers' motivations to grow cereal landraces describes very similar farmers' goals, decision-making and practices to the ones observed in Chapter 3. I hope that more studies will further explain why, currently, some European farmers deliberately choose to grow UCs, and how they manage to make a living from their activity. In Chapter 4, the value chain case studies are also small-N, and I also favor long and details analysis rather than a larger sample. Still, I can observe that across countries with different regulations (e.g. food safety), value chain actors are very much aligned in their goals, challenges and practices towards the resilience of their chain. As an example, in all cases, actors highly value their social network and spend efforts in building strong relationships with their value chain partners, also favoring collaboration, information exchange, and circularity of by-products. Here again, more studies could further explain their motivations for using UCs, and how they manage their chains.

In Chapter 5, the small number and the large diversity of participants (e.g. farmers, breeders, processors, NGOs), cannot bring any representativeness regarding a certain actor group. But despite the differences between local actors, their vision and advices were aligned both regarding (i) the current situation of UCs in the Netherlands (e.g. lack of time, coordination, low suitability of regulations to smaller scale businesses) and (ii) how a better future situation could be envisioned (e.g. public involvement, emphasizing on cultivated biodiversity in educational programs, establishment of free trainings and shared facilities for seed saving).

6.5 Policy recommendations

Several policy recommendations at European and national levels can be drawn from this thesis to counter challenges faced by UC actors and uncovered through this research. To support current and future farmers and processors, I first give recommendations at European level (where most of the relevant agricultural policies are enacted), then at national and local levels (which translate EU policies into the local context). My fourth policy recommendation concerns customers' awareness.

More flexibility in the regulation regarding seed exchange between farmers is needed for farmers to access UC seeds. While the EU wants more crop diversity according to the farm-to-fork strategy (European Commission, 2020), the EU also restricts access to UCs for farmers by forbidding exchanges of UC seeds between farmers (Council Directive of 14 June 1966 on the Marketing of Fodder Plant Seed (66/401/EEC), 2022). Regulations on seeds (international, EU, and national levels) should authorize access to UC seeds to farmers by relaxing regulations that forbid exchange and selling between farmers. Tests for seed-borne disease should be organized independently from crop registration. This is a condition for farmers' access to UCs. While the farm-to-fork strategy explicitly mentioned crop and variety diversity, the new vision for agriculture of the European Commission from 2025, however, omits the topic of 'agrobiodiversity' or 'crop diversity' explicitly, and only mentions 'biodiversity' (European Commission, 2025). Speaking about biodiversity in general may lead to a focus on wild and macro biodiversity only (e.g. birds, wildlife), and may overlook living soils or intrinsic crop diversity, which are also part of agrobiodiversity and boost resilience in crop production (FAO, 2005).

A larger allocation of funds for rural development is needed to support projects of growing, processing and selling UCs. Today, 75% of the Common Agricultural Policy (CAP) budget is allocated to the first pillar (i.e. direct payments) while the remaining 25% is for rural development (European Commission, 2026). Growing and processing UCs, and more generally local food, is connected to the ability of local actors to connect with each other for growing, processing, and selling their UC products (Chapters 2 and 4). The allocation of the Common Agricultural Policy (CAP) budget could be more turned towards rural development than individual farms, i.e. towards the second pillar and collective actions. This can be done at national level as countries have the possibility to reallocate up to 25% of their direct payments budget to rural development or vice versa (Regulation - 2021/2115 - of the European Parliament and of the Council of 2 December 2021 Establishing Rules on Support for Strategic Plans to Be Drawn up by Member States under the Common Agricultural Policy (CAP Strategic Plans) and Financed by the European Agricultural Guarantee Fund (EAGF) and by the European Agricultural Fund for Rural Development (EAFRD) and Repealing Regulations (EU) No 1305/2013 and (EU) No 1307/2013, 2021). Transfers in the direction of rural development is done by some countries (e.g. the Netherlands), but could be done to a larger extent and by more

countries (European Commission, 2023). This way, more collective projects targeting farmers' long-term financial autonomy could be supported (e.g. processing of UCs). This re-allocation could also counter the often-cited downside of direct payments, which risk maintaining farms in a financial dependency on subsidies (Mazancová et al., 2025). Local governments could then better support knowledge sharing, partnerships and collaborative projects (e.g. creation of open markets, fairs, producers' shops, new short chains, more circularity, local food in collective catering, projects for reconnecting society and farmers). In regard to the first pillar of the CAP, modifications in the delivery of the subsidies could also support UC farm businesses further. An amount of subsidies that is largely computed based on the number of hectares incentivizes increasing farm size, rather than creating a diversity of different business farms and production over the territory. While environmental preservation is gaining more attention, and is more often valued, e.g. through eco-schemes (European Commission, n.d.), taking more into account social criteria as well, could be thought of, such as the wages of employees as a 'social' added value in the calculation.

To boost UCs and agrobiodiversity, empowering farmers is needed, for instance, through projects developing local selling channels and cooperation between farmers. As seen in the case of the Netherlands, farmers are often interested in producing local cereal for shorter value chains, but bakeries and breweries are not yet large or numerous enough (Chapters 4 and 5). In order to stimulate UC growing, the presence of mills, bakeries and other processing facilities, as well as local selling channels (e.g. shared local food producers' shops, open markets) need to be re-created and supported by national and local policymakers, as they are the main selling channels for UCs. Local policymakers have also a role to play in (1) empowering farmers and supporting them in more tailor-made projects for their farm, (2) supporting the creation of local processing and selling companies and facilities, and (3) boosting customers' awareness of the differences between food products that may look similar but vary in quality and economic, social and environmental impacts. Promotion of these alternative selling channels is also a goal of the EU strategy for agriculture, in both the farm-to-fork strategy and the new 2025 vision (Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. A Vision for Agriculture and Food: Shaping Together an Attractive Farming and Agri-Food Sector for

Future Generations, 2025; European Commission, 2020). However, for this to be concretely applied, it requires adapting national food selling and processing regulations to the socio-economic situation of small and medium enterprises (e.g. farms and other food businesses), e.g., regarding safety, noise, smell, area of settlement, and level of taxes on workforce and finished products.

Raising societal awareness of the quality differences between food products is needed, for instance, through specific labelling and in educational programs. In regard to informing consumers, labels for organic products exist; however, more information regarding local products and how products have been produced remains limited for consumers. Tighter connections between customers and farmers (and/or nature) may enable customers to fully understand and connect with their food (Chapter 4). This needs to be accompanied by an increased societal understanding of what biodiversity is, also encompassing genetic diversity in soil and crops. To support future customers to make more conscious choices, a larger emphasis on biodiversity and agriculture in educational programs from kindergarten to university level can greatly support understanding of biodiversity and awareness of agriculture and food production.

6.6 Business recommendations

In light of the various strategies and solutions implemented by the UC farmers and processors encountered for this research, I emphasize recommendations that may benefit farmers interested in growing new crops and potentially UCs. More generally, I highlight how farmers and local processors can also systematically implement some of the solutions in this thesis, in order to increase the resilience of their own business. However, to be implemented by farmers and processors, these recommendations likely need support from policies, such as project coordination and funding. My last recommendation is regarding lenders.

More farmers could be inspired by UC farmers to launch shared projects, increase cooperation and create partnerships between each other. Instead of competition between each other, UC farmers create partnerships with each other and with processors to ease the—mostly local—crop production, processing and selling (Chapters 3 and 4). This could inspire more farmers and processors (e.g. mills, bakers, brewers, malters, local sellers) to develop formal and informal partnerships and shared projects (e.g. cooperative, shared

ownership business model, associations). Positive outcomes encountered in this thesis are more local selling channels for farmers' products and the advantages of such local chains, e.g. better margins for farmers, a boosted local economy for communities, and less transportation needed. Local selling channels can also be developed together with municipalities (e.g. new open markets, producer shops, collective catering projects).

More knowledge sharing between farms as well as with processors can support UCs adoption by more farmers, and more generally, any farm businesses. Growing UCs, similarly to innovative cultivation practices, requires knowledge (Chapter 2) and experience that can be more quickly obtained through knowledge sharing between farmers (EU CAP Network, n.d.). In general, knowledge sharing between farmers as well as processors can greatly boost crop diversification (e.g. farmers can learn from each other how to grow new crops, techniques of intercropping or seed sorting) and, more broadly, the resilience of the farm cropping system by finding quicker solutions to new stressors arising. Networks focusing on sharing knowledge about more environmentally friendly farming practices can also support farmers not to follow the main trend but adopt more locally adapted crops (e.g. UCs) and methods specific to their context (e.g. in terms of rotations, and tillage techniques) and eventually differentiate themselves. Experiments (e.g. using a new UC or a new technique) can be done on a small part of the field to minimize risks at maximum in a first stage.

More farmers could adopt UC farmers' way of thinking to see their farm from a different angle, less influenced by norms and the private interests of suppliers. Spending time to analyze the farm as a whole system, embedded into a natural ecosystem and a socio-economic context, may contribute to decision-making less influenced by private technical advisors or what other farms do, and more tailored to individual farms and farmers, e.g., regarding purchases, investments, agricultural practices and selling strategies. For example, UC farms invest carefully, balancing the advantages of new machinery with the financial risk it represents (Chapter 3). Indeed, machinery is expensive and not always worthwhile if used only once in a while. While mainstream farms often have a large amount of debt, thinking more carefully about investments and how to reduce debts could also enable farmers to ensure more cash flow and, thus, freedom to experiment with new crops and practices. UC farms also minimize external inputs and, consequently, external costs, not following common trends in farming, nor advisory services' recommendations.

In general, UC farmers try to emancipate from advisory services that do not support their financial autonomy and distinguish themselves from the norms. Concretely, they believe that it is not because everyone else operates one way that this is also the best for themselves. More farmers could get inspired by this way of thinking, looking at their farm as a whole system, and deciding for themselves what is best. This point also requires empowering farmers, as low self-esteem was pointed out as an issue constraining them from experimenting with new practices or crops.

More farmers could draw inspiration from the strategies implemented by UC farmers to increase their autonomy from suppliers and retailers. More broadly, farmers as well as processors could try to gain greater autonomy from suppliers and retailers; this way, they could be less reliant on price fluctuations and eventually stabilize their incomes better. In addition, using UCs often implies seed saving, which enables more autonomy from seed suppliers (Chapters 2 and 3). Although seed saving can be challenging for some crops, it can support the autonomy of the farm. Other ways to increase autonomy are the reduction of inputs, the creation of added value locally by implementing local selling channels with fewer intermediaries, and more on-farm processing or further collaboration with other local enterprises. While acquiring more land enables increasing production volume, prices may remain too low compared to the costs of buying land. UC farmers increase farm-level added value through on-farm sales at a higher price. This supports them to escape from the yield maximization logic. Although strategies like giving added value to the crops and selling through fewer intermediaries can be very challenging to implement for farmers, collaborative projects, such as the joint creation of a cooperative that organizes the processing and selling activities, likely increase the feasibility.

More farmers could mirror UC farmers in developing more processing and local selling activities in order to feel better empowered and proud. Bulk production for export is often little rewarding for farmers, and farming is often seen by society as a polluting activity. UC farmers expressed that creating specific quality products through environmentally-friendly farming practices, and being closer to consumers, was rewarding and made them proud of their work (Chapter 3). Increasing the quality of products through environmentally-friendly farming practices, and getting closer to customers could enable more farmers and processors to make sense of what they do, and to boost their pride and

self-esteem. To achieve such changes, farmers need to be supported through policies, such as those mentioned under the policy recommendations.

Lenders need to get to know and be able to lend to entrepreneurs with new business model projects, such as craft brewers or mills. As seen in both France and the Netherlands, access to funding to get started is a challenge for new and small entrepreneurs with food production or processing projects (Chapter 4). Loans, and if possible, specifically adapted (e.g. longer terms) loans for these SME starters, should be accessible. Bankers should investigate further the business models of these alternative enterprises to be able to propose suitable loans to these entrepreneurs. New forms of lending could be thought of, such as (i) partnerships of businesses together that could be financed together as they reflect a resilient chain, or (ii) shared business creation, such as processing facilities for UCs that could be shared by different farms.

6.7 Future research

In this section, I discuss five points. I first point out the lack of data for UC farm and processing businesses. Second, I highlight the need for considering more systematically 'new' indicators regarding business performance and value chain performance. Third, I point out the need for methods that account for UCs' contribution to environmental preservation and social well-being, which have indirect economic impacts. Fourth, I emphasize the importance of studying UCs' performance at a higher level (e.g. territory, local communities) where some of their benefits may be better expressed. Fifth, I outline that research programs aiming at scaling UCs must be envisioned through an integrative thinking, encompassing not solely technical measures but also modification of societal mindsets and institutional adaptations.

In general, more economic data is needed on UC farms and food processing businesses to support economists' understanding of how these businesses operate. Studies similar to the farm management assessment of Chapter 3, but based on panel data over several years, could then bring more insights into the profit stability of UC farms in the long-term. With more economic data on these businesses, which are often small or medium-sized enterprises, finance providers may better understand how these business models work and may be better able to provide finance to future entrepreneurs with similar projects. Regarding agronomic data, more studies on UC yields under different low-input and

abiotic stress conditions, such as the one performed by Korpetis et al. (2023), could enable studying the resilience of UC farms over several years. In order to fully uncover the potential added value of UCs, the nutritional value of these crops has also not been well examined yet. Although these aspects have gained more attention in recent years (André et al., 2024), more data is still needed on nutritional aspects, such as protein and vitamin contents. This would enable more accuracy in determining the value of these crops.

Economic data should be complemented with novel indicators to compare UC farms to mainstream farms through the lens of long-term resilience indicators rather than yearly yield or profit indicators. In mainstream systems, farm yields and margins can vary greatly and are not always correlated because farmgate prices can also largely vary. Instead of optimizing yearly yields or profit, UC farmers strive for resilience in the long run. This drives them to implement long-term strategies, such as diversifying their cropping system or processing their products. These examples could inspire economists to focus more systematically on long-term resilience indicators rather than yearly efficiency indicators. Concretely, indicators such as the stability of the whole farm crop production, the farm margin, and the farm level of debts over several years, show whether a farm business is able to overcome environmental or financial shocks and stresses repeatedly. Additionally, instead of studying the yield per land unit (per hectare) as a measure of efficiency, the yield per energy unit, per external input unit, or regarding the degree of investment made would give better insights into the level of risks taken by the business to run. These indicators may show new insights into both UC and other types of farms and how to improve their resilience level. At the value chain level as well, new lenses, and thus, new indicators, may shed a different light on the performance of value chains from a resilience perspective rather than short-term efficiency. When analyzing the performance of UC value chains, economists could look further into the distribution of profit between the UC value chain actors, taking into account the production costs incurred by each chain actor. Indeed, fairer distribution may contribute to each chain business's survival.

Social and environmentally-friendly practices used by UC value chain businesses also represent an "indirect" economic value (e.g. help preserve the environment through implementing circularity, reusage of materials, or support for the well-being of their community through organizing events). Hence, to fully compare the performance of UC

and non-UC value chains, methods and indicators should attempt to value these “indirect” economic impacts.

This thesis shows that UCs' economic contributions do not only occur at farm or value chain level, but they can also support the local economy by attracting more workers through job creation, or by supporting the tourism sector. In general, there is a contribution of UCs to food autonomy and the local economy of territories. As a consequence, more research is needed (1) on UCs' economic contributions to the territories where they are grown and processed, and (2) on the contribution of the local economy and food autonomy to the resilience and sustainability of these territories.

Scaling UCs, as well as other solutions towards more sustainable agriculture (e.g. agroecology, local food systems), should be envisioned through an integrated roadmap, taking into account scaling-up, -deep, and -out together. This would boost initiatives for agricultural transformation by aligning regulations and individual motivations with these initiatives. While this thesis focuses on the case study of the Netherlands for scaling UCs, similar research in other countries across Europe should also look at initiatives in an integrated way.

6.8 Overall conclusions

The overall conclusion of this thesis is that the functioning of European food systems using UCs is characterized by actors who implement specific practices and decision-making, and share motivations related to society's well-being and environmental preservation. They greatly value resilience, even if it means trying ways outside norms.

The conclusions of this thesis per subobjective (SO) are:

SO1: *To assess the economic performance of UC farms and value chains.*

- UC farms are profitable. Their profitability comes with several specificities. For instance, after their establishment phase, they often operate with low levels of costs, debts and subsidies. Also, profitability is achieved through non-mainstream decision-making; related to increasing farm autonomy, diversity (e.g. in terms of crops, partnerships, finished products, and selling channels), and enhancing nature and local social connections. UC farmers achieve sufficient income levels to support their households (Chapters 2 and 3).

- UC value chains are composed of profitable businesses operating through collaboration, information sharing and long-term partnerships. Instead of competing to optimize individual margins, they support each other so that each partner can stay in business. Their functioning can inspire other value chain actors and new entrepreneurs (Chapter 4).

SO2: *To explore UC farmers and other value chain actors' motivations for using UCs.*

- UC farmers' motivations differ from those of mainstream farmers. For instance, they aim to feed their family and local community with quality local food, to live close to nature, and to contribute to the local economy of their place. Farm profitability is a means rather than an objective (Chapter 3).
- UC value chain actors aim at participating in the food autonomy and local economy of their territories. They do this, among others, through the creation of more local businesses, more collaboration in value chains, and the development of new selling channel opportunities. These contributions represent a significant share of UC actors' motivations (Chapters 3 and 4).

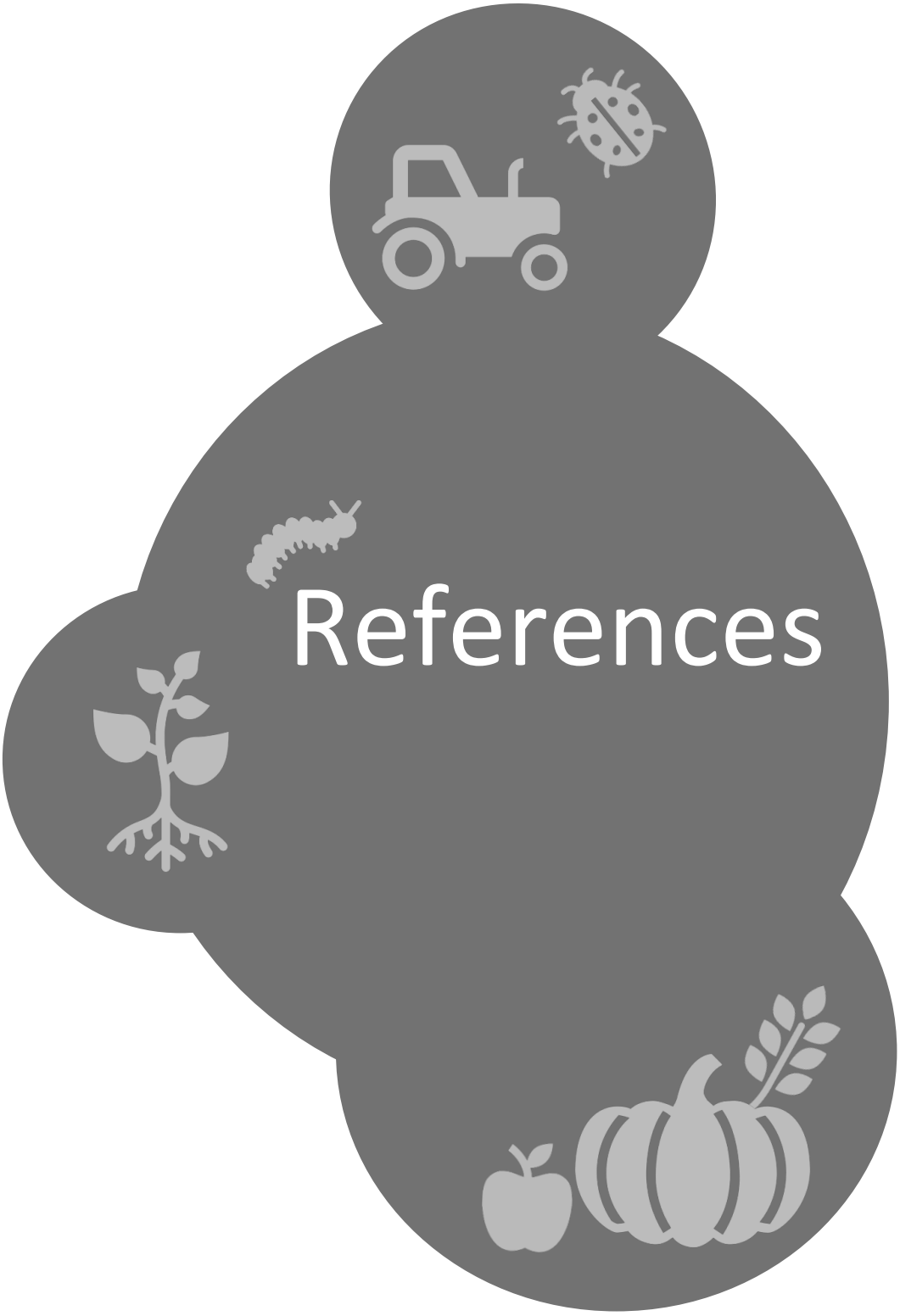
SO3: *To analyze the resilience of UC farms and value chains.*

- UC value chains demonstrate a satisfying level of resilience despite challenges such as unfit policies. They operate through implementing numerous innovative strategies to boost their agency, connectivity and diversity levels. Developing these attributes is key to dealing with shocks (Chapter 4).
- This thesis shows that UCs contribute to resilience aspects. However, economic and social aspects of UCs in Europe have been mostly overlooked by economists until recently. Data and research on economic arguments regarding UCs are sparse and scattered across different disciplines, especially in the European context. When economic analyses are done, they often focus on farms rather than potential impacts on value chains and the local economy, and often look at economic returns rather than at resilience. This thesis contributes to filling this research gap. The contribution of UCs to economic stability and resilience of the farming and food system at different levels is not yet fully uncovered (Chapters 2, 3, and 4).

SO4: *To investigate scaling pathways for UCs.*

- For UCs to be scaled, a space needs to be created in mindsets and in policies for them, their farms and processors. For example, a deeper understanding of biodiversity, but also of the socio-economic contributions of local foods to communities, could support this change in mindsets. Moreover, policies need to take into account more systematically diversified farms and local food SMEs, rather than focusing solely on mainstream value chains (Chapter 5).

- Reintroducing UCs and lifting crop diversity should be done through a plan that integrates education and awareness-raising strategies, policy changes and concrete initiatives for UC growing simultaneously. The large institutional lock-ins and a lack of societal awareness regarding both farming and food processing of UCs currently hold UCs back (Chapters 2 and 5).



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Summary

Summary

This thesis aimed to explore the functioning of European food systems using underutilized crops (UCs). UCs, as genetically diverse and locally adaptable crops, have been identified as potential contributors to more sustainable food systems. For example, through diversifying farms and due to their good adaptability to various environments, they may support farms and value chains' resilience, especially in the face of climate change. The literature on UCs and, especially, economic aspects related to UCs is dispersed across different disciplines, which impedes possibilities to get a full picture of their potential challenges and contributions in European contexts. Additionally, little information is available on the farm management and performance of the farms using UCs. Similarly, at value chain level, the processing and marketing of UCs are little reported in the literature. Last, although scaling UCs may benefit the resilience of food systems, it appears that unlocking these potential benefits depends crucially on how UCs are scaled. The overall objective of this thesis was broken down into four sub-objectives, each covered by various chapters.

In Chapter 2, the scientific literature on the economic aspects of UCs in Europe was scoped by categorizing findings into three levels: farm, value chains and communities, and by looking at opportunities and challenges. At farm level, the economic performance indicators of yield, price, costs, profit and risks were investigated in further detail. Additionally, social and institutional aspects impacting the economic performance of UCs were reported as opportunities and challenges. Fifty-five papers were found. Results showed that UCs mostly related to specific farm types, i.e. with agroecological or low-input practices, and mostly involved local selling. Some UC farm characteristics repeated across the literature were lower input costs, moderate but stable yields, low production risks, sometimes relatively high selling prices and higher market independence. However, the literature reported challenges, e.g. farmers faced difficulties in accessing UC seeds and UCs were mostly commercialized outside of mainstream food systems due to incompatibility with crop registration rules and standardization requirements. To stimulate wider adoption, releasing UCs from their informal status and supporting bottom-up initiatives of producing UCs appeared essential to widen their use and eventually contribute to development paths towards more sustainable and resilient food systems.

In Chapter 3, the farm management of UC farms was analyzed. The farm structure, farmers' goals and decision-making, farm performance, and farmers' perceived resilience and challenges were investigated for 17 farms using UCs in France. Values found for structure and performance indicators were compared with data from the Farm Accountancy Data Network (FADN) for the same farm production, regions and year. Interviewed UC farmers often had specific goals, e.g. they wanted to contribute to the local economy and food autonomy. Decision-making focused on boosting farm autonomy through seed saving, using little inputs, and on-farm processing. The studied UC farms were profitable with moderate levels of debt, and farmers considered their income sufficient to support their households. Outputs were usually valorized through direct sales and short chains. Overall, interviewed UC farmers deemed their farms resilient but still faced challenges, such as limited know-how and limited access to seeds when starting with new UCs. It appeared that more effort was needed to integrate UCs effectively into EU policy frameworks such as the Farm-to-Fork strategy.

In Chapter 4, the resilience of three value chain case studies using UC cereals was investigated in Scotland, France and the Netherlands. Via semi-structured in-depth interviews with the main chain actors, it explored how actors of these chains build resilience of their business and the value chain as a whole, through the four resilience attributes of agency, buffering, connectivity and diversity. Results showed a strong agency, observed through actors' knowledge and skills to save natural resources and implement circularity. Buffers were limited, e.g., regarding workforce or cash flow. Connectivity materialized through tight partnerships to jointly manage transportation, price setting or quality and quantity variations in harvest. Diversity was observed through enhancing farm-level agrobiodiversity, cultivating several crops next to cereals, saving different UC varieties per cereal species and developing different finished products sold in multiple places. As a conclusion, both farm and post-farm stages of UC chains were configured based on principles of resilience. These chains provided practical examples to configure other resilient value chains and may inspire the modification of mainstream chains.

In Chapter 5, the scaling of UCs in the Netherlands was explored by considering three types of scaling: scaling deep (farming systems can be redesigned by changing institutions, rules, and policies), up (changing narratives, beliefs and ideas), and out

(replicating successful initiatives and tools across different contexts or regions). Through two workshops with different types of local actors using UCs, it performed a SWOT analysis of the current situation, then explored a future desired situation for UCs in the Netherlands. Results showed mismatches between farm and food policies and UC production and processing, and a lack of societal awareness. Yet, active networks and field initiatives demonstrated that knowledge for producing UCs still exists. The desired future situation for UCs was characterized by (i) regulations specifically adapted to fit UC farms and processors, creating a favorable entrepreneurial environment for local food systems, (ii) societal knowledge on UCs, with media spotlighting UCs and crop diversity and educational programs emphasizing on UCs at different levels, (iii) an outreach organization helping farmers learn about seed saving and access seeds through shared facilities, paying with seeds they have produced.

The main conclusions are:

1. The overall conclusion of this thesis is that the functioning of European food systems using UCs is characterized by actors who implement specific practices and decision-making, and share motivations related to society's well-being and environmental preservation. They greatly value resilience, even if it means trying ways outside norms.
2. UC farms are profitable. Their profitability comes with several specificities. For instance, after their establishment phase, they often operate with low levels of costs, debts and subsidies. Also, profitability is achieved through non-mainstream decision-making; related to increasing farm autonomy, diversity (e.g. in terms of crops, partnerships, finished products, and selling channels), and enhancing nature and local social connections. UC farmers achieve sufficient income levels to support their households (Chapters 2 and 3).
3. UC value chains are composed of profitable businesses operating through collaboration, information sharing and long-term partnerships. Instead of competing to optimize individual margins, they support each other so that each partner can stay in business. Their functioning can inspire other value chain actors and new entrepreneurs (Chapter 4).

4. UC farmers' motivations differ from those of mainstream farmers. For instance, they aim to feed their family and local community with quality local food, to live close to nature, and to contribute to the local economy of their place. Farm profitability is a means rather than an objective (Chapter 3).

5. UC value chain actors aim at participating in the food autonomy and local economy of their territories. They do this, among others, through the creation of more local businesses, more collaboration in value chains, and the development of new selling channel opportunities. These contributions represent a significant share of UC actors' motivations (Chapters 3 and 4).

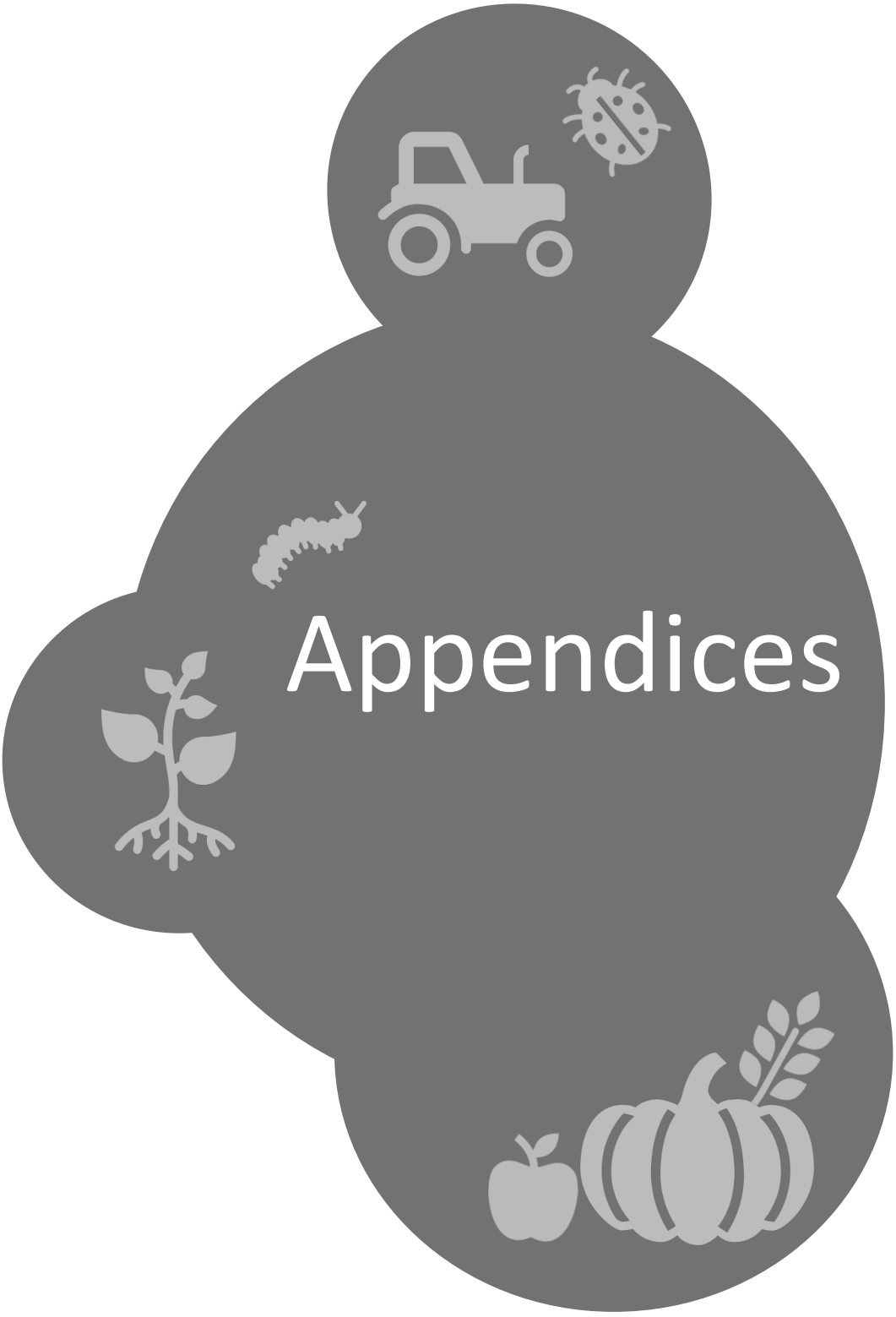
6. UC value chains demonstrate a satisfying level of resilience despite challenges such as unfit policies. They operate through implementing numerous innovative strategies to boost their agency, connectivity and diversity levels. Developing these attributes is key to dealing with shocks (Chapter 4).

7. This thesis shows that UCs contribute to resilience aspects. However, economic and social aspects of UCs in Europe have been mostly overlooked by economists until recently. Data and research on economic arguments regarding UCs are sparse and scattered across different disciplines, especially in the European context. When economic analyses are done, they often focus on farms rather than potential impacts on value chains and the local economy, and often look at economic returns rather than at resilience. This thesis contributes to filling this research gap. The contribution of UCs to economic stability and resilience of the farming and food system at different levels is not yet fully uncovered (Chapters 2, 3, and 4).

8. For UCs to be scaled, a space needs to be created in mindsets and in policies for them, their farms and processors. For example, a deeper understanding of biodiversity, but also of the socio-economic contributions of local foods to communities, could support this change in mindsets. Moreover, policies need to take into account more systematically diversified farms and local food SMEs, rather than focusing solely on mainstream value chains (Chapter 5).

9. Reintroducing UCs and lifting crop diversity should be done through a plan that integrates education and awareness-raising strategies, policy changes and concrete

initiatives for UC growing simultaneously. The large institutional lock-ins and a lack of societal awareness regarding both farming and food processing of UCs currently hold UCs back (Chapters 2 and 5).


Appendices

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I would like to say a big thanks to the farmers and local actors who agreed to be interviewed or participated in my workshops for this research. This thesis is largely built on their inputs. Beyond this thesis, their vision and experience will remain a personal enrichment.

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My last word goes for my old and far away friends, as well as family, including my 'adopted' family members.

List of publications

Publications in refereed journals

Marie-Fleur E Nguyen Brémaud, Yann de Mey, Miranda P M Meuwissen, The Economics of Underutilized Crops in Europe: a Scoping Literature Review, *WJSA-Agroecology and Sustainable Food Systems*, pp. 1-35, 2026. http://dx.doi.org/10.1080/21683565.2026.2626312

Marie-Fleur E Nguyen Brémaud, Yann de Mey, Miranda P M Meuwissen, Uneconomic hobby or pursuit of autonomy? Exploring the farm management of underutilized crop farms, *Q Open*, Volume 5, Issue 2, 2025, qoaf031, https://doi.org/10.1093/qopen/qoaf031

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Styles, D., Bassignana, C., Bortolazzo, E., **Brémaud, M.-F.**, Debeljak, M., de Mey, Y., Migliorini, P., Saget, S., Williams, M., & Vasconcelos, M. W. (2022). Conceptual framework for holistic sustainability and resilience analysis of multifunctional value chains - Deliverable 4.1. Zenodo. https://doi.org/10.5281/zenodo.7032291.

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Gelderland. (24/04/2025) Vergeten gewas zonder bestrijdingsmiddelen: wetenschappers en boeren praten erover [Press release] https://www.gld.nl/nieuws/8300975/vergeten-gewas-zonder-bestrijdingsmiddelen-wetenschappers-en-boeren-praten-erover.

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Yann de Mey (24/04/2025) Vergeten gewassen [staring at 1:14:30], Goedemorgen Gelderland, https://www.gld.nl/radio/aflevering/goedemorgen-gelderland/295690

Marie-Fleur Brémaud
Wageningen School of Social Sciences (WASS)

Completed Training and Supervision Plan



Name of the learning activity	Department/Institute	Year	ECTS*
A) Project related competences			
A1 Managing a research project			
WASS PhD Introduction	WASS	2021	1
Systematic approaches to reviewing literature	WASS	2022	4
'Literature review on economics of UCs'	European Association of Agricultural Economists (EAAE), Rennes, France	2023	1
'*Assessment of UC farms' functioning'*	PhD workshop Budapest, Hungary	2024	1
'Beyond monoculture: how do UC farms operate and perform?''	Lighthouse Farm lab workshop 'Beyond monoculture'	2024	1
'Resilience assessment of UC value chains'	EAAE Bonn, Germany	2025	1
'Crop diversity towards resilience'	MBA Food & Agribusiness track	2026	1
BEC PhD meetings	BEC	2022-2024	1.5
Writing PhD research proposal	WASS, BEC	2021-2022	3
Scientific writing	Wageningen in'to Languages	2023	1.8
Intensive writing week	Wageningen in'to Languages	2024	1
A2 Integrating research in the corresponding discipline			
Presentations at Radiant consortium meetings (Porto 2021, Chania 2022, Dundee 2023, Turin 2024, Porto 2025)	Radiant project	2021-2025	1
Summer school - Risk analysis and risk management in agriculture: updates on modelling and applications	WASS	2022	3
Advanced qualitative research design and data collection methods, GEO 55804	WUR	2024	6
From business theory to practical applications	WASS	2024	2
B) General research related competences			
B1 Placing research in a broader scientific context			
Academic publication and presentation in the social sciences	WASS	2022	4
Effective and efficient communication in academia and beyond	WGS	2022	0.9

B2 Placing research in a societal context			
Making impact: increasing the relevance of research through science-society interaction	WGS	2022	1
Scientific artwork, data visualisation and infographics with Adobe Illustrator (online training)	WUR Library	2022	1.2
Participatory plant breeding & resilient seed systems: options for stakeholder engagement and benefit sharing	PE&RC	2023	2
C) Career related competences/personal development			
C1 Employing transferable skills in different domains/careers			
Teaching (Financial management in agriculture, BEC20806)	BEC, WUR	2022	1
Teaching (Analytics for business economics, BEC30306)	BEC, WUR	2023	0.5
Participation in 4TU methodology workshop (Transdisciplinary approaches for co-producing resilience assessment)	4TU	2024	0.5
BSc. student thesis supervision	BEC, WUR	2025	1
Career orientation	WGS	2025	1.5
Total			**42.9**

*One credit according to ECTS is on average equivalent to 28 hours of study load.

About the author



Marie-Fleur Nguyen Brémaud was born in Lyon, France, and grew up close to nature and farms. First in the North East, then in the South West of France, and developed there her passion for nature, farming, and a lively countryside.

After two years of preparatory school in biology at Sainte Geneviève, Versailles, she entered the National Engineering School of Agronomy in Montpellier. Her Erasmus semester at the Technical University of Munich and her internships on farms, as well as her research in New Zealand and Vietnam, gave her a taste for working in international environments. Looking to develop a strong technical background, she specialized in statistics in her last year of her Master's. Thanks to this program, she graduated with a double degree as an Engineer in Agriculture and Statistics.

Afterwards, realizing that she was also truly interested in qualitative methods and a deep understanding of the farming field, she enrolled in an international Erasmus Mundus Joint Master's programme in the field of sustainable territorial development, where agriculture, environmental and social aspects were addressed, as well as geography and economic components. This fully funded two-year program, divided between Padova University, KU Leuven, Paris Sorbonne, and with a summer school at Johannesburg University, greatly motivated her to focus more on the socio-economic dimensions of environmental and agricultural issues. Thanks to this experience, she graduated with a double degree in Applied Economics from Paris Sorbonne and in Geography from KU Leuven and Padova University.

After a short period working in France at an environmental consultancy company, she went abroad again to start a PhD in Agricultural Business Economics at Wageningen University and Research (WUR), within the Business Economics Group (BEC). Since 1 March 2026, she is postdoc at Utrecht University at the Copernicus Institute of Sustainable Development. Her position focuses on governance models for financing ecosystem services and is part of the programme for regenerative agriculture in the Netherlands (ReGeNL).

For any questions regarding the content of this thesis, she can be reached by email at marie-fleur.bremaud@gmx.com.

Colophon

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