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Integrating Transboundary Climate Risks into Local Agricultural Adaptation: Evidence from Norway's Livestock Sector

Synnøve S. Beitnes

sbe@vestforsk.no

Western Norway Research Institute

Carlo Aall

Western Norway Research Institute

Marta K. Jansen

Western Norway Research Institute

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Abstract

Global food systems are increasingly exposed to transboundary climate risks (TCRs), yet these risks fall between two stools: omitted from national agricultural policies and overlooked in municipal climate change adaptation planning. Though a qualitative case study in Western Norway, this study explores how incorporating TCRs, specifically linked to imported soybean feed, reshapes climate risk perceptions and discourses, and its potential governance implications for Norway. Drawing on stakeholder interviews, workshops, and a co-production approach, we develop an integrated climate risk framework that links TCRs with physical climate risks and transition risks.

Our findings reveal that TCRs resonate with local actors but are difficult to disentangle from broader socio-economic pressures. Introducing TCRs shifts climate discourse from a narrow focus on local hazards and mitigation toward a systemic understanding of global interdependencies. We identify a risk ownership gap in which local actors bear the material consequences of global disruptions while lacking the authority and institutional support to adapt proactively, rendering TCRs a local vulnerability factor. Crucially, incorporating TCRs reveals the potential to reframe grass-based livestock production systems from climate liabilities to resilience assets, emphasizing the strategic adaptive value of local resource use.

However, integrating TCRs exposes significant policy tensions and maladaptation risks, particularly between reducing import reliance and managing both local climate hazards and carbon footprint. Because climate risks are experienced locally while authority to address their underlying causes resides elsewhere, effective adaptation requires alignment of national agricultural, climate change mitigation, and adaptation policies to support resilient food systems.

1. Introduction

In an increasingly interconnected global food system, food security is shaped by exposure to both local and transboundary disruptions. Climate change, geopolitical instability, economic shocks, and biological threats can directly disrupt agricultural production, supply chains, and service provision, while also generating indirect effects through price volatility, displacement, and political instability (FAO, 2023). Recent events have underscored how tightly coupled global trade systems and food security have become, exposing vulnerabilities inherent in just-in-time supply. For example, in 2022, extreme droughts affected major agricultural regions in Europe, the United States, and China while the world was recovering from COVID-19, and the war in Ukraine led to global grain and fertilizer shortages and rising prices (Chepeliev et al., 2023; Glauber et al., 2022). Yet, international trade remains an essential feature of food system resilience by enabling countries to buffer local production failures (Li et al., 2024). This dual nature of trade creates a fundamental governance tension. It serves as a vital buffer against localized shocks and also as a driver for transboundary climate risks (TCRs).

How food security should be conceptualized remains a subject of ongoing debate, often contested between market-oriented approaches emphasizing global trade and territorial approaches focusing on

national self-sufficiency (Jarosz, 2014). The Intergovernmental Panel on Climate Change (IPCC) underscores that climate change risks have been considerably underestimated, with projections indicating more severe long-term impacts than previously assumed (Pörtner et al., 2022). To increase global food security, food systems must undergo substantial transformations in both production and consumption to enhance sustainability and resilience, with no single solution fitting all contexts (UN SG, 2021). Consequently, international bodies and research communities have called for a substantial transformation in how climate adaptation is managed (Bednar-Friedl et al., 2022; Benzie et al., 2025, 2022; EEA, 2024; Talebian et al., 2025). However, institutional frameworks remain largely bound to a territorial idea: the assumption that climate risks can be managed and mitigated within national or administrative borders (Mikaelsson et al., 2025).

This territorial trap is highly evident in affluent, high-latitude countries like Norway. Norway is often perceived as highly resilient to global shocks, with strong state institutions and an agricultural production largely protected from international competition. Yet, its food production system remains highly exposed to TCRs due to a structural dependence on imported agricultural inputs, most notably high-protein, GMO-free, and non-rainforest-certified soybean originating from climate-vulnerable regions in Brazil (Bardalen et al., 2022; Berninger et al., 2022; Lager, 2025). While national adaptation strategies address territorially bounded physical hazards, such as local flooding or infrastructure disruptions, the systemic risks embedded in global supply chains remain largely unaddressed in domestic governance (Aall et al., 2023a).

While national policy bodies and market industry actors in Norway exhibit lower levels of concern regarding transboundary vulnerabilities, operating under the assumption that state interventions or economic buffers will offset supply chain disruptions (Skagen et al. in press), local authorities and farmers lack both the mandate and tools to address risks originating far beyond their jurisdictions (Aall et al., 2023a). Addressing this gap requires moving beyond top-down, quantitative risk modelling. Instead, we must capture how these transboundary risks originating elsewhere are perceived, interpreted, and negotiated at the local level, where climate adaptation is ultimately implemented (Bednar-Friedl et al., 2022; Carter et al., 2021; Talebian et al., 2025; West et al., 2021).

The recognition of TCRs marks a significant departure from traditional, territorially focused climate risk assessments, acknowledging that local vulnerabilities are often impacted by events occurring far beyond geographical boundaries (Aall et al., 2023a). This study contributes to the literature on TCR governance by examining how TCRs, linked to soybeans for concentrated feed in particular, reshape local understandings of climate risk in agriculture and risk ownership configurations. Utilizing a qualitative case-study approach, we focus on a livestock-based agricultural system in the Sogn region of Western Norway and address the following research questions: How can TCRs be understood and integrated into local agricultural risk discourses? What political implications follow from introducing TCRs into local and national adaptation agendas?

This study is part of a research project investigating how TCRs can become a salient issue for cross-sectoral and multi-scalar governance (Transadapt). This research agenda includes the development of indicators to analyse TCRs at the national level (Lager, 2025), approaches to risk ownership analysis across value chains and policy levels (Canales et al., 2025), cross-sector governance analysis of TCR adaptation (Skagen et al. in press), and the demonstration of how TCRs can be analysed for specific industry sectors, namely fish farming and livestock production, the latter of which is described in this article.

We will first delineate the study's theoretical underpinnings, then describe the Norwegian agricultural context, and our methodological approach. Subsequently, we will present the findings from our case-study analyses and explore their potential implications for climate adaptation and policy development at local and national scales.

2. Theoretical lens: Climate risk and risk ownership

This study draws on the IPCC conceptualization of climate risk as arising from the interaction between hazard, exposure, vulnerability, and response (Pörtner et al., 2022). This framing emphasizes that climate risk is not solely determined by biophysical hazards but is co-produced by socioeconomic factors and policy responses. Within this broader understanding, transition risks, linked to regulatory, technological, and market changes associated with climate change mitigation, form an important component of the overall risk landscape.

The concept of transboundary (Benzie et al., 2022) or cross-border climate risk (Carter et al., 2021) extends this perspective by capturing how climate impacts propagate across national borders through interconnected systems. Such risks materialize when climate-related hazards in one country have consequences in another through pathways such as trade, finance, people, geopolitics, biophysics, and infrastructure. In both research and policy arenas, the trade pathway, specifically concerning food supply chains and agricultural inputs, has been identified as a key source of systemic vulnerability (Bednar-Friedl et al., 2022; Berninger et al., 2022). TCRs thus challenge territorially bounded approaches to climate risk assessment by highlighting dependencies embedded in global value chains, and the underlying cause-and-effect chains become significantly more complex and diffuse for TCRs compared to localized physical climate risks. This heightened complexity arises because biophysical hazards and socioeconomic risk drivers, namely vulnerability, exposure, and response, can be distributed across disparate geographical locations (e.g., primary production in one country and transport logistics in another) as well as across highly diverse economic sectors (such as transport, trade, in addition to agriculture). Consequently, this fragmentation poses a fundamental challenge to identifying "risk ownership".

ISO 31000 defines a risk owner as a person or an entity with the accountability and authority to manage risk. As a TCR propagates through intricate global networks and changes hands among numerous public and private actors, accountability becomes obscured (Hedlund, 2023), and risk ownership can literally be

lost in transit. Managing such diffuse risk landscapes, therefore, demands a broader and more dynamic perspective on ownership than what is offered by ISO guidelines. Young and colleagues (2015) present such a conceptual shift by differentiating between who experiences the problem, who manages the risk (holds responsibility), and who possesses the necessary agency to mitigate, transfer, accept, or avoid the risk (accountability).

While seemingly straightforward in conventional, localized climate contexts (e.g., a municipality building flood defences), assigning ownership becomes inherently complex for TCRs, which transcend jurisdictions, sectors, and public-private boundaries (Hedlund, 2023). Because national adaptation policies are predominantly developed within such localized framing, they fail to account for the transboundary nature of globalized risks. Consequently, ownership concerning TCRs is rarely explicitly stated in national adaptation policies (Mikaelsson et al., 2025). Moreover, private businesses and agricultural actors often demonstrate low awareness of TCRs, operating under the assumption that national governments will serve as the ultimate insurer or financial buffer during global crises (Skagen et al., in press).

Risk ownership is not a static condition; it evolves with changing stakeholder perceptions, values, and political frameworks (Young et al., 2015). Managing systemic risks requires shared responsibility among multiple actors across scales (Aall et al., 2023a; Adams et al., 2021). Crucially, sharing risk ownership does not imply an equal allocation. Different actors possess varying capacities to influence the risk landscape (Raikes et al., 2022).

The governance of TCRs further raises questions of coordination and equity. Effective responses require alignment across national borders and between public and private actors (Adams et al., 2021; Bednar-Friedl et al., 2022). Yet, climate risks are largely examined within national borders and in silos, leading to an incomplete understanding of cascading impacts and interdependencies between sectors (Canales et al., 2025). Consequently, responses to TCRs may take multiple forms, including cost absorption, substitution of inputs and commodities, financial risk transfer, or altering the objectives at stake (Talebian et al., 2025), all of which have implications for who ultimately owns the burden or the solution.

3. Case and methods

3.1 Norwegian agriculture context

Norway’s agricultural sector operates outside the EU, extensively shielded from international competition through tariffs and subsidies to support food security, regional production, value creation, and environmental sustainability (Meld. St. 11 (2023–2024)). To understand how TCRs reconfigure local risk perceptions, the Norwegian agricultural model must be viewed beyond its biophysical constraints. Although most farmland would qualify as Areas facing Natural Constraints (ANC) (OECD, 2021), the system is best understood as a politically constructed model to overcome these limits through state-subsidized spatial decoupling of crop and livestock production.

Since the 1950s, a *canalization policy* concentrated grain production in fertile lowland regions, while peripheral areas like Western Norway were designated for grass-based livestock (Almås, 2004). Post-war structural rationalization has altered the farming landscape, reducing the number of farms from nearly 100,000 in 1989 to 36,790 in 2024 (Almås, 2018; Statistics Norway, 2024a). State policies incentivized this by tying subsidies and investment support to maximizing yields, technological upgrades, and efficiency (Forbord and Vik, 2017). This spatial specialization increased national output and sustained rural settlement but restructured material flows (Vik et al., 2019). Separating livestock from domestic grain production fostered dependence on centralized feed supply chains, linking marginal livestock systems to national and global market dynamics. A prominent contemporary manifestation of this path-dependency is the 2034 statutory loose-housing mandate, a regulation that acts as a structural shock, forcing farmers into high debt or retirement (Hansen et al., 2022).

Crucially, this intensification has shifted feeding regimes toward high-protein imports, particularly GMO-free soybean meal from Brazil. This globalized dependency was catalysed by a previous transboundary crisis, namely the bans on animal-derived meat and bone meal for livestock feeding following the 1990s Bovine Spongiform Encephalopathy (BSE, or “mad cow disease”) (Bertheau and Davison, 2012). While total meat consumption in Norway has doubled since 1960 (primarily driven by grain-dependent poultry and pork production), even grass-based dairy and sheep sectors have internalized a high-intensity feeding paradigm. Despite some substitution with European rapeseed, reliance on overseas soybean meal remains an unsolved systemic challenge (Landbruksdirektoratet, 2026; Meld. St. 11 (2023–2024), n.d.).

National food security is officially conceptualized as resting on three pillars: stable domestic production, the safeguarding of the domestic resource base, and reliable access to international markets (Meld. St. 11 (2016–2017), n.d.). Historically, this framework has treated international trade as a buffer against local hazards, such as the 2018 drought that forced Norway to import forage from abroad, and soy imports went record-high (Beitnes et al. 2022).

However, national climate risk perceptions have shifted fundamentally over the past decade. While early assessments framed Norway as a "climate winner" with increasing local yields (NOU 2010: 10, 2010), compounding global climate shocks and geopolitical crises led national authorities to warn by 2022 that international market disruptions could threaten domestic food security and ultimately require food rationing in Norway (Bardalen et al., 2022). This has reframed climate adaptation into a national preparedness issue, contributing to a revised 50% self-sufficiency target and raising municipal concern over global market risks from 15% in 2017 to 45% in 2024 (Aall, 2026).

From a transboundary perspective, the national food security framework reveals tension. Nominal 44% self-sufficiency drops to 39% when adjusted for imported feed inputs (Svennerud et al., 2023). While national adaptation strategies treat climate change as a territorial threat to be mitigated through local infrastructure (e.g., drainage or flood protection) (Aall et al., 2023a), they tend to overlook systemic supply chain risks (Berninger et al. 2022). Consequently, sub-national authorities and farmers operate

under a decentralized adaptation mandate while bound to a centralized high-input, high-efficiency paradigm (Bjørkhaug and Rønningen, 2014; Flemsæter et al., 2018).

This institutional configuration tightly links geographically dispersed livestock systems to external feed production, making Norwegian agriculture an informative case for examining how TCRs are perceived and managed at the local level.

3.2 Sogn as a regional livestock system

The case study covers five municipalities in inner Sogn, Vestland County: Vik, Sogndal, Luster, Aurland, and Lærdal. This region is characterized by fjords and steep terrain, reflecting typical conditions for a large proportion of Norwegian agriculture, with small, fragmented, and partly steep agricultural land alongside extensive outfield grazing areas. Besides being an important Norwegian district for fruits, vegetables, and berries, livestock is a key production.

Agricultural production in this area is facing mounting pressure from climate change: Climate projections toward 2100 indicate a temperature increase up to 4°C (most prominent in winter) and a two-month extension of the growing season compared to the 1971–2000 baseline. Concurrently, a 15% increase in precipitation, primarily during summer and autumn, alongside more frequent extreme weather events, is expected (Hisdal et al., 2021). While warmer temperatures may extend plant growth, they increase the risk of frost damage from premature spring growth and of summer drought due to reduced winter snow cover. Furthermore, wetter autumns complicate harvesting, increase the risk of soil compaction by heavy machinery, and threaten the overwinter survival of forage plants (Rivedal et al., 2022).

Mirroring national trends, Sogn has undergone substantial structural rationalization over the past 50 years. While the total area of actively managed agricultural land has remained relatively stable, the number of farms has dropped sharply, declining by up to two-thirds in some municipalities (Statistics Norway, 2024a). Consequently, the reliance on leased land per farm and loss of knowledge holders has increased substantially.

Livestock configurations have shifted accordingly: sheep numbers peaked around the turn of the millennium before entering a slight decline, while dairy cow and goat numbers decreased. Conversely, suckler beef cows have increased in most parts of the region, while in some parts, a large goat population (Statistics Norway, 2024b). Crucially, to maintain yields amidst these structural contractions, feeding intensity has amplified dramatically. Vestland County currently exhibits Norway's highest regional consumption of concentrated feed, averaging 33 kg per 100 kg of milk produced (Landbruksdirektoratet, 2021).

3.3 Methodological approach

This study employed a qualitative case study (Yin, 1981). Municipalities were selected as primary units of analysis because agricultural statistics are aggregated at this level, and key advisory services,

regulations, and support mechanisms are administered locally. Moreover, we deployed a critical case design based on a least-likely scenario rationale (Flyvbjerg, 2004), justified by the region's structural paradoxes. Despite vast underutilized outfield grazing potential to displace imported concentrated feeds, the region relies on high-intensity feeding and faces strong pressures from structural policy demands and climate mitigation policies due to its high ruminant density. If concerns about TCRs emerge under such conditions, similar concerns may reasonably be expected elsewhere in the Norwegian livestock sector.

To investigate local agricultural responses to TCR, our study was guided by Harris and colleagues' (2022) TCR protocol. This protocol integrates impact chain thinking (Zebisch et al., 2017, 2021) and emphasizes risk ownership and the uncertainty of climate risk (Florin & Bürkler, 2017; Young et al., 2015) through seven steps, from scoping to iterative validation.

Engaging knowledge users and stakeholders in knowledge co-production is essential to fostering legitimate, effective risk management and clear risk ownership distribution (Dilling and Lemos, 2011; Harris et al., 2022). Through purposive sampling, we recruited a case-participant group of 14 regional and local actors representing regional livestock production. These included two farmer union representatives, two advisors from the Agricultural Extension Service, four municipal agricultural officers, and administrative representatives from the Vestland County Municipality and the County Governor's agricultural development division. Additionally, two informants from the regional agricultural cooperative (Felleskjøpet) and a national expert on agricultural climate risk contributed through semi-structured interviews. Crucially, eight participants also operated part-time family farms, bridging the bureaucratic-practical divide. The stakeholder involvement process ran from November 2022 to March 2024 in three progressive phases, which are described under (Harris et al., 2022). All participants gave written informed consent. Interview guides and consent procedures were approved by the Norwegian Service for Data Protection and Privacy in Research (Sikt).

Co-production was ensured by involving case participants in both defining the problems and their possible solutions through interviews and workshops and by gathering their feedback on our (the researchers') interpretations and analyses of the data material, including data from the co-creative activities. Moreover, the findings have been discussed within the wider Transadapt project team, drawing on parallel and related studies under this umbrella (see section 1). Detailed notes were taken during each interview, roundtable meeting, and workshop, and key insights were immediately summarized afterward (Rutakumwa et al., 2020). The collected data material was analysed using the core categories of the IPCC risk framework alongside the case participants' perceived risk areas associated with TCR, namely agricultural policy, physical climate risk, and climate policy.

The process was guided by the TCR protocol of Harris et al. (2022), which was used as an overarching framework rather than applied as a fixed sequence. As suggested by Harris and colleagues (2022) the empirical activities were conducted in three phases progressing from scoping and classification, through

risk assessment and risk ownership, to adaptation and evaluation. TCRs, physical climate risks, and non-climatic drivers were considered within an integrated risk scope throughout the process.

3.3.1 Scoping and classification

To understand how TCR impacts local risk perceptions, we focused on soy being a key input for grass-based livestock with a relatively robust knowledge base. System boundaries were defined upstream, from GMO-free Brazilian soy crops to Norwegian livestock production.

Initial insights were gathered through semi-structured telephone interviews with all municipal representatives and the agricultural cooperative, the latter of which provided regional feed data and supply-disruption risk assessments. The questions covered local agricultural challenges, climate change impacts, climate risk assessments, and experiences with TCRs and responses to these. The interviews lasted from 30–60 minutes. Additionally, relevant municipal and regional policy documents, including agricultural plans, climate action plans, contingency plans, and the social sections of municipal master plans, were reviewed to increase understanding of the political frameworks for climate risk and adaptation.

These findings informed a roundtable meeting in Sogndal with the complete case-participant group. *Roundtables* are well-suited for professional deliberation and for understanding how key stakeholders navigate complex societal challenges (Ross et al., 2015). The discussion explored the relationships between physical climate risks, TCRs, and other risk drivers that came up in the interviews. As TCR per se was an unfamiliar concept, it was contextualized through known risks emerging from agricultural policy, climate policy, and physical risk (van Aalst et al., 2008). The study is thus classified as "TCR integrated", with the transboundary focus determined from the outset (Harris et al., 2022).

3.3.2 Risk assessment and risk ownership

This study prioritizes a concern-based assessment, focusing on perceptions, values, interests, and concerns for TCR (Florin and Bürkler, 2017; Harris et al., 2022). During a one-day workshop, the researchers and case-participants collaboratively explored the risk landscape that emerged from the scoping and classification phase. To guide the discussions, the researchers structured the workshop around three scenarios looking toward 2050 (Nygrén, 2019): (1) “business as usual” under current policies, (2) adaptation to physical climate risks, and (3) adaptation to TCR. The scenario discussions were centred around risk development and possible adaptive strategies for Norwegian and local livestock production, with emphasis on the political, industry, and practical levels. Representatives from the farming organizations and regional administration could not attend. To initiate discussions, the researchers presented context on soy-related TCRs drawn from Lager (2025), national TCR literature (Bardalen et al., 2022; Berninger et al., 2022), and industry input from *Felleskjøpet*. Risk ownership considerations were integrated into the scenario discussions. The participants were divided into three groups, with one researcher participating in each. The discussions were summarized and continued in

plenum. Finally, a subsequent digital meeting with regional administrators was held to review and enrich the workshop outcomes.

3.3.3 Adaptation options and evaluation

A final one-day meeting validated and refined the findings. Except for the County municipality, all case-participant organizations attended. A preliminary qualitative framework was prepared by the researchers and used to assess the composite climate risks. The local significance of TCRs was thus evaluated qualitatively relative to physical risks and non-climatic drivers (Harris et al., 2022). Based on the participants' perceptions of resilience, this assessment approach aimed to understand the extent of "double exposure" to these risks (Benzie and Persson, 2019, p. 375). Departing from such a whole-of-system approach, adaptation options were discussed to address multiple entangled risks, and risk ownership considerations were further detailed (Harris et al., 2022).

4 Results

4.1 Framework for assessing TCRs in agriculture at a local scale

Initial scoping interviews confirmed that isolating TCRs from the broader socio-economic reality of farming made little sense to local actors. Consequently, we adopted a "TCR integrated" approach (Harris et al. 2022), co-developing a composite risk framework with the case-participant group.

The proposed framework (see Fig. 1) mirrors the IPCC's climate risk concept, namely that non-climatic risk drivers contribute as much to climate risk as climate hazards, but extends the assessment approach through the explicit integration of transition and transboundary climate risk. Rather than treating TCRs as an isolated category, case-participants positioned local livestock production alongside three other perceived key risk domains: agricultural and climate policy, and physical climate risk. In the framework, agricultural policy is a feature of vulnerability, but also response. Thus, responding to our first research question, TCRs can be meaningfully incorporated into local agricultural risk discourses when anchored in familiar risk drivers and interpreted through a whole-of-system framework.

Crucially, the framework illustrates that there may be trade-offs associated with adaptive strategies to respond to the various types of climate risk. This is further discussed in the discussion chapter.

4.1.1 Agricultural policy as a driver of systemic vulnerability

Across both farmers and bureaucratic participants, agricultural policy was highlighted as a dominant driver of vulnerability. Policies promoting efficiency, structural consolidation, and production maximization were perceived to increase dependency on external inputs and reduce system flexibility. In Vestland, the number of farms and farmland going out of production has declined faster than in the rest

of Norway (Johnsen and Smedshaug, 2016). The fragmented structure of agriculture limits farm expansion without substantially increasing emissions or transport costs (Hansen et al., 2022). The statutory 2034 loose-housing mandate acts as a massive structural shock. Participants referenced recent regional surveys indicating that up to 43% of dairy farmers in Vestland plan to exit the industry rather than take on the multi-million NOK debts required to build new loose-housing facilities (Haukås et al., 2022). One participant from the County Governor noted that this regulation may mean that only one-third of the barns will remain. In practice, some villages will likely be strengthened and become "hubs" for dairy production, while others will be abandoned.

One informant summarizes agricultural development both locally and nationally: "The subsidy system dictates the development and adjusts all parameters. It can also reverse trends very quickly." Investment support is provided on the condition that performance and efficiency are maximized. As a result, livestock production is becoming increasingly dependent on concentrated feed and proximity to barns, while outfield grazing will likely decrease as the number of farmers declines and farmland is abandoned.

The current development path concerns the informants, both for the agricultural industry itself and for society. With all agricultural production in mind, a farming advisor emphasizes: "It is important to keep the small farms running in case of a crisis; it is crucial to maintain this land."

4.1.2 Transition risks and contested mitigation pathways

In the case-participant group, significant concern centres on national climate mitigation policies, particularly potential future carbon taxes and stricter emissions requirements, as seen in Denmark (Skagen, 2026). While the agricultural sector's climate plan and Vestland County's position aim to reduce emissions without cutting livestock numbers (Norges Bondelag, 2024; Vestland fylkeskommune, 2023), both farmers and bureaucrats view top-down CO_2 accounting methods as a threat to the local livestock production system. Thus, there is a perceived risk not only of *maladaptation* by shifting to less climate-resilient crops or to poultry and pork production that merely bypass local physical risks, but also of *malmitigation* by replacing locally based production with alternatives that rely heavily on imported inputs and foreign emissions (Aall et al., 2023b). A representative from the regional administrative level argued:

"In many ways, the political risk is greater, for example, in the way emissions are calculated. It undermines local livestock production and diverts attention from the many other effective measures that could reduce emissions and increase sustainability from a broader perspective."

Furthermore, expectations of rapid electrification of agricultural machinery are also seen as unrealistic in Sogn due to limited technological and economic feasibility. However, the participants show willingness to reduce emissions, highlighting precision fertilization as a promising and increasingly adopted solution.

Several of the case-farmers describe personal discomfort with farming and climate policy, noting that many farmers feel they are being disproportionately blamed for climate change. As one farmer put it during the scenario workshop, *"I think this is the first time when in climate discussions I do not only feel*

like a climate villain". Another participant from the regional administrative level expresses concerns about recruitment to the farming profession: *"There are many opportunities to integrate sustainability into agriculture, but this isn't being communicated. It could be part of the solution."*

Looking ahead, with support from the Climate Committee 2050 (NOU 2023: 25) in Norway, climate policy may increasingly incorporate consumer perspectives into CO_2 accounting, emphasizing reductions in indirect emissions (e.g., from imported feed) and promoting practices that enhance carbon storage and biodiversity, such as grazing and cultural landscape management.

4.1.3 Local physical climate risks under structural pressure

Local physical hazards are a tangible reality for farmers in Sogn, who frequently navigate summer droughts, winter freeze-thaw variability, and waterlogged harvests. Yet a national expert notes that physical climate risk has received less attention than transition risk in policy and agricultural subsidies.

A farmer notes that water extremes can be managed through irrigation and drainage, but participants agree that current subsidies for climate adaptation are insufficient and poorly suited to Western Norway. Drainage remains costly, with a significant backlog in drainage, flood protection, and erosion control. Other measures, such as slurry application with hoses or injection to reduce soil compaction, emissions, and nutrient loss, require field layouts often not available locally. Farmers must therefore plan simultaneously for frost, drought, and excess water. While a longer growing season presents opportunities, several participants emphasize the need for faster-growing grass varieties to enable multiple annual harvests.

Participants also stress that state-driven efficiency measures can increase climate vulnerability. The shift toward larger farms requires heavier machinery, accelerating soil compaction. This degrades drainage capacity, heightens erosion risk during wetter autumns, reduces water retention during summer droughts, and compromises infection control.

Although physical climate risks are rising, grass production in the region remains relatively resilient (Rivedal et al., 2022), and large outlying pastures strengthen resilience (Strand et al., 2021). However, case participants identify the weak financial situation in agriculture as a key barrier to implementing necessary adaptation measures.

4.1.4 Transboundary climate risks as experienced through input volatility

TCRs, though not explicitly named, resonated with the participants' experiences. When asked about crises that have affected or could affect farmers in Sogn, rising operating costs linked to European energy markets and Russia's invasion of Ukraine were highlighted, driven by higher interest rates and prices for electricity, fertilizers, concentrated feed, and fuel. The COVID-19 pandemic also exposed the vulnerability of reliance on foreign seasonal labour, particularly for fruit harvesting.

The multiple crises increase risks for investment and operations, making generational successions more difficult. Participants pointed out that this could lead to reduced agricultural production and cultivated land over time. An expert on climate risk and agriculture highlighted the target price system as a driver of vulnerability due to its slow response to market changes. This poses significant challenges for farmers, with consequences for continued operations, and leads to investment aversion. Since 2021, agricultural price-cost growth has outpaced the consumer price index (Agri Analyse, 2025). The expert informant emphasized that the ability to adapt to unpredictable conditions will be crucial in an increasingly unstable world.

The case study participants painted a picture in which farmers bear significant risks related to climate, economics, and politics. Both local and regional case participants expressed an intuitive desire for greater diversification of production methods and greater circularity in the use of local resources to strengthen resilience. At the same time, the current production system is perceived as rigid. For example, slaughterhouse pricing structures favour specific seasonal windows, and distribution networks are highly centralized, leaving little room for localized adjustments.

The complexity of this risk landscape makes it challenging to identify local patterns and design tailored policies for TCRs. As a result, proposed measures often rely on precautionary approaches, such as limiting investments or reducing dependence on imported soy through increased pasture-based feeding.

4.2 Unpacking the transboundary risk ownership gap

When initially questioned about who bears responsibility for managing TCR, local stakeholders assigned TCR responsibility to a diffuse collective “everyone,” including public governance actors, consumers, retailers, farmers, and relevant public and private actors in the food system, or directly to national authorities. However, scenario-based discussions revealed a more complex picture of how risk ownership is perceived. While authority over the agricultural system is perceived as highly centralized, primarily with national authorities shaping agricultural policy, subsidy programs, and market frameworks, the material risk is profoundly localized (Young et al. 2015). Rather than being responsible, farmers perceive themselves as accountable to some extent. Because they bear the immediate consequences of input disruptions, price shocks, and supply instability, they are forced to respond reactively, as they do not hold the authority to shape system conditions (Juhola 2019). Although stakeholders unanimously agreed that TCRs can and should be addressed locally, this highlights a clear capacity asymmetry (Raikes et al. 2022). Local actors are willing to assume responsibility but lack the institutional levers to influence systemic risk drivers.

Consequently, following Talebian et al. (2015), participants view risk distribution as a national concern requiring coordinated public-private adaptation. While literature suggests private actors often view the state as a financial buffer during crises (Skagen et al., in press), we argue that farmers experience current policy as forcing them to reactively absorb risk. They explicitly call for proactive national governance of climate risk, TCRs included. Current vulnerability stems partly from longstanding policy trajectories of intensification and input dependence (Almås, 2004; Forbord and Vik, 2017). Although

stakeholders desire systemic change through localization and diversification (cf. Hartley et al., 2024; Zango-Palau et al., 2024), such transformations remain contingent on national regulations, incentives, and coordination. This reveals a transboundary risk ownership gap. Those most exposed to TCR lack the authority to reshape the system, while national authorities have yet to fully embed proactive governance.

Distributions of risk ownership evolve as stakeholders' perceptions and values change (Young et al., 2015). Under dominant mitigation frameworks, livestock production is frequently framed as an emission source, positioning farmers as “climate villains” (cf. Hallgren et al., 2020). However, introducing TCRs into local discussions expanded the analytical scope and enabled alternative interpretations. Framing local production against global supply chain vulnerabilities and land-use changes in the Amazon allowed Western Norwegian grass-based productions to be reframed toward potential “climate heroes.” For instance, Sogn possesses vast outfield grazing resources, maintaining a 29% underutilization buffer in feed units per sheep (Rekdal & Angeloff 2021). This shift enabled case participants to articulate a narrative of livestock farming as part of the solution through enhancing climate resilience in production, utilizing marginal land, and contributing to national food security. The recognition that local systems may buffer global vulnerabilities fosters a form of discursive agency in which actors move from passive recipients of risk to contributors to systemic resilience.

5 Discussion

5.1 Implications for adaptation policy and systemic conflicts

To address our second research question, this chapter explores how integrating TCRs into the agricultural discourse has profound, yet highly contested, implications for future adaptation policy agendas, uncovering deep systemic conflicts between incremental mitigation and transformative adaptation.

5.1.1 Maladaptation risks in a composite risk landscape

The coexistence of multiple risk domains creates potential for maladaptation (see Fig. 1). While national agendas remain entrenched in incremental physical risk management and efficiency-driven GHG mitigation (Amundsen and Hermansen, 2021), the case participants intuitively lean toward more transformative, systemic restructuring. This disconnect is evident in how local adaptation strategies, as suggested in this study, often find themselves at odds with established national climate and agricultural policies (Beitnes et al., 2022; Wiréhn, 2018). For instance, participants highlighted strategies like increased grazing, while national agricultural frameworks stimulate high productivity and reliance on concentrated feed (Asheim et al., 2020). Furthermore, market mechanisms like late-summer optimal slaughter prices reinforce the use of concentrated feed at the expense of utilizing local grazing resources (Flaten, 2023).

This friction highlights the potential for profound trade-offs between addressing TCRs, local climate risks, and achieving GHG mitigation goals (see Fig. 1). For example, decoupling from external inputs like soy to decrease exposure to TCRs may increase vulnerability to local climate risk. This was evident during the 2018 drought in Norway, when soy imports for concentrated feed reached record highs, serving as a primary coping mechanism for livestock production due to domestic forage failures (Beitnes et al., 2022). Furthermore, regulatory or market-driven policy shifts towards mitigation objectives, e.g., shifting subsidies toward lower-emission food production, may entail increasing the production of largely import-dependent monogastrics such as poultry and pork, thereby escalating TCR exposure. Conversely, expanding grass-based livestock production to reduce TCR exposure could increase national methane emissions if the total number of ruminants increased (Olsen et al., 2025). Also, decreasing pasture use allows for a faster encroachment of the landscape and deterioration of pasture quality (Asheim et al., 2020), which implies weakened food security resilience (Bardalen et al., 2022).

Adaptation measures targeting one risk dimension may exacerbate others (Juhola et al. 2016). Frameworks that illuminate the interplay between multiple risk areas, TCR included, enable a deeper understanding of the inherent contradictions and paradoxes associated with various adaptation and mitigation strategies. Such integrated frameworks can help navigate this composite risk landscape and prevent policy interventions from reinforcing systemic vulnerabilities (Aall et al., 2023a).

5.1.2 The governance gap and limits of local action

Finally, our findings underscore a governance gap. While local stakeholders demonstrate awareness and willingness to adapt, their ability to enact transformative change is limited. In the absence of clear national strategies addressing TCRs, local initiatives remain fragmented or symbolic (Skagen et al., in press). Thus, systemic transformation is constrained. That said, the suggested measures to mitigate TCRs resonate with factions of the farming community already advocating for extensive practices based on local resources, which also address issues such as preserving biodiversity and cultural landscape qualities (Logstein and Bjørkhaug, 2023), or downscaling production and investment as they deem appropriate given the economic and political context (Fuglestad, 2025).

Ultimately, the national governance level holds the mandate to hold system actors accountable. Our findings suggest that effective adaptation to TCRs, alongside other key risk domains, requires recognition of TCRs at the national level (Berninger et al., 2022). Next, coordination across governance scales and alignment between policy domains, agricultural and climate policies, are crucial to navigate conflicting goals and trade-offs.

The stakeholders-researcher coproduced framework demonstrates potential as a practical tool for policymakers and institutions with formal authority to coordinate collective action. Integrating TCRs into the national agenda can steer agricultural policy in a transformative direction, aligning with the IPCC AR6 recommendations to overcome soft adaptation limits. For example, while national storage strategies might offer reactive adaptation, more protective and preventive adaptation options, such as diversifying

protein import sources, transitioning to domestic protein sources, and increasing grass-based and vegetable production, align better with transformative goals (Aall et al., 2023a).

5.2 Addressing TCRs in a global justice perspective

Although TCRs are global in nature and conceptually distinct from localized physical climate risks, policy responses risk a form of localization reductionism as they rise on the political agenda. This is particularly salient where risks link *senders* in the Global South (e.g., Brazilian soy producers) with *receivers* in the Global North (e.g., Norwegian feed importers), given the latter's greater institutional and financial adaptive capacity (O'Neill et al., 2022). Consequently, responses in countries like Norway may shift toward defensive decoupling with shorter trade routes. This could manifest as replacing climate-sensitive soy imports with domestic and European feed ingredients or shifting toward increased utilization of local outfield pastures and domestic forage production.

However, substituting global trade flows with local circularity raises critical questions of global justice (Canales et al., 2025). Moves towards reduced import dependence put international compensation and shared responsibility under renewed scrutiny. Specifically, it remains a critical debate whether affluent importing nations, having historically built agricultural productivity on external resources, are obligated to provide adaptation support to the vulnerable origin regions. Such dilemmas underscore that risk governance cannot be resolved through national reorganization alone. Central governments must coordinate adaptation to avoid a narrow *securitization* of TCR responses. If wealthy nations respond to transboundary threats with isolationist protectionism, they risk exacerbating vulnerabilities in the Global South while destabilizing the global food system (Benzie et al., 2025).

Conversely, TCRs may reinvigorate critiques of food system globalization. Historically, globalized supply chains have contributed to agricultural homogenization, making the global food system increasingly dependent on a narrow range of crop species, livestock breeds, and genetic varieties produced within highly specialized and climate-vulnerable production systems (Friedmann and McMichael, 1989; McMichael, 2009). Recognizing the systemic nature of TCRs may renew calls for partial de-globalization and re-diversification (Bello, 2008). From a transformative adaptation perspective, such responses may involve broader reconfigurations of food-system structures and values (O'Brien, 2012), aligning agricultural policy more closely with the principles of agroecology and food sovereignty (Altieri, 2018; McMichael, 2014; HLPE 2019).

Crucially, these debates unfold amid a shifting geopolitical landscape. While the historical critiques from the 1970s and the alternative food movements of the early 2000s framed re-localization as a progressive path toward ecological sustainability, food democracy, and global solidarity, these ideas risk being reinterpreted in ways that diverge substantially from their original foundations. Today, discourses of economic decoupling and trade barriers are increasingly linked to right-wing populism and protectionist political agendas that cast international trade as a zero-sum game (Mamonova and Franquesa, 2020; Żuk, 2025). At the same time, state-led geo-economic strategies, such as China's extensive investments to secure foreign supply chains, processing capacity, and logistics for commodities like Brazilian soy, are

fundamentally reshaping global food trade. This growing concentration of supply chain control by major geopolitical actors complicates access for smaller importing nations and further fuels national security concerns (Fares, 2023). The TCR governance challenge is thus twofold. National governments must reduce vulnerabilities associated with transboundary dependencies through local circularity and diversification, without letting isolationist rhetoric co-opt these adaptive measures and undermine the international cooperation required to stabilize global systems. Such tensions illustrate the broader challenge of pursuing deliberate transformations that enhance resilience while remaining attentive to questions of justice, power, and responsibility (O'Brien, 2012).

6 Conclusion

Based on a qualitative case study in Norway, this study explores how integrating transboundary climate risks (TCRs) into agricultural and climate policy discourses reshapes local understandings and discourses of climate adaptation in agriculture. By coproducing an integrated risk assessment framework with local stakeholders, we demonstrate that global supply chain vulnerabilities can be localized and qualitatively understood when anchored to familiar climate and non-climate risk drivers. TCRs thus manifest locally as a vulnerability factor. Our findings reveal a critical transboundary risk ownership gap between the national governance level, which formally holds responsibility, and local agricultural stakeholders who experience the material impacts firsthand. Although showing willingness to take on responsibility for TCRs, farmers tend to adopt reactive coping measures while lacking authority to transform the production system for increased resilience to climate risk. Rather than being positioned as "climate villains" burdened by the high carbon footprint of livestock, integrating TCRs into local discourse helped participants recognize their strong toolbox for facing climate change. Relatively climate-resilient production, with redundant outfield pasture resources, makes extensive livestock production in Western Norway a potential "climate hero" in the global food system. However, policy conflicts and maladaptation and malmitigation potentials remain acute. The integrated risk assessment framework underscores how sectorized policies can inadvertently amplify systemic vulnerabilities. For instance, narrow mitigation targets that prioritize livestock emission cuts risk escalating reliance on imported feed inputs, thereby heightening exposure to transboundary supply shocks. Conversely, decoupling from global markets removes vital buffers during localized climate disasters, as demonstrated during severe domestic forage failures. Such a holistic approach can help both policymakers and practitioners navigate trade-offs and set out more resilient courses for agricultural development. Reducing reliance on imported agricultural inputs, however, raises questions about the global distribution of responsibility for climate risk in globalized food systems.

Declarations

Author Contribution

All authors co-developed the study's main idea and its theoretical and methodological approach and carried out the research activities with case participants. M.K.J. conducted the initial interviews and

analysed the interview material. All authors analysed the workshop material in collaboration. S. S. B. prepared the figure and, with substantial contributions from C. A., wrote most of the article text in close communication with the co-authors.

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Compliance with Ethical Standards

All informants have given their informed consent. The authors declare that they have no competing financial interests or personal relationships that could have influenced the work reported in this paper.

Data Availability

The data that support the findings of this study are available from the corresponding author (S.S.B) upon reasonable request.

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Figures

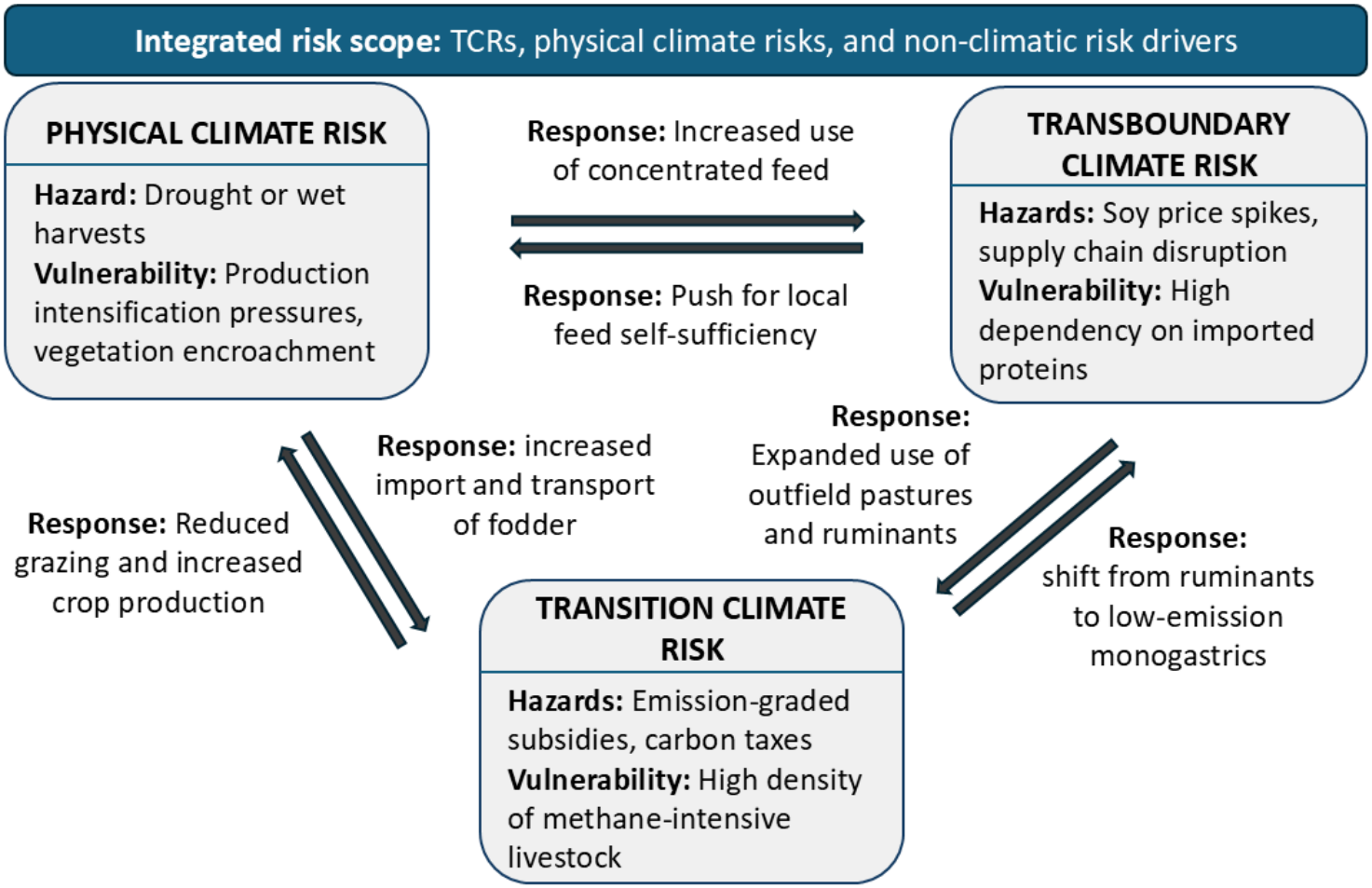

Figure 1

A framework for integrated climate risk assessment applied to the exposed local agricultural system and national food security goals