“Apparent stability, Structural fragility”

A study of Energy Dependence and Food Preparedness through Agroecological Assessment Tools in Swedish Agriculture

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Independent project • 30 credits
Swedish University of Agricultural Sciences, SLU
Faculty of Natural Resources and Agricultural Sciences
Rural Development and Natural Resource Management - Master’s Programme
Uppsala 2026

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Credits:	30 credits
Level:	Second cycle, A2E
Course title:	Master thesis in Rural Development
Course code:	EX0889
Programme/education:	Rural Development and Natural Resource Management - Master’s Programme
Course coordinating dept:	Department of Urban and Rural Development
Place of publication:	Uppsala
Year of publication:	2026
Copyright:	All photographs are in this thesis were taken by the author.
Online publication:	https://stud.epsilon.slu.se
Keywords:	Agroecology, Resilience, Preparedness, Energy Dependence, Political Agroecology, Rural Development, Sweden

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Abstract

This thesis examines how three agroecological assessment tools (TAPE, LUME and OASIS) conceptualise resilience in Swedish agriculture, with particular attention to energy dependence, preparedness and structural vulnerability. Drawing on political agroecology and rural development perspectives, the study compares three agroecological assessment tools with farmers experiences of energy dependence, vulnerability, adaptive capacity and preparedness. Using a qualitative research design combining tool analysis, semi-structured interviews and field observations on Swedish farms, the study identifies recurring patterns related to energy dependence, resilience and preparedness. The analysis draws on by political agroecology, which views agricultural systems as embedded within broader political-economic and infrastructural structures.

The findings reveal a mismatch between farmers experiences and the way resilience is presented within the three agroecological assessment tools. While farmers describe resilience in terms of maintaining essential functions during disruptions, including access to for example electricity, fuel, water, heating and feeding systems, these dimensions remain implicit or absent within these agroecological assessment tools. Instead, within these tools, resilience is primarily framed indirectly through indicators related to ecological practices, productivity and input efficiency. The study demonstrates that energy dependence functions as a structural condition shaping agricultural production, rather than as a simple technical input. Therefore, this thesis argues that current agroecological assessment frameworks (TAPE, LUME and OASIS) risk overlooking vulnerabilities related to energy systems, infrastructure and external dependencies. It further highlights the need for these agroecological assessment tools and agricultural policy frameworks to more explicitly address energy dependence, preparedness and structural vulnerability within highly industrialised farming systems such as Sweden. By foregrounding farmers lived experiences, the findings demonstrate that resilience in contemporary agriculture cannot be separated from broader socio-technical and political-economic conditions shaping food production and rural development.

Keywords: Agroecology, Resilience, Preparedness, Energy Dependence, Political Agroecology, Rural Development, Sweden

Acknowledgments

I would like to thank all participating farmers for generously sharing their time, experiences and reflections throughout this study. Your openness and willingness to discuss both challenges and everyday realities made this thesis possible. I would also like to express my gratitude to my supervisor for valuable guidance, constructive feedback and support throughout the research and writing process. Finally, I would like everyone who supported and encouraged me during the completion of this thesis.

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1. Introduction

1.1 Background and problem formulation

Agricultural production in rural areas within Sweden is increasingly characterised by tensions related to land use, domestic food production, national preparedness and energy dependence (KLSA, 2024). Recent crises, including rising energy prices, geopolitical instability and disruptions in global supply chains, have intensified debates surrounding agricultural resilience and the role rural areas are expected to play in ensuring food preparedness and long-term food security (European Scientific Advisory Board on Climate Change, 2024; Swedish Energy Agency, 2021). In Sweden, these discussions have become increasingly urgent following renewed concerns regarding national preparedness and the vulnerability of highly specialised and globally integrated food systems (Regeringen, 2025).

One critical but often underexplored dimension within these debates is energy. Modern agricultural systems depend heavily on fossil fuels, electricity, mechanisation, transport and energy-intensive inputs such as mineral fertilisers and feed (Swedish Energy Agency 2021; Oswald et al., 2012). The Swedish agricultural sector remains particularly dependent on diesel and imported inputs, creating vulnerabilities linked to fluctuating energy prices, global markets and external infrastructure (LRF et al., 2026). In this context, food preparedness refers not only to maintaining food availability, but also the capacity of agricultural systems to continue functioning during disruptions affecting energy supply, transport systems or trade flows (KSLA, 2024). Energy dependence therefore directly shapes farmers vulnerability, adaptive capacity and ability to maintain production under crisis conditions. However, energy is often treated as a technical input or efficiency issue within agricultural policy and assessment frameworks, rather than as a structural dependency embedded within broader political-economic and socio-technical systems (Swedish Energy Agency 2021).

At the same time, agroecology has increasingly gained attention as a pathway towards more sustainable and resilient food systems globally. Agroecology is widely promoted within research, development programmes and policy incentives, particularly in Latin America, Africa and parts of Asia, where it has often been linked to food sovereignty, rural livelihoods and reduced dependence on external inputs (Holt-Giménez & Patel, 2009; Gonzalez de Molina, 2013). International organisations such as the FAO (Food and Agriculture Organization of the United Nations) increasingly frame agroecology as a response to interconnected environmental, social and economic challenges, including climate change, biodiversity loss and land degradation (FAO, 2025b). Agroecology is therefore not only understood as a set of agricultural practises, but also as a broader framework connected to rural development, governance, resilience and social justice (Gonzalez de Molina, 2013; Pimbert & Uhnák, 2019).

As agroecology has become increasingly institutionalised within international policy and development contexts, a growing number of agroecological assessment tools have emerged to evaluate sustainability and resilience within farming systems. Tools such as FAO´s Tool for Agroecological Performance Evaluation (TAPE), together with frameworks such as LUME and OASIS, are primarily developed and applied within Global South contexts, where they are used in research, advisory work and development initiatives to assess agroecological transitions and rural sustainability. These tools typically rely on measurable environmental, social and economic indicators to evaluate agricultural performance. However, their increasing influence also raises questions regarding what dimensions of resilience become visible through these assessment frameworks, and what risks being overlooked. While these tools are often designed to assess sustainability and resilience broadly, it thus remains unclear whether they enough capture structural vulnerabilities related to energy dependence, preparedness and external infrastructural systems, particularly within highly industrialised agricultural systems such as Sweden.

The vulnerabilities of Swedish agriculture are not simply technical or farm-level issues but rooted in broader historical and political transformations. During the Cold War, Sweden maintained extensive food preparedness systems and strategic reserves. However, many of these systems were dismantled during the 1990s following deregulation, EU accession and increasing reliance on global trade (Eriksson, 2018). Contemporary agriculture has consequently become increasingly specialised, mechanised and dependent on imported fuel, fertilisers, feed and technological systems. This has increased exposure to disruptions within global supply chains and energy systems (Eriksson, 2018). At the same time, agricultural policy frameworks have often prioritised efficiency, competitiveness and income supports, rather than long-term preparedness and resilience capacities (Mathijs et al., 2021).

Recent geopolitical developments, including the war in Ukraine and increased energy market volatility, have further exposed these structural vulnerabilities and renewed policy attention towards Swedish food preparedness and domestic production capacity (Regeringen, 2025). Against this background, understanding how resilience is conceptualised within agroecological frameworks, particularly in relation to energy dependence and preparedness, becomes very important.

This thesis therefore examines how three agroecological assessment tools (TAPE, LUME and OASIS) conceptualise resilience within a Swedish agricultural context, with particular attention to energy dependence, preparedness and structural vulnerability. Drawing on political agroecology theory and rural development perspectives, the study combines tools analysis and thematic analysis with empirical interviews and field observations conducted on Swedish farms. By comparing farmers lived experiences with agroecological assessment tools, this thesis explores how resilience is measured, operationalised and understood both within the tools and in practise. In doing so, it contributes to ongoing discussions about agroecology, food preparedness and rural development while critically examining whether the three agroecological assessment frameworks chosen, can capture structural conditions shaping resilience within highly energy-dependent agricultural systems such as Sweden.

1.2 Aim and Research Questions

The aim of this thesis is to examine how the three agroecological assessment tools (TAPE, LUME and OASIS) define and measure resilience put in a Swedish agricultural context, with a particular focus on energy dependence and food preparedness, and to compare these contextualisation's with farmers lived experiences of vulnerability, adaptive capacity and resilience.

In this study, resilience is understood not only as a farm-level outcome, but as shaped by border structures, defined here as the political-economic, institutional and infrastructural systems that condition farmers possibilities to act. Drawing on the theoretical framework of political agroecology, these structures include energy systems, policy frameworks, global markets and supply chains, which together shape both dependency and autonomy within agricultural production.

By explicitly comparing tool-based representations of resilience with farmers lived experiences, this thesis seeks to identify how structural dependencies, particularly related to energy, are captured, simplified or overlooked within these agroecological assessment frameworks. In doing so, the study contributes to a broader understanding of how resilience is constructed in highly industrialised agricultural systems. To explore this, three agroecological assessment tools have been selected (TAPE, LUME and OASIS). Because these tools increasingly inform advisory work and policy, there is a risk that resilience is overestimated for Swedish farmers if key dimensions such as energy are not adequately addressed in the tools.

Furthermore, the thesis positions agriculture not only as a site of production, but as a central component of rural development. In the Swedish context, the ability of agriculture to maintain production under conditions of crisis is closely linked to questions of regional resilience, food security and the long-term viability of rural areas. By analysing how energy dependence shapes both farm-level practices and broader system vulnerabilities, the study contributed to debates on whether the three agroecological tools TAPE, LUME and OASIS can function as, or be a part of, a strategy for strengthening rural development and food preparedness in Sweden.

The research is guided by the following research questions:

1. How are resilience and energy-related vulnerability conceptualised and operationalised in the three selected agroecological assessment tools (TAPE, LUME and OASIS)?
2. How do Swedish farmers describe their experiences of resilience, energy dependence, vulnerability and preparedness?
3. Why do tensions emerge between tool-based constructions of resilience and farmers lived realities, particularly in relation to structural dependencies such as energy systems and their implications for rural development and preparedness?

These questions are particularly relevant in high-income context such as Sweden, where agricultural resilience is often assumed to be great due to technological development and mechanisation. However, underlying structural dependencies, especially reliance on external energy systems and imported inputs, remain relatively underexamined both within European research and in the Swedish context specifically.

2. Literature Review and Theoretical Framework

2.1 Literature Review

Food production around the world is unequal, with different farming systems having different resources and opportunities. At the same time, agriculture globally faces increasing challenges such as climate change, land pressure, and economic constraints. A key question in the literature concerns who produces the world's food and how this shapes food security and sustainability outcomes.

Research by the FAO on global crop production demonstrates that production is highly concentrated to larger farms. Farms exceeding 50 hectares account for roughly 60% of global calorie and nutrient production, indicating a strong dominance or large-scale agriculture (FAO, 2025a). At the same time, smallholder farmers contribute to play a crucial role, though often being overlooked. Farms smaller than 2 hectares contribute to around 16% of global calorie production and 12% of plant-based protein (FAO, 2025a). This shows that the global food system relies on both large-scale and small-scale farming rather than a single dominant model. These production patterns must be understood within the broader context of food systems challenges. The FAO's *State of Food Security and Nutrition in the World 2025 report* highlights how food systems are increasingly affected by economic instability, rising food prices, and unequal access to food (SOFI report, 2025). These dynamics affect low-income populations the most and contribute to persistent food insecurity and malnutrition.

Land use and land degradation further complicate the sustainability of food production. According to FAO's *State of Food and Agriculture*, agricultural land is under growing pressure due to both climate change and intensified use, which threatens long-term productivity (FAO, 2025b). Land degradation is therefore identified as one of the most critical constraints on future food production. Policy interventions are therefore essential in addressing such challenges. FAO's analysis of *land improving policies* emphasizes the importance of targeted governance measures aimed at enhancing land quality and supporting sustainable productivity (FAO, 2025c). These findings underline the need for long-term institutional frameworks and investments in agriculture.

Beyond global production patterns, the literature emphasizes the need to transform food systems to address climate change, systematic risks, and long-term sustainability. A key concept in this transformation is resilience, understood as the capacity of food systems to absorb shocks, adapt to change, and maintain functionality. From a critical perspective, it is possible to argue that food systems are not only forms of technical or economic systems, but they are also shaped by power relations. Gonzalez de Molina (2013) highlights that agroecosystems are socially constructed and that meaningful sustainability transitions require political transformation, not just technological innovation. This argument is further developed within political agroecology, which focuses on how inequalities, institutions, and power structures shape access to resources and the organization of food systems (Gonzalez de Molina et al., 2020).

A policy brief in European food systems highlights the importance of adopting a systems perspective that integrates production and consumption as interconnected processes (KSLA, 2024). Sustainable transitions cannot focus solely on production; they must also involve shifts in consumption patterns. Furthermore, agricultural practices that reduce dependence on external inputs are seen as critical for strengthening both environmental sustainability and system resilience (KSLA, 2024). In this context, the transition away from fossil fuels becomes a central component of food system transformation. An IISD policy guide argues that such a transition requires comprehensive policy frameworks, substantial investments towards the agricultural sector, and strengthening of institutional capacities (International Institute for Sustainable Development, 2026).

The Swedish context reflects these broader dynamics while also presenting specific opportunities. The action plan for Stockholm's regional food strategy from Stockholm County Administrative Board (Länsstyrelsen Stockholm) emphasizes the need to increase local food production, maintain the productive capacity of agricultural land, and strengthen food system preparedness (Länsstyrelsen Stockholm, 2021). For agriculture, this involves both technological innovation and structural changes in production systems. Similarly, the report *Green Upscaling* (Grön Uppväxling) highlights the challenge of increasing domestic food production while simultaneously meeting environmental and climate goals (LRF et al., 2026). The report describes the current situation as "a critical moment" for Swedish food production, requiring investments, innovation, and strengthening preparedness (LRF et al., 2026).

From a farmer's perspective, the report *Visions for Fossil-Free Agriculture and Food Systems in Sweden* (Visioner för fossilfria lantbruk och livsmedelssystem i Sverige) suggests that future agricultural systems may be characterized by increased circularity, collaboration, and shorter value chains (Johansson et al., 2026). However, there are different views on the role of technology; while some emphasize precision agriculture and technological solutions, others highlight the need for broader societal changes beyond technical fixes (Johansson et al., 2026). These perspectives are complemented by *Future Agriculture* (Framtidens Jordbruk*)* from the Swedish Farmers' Supply and Crop Marketing Cooperative (Lantmännen), which frames sustainable agriculture as a balance between environmental suitability, economic viability, and resource efficiency (Lantmännen, 2025). This report also underscores the need to immensely increase productivity and reduce environmental impacts.

Much of the research on food systems, sustainable transitions and agroecological farming published is mostly focused on the global south where agroecology tends to be framed as a response to poverty, food insecurity and land inequality (Altieri, 2008; Pimbert & Uhnák, 2019). In contrast, less attention has been given to how agroecology can function within highly industrialised agricultural contexts such as Sweden, where farming systems are technologically advanced, but on the other hand deeply embedded in fossil-based energy systems and global supply chains.

Moreover, we see that "resilience" is widely discussed within food systems literature, but it is often conceptualised in ecological or system-performance terms, with limited attention to energy as a structural dimension of vulnerability. Existing frameworks within agroecology thus tend to treat energy as a technical input or efficiency issue, rather than as a political-economic dependency shaping farmers capacity to act under crisis conditions. This creates a gap between how resilience is presented and how it is experienced in practice. Specifically, there is limited research examining how agroecological assessment tools operationalise resilience in real-life contexts, also on whether these tools adequately can capture farmers lived experiences of vulnerability and preparedness. With that said, the relationship between energy dependence, food preparedness and agroecological resilience remains underexplored within Europe.

Despite this, literature shows that food systems are shaped by environmental pressures and political dynamics. While technological innovation and policy reforms are essential for positive development within rural areas, achieving sustainable and resilient food systems also requires addressing power relations and governance structure, both within Sweden and internationally. This thesis therefore analyses three agroecological assessment tools in relation to Swedish farmers experiences, with a specific focus on how dependencies shape resilience and food preparedness for Sweden and Swedish farmers, through the lens of political agroecology. By doing so, this thesis contributes to both agroecological and rural development debates by highlighting how structural dependencies shape resilience in high-income, industrialised agricultural systems such as Sweden.

2.2 Theoretical Framework

Agroecology has emerged as both a scientific discipline and a development model aimed at transforming food systems toward sustainability, resilience and social justice (Gonzalez de Molina et al., 2020). Early agroecological research focused primarily on ecological interactions within farming systems, more recent scholarships emphasise agroecology as a political project embedded in struggles over land, knowledge, power and development pathways (Gonzalez de Molina et al., 2020). While agroecology is interpreted differently across contexts and traditions, it is commonly understood as an approach that integrates ecological, social and economic dimensions within food systems. The Food and Agriculture Organization (FAO) describes agroecology as the application of ecological principles to the design and management of sustainable food systems, while also emphasising issues such as governance, resilience and social equity (FAO, n.d.). This broader understanding is important for the present study, as it situates agricultural resilience within wider questions of dependency, resource access and rural development, which are further developed through the lens of political agroecology.

Political agroecology builds on insights from political ecology to examine how agricultural systems are shaped by political-economic structures, governance regimes and historical processes. Rather than treating farming practices as isolated choices, political agroecology situates them within broader relations of power, capital accumulation and state policy (Cohn et al., 2006). From this perspective, agroecology is not only about reducing inputs or enhancing biodiversity, but about reconfiguring relations of dependence, autonomy and control within food systems.

Agroecology is increasingly understood not only as a set of practices or a scientific discipline, but also as a transformative framework that challenges dominant food systems paradigms. As highlighted by Pimbert and Uhnák (2019), agroecology is closely linked to the concept of food sovereignty, which emphasizes local control over food systems, equitable access to resources, and the re-localisation of production and consumption. This perspective positions agroecology as a bottom-up alternative to industrial, fossil-fuel dependent agriculture, foregrounding autonomy, participation and social justice. Similarly, Altieri (2008) argues that small-scale and biodiverse farming systems play a crucial role in enhancing ecological resilience, reducing dependence on external inputs, and sustaining food production under conditions of environmental and economic stress. Agroecological farming systems are often characterised by higher levels of biodiversity, local knowledge and internal resource cycling, which contribute to their adaptive capacity. However, the potential is often marginalised within dominant agricultural systems that prioritise large-scale and input-intensive production.

Resilience is commonly understood as the capacity of a system to absorb disturbances, adapt to changing conditions and maintain core functions over time (Folke, 2006). Within agroecological research, resilience often refers to the ability of agricultural systems to respond to environmental, economic and social stresses while sustaining food production and ecosystem functions (Altieri, 2008). However, political agroecology challenges purely technical or system-based understandings of resilience by emphasising that resilience is shaped by broader political-economic and infrastructural structures. From this perspective, resilience is not equally distributed or neutral, but conditioned by access to resources, infrastructure, energy systems and decision-making power (Holt-Giménez & Patel, 2009). This means that the capacity of farmers to adapt or maintaining production during crises depends not only on ecological practises at farm level, but also on structural conditions beyond their direct control. In highly industrialised agricultural systems such as Sweden, resilience therefore becomes closely linked to issues such as energy dependence and autonomy within wider socio-technical systems. From a systems perspective, alternative models of food organisation further highlight the importance of relation and localised structures. Samuels-Ballantyne (n.d.) conceptualises “food communities" as a form of distributed civic infrastructure, where relationships between households and farmers create more resilient and locally embedded food systems. Such approaches shift the focus from global supply chains to local networks, reducing vulnerability to external disruptions and strengthening regional economics.

Within rural development debates, political agroecology questions dominant ideas of development that focus mainly on technological intensification, market integration, and efficiency. Instead, it asks who benefits from these changes, who carries the risks, and whose knowledge is valued in agricultural transitions (Holt-Giménez & Patel, 2009). In this way, it connects to critical rural development perspectives that instead of seeing rural areas as “behind” urban development, seeing it as places where alternative development paths are possible. From this perspective, it is about the ability to cope with and change the deeper structural problems that shape agriculture, such as economic dependencies and power relations. This is especially relevant in high-income countries like Sweden, where agriculture is often seen as resilient due to advanced technology, while dependencies on global energy systems, inputs, and centralized infrastructures are often overlooked.

The concept of preparedness focuses more directly on the ability to maintain essential functions during crises, particularly in relation to food security and national self-sufficiency (Länsstyrelsen Stockholm, 2021). Research highlights that strengthening resilience requires a systems perspective that connects production and consumption and reduces dependence on external inputs, which can increase both sustainability and crisis preparedness (KSLA, 2024). From a political agroecology perspective, resilience achieved through continued dependence on external energy inputs may reveal deeper vulnerabilities. Apparent stability can therefore coexist with structural fragility (Pellow & Brulle, 2005).

Political agroecology as a field argues that agrarian sustainability is not merely an ethical or agronomic challenge, but fundamentally a political issue shaped by power relations, governance structures and unequal access to resources (Gonzalez De Molina, 2013; Holt-Giménez & Patel, 2009). Agroecosystems are therefore understood as socio-ecological constructions in which food production is inseparable from political-economic systems and institutional arrangements (Pimbert & Uhnák, 2019; Gonzalez de Molina et al., 2020). A central argument within political agroecology is that agroecology cannot be limited to improving practises at farm level alone but requires broader transformations of the economic and structural systems that govern food production (Giraldo & Rosset, 2017). Without such transformations, agroecological initiatives risk remaining isolated "islands of success" within wider systems that continue to reproduce dependency and environmental degradation (Gonzalez de Molina et al., 2020).

A concept for understanding the vulnerability of agriculture is ´social metabolism´, which describes how energy and material flows between nature and human society (Gonzalez de Molina, 2013; Gonzalez de Molina et al., 2020). In industrialized agriculture, this exchange has become linear and dependent on fossil fuels, creating a "metabolic rift" in which agroecological systems lose their capacity for self-regulation (Petersen et al., 2020). From a political agroecology perspective, addressing this metabolic rift requires restoring more circular energy and material flows and strengthening farmers autonomy by reducing dependence on external energy inputs, such as synthetic fertilizers and machine fuels, which are often controlled by global market forces (Gonzalez de Molina 2013; Gonzalez de Molina et al., 2020).

Swedish agriculture is dependent on energy in several ways. Previous research shows that dependencies, both internal and external, are not accidental but have developed over time through processes of agricultural modernisation, mechanisation, and increased use of external inputs. While these changes have increased productivity, they have also tied farming systems more closely to global markets and energy flows (Swedish Energy Agency, 2021; LRF et al., 2026). This means that energy is not just one input among many, but a structural condition that shapes both the possibilities and vulnerabilities of agriculture. At the same time, literature on resilient food systems shows that reducing dependence on external inputs can strengthen both sustainability and preparedness (KSLA, 2024).

Political agroecology also highlights that these tools used to measure sustainability are not neutral. Indicators and assessment frameworks are essentially based on assumptions about what counts as "good" farming, resilience and sustainability. Agroecological assessment tools such as TAPE, LUME and OASIS therefore do more than measure reality, they shape how resilience is understood and acted upon. By focusing on certain indicators while leaving out others, they can influence advisory practices, research priorities, and even policy decisions. From this perspective, the limited attention given to energy dependence in these tools is not only a technical issue but also reflects broader ideas about rural development and resilient agriculture systems. As argued in literature, dominant approaches apart from agroecology, often prioritise efficiency and productivity, while paying less attention to structural dependencies and power relations (Holt-Giménez & Patel, 2009). Political agroecology thus provides a way to critically examine structural dependencies in Sweden by asking how resilience is defined, what kinds of vulnerabilities that are included, and which ones are left out.

Taken together, these perspectives suggest that resilience in agroecology cannot be understood only through ecological indicators or farm-level practices. Instead, resilience is shaped by broader factors such as power relations, energy systems, institutional structures and socio-economic organisation. Political agroecology therefore provides a critical framework for examining how resilience is defined, measured and operationalised within the three agroecological assessment tools analysed in this study. It also enables an analysis of which dimensions of resilience, particularly energy dependency, structural vulnerability and preparedness, are included, marginalised or overlooked within these frameworks.

In this study, political agroecology is used as the primary theoretical framework to examine how the three agroecological assessment tools construct resilience, and how these constructions align with, or diverge from farmers lived experiences. In addition, concepts such as social metabolism and food sovereignty, together with perspectives on structural dependency within socio-technical and political-economic systems, are used to analyse how energy dependence shapes vulnerability and adaptive capacity for Swedish farmers. This approach enables a critical comparison between indicator-based representations of resilience and the practical realities of maintaining agricultural production under conditions of uncertainty and disruptions.

3. Methodology

3.1 Research design

A qualitative research design is suitable for exploring complex socio-ecological processes and capturing farmers lived experiences of vulnerability and resilience within agricultural systems (Peterson et al., 2020). Following this, this study adopts a qualitative, mixed-methods research design combining document analysis of agroecological assessment tools with semi-structured interviews and on-farm observations. The study is structured as a comparative analysis of three assessment frameworks (TAPE, LUME and OASIS), examined alongside empirical material from Swedish farms.

Semi-structured interviews were used to explore farmers' perspectives on resilience, energy use, vulnerability and preparedness. This format allows for consistency across interviews while also providing flexibility to follow up on emerging themes and context-specific experiences (Creswell & Creswell, 2018). The interviews focused on everyday practices, perceived risks, and strategies for maintaining production under changing or uncertain conditions.

The use of interviews and observations also aligns with agroecological research approaches, which emphasize understanding farming systems as lived socio-ecological processes shaped by structural conditions (Gonzalez de Molina et al., 2020). Field observations were conducted alongside the interviews to contextualise the data and provide insight into the material and infrastructural conditions of farming systems. Observations included farm layout, machinery, energy systems and general management practices. Within political agroecology research, such methods are important for linking abstract structures to concrete practices and lived realities (Robbins, 2012). Together, interviews and observations enable a holistic understanding of how resilience is both experienced and enacted at farm level.

3.2 Study Area and Selection of Case Farms

The Swedish context is particularly relevant for this study, as agriculture is characterised by high levels of mechanisation, technological integration and reliance on external inputs such as fuel, electricity and imported fertilisers. By focusing on farms operating within high-input context, the study can examine how resilience is shaped under conditions of structural dependency. Central Sweden provides a relevant empirical setting due to its mixed crop-livestock systems, reliance on mechanised production, and exposure to energy price fluctuations following recent geopolitical crises. The region thus offers a meaningful context for examining energy dependence and preparedness in primary agricultural production. The selection of farms was guided by a purposive sampling strategy, aiming to capture variation in farming practises, production systems and degrees of dependence on external inputs, particularly energy. Rather than seeking statistical representativeness, the goal was to select cases that provide insights into how resilience and dependency is experienced across different contexts within Swedish agriculture.

The selected farms reflect diversity in terms of production type (e.g. livestock and crop farming), scale and management approaches. This variation allows for identifying both common patterns and differences in how energy dependence and vulnerability are understood and managed. Moreover, the selection of farms also reflects a rural development perspective. Agriculture plays a central role in maintaining economic activity, food protection and social structure in rural areas. Understanding how farmers navigate energy dependence and vulnerability therefore provides insight not only into farm-level resilience, but also broader questions of rural sustainability and food preparedness in Sweden.

3.3 Data analysis

The empirical material was analysed using thematic analysis, focusing on identifying recurring patterns related to energy dependence, vulnerability, adaptive strategies and resilience. The analysis began by identifying themes emerging from the interviews, while later stages of interpretation were informed by the theoretical framework of political agroecology. This approach made it possible to connect farmers lived experiences to broader structural and political-economic dynamics. This approach made it possible to connect farmers lived experiences to broader structural and political-economic dynamics. For example, experiences of rising fuel costs or dependence on electricity are analysed not only as individual farm-level challenges, but as shaped by wider socio-economic, infrastructural and energy systems.

The analysis also includes a comparative element, in which empirical findings are contrasted with the indicators and conceptual frameworks of TAPE, LUME and OASIS. This enables an examination of how resilience is constructed within agroecological assessment tools, and to what extent these frameworks reflect the dimensions of resilience that farmers themselves identify as most important, particularly in relation to energy dependence, preparedness and vulnerability.

3.4 Methodological Considerations and Limitations

As a qualitative study based on a limited number of case farms, the findings are not statistically generalisable. However, the aim of the study is not to produce generalisable results, but to generate in-depth understanding of how resilience is experienced and constructed within a specific context.

The use of qualitative methods also involves interpretative elements, as the analysis is shaped by the researcher's theoretical perspective. This is addressed by maintaining transparency in the analytical process and grounding interpretations in both empirical data and relevant literature. A limitation of this study can be related to the focus on Sweden, which represents a high-income, individualised agricultural context. While this limits direct comparability with countries in Global South, it is simultaneously one of the strengths of the study due to such contexts being highly underrepresented in agroecological research in general.

3.5 Ethical Considerations

All participants were informed about the purpose of the study and their rights as participants. Informed consent was obtained, and data has been handled in accordance with ethical research guidelines. In the presentation of empirical findings and analysis, interviewed participants are referred to using functional identifiers (e.g. Farm A and farmer A, Farm B and farmer B) etcetera to ensure anonymity throughout the thesis.

4. Tool analysis

4.1 Introduction to the Analysis of Tools

This section is about to analyse the agroecological assessment tools TAPE, LUME and OASIS to examine how resilience is conceptualised, structured and operationalised within these frameworks. The purpose of conducting this analysis prior to the empirical findings is to establish a conceptual baseline against which farmers lived experiences can be compared.

By identifying which dimensions of resilience that are included, emphasised or excluded in the tools, the analysis provides a framework for interpreting the empirical data. It enables a critical examination of how structural dependencies, such as energy use and external inputs, are represented within standardised assessment approaches. This approach is informed by political agroecology, which emphasises that measurement frameworks are not neutral, but shape what is made visible or invisible within agricultural systems. The tool analysis therefore goes beyond describing the content of the frameworks themselves. It also examines the underlying assumptions about what counts as resilience, sustainability and vulnerability within agricultural systems, as well as which dimensions are prioritised, marginalised or excluded.

This analytical step is therefore central to addressing the research questions, as it allows for a systematic comparison between tool-based constructions of resilience and farmers experiences of vulnerability, preparedness and adaptive capacity.

4.2 TAPE (Tool for Agroecology Performance Evaluation) by the FAO (Food and Agriculture Organization of the United Nations)

The FAO's Tool for Agroecology Performance Evaluation (TAPE) was developed as a standardized framework to assess agroecological transitions across environmental, social and economic dimensions (FAO, 2019). It is structured around a three-step process consisting of; (1) Characterization of Agroecological Transition (CAET), (2) Assessment of ten core performance criteria, and (3) Joint analysis and interpretation (FAO, 2019).

The ten core criterions include (1) productivity, (2) income, (3) added value, (4) exposure to pesticides, (5) dietary diversity, (6) women's empowerment, (7) youth employment, (8) agricultural biodiversity, (9) soil health and (10) secure land tenure (FAO, 2019). These indicators reflect a broad understanding of sustainability, combining ecological, socio-economic and governance-related dimensions. In this sense, TAPE aligns with a systems-oriented approach to agroecology, aiming to capture multiple aspects of farm performance.

However, despite this comprehensive structure, energy does not appear as a distinct or measurable category within the framework. Instead, energy is indirectly embedded within broader indicators such as productivity, input use, and soil management, for example, energy-intensive inputs such as synthetic fertilisers or mechanised operations may influence productivity or environmental indicators, but the framework does not explicitly assess fossil fuel dependence, electricity use, or exposure to energy price fluctuations. As a result, energy dependence is subsumed under the broader category of "external inputs", without differentiation between types of dependencies. This limits the ability of the tool to capture how different forms of external reliance, such as imported fertilisers, diesel or electricity, may create distinct vulnerabilities. Furthermore, TAPE does not explicitly link external input dependence to broader political-economy risks, such as geopolitical instability or disruptions in energy supply chains. In this way, TAPE operationalises resilience primarily as performance stability and progress along an agroecological transition pathway, rather than as the capacity to withstand systematic disruptions. Resilience is inferred through indicators such as diversification, reduced input use and improved ecological performance. While these dimensions are important, they do not necessarily capture whether a farm can maintain essential functions under conditions of crisis, particularly in relation to energy availability.

The indicators prioritised within TAPE suggest that resilience is primarily understood through ecological diversification, management practises and reductions in external inputs. While these dimensions are central within agroecological transitions, the framework places less emphasis on broader structural vulnerabilities related to energy systems, infrastructure and preparedness. This indicates that resilience is largely conceptualised at the farm-management level, rather than in relation to wider political-economic dependencies.

From a political agroecology perspective, this suggests that TAPE primarily approaches energy as an issue of input management and efficiency, rather than as a broader structural dependency shaping agricultural vulnerability. By embedding energy within general categories of external inputs, the framework risks obscuring the extent to which modern farming systems in Sweden rely on continuous access to fuel, electricity and wider energy infrastructures. This may contribute to an overestimation of resilience, particularly in highly mechanised agricultural contexts such as Sweden, where stable energy access is a fundamental precondition for maintaining production.

4.3 LUME (A Method for the Economic-Ecological Analysis of Agroecosystems)

The LUME framework takes a different approach by conceptualising agriculture through the lens of ecological economics and social metabolism (Petersen et al., 2020). Rather than focusing primarily on performance indicators, LUME analyses the farm as a socio-economical system embedded within broader political-economic structures. A central feature of LUME is its focus on the relationship between endogenous (internally generated) and exogenous (externally sourced) resource flows. This includes energy, nutrients, labour and capital. The framework specifically examines the extent to which a farming system depends on external inputs, and how this dependence affects autonomy, resilience and long-term sustainability.

Within this perception, energy is not treated as a discrete input, but as a part of broader “metabolic exchange” between society and nature. Fossil fuels, synthetic fertilisers and purchased feed are thus understood as external energy flows that connect the farm to industrial systems and global markets. This allows LUME to conceptualise energy dependence as a structural condition, rather than a technical variable. This approach aligns closely with political agroecology, as it highlights how agricultural systems are shaped by processes of capital accumulation, industrialisation and externalisation of resource flows. By focusing on the balance between internal and external resources, LUME highlights how agricultural resilience is shaped not only by farm-level practises, but also by the broader socio-economic structures on which farming systems depend.

However, despite LUME providing a strong conceptual framework for understanding external dependencies and resource flows, its operationalisation of these dynamics remains relatively limited. Although the framework acknowledges dependence on external resources, it does not clearly assess how energy dependence may translate into vulnerability under conditions of disruption or crisis. For example, the framework does not explicitly examine how reduced access to fuel, electricity or external inputs may affect the capacity to maintain agricultural production, nor does it directly address issued of preparedness. Because of that, LUME is effective in identifying structural dependencies, but less suited for capturing their practical implications at farm level. It highlights the existence of vulnerability but does not fully account for how that vulnerability is experienced or managed in everyday agricultural practice. However, compared to the other tools, LUME engages more directly with resource flows and external dependencies, which aligns more closely with political agroecological perspectives on structural vulnerability.

In the context of this study, LUME thus represents a framework that aligns conceptually well with political agroecological understandings of energy as a structural dependency. The framework highlights how agricultural systems are embedded within broader resource flows and external dependencies. Despite this, these dimensions remain relatively abstract within the framework and are not fully translated into practical indicators capable of capturing how energy dependence is experienced and manged in everyday agricultural practises in Sweden. This limits its ability to evaluate preparedness and operational resilience at farm level, particularly within highly energy-dependent agricultural systems such as Sweden, which ultimately creates a gap between conceptual understanding and practical applicability.

4.4 OASIS (The Original Agroecological Survey Indicator System) by Agroecology Europe

The OASIS framework represents a more operational and indicator-based approach to assessing agroecological systems. It is structured around five main pillars; (1) Farming practices, (2) Economic vulnerability, (3) Socio-political aspects, (4) Environment and biodiversity, and (5) Resilience (Škorjanc et al., 2021).

Compared to TAPE, OASIS provides a more operational and detailed assessment of farm-level practises and performance. The framework places particular emphasis on diversification, input autonomy and ecological management as key components of agroecological transition. Within OASIS, energy dependence is addressed indirectly through indicators related to practices such as reduced tillage, synthetic fertiliser uses and input autonomy. These indicators may reflect varying levels of dependence on energy-intensive inputs, but energy itself remains embedded within broader categories of farm management rather than being assessed explicitly. Importantly, OASIS conceptualises resilience primarily through the capacity of farms to adapt through ecological diversification and management strategies. While this captures important dimensions of agroecological resilience, the framework gives limited attention to how external disruptions, such as energy shortages, electricity failures or fuel price volatility, may affect the capacity to maintain production.

From a political agroecology perspective, this suggests that OASIS primarily approaches resilience at the farm-managed level, while giving less attention to the broader socio-technical and infrastructural systems upon which modern agriculture depends. As a result, structural vulnerabilities linked to energy infrastructure, global supply chains and external resource dependence risk remaining insufficiently addressed within the framework.

This becomes particularly significant in the Swedish context, where agricultural production is highly dependent on mechanisation, electricity and external supply systems. In such contexts, resilience may depend not only on ecological management practises, but also on the capacity to maintain essential functions during infrastructural or energy-related disruptions. By primarily focusing on farm-level management and ecological indictors, OASIS may therefore provide a partial understanding of resilience, while overlooking how broader structural dependences shape preparedness and vulnerability in practice.

5. Empirical findings

This section introduces the participating farms to provide contextual grounding for the analysis. Rather than presenting full case narratives, the description focuses on key dimensions relevant to this study: energy use, vulnerabilities, preparedness and adaptive strategies. Together, these profiles will illustrate both variation and commonalities across Swedish farming systems.

5.1 Farm 1 (Farmer 1)

Farmer 1 has managed farm 1 for approximately twenty-five years with an ecological tradition as the earlier generation converted to organic farming in 1988, today operating a mixed farming system of livestock, crop production and forestry. Over time, the farm has undergone a gradual shift from maximising production towards improving long-term sustainability and energy efficiency. This transition includes for instance expanding natural grazing areas from around 15 hectares to about 40 hectares by clearing forest on land that previously had been pasture, investing in a vortex mill to produce flour from grain directly on the farm, in which this flour is sold through a specialty store in Stockholm, creating a shorter value chain between farm and consumer. Farmer 1 has also adopted new technologies such as solar panels and an electric loader.

Energy use on the farm is deeply integrated into multiple aspects of agricultural production and constitutes a fundamental precondition for daily operations. Diesel (or HVO) is required for machinery, electricity powers water systems and infrastructure, and wood chips are used for heating. These different forms of energy are closely integrated into everyday farm operations, making energy access a fundamental condition for maintaining production. This dependence is clearly articulated by farmer 1, who explains that *"without electricity or fuel, daily operations would quickly stop"*. Energy is therefore not perceived as one input among others, but as a structural condition upon which key farm functions depend. At the same time, farmer 1 identifies several vulnerabilities linked to energy dependence. These include exposure to fluctuating energy prices, reliance on external inputs and policy frameworks that shape economic incentives. For example, although the farm uses fossil-free HVO instead of conventional diesel, this results in higher costs due to both higher fuel prices and the absence of tax benefits. This highlights how policy structures influence the feasibility of energy transitions at farm level.

In response, the farm has implemented several strategies aimed at increasing energy autonomy. Solar panels on one of the farms barns produce approximately 16,000 kWh annually, covering a significant share of electricity demand. The farm has also invested in electric machinery and explores future options such as hydrogen-based energy storage. In addition, locally spruced wood chips provide a degree of independence from external heating systems. In the long run, this farmer hopes to build a hydrogen system that would allow the farm to store solar energy seasonally and become largely energy self-sufficient during all seasons and weathers.

For farmer 1, resilience in agriculture relates to long-term sustainability and the ability to cope with disturbances and changes. It is suggested that resilience often conflicts with the economic structure of modern agriculture, which tends to be prioritized short-term profitability rather than long-term stability. One particularly challenging event for this farm was the drought in 2018, which significantly reduced both grain and grass production, approximately halving yields. Another example was the storm Alfrida winter 2019, which caused a power outage for seven days. During that period, the farm relied on a small diesel generator to maintain essential functions such as heating and water supply. Moreover, for this farm, the most significant vulnerability is political dependency as the farm relies on environmental and agricultural subsidies. Changes in policy could therefore threaten the economic viability of the farm. Other risks include wildlife damage, particularly from wild boars and cranes that can destroy crops quickly, and climate change, which increases the frequency of extreme weather events such as droughts and storms.

Preparedness is, for farmer 1, understood as the ability to maintain essential functions during disruptions, particularly water supply, heating and basic operations. While backup systems such as generators provide some resilience, farmer 1 emphasizes that key dependencies remain, particularly regarding fuel and spare parts. Farmer 1 also emphasized that farming is generally a difficult business economically, which forces farmers either to expand production or constantly reduce costs. To continue, it is suggested that energy is often overlooked because it is relatively invisible within agricultural systems. Farmer 1 says that many evaluations do not fully account for how much energy is required to sustain agricultural production, energy dependence and preparedness are too seldom central topics in agricultural advisory contexts because the energy embedded in agricultural systems, from photosynthesis to transports, is often taken for granted.

For this farm, greater independence would involve producing more of the farm's own energy and reducing reliance on external inputs. This farmer believes that a hydrogen-based energy system could significantly increase the farms autonomy by allowing it to store and use its own energy year-round. Looking ahead, farmer 1 argues that agriculture needs improved profitability and policy incentives that reward environmentally beneficial practices. Instead of providing tax refund for diesel, the farmer proposes redirecting those funds toward supporting investments in energy efficiency or electric machinery. The farmer believes that there is a significant potential to produce more food on existing farmland in Sweden, particularly crops that can be consumed directly by humans such as vegetables and legumes. However, this would require changes in labour costs and consumer willingness to pay.To conclude, the farm illustrates both active efforts to reduce energy dependence and the structural constraints that limit full autonomy.

5.2 Farm 2 (Farmer 2)

Farm 2 is an old family farm that has been in the family for over 300 years. Dairy cows disappeared from the farm in 1959, which led to a transition towards conventional chemical-based farming. In 1997, the farm stopped ploughing entirely, and since 2008 it has applied direct seeding (no solid tillage). In 2012, animals were reintroduced to the farm to improve solid health. Today the farm has approximately 200 cows that live outdoors year-round without a barn. Farm 2 is today a regenerative farming system combining livestock and crop production, with a strong emphasis on soil health, microbiology and reduced use of chemical inputs. Despite its regenerative orientation, energy remains central to the farms functioning.

Diesel is essential for machinery, electricity is required for infrastructure such as water supply, and fertilisers are understood as part of the farm's indirect energy dependence. As farmer 2 explains, *"without diesel or fertilizers, production would almost immediate come to halt"*. This highlights how energy is embedded both directly and indirectly within agricultural production systems. For farm 2, resilience is primarily about the resilience of the soil. Healthy soils can better withstand both extreme drought and heavy rainfall than depleted solid. Having both cattle and grain production also creates economic and biological diversification.

Farmer 2 points at the farm being extremely vulnerable to external factors such as weather, which somewhat determines the outcome, as well as political decisions and global supply flows. One example was a sudden sales ban that occurred during a period of geopolitical tension in the middle east. Moreover, farmer 2 is sceptical of certifications such as KRAV during times of crisis, the farmer continues saying that certification is a luxury during peacetime, while in a crisis, hungry consumers will primarily care that the food is available at all. Vulnerabilities are described as largely external and systematic. The farm is exposed to weather variability, global supply chains and political decisions, which together shape production outcomes. Farmer 1 characterises the agricultural systems as *"incredibly vulnerable"*, emphasizing that farmers have limited control over key resources such as fuel, fertilisers and market conditions. The farm could adapt during a crisis by allowing cattle to graze on grain fields if external inputs were to become unable.

Energy related strategies are more constrained compared to other farms. While the farm uses wood chips for heating and has considered solar investments, long-term decisions are here limited by policy uncertainty and economic risk. Farmer 2 highlights the need for stable policy frameworks over longer time horizons to enable meaningful investment in energy infrastructure.

This farmer believes that farmers contribute greatly to society, but that authorities often lack an understanding of agricultural realities. A system where the state would have the right to purchase a certain percentage of farm production, in exchange for providing support during peacetime, is suggested. To continue, an issue this farmer believes is often overlooked, is that the focus on the nutritional content of food has declined when agricultural systems instead focus on maximizing yields. Farmer 2 proposes a system where consumers in food markets could easily compare the actual nutritional value of products, which this farmer hopes could encourage more sustainable farming practices.

Preparedness is here seen as being shaped by structural constraints beyond the control of individual farms. The farm lacks extensive fuel storage capacity and depends on external infrastructure such as slaughterhouses, transport systems and supply chains. Farmer 2 highlights that the increasing concertation of slaughterhouses and mills throughout Sweden creates systematic vulnerability, as disruptions affecting only a few large facilitates could impact large parts of the food chain. For this farm, an important preparedness strategy would thus be the possibility of slaughtering animals directly on pasture, both to reduce dependence on transport infrastructure and to improve animal welfare by avoiding the stress of transport and slaughterhouses. This would also produce higher-quality meat. However, according to the farmer, such practises are constrained by bureaucratic procedure and regulatory frameworks. Industrial food systems are therefore here described as favouring standardisation and homogenous production (for example one specific wheat variety), whereas soil health benefits from diversity and polycultures rather than monocultures, thus creating barriers for diversified and localised forms of agriculture.

This suggest that preparedness is not only determined by farm-level decisions, but also by how food systems, infrastructure and regulatory frameworks are organised at a broader societal level. This farmer's philosophy is that nature is usually better than humans at managing ecological systems, and that humans should minimize their impacts by learning how natural systems function.

5.3 Farm 3 (Farmer 3 & 4)

Farm 3 has been in the same family since the 1800s, with the main farmhouse dating back to 1760. Farmers 3 and 4 took over the farm in 2011 and initially ran conventional crop farming (grain production), but they found it unprofitable on a small farm. In 2018, they purchased their first calves and gradually transitioned the farm into a regenerative and organic (KRAV-certified) farm, with diversification as a central strategy. Today the farm has approximately 60 cattle’s, 400 laying hens, 30 pigs, as well as sheep’s and lambs. They cultivate about 30 hectares of their own land and lease additional land, totalling approximately 60-70 hectares. They are certified according to KRAV standards partly because it provides additional subsidies (approximately 25,000-30,000 SEK per year). However, they note that certification fees consume a large portion of this financial support.

Energy use is significant, but actively managed. Electricity is particularly critical during the winter to keep animals' drinking water from freezing (using heated cables) and to power refrigerators and freezers for their local farm store. Diesel is required for tractors and gasoline for quad bikes, which the farmer add may be started more than 100 times per day during the summer.

The farm has employed a range of preparedness strategies. The farm has installed solar panels producing approximately 40,000 kWh per year, which is more than their own consumption. This provides some protection against rising electricity prices. They also use timers on water heating systems to shift electricity use to nighttime and rely on firewood for heating, and they have invested in a generator powered by a tractor that can supply electricity to the entire farm during power outages. They also always keep around 1,500 litres of diesel in storage.

Figure 1. Diesel in storage. (Ågren Törnros, L. (2026). "Diesel tank reservoir". [photography]. [2026-03-08]

The most significant change for them has been diversification throughout the years. Instead of specializing in one type of production, they have chosen to keep several different animal species to reduce vulnerability. Farmer 3 and 4 have also created a three-hectare wetland on the farm with financial support from environmental grants. This wetland not only increases biodiversity, but it also functions as a water reservoir. Thus farmers 3 and 4 felt confident that they could contribute to producing beef and lamb based solely on pasture. For pigs and poultry, they maintain approximately one year's supply of grain stored at the barn roof on the farm. Because of this, they have relatively strong control over their feed supply, relying on mainly grass and locally purchased grain.

However, vulnerabilities remain. The farm is still dependent on fuels, infrastructure and regulatory stems. As farmer 3 explains, resilience involves relying on *"low-tech solutions that do not depend on automated systems"*. This reflects a proactive approach to managing energy-related risks.

The farm once experienced a salmonella outbreak among their hens one summer. This forced them to put down all the birds and carry out a full sanitation process, which was both financially and emotionally demanding. The farm also faces significant problems with wild boar and wolves in the area, forcing them to invest many hours in building predator-resistant fencing. Another critical vulnerability farmer 4 mentions is the phone, without it, it would not be possible to reach out to customers and continue with their business. Thus, they are highly dependent on electronics and Wi-Fi as well.

The farmers also emphasised challenges related to policy frameworks and administrative requirements, which are often perceived as designed for large-scale systems and therefore limiting smaller-scale operations like theirs. What they consider being their greatest vulnerability is political regulation and bureaucracy. They experience stress related to for instance complicated legislation, expensive licensing requirements for animal transport, and the risk of unannounced inspections that could lead to the withdrawal of subsidies. Farmers 3 and 4 feel that municipalities and authorities have not yet fully recognized the importance of small-scale farmers for food preparedness. The focus is often placed on large storage facilities rather than local production capacity. They once again feel constrained by regulations designed primarily for large-scale industrial farming. For example, their plans to build a small-scale poultry slaughter facility have been complicated by extremely strict water quality requirements, which demand municipal water rather than their own well water, which they also consider good quality. To continue, they are critical of some academic advisory programs, which they feel lack practical grounding and focus too heavily on theoretical models rather than the economic realities faced by farmers.

Today, they themselves work with direct sales by selling all their products directly to consumers through REKO-rings and an unattended farm shop, allowing them to retain the full profit margin and at the same time educate their customers about the difference between for instance fast-growing industrial poultry hybrids and more sustainable traditional breeds. Looking ahead, the most important factor for sustainable farming for them is profitability. Farmers 3 and 4 emphasize that farmers' hourly wages have decreased significantly over time, while society expects cheap food at the expense of farmers' economic viability, which doesn't add up and contributes to a harsh reality.

5.4 Farm 4 (Farmer 5)

Farm 4 is a small-scale regenerative farm, purchased in 2011, designed to minimise dependence on external inputs through technological practises and direct relationships with consumers. Farmer 5's interest in farming developed after children came into the picture and they wanted to provide them with what the farmer describes as *"dignified food"*, rather than industrially conventionally produced meat. This family began small-scale with sheep's and chickens, but in 2017 they shifted towards a regenerative farming approach after learning about systems that could make small farms economically viable. Today, the farm keeps around 10 cows, approximately 600 laying hens, as well as chickens and pigs.

They collaborate with a neighbouring farmer, allowing them to manage cattle in larger groups. The farm itself uses about 12 hectares of pasture, but has access to additional land, totalling roughly 50-70 hectares.

Farmer 4 chooses to not pursue organic certification mainly for economic and practical reasons. Although this farmer buys KRAV-certified feed it is believed that because their farming practices exceed organic standards, this farmer see little value in paying for certification. Instead, the farm relies on direct relationships with customers. By selling through farm shops, REKO-rings, and subscriptions, customers can see their farming practices themselves. For this farm transparency and trust, *"know your farmer"*, is more important than formal certification labels.

The farm relies on limited amounts of fuel and electricity, while the primary energy sources are natural processes such as photosynthesis. As farmer 4 describes the farm uses *"less energy than a typical household"*, reflecting an intentional design aimed at reducing external energy dependence on this farm. Animals are moved frequently between fields to regenerate pasture and soil health. An innovation they are trying out is the new "No fence system", a GPS-based virtual fencing technology that allows cows to be controlled without physical fences.

Figure 2. Cow with "no fence" around its neck grazing in an open field. (Ågren Törnros, L. (2026). "Cow with no fence". [photography]. [2026-03-10]

This farmers approach on the farm significantly reduces exposure to energy prices fluctuations, but it does not eliminate vulnerabilities entirely. The farm remains dependent on purchased feed for certain animals, particularly poultry, and is therefore exposed to disruptions in supply chains. Labor is another critical factor mentioned, as their farming system relies heavily on manual management.

Preparedness is here based on the ability to rely on local resources and adapt protection systems. For farmer 4, a key principle for resilience is maintaining healthy soils. Farmer 4 says that *"Rather than relying on synthetic fertilizers, which he compares to "artificial breathing" for the soil, he emphasizes on living ecosystems with strong microbial activity".* The farm could thus continue operating at a reduced scale during disruptions, particularly for pasture-based livestock. To continue, this farmer does not feel that authorities expect small farms like this to play a significant role in national food preparedness. Farmer 5 believes that small-scale farmers are often overlooked or not taken seriously within the broader agricultural system. Greater independence would here involve eliminating reliance on external inputs. One example of this is replacing chickens with rabbits since rabbits can live entirely on grass and forage produced on the farm. This would reduce vulnerability to disruptions in feed supply chains while still providing a valuable source of protein equal to chicken.

Farmer 4 furthermore highlights regulatory frameworks as a source of vulnerability. In this view, many rules are designed for large-scale industrial farming and are poorly adapted to small-scale regenerative farms. Examples include vaccination requirements or regulations regarding outdoor animal management. Regulations and inspections can sometimes limit the farm's flexibility. For example, inspectors have criticized practices such as cows grazing directly on pasture or pigs being muddy, even though these conditions are natural outcomes of outdoor animal husbandry. It is said that this is an understandable protocol for larger industries where pigs are indoors, where mud instead can be feces, but not in this farms conditions.

Moreover, another major challenge identified from this farmer is access to farmable land, and land prices in this region. High land prices make it difficult for young farmers to enter agriculture. Instead, farmland is increasingly purchased by wealthy urban residents for hunting or recreational purposes. But overall, the farm represents an alternative model in which resilience is pursued through minimising energy dependence and increasing ecological autonomy. This farmer envisions a future in which agriculture becomes more community based with more multiple small-scale farmers cooperating and sharing resources rather than relying on fewer large industrial systems.

5.5 Farm 5 (Farmer 6 & 7)

Farm 5 is a large-scale, highly mechanised farming system combining dairy production (milk being sold to Arla), beef production and crop cultivation. Farming has here been organic since 1995. The farm has existed on the same site since the 1430s with the two current farmers (siblings) representing the 17th generation. They currently manage approximately 550 animals, of which 110 are dairy cows. The farm operates 650 heaters of land, including around 100 hectares of pasture and forest. The farm relies extensively on advanced technologies and diesel, including milking robots, automated feeding systems, a manure robot and digital infrastructure.

Energy use is central and continuous. Electricity is required for milking, feeding, water systems and digital monitoring, while diesel is essential for machinery and transport. As the farmers emphasize, *"without electricity or diesel, protection would cease almost immediately"*, which reflects a particularly high level of dependence on energy supply. Thus, energy is described as a fundamental precondition for all their farm activities. Without electricity, neither milking nor feeding systems would function, and without diesel, fodder cannot be transported either. Diesel represents a major cost for them. They have considered HVO (hydronated vegetable oil), but the absence of supportive policy incentives, current price levels and lack of tax incentives make such alternatives economically unfeasible. They have constructed manure storage closer to fields to reduce transport distances and diesel use. Solar panels have been installed on barns to cover daily electricity demand during sunny periods. Biogas has also been discussed but rejected due to high investment costs and labour requirements.

The farm is deeply embedded in border socio-ethical systems, creating multiple layers of vulnerability. Moreover, these vulnerabilities include dependence on fuel supply, spare parts, digital infrastructure and global markets. The farmers have strong control over self-produced fodder but are dependent on purchased inputs such as seeds and protein feed (i.e. European soy). They perceive limited control over regulations, infrastructure, and global milk price. A particularly illustrated example is the impact of geopolitical disruptions where the farmers describe how access to spare parts was affected when components in Russia became unavailable, and how their GPS accuracy in tractor auto-steering systems decreased during the early stages of the war in Ukraine. This was linked to disruptions in satellite systems such as GLONASS, demonstrating how global geopolitical dynamics can directly affect Swedish agricultural operations.

Preparedness is limited by this high level of system dependence. While the farm maintains fodder reserves, it lacks sufficient backup energy systems and remains dependent on continuous energy supply. Digital infrastructure is also identified as a vulnerability, as failures in communication systems can dispute automated operations and animal management. An example of that is that their farming relies on stable mobile networks. Without connectivity, alarms from automated systems fail, pose immediate risk to animal welfare and production, also during the phase-out of 2G and 3G networks.

Figure 3. Automated feeding robot in a barn. (Ågren Törnros, L. (2026). "Feeding robot". [photography]. [2026-03-30]

Figure 4. Milking machine milking a cow. (Ågren Törnros, L. (2026). "In action". [photography]. [2026-03-30]

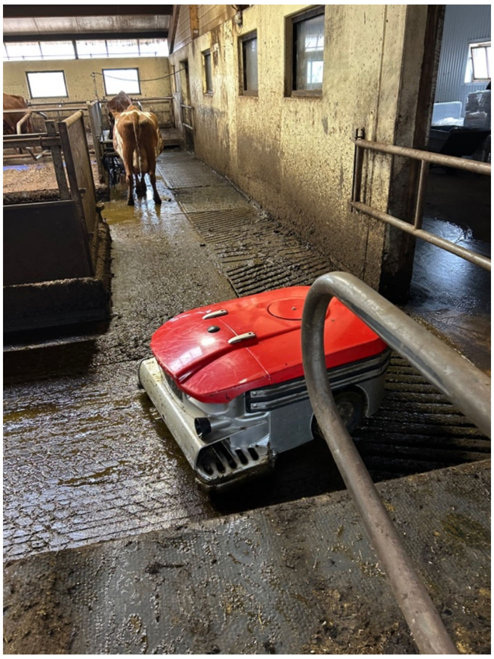

Figure 5. Manure robot in a barn going between the aisles. (Ågren Törnros, L. (2026). "Manure robot". [photography]. [2026-03-30]

Farm 5 illustrates the structural vulnerability of highly mechanised agricultural systems, where resilience is closely tied to maintaining access to energy and complex infrastructures. Current vulnerabilities are described as being economic (fluctuations in milk, grain, and diesel prices), labour (difficulty finding skilled and motivated workers), mental health (risk of burnout, especially in isolated farm operations, which in turn can lead to animal welfare issues), and lastly political and institutional vulnerability (uncertainty regarding regulation, energy taxes, and support systems). Farmers 6 and 7 describe agriculture as a high-risk sector where large investment must be made upfront, such as seeds, and labour, without knowing what yields or prices will be at the end of the season. This creates a structural vulnerability that is difficult to control. Following this, the farmers argue that society needs to change its perception of food production. Finland is highlighted as a positive example due to its stronger emphasis on preparedness and food storage. They view it positively that policymakers in Sweden increasingly recognise the importance of food production the last couple of years, but express concerns about for instance activism that can disrupt farm operations during pasture release, as an example. It is emphasized that consumers must be willing to pay for the added value of ecological farming (environmental protection and animal welfare) provided by those farmers. Regulations that increase costs must be matched by compensation.

They participate annually in climate-related advisory programmes, for instance, Greppa Näring and KRAV inspections. These programmes are intended to support sustainable farming practices and ensure compliance with environmental and animal welfare standards. However, farmer 6 and 7 express ambivalence towards these systems. While they recognize their potential value, they also experience them as bureaucratic and disconnected from practical realities.

Inspections are occasionally perceived as administrative burdens rather than meaningful support. A feeling that they have, and a specific criticism, is that authorities prioritize inspections of well-functioning farms because they are easier to manage, while more problematic cases are avoided due to the complexity involved. This creates a sense of unfairness and inefficiency in governance for the farmers.

The farmers also highlight tension between societal expectations and on-the-ground realities. For example, debates around practices such as dehorning involve complex trade-offs between animal welfare and human safety. These nuances are not always fully understood by either consumers or policymakers. They also stress that the human and social dimensions of farming are often neglected. Being constantly responsible for animals creates psychological pressure, which is rarely acknowledged in policy discussions. Finally, farmers 6 and 7 emphasised the importance of maintaining grazing systems and open landscapes, which they see as one of their primary contributions to both the environment and the local community.

6. Descriptive cross-farm analysis

This section presents a descriptive cross-farm synthesis of farmers lived experiences related to energy dependence, vulnerability and preparedness. Rather than analysing each farm individually, this section identifies recurring patterns and structural similarities across cases. The analysis is organised around four central dimensions: energy access, vulnerabilities, adaptative strategies and preparedness. Although the farms differ in scale, production systems and organisational structures, commonalities emerge regarding how energy shapes both everyday agricultural operations and broader understandings of resilience.

6.1 Energy access as a structural condition for agricultural production

Across all farms, energy is described as essential for maintaining agricultural production and everyday farm operations. Farmers consistently emphasise that diesel, electricity and energy-intensive inputs such as fertilizers and feeds are necessary for functions including machinery use, heating, water supply, milking systems and feeding technologies. Several farmers stress that even short-term interruptions in energy access could rapidly disrupt production, illustrating vulnerabilities in which energy is understood not simply as one input among others, but as a structural condition upon which these agricultural systems depend.

At farm 2, fertilisers are explicitly understood as an energy-dependent input, with farmer 2 noting that *"without diesel or fertilizers, production would almost immediately come to a halt"*. This reflects a broader understanding of energy as embedded within agricultural inputs and supply chains. At the same time, the degree of energy dependence varies between farms. Highly machined systems, such as farm 5, are heavily reliant on continuous electricity and fuel supply, while smaller regenerative farms, such as farm 4, operate with lower direct energy use. As farmer 4 describes the farm uses *"less energy than a typical household"*, reflecting an intentional effort to minimise dependence on external energy inputs.

6.2 Vulnerabilities linked to external energy systems

Across all cases, vulnerability is closely linked to dependence on external energy systems and infrastructures beyond farmer's direct control. Although the forms of dependency vary between farms, farmers consistently describe limited influence over fuel prices, electricity costs, fertiliser availability and wider supply chains.

Farmers repeatedly emphasize that many of these factors are shaped by external systems, including global markets, policy frameworks and geopolitical events. At farm 2, farmer 2 describes the agricultural system as *"incredibly vulnerable"*, highlighting how production outcomes are strongly influenced by factors beyond the farm level. Similarly, farmers at farm 5 describe how disruptions in global supply chains have affected access to spare parts and technologies, demonstrating how energy dependence is closely tied to broader socio-technical systems.

Policy structures also emerge as a source of vulnerability. For example, farmer 1 highlights how the lack of tax incentives for fossil-free fuel creates economic disadvantages, limiting the feasibility of energy transitions. This indicates that energy dependence is not only a technical issue but also shaped by institutional and economic conditions. Infrastructure-related vulnerabilities are also evident across cases. Farmers point to dependence on slaughterhouses, fuel supply systems, digital infrastructure and transport networks. These dependencies extend beyond the farm and connects agricultural production to wider systems that are not directly controllable at the local level.

6.3 Strategies to reduce energy dependence and increase autonomy

In response to these vulnerabilities, farmers adopt a range of strategies aimed at reducing dependence on external energy systems and increasing autonomy. These strategies vary depending on farm scale, resources and production systems, but several common approaches can be identified.

Technological strategies include investments in solar panels, electric machinery and energy efficiency measures. For example, four out of five farms have installed solar panels to reduce reliance on external electricity. In some cases, farms are also exploring future technologies, such as hydrogen-based energy storage. At farm 4, the farm is designed to rely primarily on natural energy flows, particularly pasture-based systems, thereby minimising the need for external inputs. Similarly, diversification strategies, as seen at farm 2, reduce dependence on single production systems and external supply chains.

Despite efforts, the capacity of farmers to reduce energy dependence remains constrained by broader economic and institutional conditions. High investment costs, policy uncertainty and existing infrastructural systems limit the extent to which farms can transition towards greater autonomy from external energy systems.

6.4 Preparedness

Practical preparedness measures also emerge as important strategies for managing energy-related risks and disruptions. Across several farms, preparedness is linked to maintaining operational capacity during crises through measures such as storing fuel, maintaining feed reserves and investing in backup energy systems. At farm 2, resilience is explicitly connected to reducing dependence on complex and highly automated systems, with farmer 2 emphasising the importance of "low-tech solutions that do not depend on automated systems".
These strategies reflect a practical understanding of preparedness centred on maintaining essential farm functions under certain conditions. At the same time, the ability to implement such measures varies between farms depending on

economic resources, infrastructure and production systems. Across all farms, preparedness is understood in practical terms as the ability to maintain essential function during disruptions. This includes ensuring continued access to water, feed, heating and basic farm operations in the event of power outages, fuel shortages or supply chain disruptions.

Farmers emphasize that even short-term disruptions can have significant consequences, particularly in systems that rely on continuous energy supply. Highly mechanised farms, as farm 5, are especially vulnerable, as automated systems for milking, feeding and monitoring depend on stable electricity and digital infrastructure. At the same time, preparedness is unevenly distributed across farms. Some farms have invested in backup systems, such as generators and stored fuel, while others remain dependent on continuous external supply. Smaller-scale diversified farms often emphasize flexibility and the ability to scale down production, while larger systems face greater challenges in adapting to disruptions.

Despite these differences, a common pattern is that preparedness is closely linked to energy access. The ability to maintain production during a crisis is fundamentally dependent on securing energy resources, either through external supply or through on-farm solutions. These findings further indicate that preparedness cannot be understood solely as an individual farm-level responsibility. While farmers actively develop strategies to maintain production during disruptions, the effectiveness of these measured remains shaped by broader infrastructural, economic and institutional conditions. Preparedness therefore emerges not only as a question of practical adaptation, but also a structural issue linked to access to energy systems, storage capacity, technological flexibility and external support structures.

6.5 Summary of descriptive cross-farm analysis

Taken together, the empirical material shows that energy dependence is deeply embedded within contemporary agricultural systems in Sweden. Across all farms, energy is understood as a fundamental condition for maintaining production, while vulnerabilities are closely connected to external infrastructures, markets and policy frameworks beyond farmer’s direct control. Although farmers actively adopt strategies aimed at increasing autonomy and reducing dependence, these efforts remain shaped and constrained by broader structural conditions. These recurring patterns provide the foundation for the following thematic analysis, which further examines how energy dependence shapes resilience, vulnerability and preparedness across cases.

7. Thematic analysis

7.1 Thematic analysis of farmers experiences

The first table presents a thematic synthesis of recurring patterns identified across farm interviews. The table organises the empirical material into central themes related to energy dependence, vulnerability, preparedness and adaptive strategies, while also connecting these patterns to broader analytical interpretations informed by political agroecology. By structuring the findings in this way, the table highlights how farmers lived experiences of resilience are shaped by structural dependencies on energy systems, infrastructure and external resource flows. The thematic analysis further provides a foundation for the subsequent comparison between farmers experiences and the three agroecological assessment tools analysed in this study.

Table 1. Thematic analysis of farmers' experiences of energy dependence, resilience and preparedness.

Theme	Empirical pattern across interviews	Energy dimension	Analytical interpretation	Link to research questions
Structural energy dependence	All farms describe reliance on diesel, electricity, machinery, and energy-intensive inputs such as fertilisers. Production would stop quickly without energy for most of the farms	Energy is a precondition for many of the farm's operations, not just one input among others	Energy functions as a structural dependency embedded in modern agriculture, rather than a variable farmers can easily adjust	Shows how energy dependence shapes vulnerability and resilience
Limited control over critical resources	Farmers repeatedly emphasize lack of control over fuel prices, electricity access, policy decisions, subsidies, infrastructure, and global supply chains	Energy systems are externally controlled (markets, policy, geopolitics)	Resilience is constrained by political-economic structures beyond the farm level, aligning with the ideas of political agroecology	Explains why tension emerges between tools and lived realities
Strategies to reduce energy vulnerability	Farmers adopt several strategies such as solar	Efforts aim to reduce dependence on	These strategies represent partial and uneven	Shows how farmers actively

	panels, generators, energy efficiency methods, diversification, low-tech systems, and storing of fuel or feed	external energy systems to increase autonomy	forms of resilience across farms, limited by costs, infrastructure, resources and policy	respond to / how they act around energy dependence
Preparedness as ability to maintain function during crisis	Farmers define resilience as the ability to maintain core functions (feeding animals, water supply, heating, machines)	Energy access is central to preparedness, especially for maintaining daily operations	Preparedness is understood practically and materially, not as abstract "resilience indicators”	Highlights mismatch with tools
Tension between sustainability and profitability	Sustainable energy transitions (e.g. HVO, biogas, electric machines or solar investments) are often described as economically risky or disadvantageous due to policy structures and market conditions	Energy transitions are shaped or hindered by economic / or policy disincentives	Structural conditions limit farmers’ ability to transition towards fossil free systems, despite willingness	Explains multiple barriers to agroecological transition
Infrastructure and system-level vulnerability	Farmers identify vulnerabilities in supply chains, slaughterhouses, spare parts, digital systems, and energy infrastructure	Energy dependence is tied to broader social-technical systems, not just farm-level practises	Vulnerability is systematic, extending beyond individual farms to national and global systems	Expands resilience beyond farm-level
Perceived gap between policy / tools / reality	Farmers express that advisory systems, regulations, and sustainability frameworks often overlook practical realities, especially energy dependence	Energy remains invisible or under-recognized in formal assessments	Indicates a disconnect between measured resilience and lived resilience	Directly supports the core arguments about agroecological tools missing out

This thematic analysis further reveals that energy is not perceived by farmers as a simple input, but as a structural condition underpinning almost all aspects of agricultural production. Across the interviews, energy dependence emerges as a central cause of vulnerability, closely linked to external political-economic systems beyond farmers' control. This includes reliance on fuel markets, electricity infrastructure, input supply chains and broader geopolitical dynamics. In this sense, energy functions as a key intermediary between farm-level practices and wider socio-technical systems, shaping both the possibilities and limits of agricultural production.

While farmers actively try to reduce dependence, such as adjusting production practices or investing in alternative energy solutions, these efforts are constantly described as constrained by economic costs, policy frameworks and infrastructural limitations. This highlights that adaptive capacity is not only a matter of individual decisions-making, but it is conditioned by structural factors that define what is realistically possible within a given agricultural system. Those findings align with political agroecology perspectives, which emphasises that farming systems are embedded within broader relations of power, dependency and resource access (Holt-Giménez & Patel, 2009).

This mismatch can also be understood through debates within political agroecology, where agroecology itself is described as a "territory in dispute" between transformative social movements and institutional actors (Giraldo & Rosett, 2017). From this perspective, agroecology is not a fixed set of practices, but a contested framework shaped by different actors with competing visions. On one side, social movements frame agroecology as a pathway for transforming food systems by reducing dependency and increasing autonomy. On the other hand, institutional actors tend to translate agroecology into measurable indicators and standardised practices. The findings in this study suggest that farmers experiences align more clearly with the former perspective, where resilience is inseparable from questions of dependency, control and structural constraints.

From this perspective, energy dependence becomes a critical lens through which broader issues of power and vulnerability can be understood. The fact that farmers repeatedly emphasise energy as a key concern indicates that resilience cannot be reduced to ecological practices or input efficiency alone. Instead, it must be understood in relation to the systems that enable or constrain agricultural production. This support arguments within agroecological literature that resilience is shaped by the degree of reliance on external inputs and the capacity to maintain internal system functions (Altieri, 2008; Pimbert & Uhnák, 2019).

Moreover, resilience is constantly framed by farmers in terms of the ability to maintain core functions during disruptions, highlighting a practical understanding of preparedness grounded in everyday experience. This includes ensuring access to water, feed, machinery, heating and energy under conditions of certainty. Such accounts point to resilience as an operational and immediate concern, rather than an abstract or long-term goal. In this sense, preparedness emerges as an essential component of resilience, closely linked to the continuity of production under stress.

Taken together, these findings demonstrate that farmers conceptualise resilience as a dynamic process shaped by structural dependencies, rather than as a fixed outcome of farm level practices. This provides an important foundation for the subsequent comparison with agroecological assessment tools, as it highlights which dimensions of resilience emerge as most important in farmers lived experiences and therefore deserve greater attention in these three assessment frameworks.

7.2 Comparative analysis of farmers experiences and agroecological assessment tools

The second table present a comparative analysis between farmers lived experiences and the agroecological assessment tools TAPE, LUME and OASIS. Building on the thematic analysis presented in Table 1, the comparison examines how key dimensions of resilience identified in the empirical material are conceptualised, included or overlooked within the assessment frameworks. Particular attention is given to how the tools address energy dependence, preparedness, autonomy and structural vulnerability. By systematically contrasting farmers experiences with indicator-based representations of resilience, the table highlights important tensions between practical understandings of resilience and the ways resilience is operationalised within the three agroecological assessment tools.

Table 2. Comparison between farmers' experiences and agroecological assessment tools.

Dimension/Theme	Farmers experiences (empirical findings)	TAPE	LUME	OASIS
Energy dependence	Explicit and central. Farms rely on diesel, electricity, fertilisers, feed/seeds, and machinery	Not explicitly measured. Embedded in inputs and productivity	Conceptualised as part of external flows (metabolism), but still abstract	Indirectly captured through inputs and practices
Energy as structural vulnerability	Seen as a systematic risk linked between global markets, geopolitics and infrastructure	Treated as a technical input	Recognised structurally, but not operationalised	Not explicitly framed as structural vulnerability

Preparedness (a crisis perspective)	Defined as ability to maintain basic functions (water, heating, feeding) etcetera during disruptions	Not included	Not explicitly addressed	Not explicitly addressed
Autonomy and control	Farmers emphasise limited control over energy, prices, policy and supply chains	Weakly addressed through general input reduction	Strong focus on autonomy (endogenous vs. exogenous flows)	Moderate focus through “input autonomy”
Adaptation strategies	Solar panels, generators, diversification, storage, low-tech solutions	Not explicitly evaluated	Conceptually acknowledged	Partially captured through diversification indicators
Economic constraints	Sustainable choices (e.g. HVO, biogas, investments) often economically risky or discouraged	Not addressed	Recognised structurally	Partially addressed (economic indicators)
System-level vulnerability	Dependence on infrastructure (fuel supply, spare parts, slaughterhouses, digital systems)	Not included	Implicit in political economy framing	Not included
Understanding of resilience	Practical, material, crisis-oriented (can the farm function?)	Performance-based (productivity and sustainability indicators)	Structural and theoretical	Indicators-based and practice-oriented

The comparison demonstrates that several dimensions identified as central by farmers remain weakly represented within the assessment frameworks. This comparison reveals a clear mismatch between farmers lived experiences of resilience and how resilience is conceptualised within these three agroecological assessment tools. While farmers constantly frame resilience in terms of energy access, preparedness, and the ability to maintain core functions during crises;

these dimensions remain largely absent or implicit within the tools. Instead, resilience is primarily constructed through indicators related to productivity, ecological practices and input use. This suggests that current assessment frameworks overlook key structural vulnerabilities, particularly those related to energy dependence and border socio-technical and political-economic systems. As a result, resilience among Swedish farmers may be overestimated if based solely on these tool-based evaluations.

A central analytical implication is therefore that energy is highly visible and critical in practice, yet largely invisible within the tools. When energy appears within in these tools analysed in this study, it is generally framed indirectly through indicators related to input use, efficiency or resource management, rather than as a distinct structural dependency. In TAPE, energy-related dimensions are primarily embedded within broader categories such as external inputs, productivity and resource efficiency. For example, reduced dependence on synthetic fertilisers or external inputs may indirectly imply lower energy use, but the framework does not explicitly assess vulnerability related to fuel access, electricity dependence or energy infrastructure.

Similarly, OASIS addresses energy indirectly through indicators connected to input autonomy, diversification and farming practices such as reduced tillage or lower reliance on synthetic inputs. While these practises may reduce exposure to energy-intensive production systems, energy itself is not conceptualised as a separate dimension of resilience or preparedness. LUME differ somewhat by engaging more directly with external resource flows though the concept of social metabolism and the distinction between endogenous and exogenous resource use. This allows the framework to recognise broader forms of dependency within agricultural systems. However, energy dependence remains primarily conceptual rather than operationalised through explicit assessments of crisis vulnerability, preparedness and infrastructural disruptions. This reflects a tendency to depoliticise energy by disconnecting it from wider systems such as global markets, infrastructure and governance. Consequently, important dimensions of vulnerability, such as exposure to energy price volatility or reliance on external supply chains, are not fully captured.

The comparison also highlights a significant gap regarding preparedness. While farmers emphasise the importance of maintaining essential functions under conditions of disruptions, this perspective is largely missing from the tools analysed in this study. This absence limits the ability of these frameworks to assess resilience in crisis, where continuity of production depends not only on ecological practices, but also on access to energy and infrastructure. Differences between the tools further illustrate these limitations. LUME aligns more closely with the concept of structural dependency at a theoretical level, particularly through its focus on external resource flows. However, it lacks the empirical specificity needed to capture how these dependencies are managed in practice. In contrast, TAPE addresses the underlying structural conditions and shape vulnerability. Across all three tools, resilience is primarily assessed at the level of the individual farm, which limits their ability to account for systematic dependencies embedded in wider socio-technical systems.

Taken together, these findings point to a fundamental tension between different understandings of resilience. Agroecological assessment tools tend to construct resilience as a measurable, performance-based outcome, whereas farmers experience resilience as the capacity to sustain production under conditions of uncertainty, disruption and contrast. In this sense, resilience is not only a matter of performance, but of survival under energy-dependent conditions.

This gap also reflects a broader shift in how these agroecological tools may be translated into policy and practice. While agroecology is often framed as a transformative approach, its integration into standardised assessment tools requires simplification and standardisation (Giraldo & Rosset, 2017). In this process, complex and politically sensitive dimensions, such as dependency on global energy systems, may be downplayed in favour of more neutral and measurable indicators. As a result, the tools analysed in this study can be understood as part of an institutionalisation process, where agroecology is adapted to fit existing governance frameworks. While this may increase usability in policy and advisory contexts, it can also limit the capacity of agroecology to challenge underlying structures of dependency and vulnerability (Pimbert & Uhnák, 2019). In contrast, the farmer's narrative in this study aligns more closely with a political understanding of agroecology, where resilience is linked to autonomy, control over resources and the ability to withstand systematic disruptions. This suggests that when agroecology is translated into assessment frameworks, it risks losing it’s critical and transformative potential, becoming instead compatible with the very stems it seeks to challenge.

8. Discussion

8.1 Tools shape reality

Beyond measuring resilience, the tools analysed in this study also play a role in shaping how resilience is understood and prioritised in practice. By focusing on certain indicators, they guide attention towards specific aspects of farming systems while leaving others in the background. This means that what is not measured enough, i.e. energy dependence, risks becoming less visible in advisory work, policy discussions and farm-level decision-making. This has complications, as it suggests that assessment tools do not simply reflect reality, but actively participate in construing it (Gonzalez de Molina, 2013; Holt-Giménez & Patel, 2009). In this case the limited visibility of energy within the assessment framework may contribute to a marginal position in discussions of agricultural sustainability and rural development.

8.2 Comparison of TAPE, LUME, and OASIS in a Swedish context

In a Swedish context, agroecological resilience clearly cannot be adequately assessed without explicitly accounting for energy as a central dimension of preparedness. Energy is not only required for the day-to-day functioning of agricultural production but also reflects broader political-economic dependencies that shape farmers' capacity to act. By overlooking this dual role, existing assessment tools underestimate the vulnerability of farms to disruptions and overestimating their resilience.

The analysis shows that TAPE and OASIS tend to treat energy as an indirect or secondary variable rather than a distinct dimension of vulnerability. In TAPE, energy use is embedded within broader categories such as productivity and external inputs, while OASIS focuses on positioning farms along an agroecological transition without explicitly assessing their exposure to energy-related disruptions. As a result, both tools may identify farms as resilient based on indicators such as biodiversity, diversification or reduced reliance on external inputs, without capturing the extent to which their production systems depend on continuous access to fuel, electricity and infrastructure. This contrasts with the empirical findings, where energy dependence emerged not as a discrete input, but as a condition for the content of agricultural protection. Across the interviews, farmers consistently linked resilience to the ability to maintain essential functions, including water supply, feeding systems, machinery use, animal care and storage. These functions are all dependent on stable access to energy, and their disruption would directly affect the viability of farm operations. In this sense, resilience is understood by farmers less as a solely ecological outcome and more as the capacity to sustain everyday functioning under conditions of uncertainty.

LUME provides a more explicit recognition of these dependencies by highlighting the balance between endogenous (internal) and exogenous (external) resources. This makes energy structurally visible, as farms can be analysed in relation to their reliance on external inputs, infrastructure and global systems. However, this perspective remains analytically abstract. While LUME identifies dependency, it does not fully capture how such a dependency works out in practice, particularly under conditions of disruptions. The framework does not assess what happens when energy supply is interrupted, nor does it account for the operational consequences of such interruptions for farm-level preparedness.

Taken together, the comparison reveals a gap between how resilience is conceptualised in assessment tools and how it is experienced by farmers in Sweden. While tools tend to evaluate resilience through indicators such as diversification, autonomy and ecological performance, farmers emphasise the ability to maintain production during disruptions. This highlights the importance of understanding energy not only as a technical input, but as a condition for operational continuity. A possible explanation for why energy dependence receives limited attention in agroecological assessment tools is methodological. Agroecological assessment tools are designed to prioritize indicators that are relatively stable, measurable and comparable across contexts (FAO, 2019). Energy dependence, however, is relational and very much context specific. It depends on fluctuating market conditions, geopolitical developments and infrastructural systems that are difficult to capture through static indicators. As a result, energy related vulnerabilities risk being systematically excluded, not because they are unimportant, but because they do not fit easily within indicator-based frameworks. This suggests that the absence of energy in these tools is not only a conceptual issue but also reflects the limitation of measurement itself. By highlighting what can be easily measured, assessment frameworks may overlook forms of vulnerability that are dynamic, indirect or embedded in wider socio-technical systems (Gonzalez de Molina et al., 2020).

Furthermore, energy dependence must be understood as a political-economic relation. Farmers capacity to manage energy use is shaped by factors beyond their control, including field prices, electricity markets, infrastructure, regulation and supply chains. These structural conditions influence the feasibility of alternative strategies, such as investing in renewable energy, reducing external inputs or increasing on-farm autonomy. As such, energy-related vulnerability reflects broader dynamics of power, control and dependence within the agricultural system. This finding is reinforced by recent European policy analysis, which highlights the current energy crisis exposed by the EU's structural vulnerability due to high dependence on imported fossil energy (European Scientific Advisory Board on Climate Change, 2024). The crisis demonstrated how disruptions in energy supply rapidly translate into broader economic and social risks, including impacts of food systems. From this perspective, the vulnerabilities described by Swedish farmers are not isolated cases, but reflect wider systematic dependencies embedded within European energy and food systems. While policy responses increasingly emphasise reducing energy demand and expanding domestic renewable energy, agricultural assessment tools have not yet incorporated these structural dimensions into their understanding of resilience. This suggests a critical gap between policy-level recognition of energy vulnerability and farm-level assessment framework. In a Swedish context, characterised by highly mechanised product systems and strong integration into European and global markets, this dual role of energy becomes particularly significant. Resilience is not only a question of ecological practices, but also of infrastructural reliability, economic viability and access to critical resources.

Current agroecological assessment tools do not adequately capture this structural dimension. As shown in the analysis, TAPE and OASIS treat energy indirectly through categories such as productivity or input use, white LUME conceptualises dependency more explicitly but remains abstract in its operationalisation. This creates a mismatch between how resilience is measured and how it is experienced in practice. The findings of this study suggest that energy should be understood not simply as an input, but as a structural condition shaping resilience. Across farms, energy is described as a precondition for maintaining core functions, including water supply, feeding systems, machinery use and storage. This aligns with broader research showing that modern agriculture is deeply embedded in fossil-based energy systems and external input flows, which have developed through processes of mechanisation and intensification (Swedish Energy Agency, 2021; LRF et al., 2026). Thus, it is safe to say that these agroecological assessment tools need to more explicitly account for energy as both an operational and political-economic dimension of preparedness to provide a more accurate representation of farm-level resilience in countries like Sweden.

8.3 Farmers Experiences of Energy Dependence and Preparedness

Empirical evidence from the Swedish cases shows that energy often functions as an "invisible" infrastructure within agricultural systems that is taken for granted until a crisis occurs (Hörndahl, 2008), such as the 2018 drought or sharp increases in electricity prices. This observation aligns with a political agroecology perspective that highlights how critical resource dependencies, such as energy, become normalised and depolarised within modern agricultural systems (Gonzalez de Molina, 2013; Peterson et al., 2020). For farmers, resilience does not only mean biodiversity but also the ability to maintain critical functions under disruptions (FAO et al., 2025), such as water pumping or feeding during power outages or fuel shortages. Strong dependence on diesel, electricity and external inputs described by farmers reflects what political agroecology conceptualises as structural dependency embedded in industrial agricultural systems (LRF et al., 2026; Gonzalez de Molina et al., 2020). The limited attention to preparedness within assessment tools contrasts with increasing policy emphasis on strengthening national food system resilience in Sweden (KSLA, 2024).

A recurring tension is that sustainable choices, such as using fossil-free HVO, often involve economic disadvantages due to tax systems that favour fossil diesel (Fossilfree Sweden, 2021). Swedish farmers highlight profitability, dependence on fossil inputs and value chain power relations as key barriers to the transition towards fossil-free agriculture (Johansson et al., 2026). These experiences illustrate how resilience at farm level is shaped not only by ecological practices, but by border political-economic structures beyond farmers control (Pellow & Brulle, 2005; Stiernström et al., 2025). *Future visions for fossil-free agriculture* emphasises circular systems, improved soil health and stronger collaboration between farms and other actors in the food systems (Johansson et al., 2026).

From a political agroecology perspective, a farming system can appear resilient even if it depends heavily on external energy inputs. In the Swedish context, this apparent resilience is often reflected in high productivity, advanced technology and somewhat well-functioning supply chains. These characteristics can create an image of stability and efficiency. However, this stability is largely dependent on contributed access to fossil fuels, imported fertilizers, machinery, and global markets. As highlighted in the literature, Swedish agriculture is still embedded in broader energy systems and external inputs flows, which are not fully controlled at the national level. When these external dependencies are disrupted through energy price volatility, supply chain disruptions, or geopolitical crises, the underlying vulnerability of the system becomes more visible. From this perspective, what appears as resilience may instead be a form of stability that depends on continued access to external inputs and functioning markets. Political agroecology therefore argues that resilience should not only be evaluated based on current performance, but also on the system's capacity to function under disruption and reduced input availability. In this sense, apparent stability can coexist with deeper structural fragility, particularly when resilience is built on dependencies that are unevenly distributed and politically shaped (Pellow & Brulle, 2005). These findings suggest that farmers lived experiences of resilience emphasises autonomy, energy access and preparedness, highlighting a gap between the dimensions of resilience valued by farmers and those captured by existing agroecological assessment tools (Škorjanc et al., 2001; Peterson et al., 2020).

Furthermore, findings suggest that Swedish food preparedness is deeply intertwined with the profitability of agriculture and access to domestically produced energy, limited by institutional and economic structures shaping agricultural systems (Stiernström et al., 2025; Gonzalez de Molina, 2013). Farmers express frustration that regulations are designed for large-scale industrial production, which limits the room for manoeuvre for small-scale or regenerative solutions that could strengthen local robustness. At the same time, literature highlight that increased domestic production of for instance bioenergy on marginal lands in southern Sweden could contribute to fossil-free energy systems, but this often conflicts with other values such as biodiversity and traditional food production (Ahlgren et al., 2015). Rising energy and input costs, as highlighted in recent policy reports, have placed increasing pressure on both primary producers and the wider food system, reinforcing the importance of energy as a key dimension of resilience (Regeringen, 2025).

8.4 Industrialised agriculture and structural dependency in Sweden

The vulnerabilities identified at farm level are not only internal but reflect broader systematic dependencies. Swedish agriculture is highly reliant on continuous flows of external inputs, including fuel, fertilizers and feed, as well as functioning transport systems, making it particularly sensitive to disruptions beyond the farm scale (Eriksson & Kuns, 2020). The findings also highlight that resilience is not solely a property of individual farms but is shaped by the broader ´enabling environment´, inducing policies, markets and institutional arrangements (Mathijs et al., 2021). Following resilience literature, the challenges faced by farming systems can be understood as a combination of shocks (e.g. geopolitical crises), long-term stresses (e.g. increasing input costs), and everyday variability (Mathijs et al., 2021).

Digging deeper into the Swedish context further complicates the picture. Unlike many contexts where agroecology is associated with low-input systems, Swedish agriculture is as mentioned often characterised by high levels of mechanisation, technological integration and dependence on external inputs (Swedish Energy Agency, 2021; LRF et al., 2026). This means that reducing energy dependence is not simply a matter of adopting new practices but involves navigating deeply embedded infrastructural and economic systems. In this sense, Swedish agriculture represents a case where resilience is clearly tied to maintaining access to complex systems rather than reducing dependence on them entirely. This challenges assumptions within agroecological frameworks that resilience can be achieved primarily through input reduction and diversification (Altieri, 2008) and highlights the need to adapt these frameworks (i.e. TAPE, LUME and OASIS) to high-input contexts.

The analysis suggests that strengthening resilience in Swedish agriculture requires moving beyond a narrow focus on productivity or self-sufficiency, towards addressing structural dependencies, particularly in relation to energy and external inputs. The findings further suggest that contemporary Swedish agriculture is characterised by a paradoxical relationship between efficiency and vulnerability. On the one hand, high levels of mechanisation, technological integration and specialisation have enabled increased productivity and reduced labour intensity for a long time. On the other hand, these same developments have simultaneously increased dependence on access to electricity, fuel, imported inputs, digital infrastructure and highly centralised supply chains. In this sense, technological modernisation does not necessarily reduce vulnerability but may instead relocate vulnerability from the local farm level to broader infrastructural and geopolitical systems. This became visible in farmers descriptions of how agricultural production depends on systems beyond their control. Across the interviews, vulnerabilities were repeatedly linked not only to weather conditions or farm management, but also to electricity networks, fuel markets, slaughterhouses concentration, transport infrastructure, imported feed, digital communication systems and policy frameworks. Several farmers also highlighted that agricultural systems have become increasingly centralised, meaning that disruptions affecting only a few actors or infrastructures may generate cascading effects throughout the wider food system.

From a rural development perspective, these findings challenge dominant assumptions that modernisation automatically strengthens resilience. Instead, this study suggests that resilience within highly industrialised agricultural systems may coexist with structural fragility. Apparent stability is maintained because complex infrastructures continue to function uninterrupted. However, when and if these systems are disrupted, vulnerabilities will be visible. This shows that resilience in industrial agricultural contexts, once again, cannot be understood through productivity or efficiency indicators, but must also account for infrastructural dependence and crisis capacity.

The findings moreover raise broader questions regarding the organisation of Swedish food systems and rural development policy. Farmers reputedly emphasised that preparedness cannot be reduced to individual farm responsibility alone, since many vulnerabilities can be found at systematic levels through market concentration, regulatory structures and infrastructural centralisation. In this sense, resilience becomes relational; it depends not only on what happens within the farm boundary, but also how wider political-economic and infrastructural systems are organised.

8.5 Conceptualising resilience, preparedness and structural dependency

A key implication of this study is the need to more clearly distinguish between resilience and preparedness at a conceptual level and a practical level. While resilience is often understood within agroecological frameworks as the capacity of a system to absorb shocks, adapt and maintain function over time, preparedness refers more specifically to the ability to sustain essential functions under immediate conditions of disruption, particularly in relation to food systems and energy access (Länsstyrelsen Stockholm, 2021; KSLA, 2024).

In this study, farmers suggest that these concepts, while closely related, refer to different dimensions of agricultural systems. Resilience, as constructed within assessment tools, tends to emphasise long-term system performance, ecological practices and gradual adaptation. Preparedness, in contrast, is grounded in short-term operational capacity; the ability to maintain water supply, feeding systems, heating and machinery during crises. This indicates that preparedness may represent a more concrete and operational dimension of resilience, particularly in highly energy-dependent systems. From a structural perspective, this distinction becomes particularly important. Preparedness is directly conditioned by access to infrastructure, energy systems and external resources, which are largely beyond the control of individual farmers. This suggests that preparedness is not only a farm-level capacity, but a system-level condition shaped by political-economic and infrastructural structures. In this sense, resilience without preparedness risks remaining an abstract concept, disconnected from the material conditions required to sustain agricultural production during disruptions. An important contribution of this study is just that, the distinction between resilience and preparedness. Within agroecological assessment tools, resilience is primarily conceptualised as a long-term system characterised associated with diversification, ecological management and adaptive capacity. Preparedness, however, emerged in farmers interviews as something more direct and practical such as maintaining water systems, feeding animals, accessing fuel, storing inputs and continuing production during infrastructural breakdowns or electricity failures.

The findings therefore suggest that preparedness captures dimensions of vulnerability that resilience may overlook. While resilience often refers to the capacity to adapt over time, preparedness focuses more directly on the ability to cope with current disruptions and maintain production under crisis condition. In highly energy-dependent agricultural systems such as Sweden, it is possible to argue that this distinction is important since agricultural production relies on infrastructures that must function all the time in everyday practise. From this, one might say that this reveals a broader conceptual tension within agroecology. Existing frameworks tend to conceptualise resilience primarily through ecological indicators and farm-management practises, whereas farmers understand resilience though dependency relations and practise. Meaning that resilience within the tools is often represented as ecological performance, while resilience in practise is experienced as the ability to sustain basic functions despite uncertainty.

8.6 Rethinking reliance and dependency in agroecological systems

The findings also invite a critical reconsideration of the concept of dependency. Within agroecological frameworks, reducing dependence on external inputs is often presented as a pathway towards increased resilience and sustainability (Altieri, 2008; Pimbert & Uhnák, 2019). However, this study shows that in the Swedish context, such dependencies cannot simply be reduced or eliminated but must instead be understood as structurally embedded and unevenly distributed.

Farmers operate within highly mechanised and interconnected systems, where energy dependence is embedded in infrastructure, supply chains and policy frameworks. From this perspective, reliance is shaped by historical processes of agricultural modernisation, market integration and energy transitions (Swedish Energy Agency, 2021; LRF et al., 2026). This challenges the assumption that resilience can be achieved primarily through input reduction at farm level. Instead, the findings suggest that different forms of reliance must be distinguished. Some dependencies, such as access to electricity or functioning infrastructure, are necessary for maintaining production and may therefore be central to preparedness. Others, such as reliance on unstable global input markets, may increase vulnerability. This indicates that the relationship between reliance, resilience and preparedness is more complex than often assumed in agroecological frameworks.

8.7 Implications for rural development in Sweden

These findings also have important implications for how rural development is conceptualised in Sweden. Within policy and institutional frameworks, rural development is often associated with increased productivity, technological advancement and market integration. However, farmers lived experiences in this study suggest that such models may overlook key vulnerabilities related to energy dependence, infrastructure and preparedness. In this sense, there is a potential mismatch between dominant visions of rural development and the realities of agricultural production here. While policy frameworks emphasise efficiency and growth, farmers highlight the importance of stability, autonomy and the ability to maintain production under uncertain conditions. This suggests that rural development in highly industrialised contexts such as Sweden may need to be rethought, not only in terms of productivity, but also in terms of reducing structural vulnerabilities and strengthening system resilience. Energy dependence plays a central role in this reconfiguration. As demonstrated in the empirical findings, the capacity of agriculture to contribute to food preparedness is closely tied to access to stable and reliable energy systems. This implies that rural development strategies must address not only agricultural practices, but also the infrastructural and energy systems that underpin production.

The findings also have implications for how rural development itself is understood within highly industrialised agricultural contexts. Rural development approaches often emphasise innovation, competitiveness, technological efficiency and market integration as pathways toward sustainable agricultural development. However, farmers in this study experiences suggest that such processes may increase dependency on external infrastructures and reduce local autonomy. From such a perspective, rural development cannot only be understood as economic growth or technological advancement, but must also involve questions of local capacity, infrastructural resilience and control over essential resources.

Several farmers described how small-scale and diversified farming systems are often disadvantaged within policy in Sweden and regulatory frameworks designed primarily around large-scale industrial production. This indicates that current agricultural governance structures may favour efficiency and standardisation over preparedness and adaptability. Consequently, the study suggests that strengthening rural resilience in Sweden may require not only technological innovation, but also institutional conditions that support decentralised production, diversification and locally embedded food systems.

8.8 Autonomy as a relational and context-specific concept

Finally, the concept of autonomy emerges as central to understanding resilience in this study. However, autonomy does not appear as a fixed or absolute condition. Instead, it is expressed in relative and context-specific terms.

In the Swedish context, autonomy is not understood as complete independence from external systems, but rather as the ability to reduce critical vulnerabilities and maintain control over key resources under conditions of constraint. For some farms, this involves investing in renewable energy or storing fuel; for others, it involves diversification, local value chains or reducing reliance on external inputs. This suggests that autonomy should be understood as a relational concept, shaped by the interaction between farm-level practices and broader structural conditions. From a political agroecology perspective, autonomy is therefore not only about reducing inputs, but about reconfiguring relationships of dependency, control and access within food systems (Gonzalez de Molina et al., 2020).

In this study, autonomy is thus best understood as the capacity to navigate and manage structural dependencies, rather than to eliminate them entirely. This perspective challenges simplified interpretations of agroecology and highlights the importance of situating resilience within its broader political-economic context. Together, these conceptual distinctions provide a foundation for rethinking how resilience is assessed within agroecological frameworks.

9. Conclusion

This thesis set out to examine how agroecological assessment tools conceptualise resilience in a Swedish agricultural context, with particular attention to energy dependence and food preparedness. By comparing three widely used tools (TAPE, LUME and OASIS) with empirical insights from Swedish farmers, the study reveals a clear and consistent mismatch between tool-based representations of resilience and farmers lived experiences.

The findings show that energy is not perceived by farmers as a marginal or technical input, but as a fundamental precondition for agricultural production. Across all cases, the ability to maintain basic functions, such as water supply, feeding systems and machinery, depends directly on continuous access to energy. At the same time, this dependence creates significant vulnerabilities, as farmers have limited control over fuel prices, electricity access, infrastructure and global supply chains. Resilience, from the farmers perspective, is therefore closely tied to preparedness; the ability to continue operating under conditions of disruption.

The agroecological assessment tools analysed in this study largely fail to capture such dimensions. Energy dependence is either treated indirectly, embedded within broader input categories, or conceptualised at an abstract level without being operationalised. Similarly, preparedness as a crisis-oriented capacity is largely absent. Instead, resilience is primarily constructed through indicators related to productivity, diversification and ecological performance. While these are important dimensions, they do not fully account for the structural and systematic vulnerabilities that farmers experience in practice in Sweden. This mismatch can be understood through a political agroecology perspective. The results suggest that these agroecological tools tend to simplify complex socio-political realities into measurable indicators. In this process, structural dependencies, particularly those related to energy systems, infrastructure and geopolitical conditions, risk becoming invisible. As a result, resilience amongst Swedish farmers and domestic food production risk being overestimated if assessed through these tools. At the same time, these findings highlight that farmers are not passive within these systems. Across all cases, farmers actively adopt strategies to reduce energy dependence and increase autonomy, including investments in renewable energy, diversification, storage or low-tech solutions. However, these efforts are uneven and often constrained by economic conditions, policy frameworks and infrastructural limitations. This points to the importance of moving beyond farm-level analysis and recognising that resilience is shaped within a broader environment of institutions, markets and governance structures.

Overall, this thesis contributes to debates within agroecology and rural development by demonstrating that resilience cannot be understood solely as ecological performance or system stability. Instead, it must be approached as a multidimensional concept that includes structural dependencies, energy flows and preparedness for disruption. For these agroecological assessment frameworks to function as a meaningful strategy for food system resilience in Sweden, both analytical frameworks and policy approaches need to more explicitly address dimensions of dependence and preparedness.

Future research could thus further explore how energy dependence and preparedness can be operationalised within agroecological assessment tools, as well as how policy frameworks can better support farmers in reducing structural vulnerabilities. Further attention could be given to the relationship between practical preparedness at the farm level and the broader policy and infrastructural conditions that shape farmers capacity to maintain production during disruptions. This includes questions related to energy infrastructure, storage capacity, decentralised food systems and institutional support for local adaptive strategies. By integrating farmers lived experiences with theoretical and methodological developments, there is potential to develop more grounded and context-sensitive approaches to resilience and preparedness within contemporary agricultural systems in Sweden.

Finally, this thesis contributes to agroecological and rural development debates by demonstrating that resilience in highly industrialised agricultural systems cannot be understood solely through ecological indicators or efficiency measures. In the Swedish context, resilience is closely connected to preparedness, infrastructure and structural dependency. These findings therefore suggest that the three agroecological assessment tools chosen in this study need to more explicitly address energy dependence and preparedness, to better capture vulnerability within modern agricultural systems. In this sense, the apparent stability of Swedish agriculture may conceal a deeper structural fragility, rooted in energy dependence and external control over essential resources.

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Popular science summary

Modern agriculture in Sweden depends heavily on energy. Electricity, diesel, machinery, fertilisers and transport systems are essential for maintaining food production. At the same time, rising energy prices, geopolitical instability and concerns about food preparedness have raised new questions about how resilient agricultural systems really are. This thesis explores how energy dependence affects Swedish agriculture and whether three specific agroecological assessment tools capture these vulnerabilities.

The study focuses on three agroecological assessment tools, TAPE, LUME and OASIS. These tools are designed to evaluate sustainability and resilience within agricultural systems. To understand how these frameworks relate to everyday farming realities, interviews and field observations were conducted with five Swedish farmer representing different production systems and scales.

The findings show a clear difference between how farmers understand resilience and how resilience is measured within the assessment tools. Farmers consistently describe energy as a basic requirement for keeping farm function. Water supply, feeding systems, heating, milking equipment and machinery all depend on stable access to electricity and fuel. Many farmers also describe vulnerabilities linked to fuel prices, infrastructure, supply chains and external political and economic systems beyond their control. In contrast, the agroecological tools analysed in this study rarely address energy dependence directly. Instead, energy is often treated indirectly through indicators related to efficiency, external inputs or farming practices. The tools also place limited attention on preparedness, meaning the practical ability to continue production during disruptions such as power outages or supply shortages. At the same time, farmers actively work to reduce vulnerability through strategies such as solar panels, diversification, fuel storage and low-energy farming systems. However, these strategies are often limited by economic conditions, infrastructure and policy frameworks.

The thesis argues that resilience in agriculture cannot be understood through ecological indicators or farm productivity. It must also include questions of energy dependence, preparedness and broader structural vulnerabilities. The results suggest that current assessment frameworks may overestimate resilience in highly mechanised agricultural systems such as Sweden if these dimensions are not considered.

By combining farmers experiences with political agroecological theory, this study contributes to discussions about food preparedness, sustainable agriculture and rural development in Sweden. The findings highlight the importance of developing agricultural policies and assessment tools that better reflect the practical realities farmers face in an increasingly uncertain world.

Appendix 1: Interview guide

This part of the document constitutes an interview guide aimed at mapping Swedish farmers' perspectives on operational resilience and future challenges. The questions focus on how farms have developed over time and their capacity to manage crises and disruptions in supply chains. A central part of the material examines agriculture's dependence on energy and how fluctuating prices of inputs affect daily operations. Furthermore, the guide explores farmers' views on their own role in Sweden's food preparedness and the extent to which they feel they have control over their resources. Finally, the interview addresses questions of independence and the need for political or structural changes to create a more sustainable agricultural system. Through these themes, a comprehensive picture is formed of the sector's vulnerabilities and its potential for development in an uncertain world.

1. **Farm Context and Farming Trajectory**
    a. Can you tell me about your farm and how it has developed over time? (Size, production type, crop/livestock mix, years farming)
    b. What does a normal farming year look like for you? (Seasonal peaks, labour, key inputs)
    c. Have there been any major changes in how you farm in recent years? (Inputs, machinery, production methods, diversification)
2. **Understanding of Resilience and Vulnerability**
    a. When you hear the term resilience in relation to farming, what does it mean to you? (Follow up: is it about production, economy, environment, or something else?)
    b. What do you feel makes your farm vulnerable today? (Prices, weather, inputs, labour, policy)
    c. Have you experienced citations where your farm felt particularly exposed or fragile? (Crises, disruptions, uncertainty)
3. **Energy Use and Energy Dependence**
    a. What kinds of energy are essential for your farm to function? (diesel, electricity, heating, fertilisers, feed, machinery)
    b. How have energy prices or access affected your farm in recent years? (costs, planning, stress, changes in practises)
    c. Are there any energy inputs you feel especially dependent on or locked into? (machinery stems, fertilisers, contractors, infrastructure)
    d. Have you made any changes to reduce energy use or energy dependency? (why/why not, what made it possible or difficult)
4. **Preparedness and Crisis Experiences**
    a. When do you think about preparedness, what does that mean at farm level?
    b. Do you feel your farm would be able to continue producing food during a major crisis? (e.g. energy shortages, supply disruptions?) Why or why not?

   c. Are there resources or inputs you would struggle most to access in such a situation? (Fuel, electricity, feed, fertilisers, spare parts)
   d. Do you think farms like yours are expected to play a role in national food preparedness? (expectations, responsibilities, support)

5. **Autonomy, Inputs and Control**
   a. To what extent do you feel in control of the resources your farm depends on?
   b. Are there inputs or systems where you feel you have little room to manoeuvre? (contracts, infrastructure, regulations)
   c. What would greater autonomy look like for your farm? (energy, inputs, markets, labour)
6. **Experiences with Advisory Systems and Assessments**
   a. Have you ever participated in farm assessments, advisory programmes or sustainability evaluations?
   b. Do these kinds of assessments reflect what you experience as the main challenges on your farm (what is missing, what feels irrelevant)
   c. Are issues related to energy, input dependence or preparedness usually discussed in these contexts? Why or why not?
7. **Looking forward: Rural development and Agroecology**
   a. What kinds of changes would make farming more secure and sustainable for you in the long term?
   b. How do you see the future of farming in this region? (energy use, land use, policy, generations)
   c. Is there anything important about farming, energy or preparedness that you think is often overlooked?

Appendix 2: Declaration of AI use

This thesis follows the AI policy of the Division of Rural Development level 2, which allows for limited AI use during preparations but not as part of the submitted thesis document. This means that all material included in the final thesis submission and presentation represents the student's own work rather than AI-generated content.

During preparations, the following AI tools have been used:

ChatGPT (OpenAI)

- The purpose of the tool was to support language editing, improve clarity of academic writing, assist with structuring sections, and help simplify or rephrase existing text during the writing process.
- Prompts used for the AI tool are available upon request.
- Outputs generated by the tool were critically reviewed, substantially revised and integrated by the author. AI-generated material was not used without modification.
- The accuracy and correctness of outputs were verified through comparison with course literature, academic sources, empirical material and supervisor feedback. All theoretical interpretations, analysis and conclusions were independently developed and evaluated by the author.

NotebookLM (Google)

- The purpose of the tool was to assist in organising literature and summarise uploaded academic sources.
- Prompts and uploaded materials used within the tool are available upon request.
- Outputs generated by the tool were critically assessed and revised by the author before being incorporated into the writing process.
- The accuracy and correctness of outputs were verified through direct comparison with the original academic sources and empirical findings used in the thesis.

The author retains full responsibility for the content, analysis, interpretations and conclusions presented in this thesis.

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