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The benefits of the dairy value chain to inclusive sustainable development in European highlands: a systems thinking approach

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Abstract

This research investigates the benefits of the dairy value chain beyond food provision, and its contribution to inclusive sustainable development (ISDH) in European highlands. Transdisciplinary teams interviewed and analysed 11 cases related to the dairy value chain sourced from three highland regions in Europe: Alps (Austria, France, Italy), Massif Central (France), Pyrenees (Spain). Actors interviewed were farmers, cooperatives, retailers and associations. A systems thinking approach was applied to develop a conceptual map (Causal Loop Diagram, CLD) describing the contribution of the dairy value chain to ISDH, through the interpretation of the viewpoints of interviewed actors. For each case, the factors contributing to ISDH were identified, then clustered within related topics. Topics from all the cases were used to develop a CLD, and subsystems and leverage points identified. Six interconnected subsystems were identified: local resources, environment, dairy production, collaboration, supply chain and socio-economic. Four leverage points were also identified: public subsidies, feed autonomy, certification of product, and added value. In conclusion, the dairy value chain provides the following benefits aligned with the dimensions of ISDH: landscape maintenance and ecosystem services, quality of dairy products and added value, inclusive governance for actors, reduction of environmental impact, and local development. This model delivers a decision-making tool for the actors involved in the dairy value chain, to prioritise strategic interventions.

Keywords Causal loop diagram, Dairy systems, European highlands mountain areas, Inclusive sustainable development

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Introduction

Highland regions are vital for humanity, due to the ecosystems they host and the multiple goods and services they provide [1]. They cover 24% of the world's land surface [2] and are inhabited by 13% of the world's population [3]. Mountains constitute an ecological backbone in the European region, covering 36% of the land area, providing essential ecosystem services, and are inhabited by 17% of the European population [4]. Highlands are a geographic, economic and social entity in which the relief, climate, natural and cultural heritage require the implementation of specific development policies [5, 6]. This is recognised by the European Commission Policies and the European Parliament on Cohesion Policy Resolution, which note the requirement for models of Inclusive Sustainable Development in many mountain areas [7]. Inclusive Sustainable Development within Highlands, may be defined as promoting wellbeing, reducing inequalities and ensuring the long-term viability of economic, social and environmental systems [8]. A principle is that the benefits of economic growth must be shared broadly, leaving no one behind and where all groups of people contribute to create opportunities, share the benefits of development and participate in decision making, while meeting the needs of the present without compromising future generations [9, 10].

In European mountain areas the dairy sector provides several positive externalities that align with ISDH, such as the maintenance of landscape with high aesthetic and natural value, carbon sequestration, economic benefits, high-quality dairy products, and plant species biodiversity [11–13].

However, the dairy value chain in mountain areas is exposed to multiple challenges. Climatic and morphological conditions limit the economic profitability, with lower yields and higher production costs than in the lowland [14]. The main effects of this lower economic viability are the abandonment of land and traditional low-input farms [15], leading to a loss of open areas, forest regrowth [11], and loss of biodiversity [16, 17], also accompanied by socio-economic changes [18].

Given the interconnected benefits and challenges, the dairy value chain in mountain areas can be viewed as a complex system. Understanding its variables and their relationships is fundamental to describing the contribution of the dairy value chain to ISDH. Systems thinking is an approach that can enable the description and exploration of complex systems to identify their behaviour, and points of leverage, where a small change or action can lead to significant and lasting shifts in behaviour, structure or outcomes [19, 20]. The purpose of this paper is to describe a representation of the dairy value chain system and its dynamics, which underlie its contribution to ISDH, and to identify leverage points that will enhance the system.

Methodology

This research was conducted under the framework of the HIGHLANDS.3 project (H2020, MSCA-RISE), whose main goal is to contribute to ISDH through collective and impact-driven Research and Innovation, based on capacity building, and sharing of local-global knowledge, experience, and ISDH tools. Three European Research and Innovation sessions (R&IS) were conducted during 2021 and 2022: *Alps (Austria, France, Italy), Massif Central (France), and Pyrenees (Spain)*. Each session provided a learning environment for the participants through an opportunity to engage with diverse place based sustainable development initiatives, while working in a transdisciplinary team. Twenty to thirty initiatives for each R&IS were selected by local organisers of the session. The initiatives were chosen to provide a diversity of sustainable business within the highland environment, permission to be interviewed was a prerequisite, and location was a constraint (i.e. initiatives should be no more than two or three hours away from the R&IS accommodation). The data platform holding all the initiative interviews from across the R&IS was interrogated and those initiatives (11) related to the dairy value chain were chosen to perform a systems analysis (Table 1; Fig. 1). These initiatives all had in common production of dairy products albeit at different scales from individual farms to cooperatives of farms and processing factories, with the objective of adding value. The production was reliant on local forage resources through pasture-based grazing or locally produced grass-based feed.

Data collection

Data from each initiative was obtained through semi-structured interviews, lasting one to two hours, aimed at obtaining information related to the different dimensions of inclusive sustainable development. Such dimensions included: types of employees (youth, gender, disability), governance model, financial viability, relationship with community, interaction with local natural resources, relationship with mountains and impact on the environment. Interviews and analyses were conducted by transdisciplinary teams of up to five people from different disciplines (e.g. nature conservation, farming, social science, agricultural science and extension). Actors interviewed were farmers, cooperatives, retailers and associations. The data was captured in a spreadsheet, an interview audio recording and a report compiled after the interview and stored on a data platform.

Table 1 Dairy value chain initiatives interviewed

Region	Initiative	Short description
Massif Central	Cooperative organic dairy farms	Dairy production is from cows, the production is organic using sustainable practices, the cows are fed on local pasture which gives the product its quality. Financial support comes from public funding. The workforce is family and local.
Massif Central	Cheese factory	Focus is on production of certified cheeses, made with cow's milk from local producers. They contribute to regional development by creating direct and indirect jobs and aim to include more female employees to achieve gender equality. Financial support comes from public funding.
Massif Central	Consortium of PDO (Protected Designation of Origin) cheese	Traditional production of PDO cheeses from cow milk, acquiring added value. Producers are organised in cooperatives and associations, contributing to local development and local economy.
Pyrenees	Cheese factory	The owners themselves are in control of the supply chain, from production of cow's milk from local feed to sale. The products are sold in different markets. Half of their employees are women. Technical training is provided every year. They have their own financing.
Pyrenees	Non-profit organisation	The focus is on social inclusiveness generating employment for people with different types of disabilities and improving people's quality of life. Activities include the production and marketing of cow sourced dairy products.
Pyrenees	Family-run farm	They produce milk and meat; the cows are fed on quality local pasture. They have invested their own capital, and all members of the family participate in the supply chain from production to direct sales.
Alps	Association of dairy producers	Consists of farmers who produce cheese in the traditional way. They use an indigenous breed of cows fed on hay from local pastures, thus contributing to the maintenance of the landscape. All members also receive public subsidies.
Alps	Dairy cooperative	Dairy products are sourced from cows certified with PDO and sold to various markets. The cows are grazed on local pastures and home-grown feed.
Alps	Dairy cooperative	Local producers of cow milk cheese varieties. The production is carried out in a traditional way, the animals are fed on local pastures, which makes it possible to obtain high quality cheeses. Tourism allows the products to be widely marketed in different markets.
Alps	Family-run farm and agro-tourism	The family raise endangered local cows that feed on local pastures, along with local breeds of goats. Participation in agro-tourism provides a complementary market activity. The labour force is family-based. They receive support from public funds.
Alps	Dairy cooperative	Management of local summer farms for the production of high quality traditional cow cheese varieties. Agro-tourism is in operation on these farms. Women play an important role in the governance of the cooperative and in the work.

Analysis

Two transdisciplinary month-long workshops using a Systems Thinking approach [19] were held, one in 2023 and the second in 2024. The data from the 11 initiatives was used to undertake an analysis of the contribution the dairy value chain makes to ISDH in European mountains. The following question guided a systemic analysis, "What are the factors and relationships that describe the dairy value chain's contribution to ISDH?". To address this question, in workshop 1, each of the 6 participants read the report of each of the eleven initiatives, and when necessary, further clarification was sought from the other material associated with the interview. The research team interpreted the perception of the interviewers, as only one of the workshop participants was part of the teams who conducted the interviews. Participants concisely described the factors of each initiative one factor per sticky note, sharing with the whole team. The team clustered the factors into themes, giving each a concise title, and then looked across the initiatives to identify common themes that were used to form a regional CLD. A CLD is a visualisation of a set of variables and their relationships depicting the behaviour of a system as interpreted by the constructor, in this case the transdisciplinary team. Variables are connected through arrows that, at their head, will have either an "S" or "O" symbol representing directionality (i.e. "S" moving in the same direction, "O" moving in an opposite direction). A feedback loop occurs when the arrows leave and return to the same variable. The loop is defined as a reinforcing loop (R) or a balancing loop (B). Reinforcing loops are feedback systems that reinforce the direction of change, they can be vicious or virtuous depending on the context. Balancing loops seek stability, return to control or aim for a specified target (e.g. a thermostat). An integrated CLD, that merged the three regional CLDs, was then developed. This provided a visualisation of the system dynamics underlying the contribution of the dairy value chain system to ISDH. The software VENSIM (Version 10.1.5 Ventana System UK Ltd) was used to present the CLDs. Feedback loops were checked and subsystems identified and named. Points of leverage for system change were identified in the integrated CLD by exploring the impact of variables throughout the system.

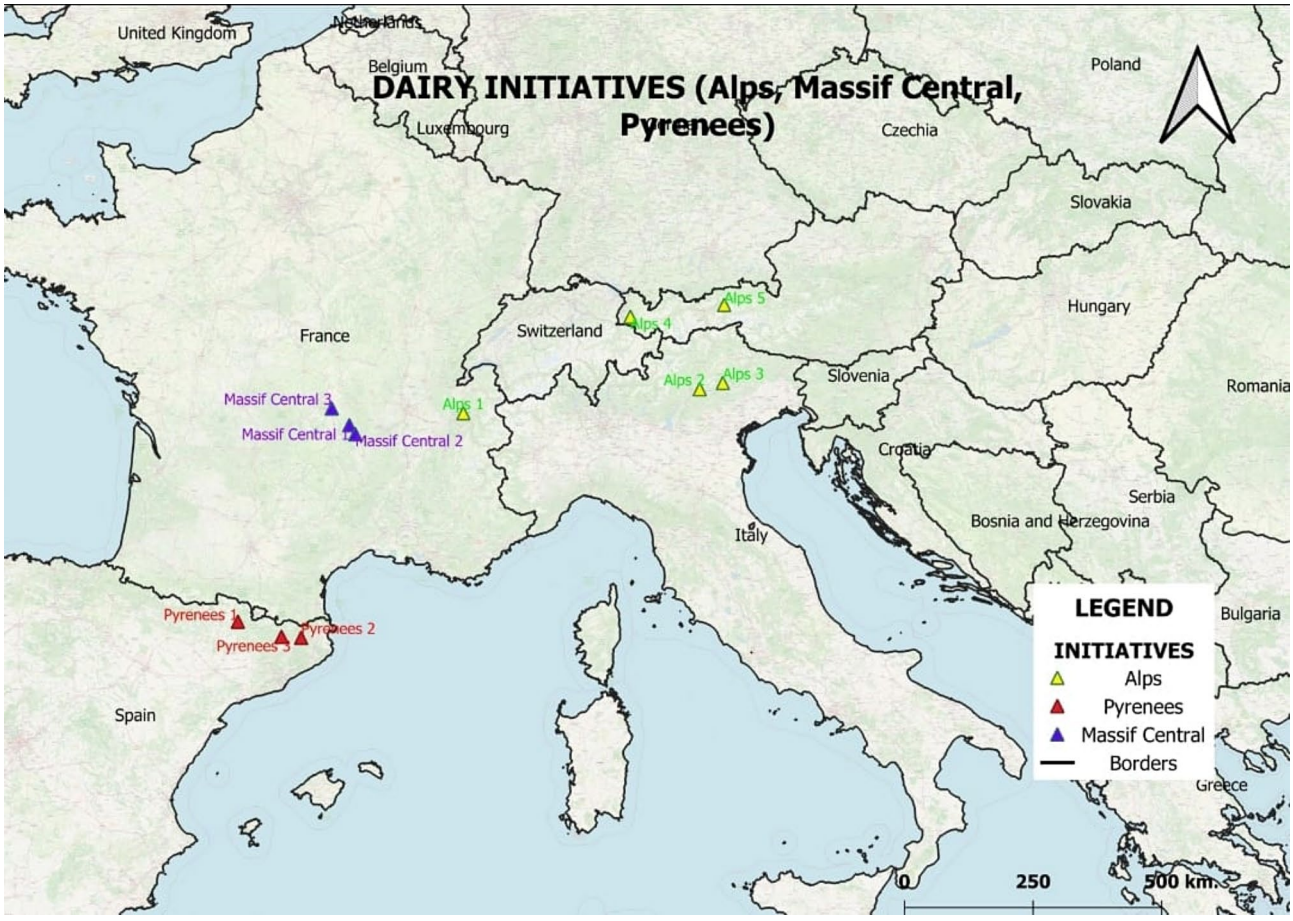

Fig. 1 Map of location of the 11 cases Alps, Massif Central and Pyrenees

Results

Subsystems

The integrated CLD describing the system of the dairy value chain's contribution to ISDH consisted of six interconnected subsystems (Fig. 2). The narrative describing the system is framed in a positive or growth direction.

Local resources

The use of local breeds, together with local feed sources, highlighted the link with the territory of the dairy value chain and increased feed autonomy, enhancing the local scale of the dairy production. There cannot, however, be unconstrained growth of local dairy production.

as there is a biological limit to local feed autonomy, and as local dairy production increases, the pressure on production of local feed increases, decreasing the availability of local feed, forming a balancing loop.

Environment

The ability to produce locally, combined with public subsidies from the European Union (EU) and National Agricultural Schemes, benefits landscape maintenance. Consequently, different ecosystem services are generated, attracting tourists to the territory and providing opportunities for additional activities such as agrotourism. The resultant market diversification increases the added value of the dairy value chain. However, an increase in numbers of agritourists may result in a decrease in environmental services (e.g. pollution of water sources, and crowded landscapes), forming a balancing loop.

Dairy production

The local dairy production, resulting from the use of local resources combined with traditional practices, improves the quality of dairy products. This, together with specific training for employees through technical public support, leads to specialised cheese production, giving the opportunity to obtain a specific certification. The certification labelling reinforces the producers' pride, enhances the promotion of dairy products in markets and enables diversification. The added value of the production is increased, encouraging the local scale of action of the dairy value chain, therefore reinforcing the system. The reinforcing cycle of continuous growth for local dairy production is countered by a balancing loop due to the limits on feed autonomy.

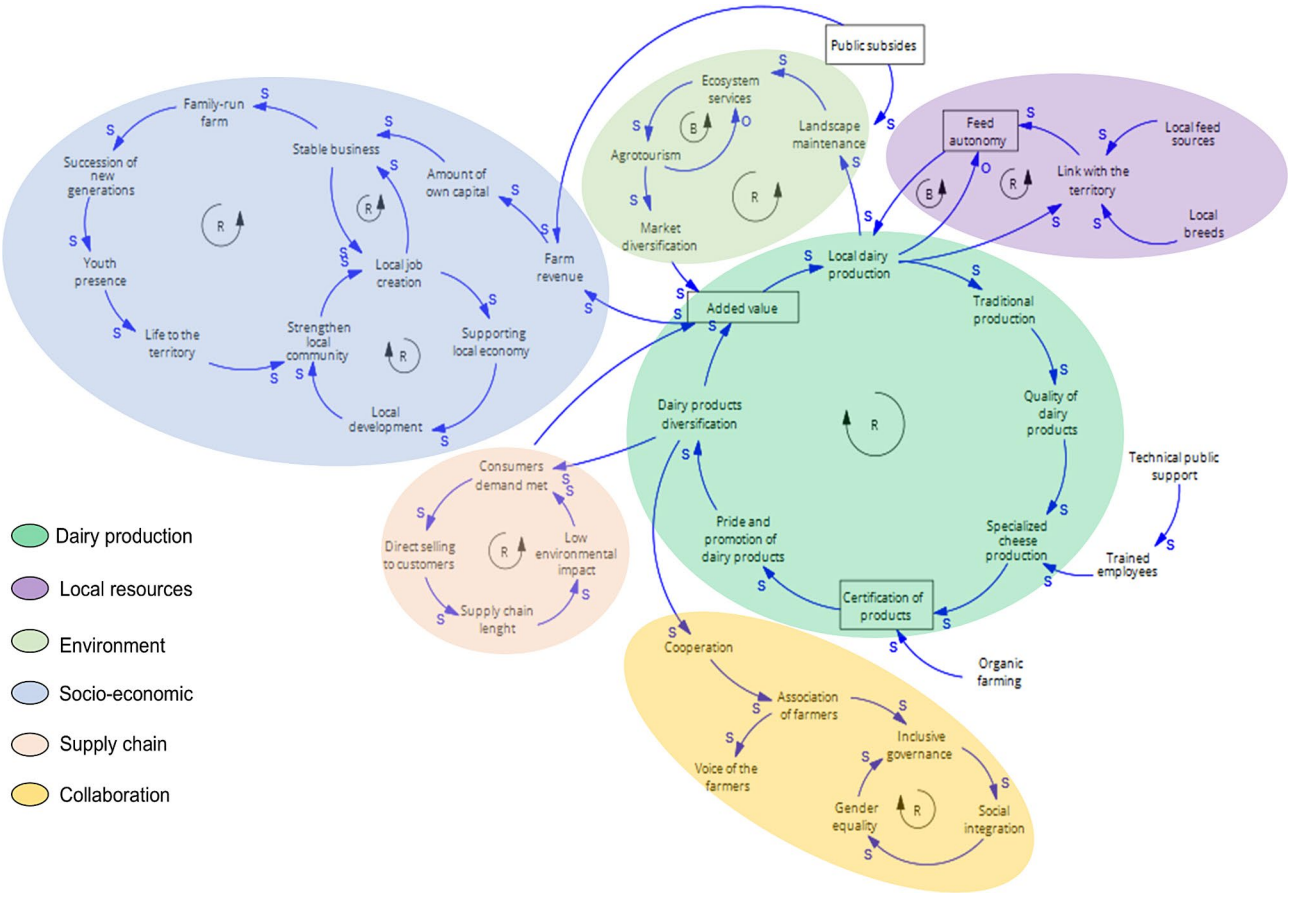

Fig. 2 Integrated Causal Loop Diagram describing the dairy value chain's contribution to inclusive sustainable development in highland. *R* Reinforcing Cycle, *B* Balancing Cycle, *S* moving in the same direction, *O* moving in the opposite direction. Leverage points are enclosed in a box

Collaboration

Dairy product diversification increases the cooperation along the dairy value chain. Farmers are therefore encouraged to form local associations of producers, acquiring a stronger voice when interacting with policy makers. This cooperation enables them to adopt inclusive governance strategies, enhancing their social integration and gender equality along the dairy value chain, reinforcing inclusive governance.

Supply chain

More added value is also generated when consumer demand is met. This happens when the supply chain is short because of the direct selling into local markets. A short supply chain also reduces the environmental impact of greenhouse gas emissions due to shorter product transportation length, contributing to further meeting consumer demand.

Socio-economic

The increased added value to dairy products, generated from diversified dairy production, market diversification and short supply chain, increases the revenue of farmers and their financial capital. The economic stability of the dairy value chain is supported, strengthening the family-run farms involved in the production system. The family scale of action encourages the younger generation within the family to be involved in the business, increasing the presence of youth in the territory. This higher vitality creates a virtuous cycle, strengthening the local community, enabling local employment, and stabilising the local businesses. The family scale of action is reinforced, giving the opportunity to create more local employment. Consequently, the local economy is supported, reinforcing local development and strengthening the local community.

Leverage points

The following leverage points were identified by exploring the integrated CLD for those variables that, when changed, would have system wide influence: **Public subsidies**, through direct influence on how land is managed and farm revenue; **Feed autonomy**, influences the success of the whole system based on local feed sources; **Certification of products**, recognizing the value of the dairy products and engendering pride in farmers; **Added value** influences the whole

system when the benefits are captured by the family farms.

Discussion

Our approach confirms and adds to the knowledge of previous studies that the dairy value chain contributes to ISDH, through the delivery of multiple benefits beyond food production. Contributing to the long-term viability of environmental systems are the landscape maintenance and ecosystem services generated through the use of local forage resources and local breeds. The added value obtained from quality local production and specialised dairy products such as cheese and yoghurt, enhance not only farm household profitability but creates flow on positive financial benefit to local business, thus enhancing long term viability of the economic system. Inclusive governance in cooperative decision making and the diversity of gender and youth present in the system aligns well with the aim of ISDH to reduce inequality. The systemic approach to exploring the contribution of the dairy value chain to ISDH demonstrates the interconnections and relationships between the dimensions of ISDH. The CLD makes transparent the dimensions of ISDH as represented by the subsystems. Enhancing the behaviour of each dimension is reliant on understanding the interconnections between them (i.e. the behaviour of the whole system between different scales, interests and sectors). In comparison, previous research analysed the sustainability of the dairy value chain in mountain areas focusing on its separate entities, farms and dairy cooperatives [15, 21] or the production chain of specific types of cheese [22, 23].

The conceptual model developed here, can be used to identify the relationships between the factors and the subsystems, and the resulting cycle behaviour (reinforcing, balancing virtuous and vicious). For instance, the dairy value chain system represented in the CLD is currently virtuous, as an excessive growth in its production is balanced by the linkage with the feed autonomy. This is in line with Battaglini et al. [12], that found forage self-sufficiency influences the quality of dairy products, strengthens the link with the territory, and imposes limits on livestock intensification.

The CLD enables the identification of leverage points, where interventions may be targeted to generate system-wide impacts via reinforcing cycles, that can enhance a positive and mitigate a negative cycle. The levers identified here enter the system through different subsystems e.g. ensuring local feed autonomy enhanced through public policy interventions, attainment of certification and pricing for added value. By targeting the whole system rather than focusing on one subsystem outcome ensures that resources are used effectively and efficiently for the benefit of the multiple benefits accrued from the system. This perspective allows the analysis of the entire system in its complexity, as recommended by the Animal Task Force vision paper for the livestock systems in Europe [24].

This conceptual model could be used by a range of actors who act at different scales and want to influence the activity in mountain areas. Consequently, by adopting the model, these actors would be able to identify relevant interventions to implement, to achieve the best effects possible, and evaluate the impacts throughout the system enabling the identification of unintended negative consequences.

The construction and exploration of the dairy value chain system for different contexts will require all the influencing actors to be present. This enables transparency through exposing world views and assumptions, reaching consensus on system representation and collective agreement on points of leverage and actions for positive change. A limitation of this study was that the construction of the CLDs was limited to an interpretation of the actors' view, as expressed in the initiatives' interviews and then interpreted by the CLD construction team.

The CLD can be used as a diagnostic method by stakeholders, local actors and policy makers to form targeted policies so that the major issues related to ISDH are addressed. For example, public entities like the EU and local government authorities (national, regional and municipalities) could use the conceptual model to guide the design of laws and regulations, such as verifying the consequences of varying public subsidies given to the farmers for the ecosystem services they provide. This model will be of interest to rural planners, in their design of rural development programmes, while farmers can explore and test future scenarios and challenges [25].

Conclusion

The conceptual model, developed through the interpretation of the viewpoints of interviewed actors, revealed the potential of the dairy value chain to deliver multiple benefits beyond food production that contribute to the different dimensions of ISDH. These benefits include landscape maintenance and ecosystem services, quality of dairy products and added value, inclusive governance for actors, reduction of environmental impact, and local development. This conceptual model enables the understanding of the complexity of the dairy value chain, by identifying factors contributing to ISDH and their interconnections. It offers insights into the intended or unintended consequences of decisions made in a dynamic system. This model delivers a decision-making tool for the actors involved in the dairy value chain, through using the leverage points to prioritise which strategic and

integrated policies and interventions have the potential to strengthen the dairy value chain in highlands.

Abbreviations

CLD Causal Loop Diagram
EU European Union
ISDH Inclusive Sustainable Development in Highlands

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Author contributions
All authors except E.S. contributed to the analysis. Authors A.C., C.P., C.B., A.S. and L.W. prepared the manuscript text, figure and tables. Authors E.S., P.S., J.F.T. and M.V. reviewed the manuscript.

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Data availability
According to the HIGHLANDS.3 project data collection policy and the information we gave to our interview partners, the only information that will be open accessible is the "ISDH platform". This platform is still under construction.We ensure all the data used in reporting is anonymized, and we do not provide access to data that could potentially reveal the identity of respondents.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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