Vulnerability and resilience of farm systems in the Gisborne-Tairāwhiti Region in the aftermath of Cyclone Gabrielle

Xiaomeng K.S. LUCOCK* and Nic J. LEES

Faculty of Agribusiness and Commerce, PO Box 85084, Lincoln University, 7647, Christchurch, New Zealand

*Corresponding author: sharon.lucock@lincoln.ac.nz

Highlights

This exploratory study aims to understand the vulnerability and resilience of farm systems in the Gisborne-Tairāwhiti Region as perceived by the farmers in the aftermath of Cyclone Gabrielle. Results highlighted the complex nature of farm systems in the region and the need to strengthen their adaptive capacity in the face of climate change and associated severe weather events. Farmers need to allow sufficient buffer within their farm systems and adopt long-term, adaptive management strategies to reduce vulnerability and promote resilience. More coordinated approaches across government agencies, rural professionals and the farming communities are needed for future recovery efforts.

Keywords: extreme weather, New Zealand, recovery, socio-ecological system

Background

More frequent and extreme weather events in recent decades have been widely attributed to global warming and climate change by scientists around the world (National Academies of Sciences, Engineering, and Medicine 2016). The impacts of these extreme weather events on agriculture have drawn the attention of scholars globally, with their major focus on food security and economic losses caused by these events (Cogato et al. 2019). These negative impacts are of particular importance to New Zealand, considering the large contribution that our agrifood sector makes to the nation's economy. In the year ending 30 June 2024, New Zealand's food and fibre sector accounted for 81% of the nation's total exports (Ministry for Primary Industries 2024). The potential damage that these extreme weather events could bring to New Zealand's agrifood sector can be devastating, as evidenced by the experiences of several regions in the North Island after Cyclone Gabrielle in February 2023 (RNZ 2024). The estimated total cost of rebuilding after the cyclone nationally was more than NZD 13 billion (RNZ 2024). Indeed, the cost of such an event to the economy goes well beyond the rebuilding in the aftermath. For sectors such as agriculture and horticulture, the loss of production for the season, as well as the ongoing impact on productivity, could be significant. For example, for the Gisborne-Tairāwhiti Region alone, the estimated damage was up to NZD 80 million, impacting around 145,000 ha of sheep and beef farming land (Robertson 2023).

The Gisborne-Tairāwhiti Region has the largest area of highly erodible land in the country, with severe earthflow risk and gully risk, and taking up 17% of the total area of such land in New Zealand (StatsNZ 2024). These high risks are attributed to the region's soft rock geology, climate and vegetation clearance (Gisborne District Council 2025). In addition to its highly erodible land, the region's vulnerability is exacerbated by its physical isolation. Located at the northeastern tip of New Zealand's North Island, it is bordered by the Pacific Ocean to the east and dominated by steep to rolling hill country, especially to its west (Gisborne District Council 2019). There is limited transport infrastructure connecting the region to the rest of the country. There is one main highway going from northwest to south (State Highway 2), and a secondary highway going north to south (State Highway 35) and joining State Highway 2. Both highways are susceptible to disruptions from slips and debris flows during intense rainfall events (Reid 2022).

The negative impacts of Cyclone Gabrielle have further fuelled the ongoing conversations within the wider communities about the vulnerability and resilience of the farm systems in the Gisborne-Tairāwhiti Region. It is within such a societal context that the present study was undertaken. Studies on the convergence of vulnerability and resilience are often set in the context of social-ecological systems (Adger 2006), where both biophysical and social activities co-exist and interact. Within such a context, vulnerability is the degree to which a system is susceptible to and is unable to cope with the adverse effects (McCarthy 2001). Adger (2006) explained that "*resilience refers to the magnitude of disturbance that can be absorbed before a system changes to a radically different state as well as the capacity to self-organise and the capacity for adaptation to emerging circumstances*". The convergence of vulnerability and resilience research lies within the "*common elements of interest – the shocks and stresses experienced by the social-*

ISSN 2463-2872 (Print) ISSN 2463-2880 (Online) https://doi.org/10.33584/jnzg.2024.85.3754

ecological system, the response of the system, and the capacity for adaptive action". Vulnerability of a system is influenced by the build-up or erosion of the elements of social-ecological resilience, which include the ability to absorb the shocks, the autonomy of self-organisation and the ability to adapt both in advance and reaction to shocks (Adger 2006).

Vulnerability is a concept that may be perceived or experienced differently by the vulnerable themselves (Kasperson et al. 2005). At the same time, vulnerable people and places are often excluded from decision-making and constrained from access to power and resources (Adger 2010). In the case of the Gisborne-Tairāwhiti Region, many farmers within the region found themselves in a situation where their recovery from Cyclone Gabrielle was dependent upon the decision-making of people outside the region, as much of the disaster relief and recovery fund came from the New Zealand Government sitting in Wellington (The Treasury 2025). This situation led to our two key questions: 1) What do these farmers think of their experiences during and after the cyclone? 2) How do they view their farm systems in terms of their vulnerability and resilience in the face of climate change? To address these questions, we set three objectives for an exploratory study:

1. Ascertain the perceptions of farmers in the Gisborne-Tairāwhiti Region on the vulnerability and resilience of their farm systems.
2. Understand the experiences and thoughts of the farmers regarding their recovery efforts in the aftermath of Cyclone Gabrielle.
3. Give recommendations to relevant stakeholders for greater resilience in the face of future severe weather events.

Methods

The exploratory study used a qualitative approach to identify key themes that reflect the vulnerability and resilience of farm systems perceived by farmers in the Gisborne-Tairāwhiti Region. Upon Human Ethics approval (Lincoln University HEC2024-58) and through purposeful sampling (Patton 2014), 10 interviews of key informants were conducted in the region during the week of 25-29 November 2024, about 21 months after Cyclone Gabrielle took place. The purposeful sampling aimed to cover a range of farming types and locations within the region. A detailed account of these farms and farmer informants is given in Table 1.

An opportunity arose for two focus groups of around 20 to 30 people each during the same week, so additional qualitative data were collected. There were in total 12 farms involved in the interviews and focus groups. During these interviews and focus groups, we investigated the vulnerability and resilience within selected farm systems in the region from ecological, economic and social (including cultural) system perspectives.

Interviews were digitally recorded and transcribed using Panopto Version 15.8.0.00043. Notes were also taken during the interviews for triangulation purposes. The two focus groups were not pre-planned, as opportunities to participate in these group visits and discussions at cyclone-affected farms only arose after we arrived. No recordings were taken of the focus groups, but detailed notes were taken on the topics discussed during the focus groups. These notes and transcripts subsequently underwent thematic analysis to draw out further insights.

Table 1 Farm and farmer informant information.

Farmer	Farm Type	Area Within Gisborne-Tairāwhiti Region	Beef+Lamb NZ Farm Class	Farmer Age
Farmer A	Sheep/beef (Māori owned)	North	North Island (NI) hard hill country	Early 60s
Farmer B	Sheep/beef, horticulture (Māori owned)	Central north	NI hill country	Late 50s
Farmer C	Sheep/beef (Māori owned)	Central north	NI hard hill country	Late 40s / Early 50s
Farmer D	Sheep/beef	Central north	NI finishing country	Early 60s
Farmer E	Sheep/beef	West	NI hill country	Mid 40s
Farmer F	Sheep/beef	North	NI hard hill country	Early 60s
Farmer G	Sheep/beef, forestry	Central north	NI hill country	Early 50s
Farmer H	Sheep/beef (Māori owned)	North	NI hill country	Mid 40s
Farmer I	Sheep/beef, cropping	Central north	NI hill country	Early 60s
Farmer J	Sheep/beef, horticulture	Central south	NI hill country	Early 50s

Results

With the study's focus on vulnerability and resilience in the context of a severe weather event, we structured our qualitative findings around three interrelated systems: ecological**,** economic and social (including cultural).

Ecological System

At an aggregated level, farmers interviewed experienced and perceived the damage caused by the cyclone rather differently, ranging from nothing unexpected to total devastation. Nevertheless, when considering the ecological aspect of the vulnerability and resilience of their farm systems, three things were mentioned the most: landslides and slips, forestry slash and sediment deposition.

Landslides and slips

Of all the land classes within the farms that we conducted interviews on, almost all farmers reported that their steep hill country land experienced the greatest damage from landslides. Differences in the degree of damage nevertheless exist among the landslides that the interviewed farmers observed on their farms. Two hill country farmers indicated that their extensive planting and/or preservation of natives or scrubs (also mostly native bush) helped their farms to only experience moderate loss. In contrast, several farmers who acknowledged less planting and more pasture cover on the hills reported that they suffered great loss from landslides. One farm manager commented, *"... anywhere that I didn't do the scrub-cutting, it stayed solid...there are no slips... and everywhere I sprayed... not just that year of coming up to Gabrielle... but even... 5 years before then... all those got hit with the slips... all through them all*". This manager went on to comment that he would think twice before clearing any scrubs in the future.

In addition to damage on farms, landslides and slips near main access roads to farms presented challenges in the recovery process. Access for resources to come on farm or for livestock to be shifted to alternative locations was cut off for several farms that we visited. One farm manager acknowledged that he took on the role of ferrying teachers and nurses four to five times a day from their farming community to Tolaga Bay using his side-by-side farm bike for a week or so, as the only access was through a track on his farm. Another farm manager spoke of delivering food supplies to a neighbouring farm on horseback, as road access was completely cut off to that farm.

Forestry slash

Forestry slash, as a byproduct of forestry harvests (often the 'off-cuts' of timber production), moved in large quantities with the landslides during the cyclone. Farmers interviewed reported that these off-cuts gathered as they moved down the hills during the storm, catching other items along the way. One farmer showed us a picture taken at a spot near a river mouth not long after the cyclone. In amongst the woody debris, we saw in the photo a quadbike, a large recreational boat, and an old telephone booth. All 12 farms that we visited had fences damaged by forestry debris, albeit to varying degrees, especially along the seaward path created by the forestry slash. On one of the 12 farms that we visited, the farm manager reported to have lost 800 km of fences. This made livestock management challenging, and in some cases, impossible. Additionally, the large amount of forestry slash caused another problem, mainly on the flats, where the timber eventually deposited after coming down the hills. On one farm, the manager reported having accumulated around 700 piles of timber on their flats, with each pile equating to four to five truckloads for clearance. According to another farm manager interviewed, clearing this timber was not the only cost, as the soils under the timber piles suffered from major compaction as a result, and the productivity of the land was subsequently reduced.

Sediment deposition

Another major category of damage from the cyclone was the deposition of sediment, referred to by all the farmers interviewed as "silt", on the flats. Many rivers and streams in the region broke their banks during the heavy flood, distributing sediment far and wide on the river flats. This deposition varied in depth depending on the location, with a general pattern of deeper deposits being closer to the riverbanks. The depth of sediment reported by interviewed farmers ranged from a few centimetres to metres. Several farmers commented on the lack of nutrients in the "silt" and the consequential loss in productivity. As a recovery strategy, land with up to around 30 cm of sediment deposits was often dug over to bring the original topsoil closer to the surface, and land with deeper sediment deposits was planted using direct drilling, with some additional fertilisers applied if the budget allowed. One farmer commented on better clover growth on the silted paddocks, but further investigation would be required to ascertain what might have fostered such growth.

Economic System

The impacts of the cyclone translated into significant economic losses for farm operations within the affected regions, revealing key vulnerabilities and varied resilience capacities within the economic system. The immediate losses reported by the interviewed farmers were twofold: the costs of repair and restoration, and the loss of productivity and income.

The farmers recalled that the biggest cost after the

cyclone was fencing, at around $40 to $45 per linear metre. Given the extent of damage caused by flooding and forestry slash, most farmers commented that fencing was the largest bill to pay. Other major costs came from repairing infrastructure such as farm tracks. These costs illustrate vulnerability in the economic system**,** particularly the limited financial buffers available to absorb the shock (absorptive capacity).

Loss of income was also twofold: the direct loss of products (livestock or crops), and the ongoing loss of productivity due to the reduced productivity of the land. For example, one farmer in Tolaga Bay reported losing around 350 lambs and 35 calves, while another said his farm used to carry 17,000 stock units but has only carried 10,000 to 11,000 since the cyclone. This decline in productivity also led to a reduction in land values, making further borrowing difficult due to diminished collateral, which further weakened financial resilience.

To buffer economic losses (absorptive capacity) and support recovery (adaptive capacity), a variety of financial support mechanisms were offered by institutions, including central and local governments and industry bodies. However, there were challenges in accessing this support, as revealed by interviewees. These included delays, administrative burdens and unclear eligibility, which limited the effectiveness of the support provided.

The economic findings highlight how the economic system is situated within the broader socio-ecological system**,** interacting with both ecological (e.g. land degradation) and social (e.g. institutional support) domains. The results illustrate the vulnerability of the economic system, and point to the importance of strengthening absorptive**,** adaptive and potentially transformative capacities for future resilience.

Confusion and frustration around accessing financial support

Institutional support immediately after the cyclone, often in the form of relief funds, was critical in enabling recovery, as all interviewees agreed. However, of the 10 farmers interviewed, six reported that the rules and efficiencies of various agencies in providing aid varied greatly, leading to confusion and frustration. This highlights a key vulnerability within the social system**,** where inconsistent and delayed institutional responses undermined adaptive capacity.

One farmer commented: "*Any money we can get, we are grateful for, but the process is taking so long*", reflecting a widespread sentiment. Another farmer noted that, because help from government agencies was taking too long, he was undertaking repairs on-farm and on major access roads without council consent. This was a decision made under pressure, but not in isolation. This response points to limited absorptive capacity and a need to act urgently despite formal constraints.

One farmer commented on the challenge of the compensation process, explaining that farmers often had to spend money upfront while cashflow was already tight, with only the hope of reimbursement: "*It's difficult to ask for compensation until you've spent the money.*" This further illustrates how delayed or conditional support strains financial resilience, particularly for those with limited liquidity or existing debt burdens.

Overall, while institutional assistance was essential, the lack of consistency and timeliness in its delivery weakened the social and economic resilience of farm systems, revealing gaps in both governance structures and support mechanisms within the wider socio-ecological system.

Competing needs on the farm

Even with financial aid, farmers interviewed described ongoing difficulty in allocating limited funds to the most urgent needs on the farm. The support received was often significantly less than what was needed to fully address the damage. In many cases, the funds were only sufficient to repair either the fences or the farm tracks, but not both. This reflects a constraint in absorptive capacity, where the available resources were inadequate to fully buffer the impacts of the cyclone. It also highlights the need for adaptive decision-making under pressure, as farmers had to prioritise among essential tasks based on what could be afforded.

Consistent with the situations described by interviewees regarding overall post-cyclone costs, the most common competing priorities were fencing, farm track repairs and fertiliser. These trade-offs reveal the economic strain and the limited flexibility that many farmers experienced during recovery, further emphasising the vulnerability of farm systems within the wider socio-ecological context.

High debts exacerbated the difficulty in recovering

Of the 12 farms involved in the interviews and focus groups, those with a high debt-to-equity ratio tended to face greater challenges during the recovery phase. One farm business, at the time of the interviews, was experiencing difficulty paying staff wages and was at risk of insolvency. The farmer acknowledged that the operation was carrying a high level of debt, which contributed to its financial strain. The financial vulnerability was compounded by the broader economic context, including high interest rates on loans offered by most banks in New Zealand as the economy responded to inflationary pressures (New Zealand Parliament 2022). These rising costs of borrowing increased the pressure on already tight cashflows, particularly in the

aftermath of the cyclone when immediate repair and recovery costs were high. While a more quantitative approach would be required to fully understand the causes of this farm's financial predicament, it is likely that high debt servicing obligations significantly reduced its absorptive capacity. This limited the ability to buffer the economic shock, placing the farm at increased risk of insolvency and exposing a key point of vulnerability within the economic system of the wider socio-ecological framework.

Social System

Unlike the ecological and economic impacts of the cyclone, the social system included a mix of both positive and negative experiences.

On the positive side, most interviewees described a strong sense of community with their neighbours because of the shared recovery efforts. Several local 'heroes' and 'heroines' emerged to take leadership roles in coordinating resources and support where it was most urgently needed. These examples reflect strong social cohesion and collective action, which contributed to the social system's absorptive and adaptive capacity in the immediate aftermath of the event.

On the negative side, bureaucratic processes surrounding the administration of relief funds were mentioned by all interviewees and both focus groups. These challenges reflect institutional barriers that may have limited the ability of the social system to respond effectively, potentially reducing the adaptive capacity of affected communities.

To overcome the bureaucratic challenges, interviewees identified a number of strategies and lessons that may be helpful for farmers facing similar events in the future. These suggestions point to opportunities for improving social resilience through better coordination, clearer processes, and more responsive local governance within the broader socio-ecological system.

A close connection to local communities helps access resources

While the entire region experienced isolation from the rest of New Zealand after major access roads were damaged by the cyclone, our informants noted that some farmers received help more quickly, either from local communities or the government, than others. This was consistent with our observations. Farmers who described themselves as closely connected to local communities reported greater access to resources and support during the recovery period. In contrast, those who relied more heavily on their own efforts appeared to face greater challenges. These differences highlight the role of social capital in strengthening absorptive and adaptive capacity within the social system. Strong community ties served as an important resilience factor, enabling quicker mobilisation of assistance and better access to critical resources in the aftermath of the cyclone.

Rural professionals are key to farmers accessing institutional support

More than half of the farmers interviewed commented on the key role rural professionals played in connecting institutional support with farmers' needs. Farm consultants, industry body coordinators, farm accountants and others involved in farmers' day-to-day operations helped their clients identify and access information about available assistance for those impacted by the cyclone. These rural professionals also supported farmers by helping to complete grant applications and, in some cases, connecting them with other individuals or organisations who could provide further assistance. Farmers interviewed expressed deep appreciation for this support during a time of high stress and uncertainty.

The involvement of rural professionals enhanced both the social and economic dimensions of resilience by improving access to institutional resources and reducing administrative barriers. Their support contributed to strengthening adaptive capacity within the broader socio-ecological system.

Connections to the land shaped farmers' strategic thinking

Alongside the recovery efforts described by farmers, we observed differences between those who had been on their land for generations (around half of the farmers interviewed) and those who had moved to the district more recently. Farmers from long-established family farms expressed a deep connection to their land and local community. This connection appeared to influence strategic thinking. These farmers chose to adopt a long-term perspective, viewing extreme weather events as part of the ongoing reality of farming in the region rather than isolated incidents. As a result, they expressed a strong commitment to employing adaptive management strategies on farm, recognising these as essential for the future viability of their operations in the region. These findings highlight the role of cultural and place-based identity in shaping adaptive capacity within the social system. A strong sense of belonging and stewardship contributed to long-term thinking and proactive adaptation, reinforcing resilience within the wider socio-ecological system.

Discussion

This study confirms that challenges faced by farmers after severe weather events are often multifaceted (Darnhofer et al. 2010). What went through a farmer's

mind after Cyclone Gabrielle extended well beyond the physical damage that occurred on-farm. Physical impacts, such as soil erosion and sediment deposition, were the starting points of the many worries that farmers endured in the aftermath. For many, it was the recovery from the damage caused by soil erosion (including the consequential damage by forestry slash) and sediment deposition that occupied their minds.

The economic and social aspects of vulnerability and resilience were often tied to how farmers were able to access resources to repair the physical damage. The economic challenges were mainly related to the difficulty of accessing and allocating relief funds or finance from banks. The social aspects were centred on the relationships and networks that influenced access to these resources, or on farmers' connection to the land, which shaped their longer-term management strategies to minimise future risk. The vulnerability of the farm systems was primarily defined by the extent of damage caused by the severe weather event. Resilience, by contrast, was seen in terms of how quickly support, especially financial, could be mobilised to begin recovery. Within this process, the social system, particularly the strength of local community connections, acted as a key catalyst in resource mobilisation.

The farmers interviewed experienced and perceived the damage caused by the cyclone differently. This ranged from nothing unexpected to total devastation. This supports the view by Kasperson et al. (2005), that vulnerability is not uniform, but may be perceived or experienced differently by those affected. In this sense, vulnerability is a social construct, shaped by personal experience and context. The farmers developed their own interpretations of the degree of damage and its impacts on their farm systems. As such, the resilience of these systems, i.e. how farmers responded and recovered, was also socially constructed and varied across individuals and communities.

Our findings echo the call by Darnhofer et al. (2010) to strengthen the adaptive capacity of farm systems. While scholars have accumulated knowledge on the impacts of soil erosion and its mitigation strategies in hill country farming within New Zealand (Trustrum et al. 1984; Sparling et al. 2003; Marden 2004; Jones et al. 2008; McIvor et al. 2011; McIvor et al. 2023) and internationally (Bennett 1933; Paningbatan et al. 1995; Evans 2005; Partap 2011; Ramser 2020) over the past decades, more research on strategic thinking at the farm system level is needed to help farmers navigate through the challenges brought by severe weather events in the face of climate change. Darnhofer et al. (2010) suggested mechanisms to strengthen the adaptive capacity of farm systems, including learning through experimenting and monitoring, flexibility to increase response options, and diversity to cope with variability within farm activities.

One could say that some of the farmers learned the hard way through the involuntary lessons brought by the impact of the cyclone. For example, the farmer who lost much topsoil on the steep hill sides where they sprayed the scrubs vowed that they would think twice before spraying again; and those with high debt levels lacked the flexibility required to see themselves out of financial strife after their farm productivity was severely dampened by the cyclone, hence putting their farm systems in a more vulnerable state. The lesson here could be to not 'push too hard' on the farm system, i.e. farming the marginal land or having a high debt-to-equity ratio, because of the degree of damage (slips) and lack of liquidity when the farm system was put under immense pressure brought by severe weather events. In other words, there could be merit in allowing some 'buffer' in the system when farming in a region where the geological condition is fragile, such as in the Gisborne-Tairāwhiti Region.

For most farmers interviewed, strengthening the adaptive capacity of their farm systems in the face of climate change and consequential severe weather events was a fine balancing act across the ecological, economic and social aspects of their farm systems because of the competing demands on-farm. Future research should therefore explore mechanisms that can help farmers better prioritise various needs on-farm and optimise resource use post severe weather events. The farm systems also fit within the social-ecological systems context. Their vulnerability and resilience, as perceived by the farmers interviewed, reflected the convergence of the vulnerability and resilience as suggested by McCarthy (2001), where they share the "*common elements of interest – the shocks and stresses experienced by the social-ecological system, the response of the system, and the capacity for adaptive action*".

To reduce vulnerability and build greater resilience of farm systems in the face of future severe weather events, the policy aspect must be considered. Adger (2006) advocated that policy interventions for promoting resilience should address the multi-level nature of vulnerability, because adaptation to environmental risks at the local level often reduces the vulnerability of those best able to mobilise resources, rather than the most vulnerable. In other words, "*adaptive actions often reduce the vulnerability of those best placed to take advantage of governance institutions, rather than reduce the vulnerability of the marginalised, or the undervalued parts of the social-ecological system*" (Adger et al. 2005; Adger 2006). What we heard from the farmers reflected such a reality, where institutional help was not accessible with equity to all those who

needed it. Consequently, some farmers took matters into their own hands and ignored the institutions or the rules. These farmers knew the local conditions and knew what needed to be done, so they went ahead with actions to get themselves out of difficult situations. Looking into the future, it may help to promote greater equity if farmers were involved, perhaps with the assistance of rural professionals, in the decision-making processes related to reducing vulnerability and fostering resilience. Just as Adger (2006) suggested, "*equity within decision-making processes is as important as equity in outcome in reducing vulnerability*".

Conclusions

The present study highlighted the multi-faceted nature of farm systems and the need to strengthen their adaptive capacity in the face of climate change and associated severe weather events. While the study focused on the isolated Gisborne-Tairāwhiti Region, where circumstances can be extreme given its geographical characteristics, insights gained from this study can be applicable in other similar contexts. Our study revealed that, to promote resilience of farm systems, especially in geologically vulnerable areas, farmers need to allow sufficient buffer within their farm systems for greater flexibility, and not 'push too hard'. Long-term, adaptive management strategies that foster experimenting and monitoring different farm activities as well as diversity of these activities will likely equip these farm systems with greater resilience and reduce their vulnerability in future severe weather events. A key focus of the recovery process is the rapid mobilisation of resources through more coordinated approaches across government agencies, rural professionals and farming communities.

ACKNOWLEDGEMENTS

This project was funded by Lincoln University Faculty of Agribusiness and Commerce Seed Fund. We thank all our informants who kindly gave up their time during the week of our data collection and openly shared their experiences and thoughts with us.

REFERENCES

Adger WN, Arnell NW, Tompkins EL. 2005. Adapting to climate change: perspectives across scales. *Global Environmental Change 15*: 75-76. http://dx.doi.org/10.1016/j.gloenvcha.2005.03.001

Adger WN. 2006. Vulnerability. *Global Environmental Change 16*: 268-281. https://doi.org/10.1016/j.gloenvcha.2006.02.006

Adger WN. 2010. Social Capital, Collective Action, and Adaptation to Climate Change. In: Voss M Ed. *Der Klimawandel: Sozialwissenschaftliche Perspektiven*. Wiesbaden, Germany: VS Verlag für Sozialwissenschaften, pp. 327-345.

Bennett H. 1933. *The cost of soil erosion*. Columbus, Ohio: Knowledge Bank of The Ohio State University.

Cogato A, Meggio F, De Antoni Migliorati M, Marinello F. 2019. Extreme Weather Events in Agriculture: A Systematic Review. *Sustainability 11*: 2547. http://dx.doi.org/10.3390/su11092547

Darnhofer I, Bellon S, Dedieu B, Milestad R. 2010. Adaptiveness to enhance the sustainability of farming systems. A review. *Agronomy for Sustainable Development 30*: 545-555. http://dx.doi.org/10.1007/978-94-007-0394-0_4

Evans R. 2005. Reducing soil erosion and the loss of soil fertility for environmentally-sustainable agricultural cropping and livestock production systems. *Annals of Applied Biology 146*: 137-146. http://dx.doi.org/10.1111/j.1744-7348.2005.040055.x

Gisborne District Council. 2019. *Tairāwhiti - 2050, Gisborne Regional Spatial Plan*.

Gisborne District Council. 2025. *Erosion management*. Retrieved 1 May 2025 from: https://www.gdc.govt.nz/environment/land/erosion-management.

Jones H, Clough P, Hock B, Phillips CJS. 2008. *Economic costs of hill country erosion and benefits of mitigation in New Zealand: Review and recommendation of approach*. 79 p. https://www.mpi.govt.nz/dmsdocument/81-Economic-costs-of-hill-country-erosion-and-benefits-of-mitigation-in-New-Zealand-Review-and-recommendation-of-approach/.

Kasperson RE, Dow K, Archer E, Caceres D, Downing T, Elmqvist T, Eriksen S, Folke C, Han GIK, Vogel C, Wilson K, Ziervogel G. 2005. Vulnerable people and places. In: Hassan R, Scholes R & Ash N. Eds. *Ecosystems and Human Wellbeing: Current State and Trends*. Washington, DC, USA: Island Press, pp. 143-164.

Marden M. 2004. Future-proofing erosion-prone hill country against soil degradation and loss during large storm events: have past lessons been heeded? *New Zealand Journal of Forestry 49*: 11-16.

McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS. 2001. *Climate Change 2001: Impacts, Adaptation, and Vulnerability: Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom: Cambridge University Press. 1032 p.

McIvor I, Douglas G, Dymond J, Eyles G, Marden M. 2011. Pastoral Hill Slope Erosion in New Zealand and the Role of Poplar and Willow Trees in Its Reduction. In: Godone D & Stanchi S. Eds. *Soil Erosion Issues in Agriculture*. BoD - Books on Demand, pp. 257-278.

McIvor I, Spiekermann R, Mackay-Smith T. 2023.

Drivers and New Opportunities for Woody Vegetation Use in Erosion Management in Pastoral Hill Country in New Zealand. In: Mahmood S. Ed. *Soil Erosion - Risk Modeling and Management*. Rijeka, Croatia: IntechOpen, pp. 196.

Ministry for Primary Industries. 2024. *Situation and Outlook for Primary Industries*. Ministry for Primary Industries, Wellington, New Zealand. 70 p. https://www.mpi.govt.nz/dmsdocument/66648-Situation-and-Outlook-for-Primary-Industries-SOPI-December-2024.

National Academies of Sciences, Engineering, and Medicine. 2016. *Attribution of Extreme Weather Events in the Context of Climate Change*. Washington, DC: The National Academies Press. 144 p.

New Zealand Parliament. 2022. *Monthly Economic Review: December 2022*. Wellington, New Zealand. 8 p. https://www.parliament.nz/media/9885/monthly-economic-review-december-2022.pdf.

Paningbatan EP, Ciesiolka CA, Coughlan KJ, Rose CW. 1995. Alley cropping for managing soil erosion of hilly lands in the Philippines. *Soil Technology 8*: 193-204. https://doi.org/10.1016/0933-3630(95)00019-4.

Partap T. 2011. Hill agriculture: challenges and opportunities. *Indian Journal of Agricultural Economics 66*: 33-52.

Patton MQ. 2014. *Qualitative Research & Evaluation Methods: Integrating Theory and Practice*. 4 ed. Thousand Oaks, California, USA: SAGE Publications, 832 p.

Ramser CE. 2020. Prevention of the erosion of farm lands by terracing. In: Coates DR Ed. *Environmental Geomorphology and Landscape Conservation*. London, United Kingdom: Routledge, pp. 299-313.

Reid N. 2022. *'Danger everywhere': Risk of fallen boulders, trees and mud slips for East Coast roading crews*. Retrieved 6 July 2025 from: https://www.nzherald.co.nz/nz/danger-everywhere-risk-of-fallen-boulders-trees-and-mud-slips-for-east-coast-roading-crews/IOM3ICOVHD7CPX6ET3BNEIYCPU/.

RNZ. 2024. *Cyclone Gabrielle anniversary: Looking back at the devastation caused*. Retrieved 1 May 2025 from: https://www.rnz.co.nz/news/national/509128/cyclone-gabrielle-anniversary-looking-back-at-the-devastation-caused.

Robertson M. 2023. *Cyclone Gabrielle damage to Tairāwhiti farms estimated at $80m*. Retrieved 1 May 2025 from: https://www.nzherald.co.nz/nz/cyclone-gabrielle-damage-to-tairawhiti-farms-estimated-at-80m/ZUS3IJLFTJGPLB2VE7HUQ3WF6Y/.

Sparling G, Ross D, Trustrum N, Arnold G, West A, Speir T, Schipper L. 2003. Recovery of topsoil characteristics after landslip erosion in dry hill country of New Zealand, and a test of the space-for-time hypothesis. *Soil Biology and Biochemistry 35*: 1575-1586. https://doi.org/10.1016/j.soilbio.2003.08.002

StatsNZ. 2024. *Highly erodible land: Data to 2022*. Retrieved 1 May 2025 from: https://www.stats.govt.nz/indicators/highly-erodible-land-data-to-2022/.

The Treasury. 2025. *North Island Weather Events Response and Recovery Funding*. Retrieved 6 July 2025 from: https://www.treasury.govt.nz/information-and-services/nz-economy/climate-change/north-island-weather-events-response-and-recovery-funding.

Trustrum N, Thomas V, Lambert M. 1984. Soil slip erosion as a constraint to hill country pasture production. *Proceedings of the New Zealand Grassland Association 45*: 66-76. http://dx.doi.org/10.33584/jnzg.1984.45.1676