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# SOCIO-ECOLOGICAL RESILIENCE IN SMALLER COMMUNITIES – A CASE STUDY OF A RURAL HUB IN SWEDEN

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**Abstract**

Amid growing global uncertainty, including war, extreme weather events, and resource instability, self-sufficiency and resilience become crucial. Socio-ecological resilience refers to the capacity of communities to regenerate ecological systems while fostering social cohesion and adaptability. This study aims to establish mechanisms contributing to socio-ecological resilience in a rural setting. A qualitative case study approach is employed, with data collection through interviews, site visits, and document reviews. The case is a Rural Resilience Hub in Southern Sweden with a network of interconnected self-sufficiency initiatives contributing to both resilience and sustainability. The hub currently hosts a supermarket, a café, library services, elderly care facilities, art gallery, social and meeting spaces, and sports facilities. Planned activities include a circular system with locally produced solar electricity, aquaponic fish farming, tomato cultivation, and biofuel generation. Another circular initiative is the adaptive reuse of a vacant school building for short-term accommodation, with potential use as a crisis shelter. These creative efforts are aligned with circular economy, adaptive capacity and known social sustainability impacts, such as generating local employment. By reimagining infrastructure and embedding resilience in everyday life, the hub unlocks possibilities for empowerment and self-sufficiency. The study provides a grounded example of socio-ecological resilience in an uncertain world.

*Keywords:* circularity; community empowerment; integrated local systems; rural hub; socio-ecological resilience.

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## 1. Introduction

Global society is entering a period marked by profound and intersecting uncertainties [1–3]. Recent assessments highlight state-based armed conflict as the most immediate global risk, reflecting rapidly intensifying geopolitical tensions and fragmentation across regions [4]. At the same time, extreme weather events, including storms, floods, heatwaves, and other climate-related hazards, are identified as among the most severe environmental threats over the coming decade, driven by accelerating climate instability [4]. These environmental disruptions increasingly interact with geopolitical and economic pressures, amplifying vulnerabilities for communities worldwide [2, 3].

Compounding these challenges is a growing concern over resource instability, as climate impacts, conflict, and governance disruptions place additional strain on food systems, water availability, and energy security [4]. These interconnected risks collectively threaten global stability and demand urgent attention to resilience-building strategies. In this context, the capacity of communities to maintain essential functions, adapt to change, and reorganise in the face of disturbance becomes increasingly critical. As uncertainties intensify, the need for self-sufficiency and socio-ecological resilience is increasingly essential and a central prerequisite for sustainable futures [5].

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In many rural and community-based contexts, resilience is increasingly understood through what recent research describes as a dual-purpose logic, which refers to organisations or systems that deliberately integrate social and financial goals [6]. This concept is often applied to multifunctional socio-technical systems, such as green infrastructure, which serve everyday economic, social, or ecological functions while simultaneously acting as resilience capacity buffers during environmental or health crises [7, 8]. Rather than maintaining separate infrastructures for normal times and emergencies, dual-purpose systems integrate preparedness into daily life, for example, through productive urban landscapes like community gardens and urban forests that support routine needs while ensuring food security and climate adaptation during disturbances [8]. This perspective highlights how resilience can emerge from ordinary practices within the built environment, which is reframed as a complex adaptive system possessing embedded capacities for self-organisation, adaptation, and the maintenance of core functions [9].

The role of buildings and the built environment in this context has received recent attention [1–3, 5, 10]. Castaño-Rosa et al. [3] suggest three strategies for resilience of the built environment, i.e., green and healthy infrastructures, adaptable infrastructures, and equitable and inclusive infrastructures. Kyrö et al. [10] argue that circular thinking may aid responses to disruptions, e.g. through the creative reuse of existing built assets. Rashidfarokhi [11] calls for community-led, bottom-up resilience initiatives. Top-down social resilience infrastructures tend to lack trust [12]. On the other hand, bottom-up initiatives without public funding or formal processes run the risk of being exclusive and vulnerable to changes in focal actors [12, 13].

It is within this context that the concept of the socio ecological system becomes particularly valuable. A socio ecological system is a way of understanding the world that treats people and nature as deeply interconnected. Changes in society and changes in the environment influence each other through ongoing, linked processes [14, 15]. From this perspective, human communities are not separate from the environment; they actively shape ecosystems and must also respond to the changes that occur within them [14]. Indeed, socio-ecological resilience emerges from how the whole system behaves over time. It describes the system's ability to reorganise itself after a disturbance while still keeping its key functions, structures, and processes.

Research on socio-ecological resilience includes a substantial body of empirical case studies that demonstrate how resilience processes unfold in practice. Scholars have examined resilience across diverse systems, such as fisheries, agriculture, water management, urban regions, and community-based resource governance, often focusing on thresholds, feedback, adaptive governance, and learning dynamics [16–21]. Recent work has further begun to connect socio-ecological resilience to community well-being, ethics, and geopolitical conditions, extending the field beyond environmental management alone [22]. These perspectives are highly relevant not only in urban settings, where much of this research has been concentrated, but also in rural contexts where social, ecological, and economic interdependencies take distinct forms.

Rural hubs have been gaining popularity due to increasingly place-independent work [23, 24]. A rural hub is a small-scale, multi-service centre that concentrates essential amenities, jobs, and community functions to support surrounding countryside settlements. Rural hubs, specifically those making use of existing built assets in the rural areas, align with circular futures [25]. In a rural context, socio-ecological resilience is defined as the ability of a community to resist and mitigate risks posed by internal and external disturbances while utilising its environment to achieve a new state of equilibrium [26]. Rural areas are viewed as complex adaptive systems where human communities and natural resources are inextricably connected, meaning the survival of the settlement depends on its

interrelations with the ecological substrate [14, 27]. Regardless, rural community resilience remains comparatively underexplored, particularly in regard to the mechanisms that enable resilience.

The study investigates the mechanisms that enable communities to remain resilient under conditions of uncertainty and change. Using a qualitative case study approach, it examines how these resilience-building processes unfold in a rural area of southern Sweden. Accordingly, the study asks: Which mechanisms support socio-ecological resilience in a rural community facing conditions of uncertainty and change? By identifying the mechanisms that support socio-ecological resilience in a rural setting, this study contributes to a deeper understanding of how communities can sustain themselves under conditions of uncertainty and change.

The paper is organised as follows. Section 2 offers an overview of the contextual literature that informs the study. Section 3 outlines the methodological approach. Section 4 presents the empirical results. Section 5 includes a discussion of the findings and their implications.

## 2. Literature review

This section offers an overview of the key contextual literature on socio-ecological resilience and related analytical frameworks.

### *2.1. Socio-ecological resilience*

The literature defines a social-ecological system (SES) as a complex, coupled model where human communities and nature are inextricably connected, meaning social and environmental changes are linked through interdependent processes [14, 15]. Human beings are not external drivers but are central, active determinants that influence and cope with ecosystem change [14]. Within this perspective, all resources used by humans are embedded in multiple, nested subsystems, typically resource systems, resource units, governance systems, and actors, which interact to produce outcomes at the system level [28]. This conceptual lens represents a move away from one-size-fits-all prescriptions, recognising that users can often self-organise to achieve sustainability rather than being trapped in an inevitable tragedy of the commons [15, 28].

Socio-ecological resilience is described in the contextual literature as an emergent system-level property rather than a fixed state [14]. It reflects the capacity of a system to absorb disturbances and re-organise while undergoing change, so as to retain essentially the same functions, structures, and feedback [27]. This marks a significant shift from so-called engineering resilience, which focuses on the speed of return to a single steady state [26]. Instead, socio-ecological resilience views systems as complex adaptive systems that seek a new state of equilibrium through three core characteristics: suitability (the ability to provide resources), redundancy (functional diversity), and adaptability (the capacity to self-organise and adjust) [26, 27].

In the specific context of rural settlements, literature portrays these areas as social systems depending on an ecological substrate [27]. Rural resilience refers to a region's capacity to adapt to changing circumstances to maintain a satisfactory standard of living while coping with inherent economic and ecological vulnerabilities [27]. A critical theme in recent scholarship is the coordination of kernel and peripheral systems, where the resilience of a village stems from the close interaction between its internal land-use structure (the kernel) and its surrounding environmental and infrastructure support (the periphery) [26].

Disturbances to these systems are diverse, including external drivers like climate change or extreme weather, and internal forcing functions such as bark beetle outbreaks, large-scale fires, or human land-use changes like urbanisation [14, 27]. The literature highlights that these disturbances are often transmitted across subsystems; for example, a lack of economic resilience can lead to population

outflow, which in turn increases the social vulnerability of the remaining rural system [27]. Ultimately, managing for resilience is described as a ten-legged stool, where the system's stability rests on the interdependent strength of ten distinct pillars, including water security, biodiversity, and social wellbeing, that must be balanced to achieve a triple bottom line of people, planet, and profit [14].

### *2.2. Analytical framework*

A wide range of analytical frameworks have been developed to assess socio-ecological systems and their resilience, each offering a distinct lens on how human and ecological processes interact. Ostrom's [28] Social-Ecological Systems Framework (referred to as the SES framework from here on) offers one of the most comprehensive and analytically robust approaches for examining how human and ecological components interact within a shared system. Unlike frameworks that prioritise broad temporal cycles or simple asset inventories, the SES framework offers a common vocabulary and a logical linguistic structure that facilitates a multi-tiered diagnostic analysis of the specific mechanisms driving system outcomes [28, 29]. This methodology can systematically account for the diverse participants in the actions who influence the governance system without necessarily being direct consumers of a natural resource [29].

While alternative models like the Resilience Alliance framework [30] focus on systemic phases of growth and collapse, or the Social-Ecological Inventory on mapping stewardship networks [31], the SES framework centres on the 'Action Situation'. This is the conceptual space where individuals make conscious choices and engage in deliberation and investment activities, allowing for a precise examination of how the village transforms technical and social inputs into tangible outcomes like local employment and adaptive capacity [29]. The diagnostic depth of the SES framework also allows the researcher to move beyond the asset mapping of the Community Capitals Framework [32] by identifying the specific rules-in-use, including collective-choice and operational-choice rules, which govern how those capitals are managed.

Multidisciplinary research using the SES framework spans various sectors, including fisheries, forests, and water management [28]. Empirical applications include studies of Maine lobster fishers, northern Wisconsin lakes, and 48 irrigation systems in India [28]. Key findings indicate that users are more likely to self-organise for sustainability when systems are moderately sized, exhibit predictable dynamics, and contain stationary resource units. Social variables such as leadership, shared norms, and common knowledge of the system are critical for lowering the transaction costs of collective action [28]. Recent extensions of the framework have been applied to technical infrastructures, such as the Taos Valley irrigation ditches [29]. This work highlights the transition from "Users" to "Actors" to include participants like volunteers or technical experts who influence governance without directly consuming resources. Ultimately, the framework identifies that sustainability is an outcome of interactions within specific "Action Situations," shaped by the joint influence of governance, actors, and biophysical conditions [28, 29].

By providing a structure that handles multiple instances of first-tier components, the framework ensures that overlapping subsystems can be analysed concurrently within a single logical whole. It provides a multi-tiered structure that breaks the system into core subsystems, resource systems, resource units, governance systems, and actors, along with the interactions and outcomes that emerge from their relationships [28, 29]. Each subsystem contains nested variables that allow researchers to analyse mechanisms at different levels of detail, from institutional rules and community norms to ecological processes and biophysical conditions [28]. The strength of the SES framework lies in its ability to integrate social and ecological dynamics without reducing one to the other, making

it particularly well suited for rural contexts where livelihoods, land-use practices, and ecological processes are tightly intertwined [28, 29].

## 3. Method

This research employs a qualitative case study strategy to investigate the mechanisms of socio-ecological resilience within the rural context of Southern Sweden. The methodology is structured around the SES framework, which serves as a diagnostic tool to organise the complexity of community-led development and identify specific variables that influence sustainability outcomes. Rather than providing an exhaustive review, this study employs the SES framework as a diagnostic tool to provide a common vocabulary for organising the analytical focus on the most critical variables within this specific system.

### *3.1. Case selection and description*

A case study approach was selected as the purpose was to investigate a phenomenon within its real-life context, in line with Yin's [33] definition. One of the key strengths of case studies is their ability to illuminate how situations and phenomena unfold in practice [34]. Flyvbjerg [34] emphasises the value of concrete, context-dependent examples, arguing that such situated knowledge can be more insightful than abstract, general theory. This is particularly relevant for socio-ecological resilience, which is inherently complex, dynamic, and deeply shaped by local conditions.

Cases should be selected which best answer the research question and where there is sufficient access to data [33]. Cases can be selected based on certain characteristics that give promise to their information content, so-called strategic information-oriented sampling [34]. This study employs information-oriented sampling where an extreme case was selected which was deemed unusual and exhibited excellence in a predefined sense, as described by Saunders et al. [35]. The chosen community represents a high-performing example of socio-ecological resilience, exhibiting characteristics that are both distinctive and analytically valuable. Its strong performance in resilience-building processes, combined with the openness of both the focal actor and the municipality to research collaboration, ensured comprehensive data access and a high degree of transparency.

Selecting an extreme and comparatively well-resourced case is methodologically advantageous for a mechanism-focused study. Such cases tend to display a wider range of resilience-enabling mechanisms than less resilient or more resource-constrained settings, thereby making underlying processes more visible. While this may limit the direct transferability of the findings, it strengthens the study's ability to identify what is possible under favourable conditions. Importantly, not all mechanisms uncovered in an extreme case need to be transferable for the analysis to be valuable; rather, the case highlights the repertoire of mechanisms that can exist, some of which may be adaptable to other contexts.

The selected case is a community-led initiative in a sparsely populated Swedish village that has transformed itself into a pilot village for rural resilience (hereinafter the Rural Resilience Hub). Located in a municipality of 17,500 residents, the village has faced a 30% population decline since the 1980s [36], culminating in the decommissioning of its school, grocery store, and elderly home in the early 2000s. The rural hub project was triggered by a desire to reverse the protracted socio-economic and demographic decline. The project was further motivated by the 2005 Storm 'Gudrun', which left the village without electricity for over 30 days [37], highlighting the need for local self-sufficiency.

### *3.2. Data collection*

Data were collected through interviews, site visits, and document reviews. These methods complemented one another: interviews provided experiential insights, site visits offered contextual and

spatial understanding, and documents supplied formal and historical information. Together, they allowed the team to clarify issues that emerged in one source by examining them through another, and to corroborate, or occasionally challenge, preliminary interpretations.

All members of the research team participated in at least one interview and one site visit, ensuring shared familiarity with the empirical material. All interviews were digitally recorded and subsequently transcribed with the support of transcription software. Document analysis was conducted collaboratively, with each document reviewed and analysed by a minimum of two researchers. An overview of all interviews, site visits, and reviewed documents is presented in Table 1.

Table 1. Summary of data collection

| ID | Data source | Date | Location | Participants/Topic | Duration/ Pages |
|---|---|---|---|---|---|
| I1 | Site visit | 7 May 2025 | Onsite | 2 researchers; Project manager | 90 min |
| I2 | Interview | 7 May 2025 | Onsite | 2 researchers; Project manager | 90 min |
| I3 | Interview and site visit | 27 Sep 2025 | Onsite | 1 researcher; Project manager | 60 min |
| I4 | Interview | 29 Sep 2025 | Online | 3 researchers; Project manager; Business developer | 67 min |
| I5 | Interview | 16 June 2025 | Online | 1 researcher; Municipal authority | 30 min |
| D1 | Document | 1 March 2025 | - | Newsletter | 2 pages |
| D2 | Document | 20 May 2025 | - | Factsheet | 5 pages |
| D3 | Document | 1 Jan 2019 | - | Factsheet | 7 pages |
| D4 | Document | 20 May 2025 | - | Organisational model | 5 pages |
| D5 | Presentation | 29 Sep 2025 | - | PowerPoint presentation | 12 pages |
| D6 | Photographs | 7 May & 27 Sep 2025 | - | Site | 48 pictures |
| D7 | Social media | 7 May – 31 Dec 2025 | - | Facebook and Instagram | 30 posts |
| D8 | Website | 25 Sep 2025 | - | Rural hub website | - |
| D9 | Website | 25 Sep 2025 | - | LinkedIn | 3 pages |
| D10 | Website | 25 Sep 2025 | - | Naturkartan | - |
| D11 | Website | 25 Sep 2025 | - | Postkodlotteriet | - |
| D12 | Website | 25 Sep 2025 | - | ChargeFinder | - |
| D13 | Website | 25 Sep 2025 | - | Municipality | - |
| D14 | Website | 25 Sep 2025 | - | Convenience Stores Swe | - |
| D15 | Website | 25 Sep 2025 | - | Hela Sverige | - |

### *3.3. Analysis process*

This study employs Ostrom's [28] SES framework updated by McGinnis and Ostrom [29], as it provides a robust capacity for dissecting and harnessing complexity within a multi-faceted rural environment. Furthermore, the framework's explicit suitability for Social-Ecological-Technical Systems is pivotal for this case study, as it allows for the integrated analysis of human-constructed facilities, as resource systems that interact directly with ecological units and social actors. The study operationalises the SES framework as a diagnostic lens. Its categories and variables were used to organise and interpret the empirical material, ensuring that interviews, site visits, and documents were analysed in relation to the key components of the system.

One researcher carried out the initial coding, after which the other two researchers validated and reviewed the categorisation. The analysis process was collaborative and iterative between the three authors.

In analysing the empirical material, the study relies on what was reported in interviews and observed during site visits, as well as what was stated in the reviewed documents. These accounts were taken at face value and treated as representations of how actors themselves understand local conditions, events, and developments. The study did not independently verify factual claims, such as whether a specific storm occurred, whether house prices have increased, or whether particular policy actions were implemented as described. Instead, the focus is on how respondents perceive and articulate these issues, and how such perceptions shape the mechanisms of socio-ecological resilience within the community.

The application of the SES framework involves a three-step process. Firstly, the focal level of analysis is defined. This step involves defining the boundaries of the study by identifying the core components of the village hub as an SES, such as *Resource Systems (RS), Resource Units (RU), Governance Systems (GS), Actors (A) and Action Situations (AS)*. The AS sets out the interactions between RS, RU, GS, and A. Next, the relevant variables and indicators are selected from the common vocabulary provided by the framework. Finally, interactions and outcomes stemming from the AS are evaluated, where sustainability and resilience are treated as *Outcomes (O)* resulting from the *Interactions (I)* between the components defined in previous steps. The steps are presented in Fig. 1.

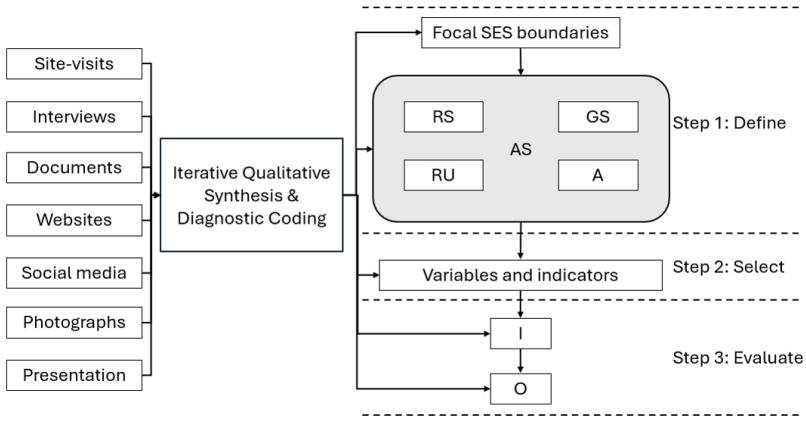


Figure 1. Overview of the research process including the SES framework's three-step analytical process

Within this logical whole, RU is defined as parts of or outputs drawn from the larger RS, while GS define the specific responsibilities and set the rules for A. These components interact within the AS, where A participate and RU serve as direct inputs, leading to I that generate measurable O. These relationships are dynamic rather than static, as the RS and GS collectively set the conditions for choice, and the O provide critical feedback that can change the state of the top-tier components at subsequent points in time. Furthermore, the focal system remains open to exogenous influences from the surrounding settings and ecosystems, which can affect any individual component or the operation of the system as a whole.

The data collection for this study, comprising semi-structured interviews, site visits, and extensive document reviews, was initially conducted as a qualitative exploration of the Rural Resilience Hub's development and activities. Following this empirical phase, the SES framework was identified as a robust diagnostic tool capable of organising the multi-faceted empirical material into a coherent

logical whole. Consequently, while the data collection did not strictly follow the framework's tiered steps, the analysis phase was systematically structured around its diagnostic logic to move beyond a descriptive inventory toward identifying the specific mechanisms driving resilience. This analytical process followed the three-step diagnostic application outlined by McGinnis and Ostrom: first, defining the focal SES boundaries (RS, RU, GS, and A); second, selecting relevant second-tier variables from the framework's common vocabulary; and third, evaluating the interactions (I) and outcomes (O) that emerge within the Action Situation.

The intent of the framework is to provide a structured list of variables to be used to determine which factors are most critical for a specific community's resilience. By applying the SES framework, the study can systematically identify the mechanisms that support socio-ecological resilience, trace how they interact across scales, and reveal how governance arrangements, community practices, and ecological conditions jointly shape resilience outcomes.

## 4. Results

The results of the diagnostic analysis of the Rural Resilience Hub SES, based on the case study data and the SES framework, are presented in the following sub-sections. An overview of the results is provided in Fig. 2.

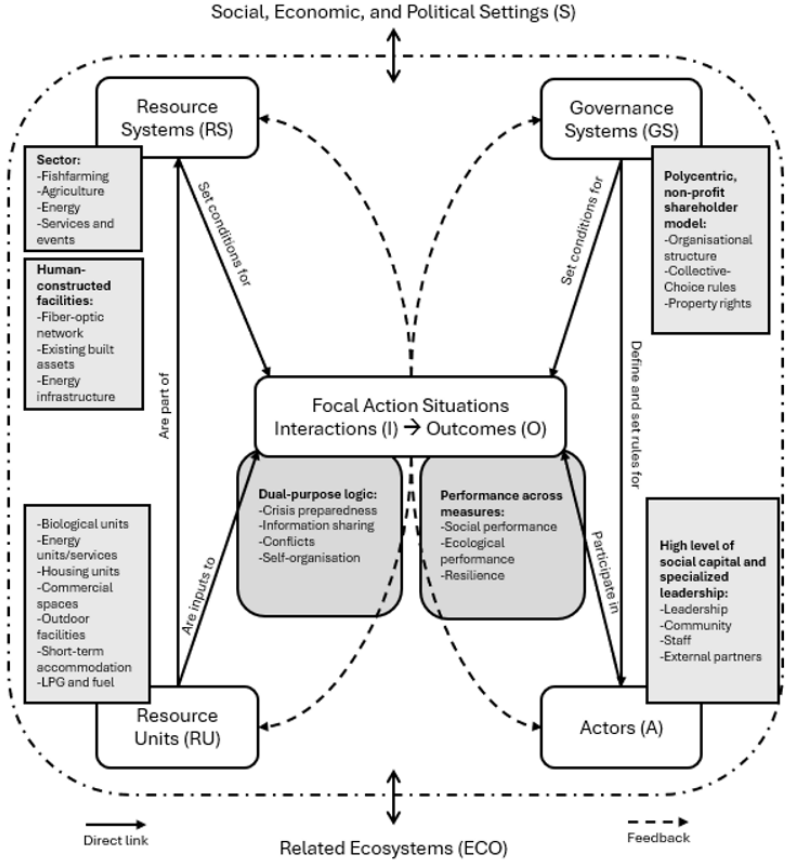


Figure 2. Overview of results within the SES framework by McGinnis and Ostrom [29]

### *4.1. Focal system and context (S)*

The focal system is the Rural Resilience Hub, located in Southern Sweden. The primary vision of the initiative is to '*create a place for social interaction that contributes to sustainable social value*

*and eases everyday life for rural inhabitants*'.

*S1 – Economic development:*

- The rural area had been experiencing economic decline, marked by service withdrawal and a shrinking population. In recent years, however, these trends have begun to reverse, an improvement attributed, at least in part, to the hub and its associated initiatives.

*S2 – Demographic trends:*

- The village (158 inhabitants) and parish (450 inhabitants) are characterised as sparsely populated.

The remaining indicators for (S) were not considered to have a high impact on the hub. The remaining indicators are: S3 – Political stability, S4 – Other governance systems, S5 – Markets, S6 – Media organisations, S7 – Technology. However, the hub does implement new technology such as hydrogen gas produced through fish farms and connected to a greenhouse for tomatoes.

### *4.2. Resource Systems (RS) and Resource Units (RU)*

The system's physical infrastructure relies heavily on the adaptive reuse of buildings. Using, reusing and adapting existing built assets are key circular strategies for the case. One planned initiative involves repurposing a vacant school building for short-term accommodation, with the added potential of serving as a crisis shelter. Other planned activities build on circular principles, integrating locally produced solar electricity with aquaponic fish farming, tomato cultivation, and biofuel generation. The goal of these initiatives is to strengthen adaptive capacity and support local employment.

The key RS for Rural Resilience Hub is strongly supported by the framework's RS4 (Human-constructed facilities) and RS1 (Sector) variables and include:

*RS1 – Sector (e.g., water, forests, pasture, fish):*

- Fish farming
- Agriculture
- Energy
- Services and events

*RS4 – Human-constructed facilities:*

- Infrastructure Systems: The 120 km fibre-optic network is a classic human-constructed resource system providing digital communication services. This enables remote work and local business growth, which is essential for attracting new residents.

- Existing Built Assets: The physical structures of the Rural Resilience Hub (the former taxi garage, the grocery store, and the elderly home) are resource systems that house various services of the hub.

- Energy Infrastructure: The solar voltaic parks (3 MW capacity) and the planned hydrogen storage modules function as technical resource systems. This is complemented by the development of an energy self-sufficiency model, a sociotechnical approach aimed at ensuring fourteen days of energy self-sufficiency for vital functions like water pumps and food refrigeration.

*RU:s produced or managed by the hub through its RS include:*

- Biological Units: The 40 tons of Clarias fish and the greenhouse tomatoes are discrete biological units generated by the land-based farming system.

- Energy Units/Services: The solar electricity and hydrogen gas are the units produced. Note that McGinnis and Ostrom [29] clarify that in technical systems, these are often experienced as a continuous service rather than discrete products.

- Housing Units: The 16 apartments within the senior residence are the specific units of housing provided by the senior home infrastructure.

- Commercial spaces: The grocery store, café and restaurant, and the former taxi garage which serves as a space for events. Alongside these infrastructural efforts, the community is investing in social and cultural assets, including a gallery, meeting spaces, and sports facilities.

- Outdoor facilities: Large playground behind the café.

- Short-term accommodation: A planned initiative involves repurposing a vacant school building for short-term accommodation, with the added potential of serving as a crisis shelter.

- LPG and Fuel: The Liquefied Petroleum Gas (LPG) sold in bulk and the electricity from charging stations are further resource units drawn from the hub's infrastructure.

The resource units are defined by strong Interaction among units (RU3) and High economic value (RU4), both of which are pronounced in the case of the hub.

### *4.3. Actors (A)*

The actor group is defined by high levels of social capital (A6) and specialised leadership (A5):

- Leadership: The project manager is the focal actor and a central driving spirit, leveraging their corporate and pedagogical background and local knowledge to network and secure funding. The reliance on a strong focal actor can be considered a risk as the project may not continue without them. However, the employed business developer has a strong professional background.

- Community: The 450 parish inhabitants are integrated through ten local associations (sports, farming, culture). The associations are shareholders in the company operating the hub.

- Staff: The hub has become the village's largest employer with 15 staff.

- External Partners: Key collaborators include a university (research), the municipality, and local large company, though interactions with the latter have shifted due to regional economic trends.

### *4.4. Governance Systems (GS)*

The governance structure is a polycentric, non-profit shareholder model.

- Organisational Structure (GS1, GS3): The parent entity is a non-profit association. Underneath, a holding company separates property management (a limited liability company) from operations like the shop and café to safeguard assets.

- Collective-Choice Rules (GS6): A limited liability company where the ten local associations hold shares. The company is of a type that legally restricts dividends, ensuring profits are reinvested into the Rural Resilience Hub.

- Property Rights (GS7): The community owns the buildings and real estate assets, providing a level of independence from municipal service withdrawals. However, the proposed redevelopment of the school is a building owned by the municipality.

### *4.5. Action situations and interactions (I)*

Interactions within the hub are driven by a dual-purpose logic, where every initiative must serve both daily economic growth and crisis preparedness.

- Crisis preparedness (I5): The developed energy self-sufficiency model aims for 14 days of energy self-sufficiency for vital functions (water pumps, food refrigeration, senior care) using solar-to-hydrogen technology. The fish and tomatoes may also act as a food supply in a crisis.

- Information sharing (I2): Communication is maintained through the local newspaper, social media, and frequent community meetings.

- Conflicts (I4): There are ongoing tensions with the municipality regarding a vacant school building; the hub proposes its use for senior health and emergency housing, while the municipality prioritises demolition due to maintenance costs.

- Self-organisation engine (I7): This variable is a second-tier interaction and takes place within the Action Situation. This is where Actors design and implement their own governance systems. The Self-Organisation Engine is implemented by leveraging specialised leadership and the community's high social capital through a polycentric, non-profit shareholder model involving ten local associations. This governance structure applies a reinvestment rule that legally restricts dividends, ensuring all economic surpluses are redirected into maintaining and developing the hub's physical infrastructure and services.

### *4.6. Outcomes (O)*

The system demonstrates significant performance across social and ecological measures:

- Social performance (O1): The activities at the hub have contributed to the attractiveness of the village to new residents, visible in e.g. suggested significant increases in local house prices compared to neighbouring villages. Also, the housing units have enabled the elderly to stay in their home village. Further, the hub creates employment opportunities for those in the village.

- Ecological performance (O2): Optimising the use of existing built assets has saved significant embodied energy and carbon emissions. Operational energy may be produced locally in a cleaner way with the planned circular reuse of heat from biochar production for fish and tomato farming. Additionally, by providing local services the need for transport has reduced.

Resilience: The development of a local task force and self-sufficient energy system. The hopes are that the village will be recognised as a pilot village for European rural resilience.

In line with the SES framework, this study treats Resilience not merely as an abstract concept but as a measurable Ecological Performance Outcome (O2). Within the framework's hierarchical structure, the Outcomes (O) category serves as the evaluative container for the results generated by the Interactions (I) occurring within the Action Situation. Therefore, while socio-ecological resilience is the primary dependent variable under investigation, it is operationalised here as a specific performance criterion (O2) alongside social performance (O1), allowing for a systematic assessment of how effectively the hub's initiatives contribute to the system's long-term sustainability.

### *4.7. Diagnostic analysis: Causal mechanisms of rural resilience*

This sub-section moves from a descriptive inventory of the Rural Resilience Hub's components to a diagnostic analysis of the generative processes that facilitate sustainability. By examining the Action Situation, we identify three primary causal mechanisms:

- The Self-organisation engine (A+GS→I7): The resilience of the hub is not merely a product of its assets but a result of Leadership (A5) and Social Capital (A6) interacting with Collective-choice rules (GS6). The diagnostic finding is that the non-profit shareholder model acts as a "reinvestment rule," ensuring that social capital is not just an asset but a functional mechanism that converts economic surplus back into community infrastructure (RS4), thereby reversing the downward spiral of service withdrawal. These dynamics constitute the self-organising activities captured in (I7).

- The Dual-purpose feedback loop (I5→O2): A critical mechanism identified is the "dual-purpose logic" within the Action Situation, where daily investment activities (I5) are explicitly coupled with Crisis Preparedness. Unlike traditional engineering resilience focused on a return to a steady state, this

mechanism creates Suitability and Redundancy. For example, the solar-to-hydrogen infrastructure (RS4) is not just a technical component; it is a mechanism that transforms the Interactions of daily energy production into the Outcome of 14-day self-sufficiency (O2).

- Socio-technical-ecological synergy (RS+RU+A→O2): The diagnostic analysis reveals a generative process linking Human-constructed facilities (RS4) with Biological Units (RU). In this SETS (Social-Ecological-Technical System) mechanism, the technical grid (fibre-optic and solar) attracts the necessary human Actors (A) (remote workers/15 staff), whose presence provides the labour and knowledge (A7) required to manage the ecological regeneration of fish and tomato farming. Resilience here is an emergent property of the feedback between technical connectivity and ecological production.

## 5. Discussions

This study aimed to identify the mechanisms that support and strengthen socio-ecological resilience within a rural context to provide a deeper understanding of how communities can sustain themselves under conditions of uncertainty and change. By employing the SES framework, the mechanisms and outcomes could be identified.

The findings align with the previous knowledge about escalating geopolitical tensions and resource instability which demand urgent resilience-building strategies [2, 4]. By utilising Ostrom's [28] SES framework, updated by McGinnis and Ostrom [29], this study moved beyond one-size-fits-all prescriptions to diagnose how a specific community can self-organise to avoid a tragedy of the commons. The framework's capacity to handle Social-Ecological-Technical Systems was pivotal, allowing for the concurrent analysis of human-constructed facilities, like the existing built assets, 120 km fibre-optic network and solar power grids, alongside biological resource units such as fish and greenhouse tomatoes. Yet, the strong emphasis on human made facilities within the village hub indicates that additional work is needed to more fully integrate the surrounding natural resources into local resilience efforts, particularly the extensive forestry landscape around the village. These interdependencies between built and ecological systems, highlighted by Manley et al. [14] and Schouten et al. [27], point to a clear opportunity for strengthening the socio ecological resilience of the Rural Resilience Hub by more deliberately linking its infrastructural initiatives with the capacities of its local ecosystems.

Utilising the updated category of 'Actors' rather than 'Users' in the framework, however, allowed for a systemic accounting of diverse participants, including the village hub's 15 staff and the village's 10 local associations, who influence the system without necessarily consuming natural resources. Central to the hub's success is the Action Situation, where the community makes conscious choices based on a dual-purpose logic. Every initiative serves both daily economic growth and long-term emergency preparedness, a strategy necessitated by the 30-day blackout following Storm Gudrun. This reflects the TPOR framework's emphasis on linking concrete treatments (like the solar-to-hydrogen energy sufficiency model) to outcomes, such as 14 days of energy and food self-sufficiency. By coordinating its kernel (internal land-use for circular food production) with its periphery (external infrastructure like digital connectivity), the village demonstrates the rural resilience described by Cao et al. [26].

The observable outcomes of these mechanisms, as described by respondents and reflected in local documents, are significant: the hub is considered to have contributed to increased local house prices and reversed a population decline by maintaining opportunities for remote work and a local service offering which aligns with previous findings by Kiviaho et al. [38] and Vogl and Micek [24]. Furthermore, the initiative leverages aspects from the Community Capitals Framework, using high

levels of social and political capital to secure funding and compensate for reduced state and municipal services. The polycentric, non-profit governance model ensures that surpluses are reinvested locally, effectively balancing the ten-legged stool of stability across economic, social, and ecological pillars as described by Manley et al. [14]. Through suitability, redundancy, and adaptability, the hub has achieved a new state of equilibrium that may position it as a pilot village for European rural resilience, as intended by the founder. By reimagining infrastructure and embedding resilience in everyday life, the hub presents possibilities for empowerment and self-sufficiency.

While there are ample opportunities, the case also faces major challenges. Firstly, several critical mechanisms, such as the solar-to-hydrogen storage and the aquaponic fish and tomato farming, are currently in the planning stage, meaning the reported ecological performance consists of expected rather than fully operationalised outcomes. A new analysis should be conducted once the plans are operationalised. Secondly, the ongoing tensions with the municipality over the vacant school building highlight that even resilient local kernels remain vulnerable to conflicts within the broader governance system. Finally, the project is reliant on one focal actor, leaving it vulnerable to changes in the presence and capabilities of one person [12].

This study effectively utilises McGinnis and Ostrom [29] SES framework as a diagnostic tool to organise the complexity of community-led development. However, the research design does entail limitations. Several alternatives for a SES framework exist, and employing a different framework may have yielded different results. However, the McGinnis and Ostrom [29] framework was chosen as it avoids the one-size-fits-all approach of policy solutions, instead acting as a diagnostic tool to identify the unique variables, such as leadership, social capital, and resource predictability, that jointly shape the village's socio-ecological resilience [28, 29]. The selection of specific second-tier variables and indicators from the SES framework was a diagnostic process driven by their demonstrated relevance to the Rural Resilience Hub's unique context. Rather than an exhaustive inventory of all possible variables, indicators were prioritised based on their critical role in the community's specific resilience strategy. For instance, Existing Built Assets (RS4) were identified as a primary indicator because the hub's survival and circular logic are fundamentally built on the adaptive reuse of the former grocery store, elderly home, and taxi garage to house essential services. Similarly, variables such as Leadership/Entrepreneurship (A5) and Social Capital (A6) were selected because the empirical data revealed them to be the core drivers of the community's ability to self-organise and secure funding. This selection process follows the framework's intent to act as a common vocabulary for identifying the most critical influences on outcomes in a specific empirical setting.

Moreover, as the aim was to identify the mechanisms that support socio-ecological resilience, the case selection purposively focused on a successful extreme case. Among other strengths, the Rural Hub has an active focal actor and secured funding. Thus, the transferability of the findings to other rural communities with lower levels of economic and social capital is limited. Nevertheless, the qualitative case study approach provides deep context-dependent knowledge [34]. To complement the qualitative knowledge, further studies could develop quantitative ratings systems for the evaluation and measurement of resilience in rural communities.

## 6. Conclusions

This study shows that rural resilience in a post-disturbance Nordic context is fundamentally driven by a dual-purpose logic, where crisis preparedness is strategically embedded within the everyday economic viability of community-led socio-technical systems. For peripheral communities, the capacity to absorb shocks emerges from activities such as renewable energy production, circular food systems, and local service provision.

The findings further demonstrate how local activities, relationships, and ecological processes interact to strengthen resilience, offering practical insights for rural development and community-based adaptation strategies. The case illustrates how a community can self-organise, leveraging high levels of social capital to reinvest surpluses locally and maintain essential services. Ecological regeneration is fostered by aligning infrastructural initiatives with the capacities of local ecosystems.

Together, these insights provide a grounded example of socio-ecological resilience in an uncertain world and offer understanding into what enables rural communities to remain viable, adaptive, and ecologically regenerative over time.

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