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ORIGINAL ARTICLE

Communicating change, transition, and transformation for adaptation in agriculture: a comparative analysis of climate change communication in Aotearoa New Zealand

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Abstract

Effective communication is a key enabler of climate change adaptation in agricultural systems. However, different actors frame adaptation, transition, and transformation in varied ways, influencing how change is understood and acted upon. This study uses Natural Language Processing (NLP) and machine learning to analyse how climate adaptation is communicated across five actor groups in Aotearoa New Zealand: media, farm advisory services, researchers, Indigenous Māori, and government. We apply topic modelling, sentiment analysis, collocation network analysis, and word embedding models to five purpose-built corpora to identify dominant themes, emotional tones, and framings of responsibility and agency. This methodological approach enables systematic, large-scale comparison of discourses, offering insights into how adaptation narratives evolve and diverge across sectors. Our findings highlight both overlaps and tensions in how different actors communicate about climate risks and responses. For example, while some narratives emphasise innovation and opportunity, others centre on uncertainty or systems-level transformation. These differences have practical implications for how messages are received, interpreted, and acted upon by farmers and stakeholders. By identifying areas of alignment and dissonance, we show how NLP tools can support the design of more targeted and effective communication strategies. This contributes to methodological innovation in climate communication research and offers practical value for policymakers, advisors, and communicators seeking to accelerate adaptation through more resonant messaging. Our study demonstrates the potential of data-driven discourse analysis to support climate-resilient agricultural futures.

Keywords Climate change adaptation · NLP · Corpus analysis · Agricultural change · Climate change communication · Aotearoa New Zealand

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Introduction

Climate change is marked by decreasing rainfall, more frequent heatwaves, droughts, storms, and floods, all of which disrupt our environment and affect lifestyles, economies, governance, and planning (Campbell-Lendrum et al. 2023; IPCC 2023; Adger 2006). As the sector most sensitive to climatic shifts, the primary sector is being profoundly (re) shaped by climate change, which alters the conditions essential for food production and availability, creating cascading effects on food security and global economic stability (Abbass et al. 2022; Ortiz-Bobea 2021). Reducing agricultural vulnerability to climate change is a global concern that requires strategic, cross-sectoral adaptation (Thiault et al. 2019). As the impacts of climate change become more acute, there are growing calls for transformational adaptation and economic and social transitions to more sustainable and

resilient practices (Berrang-Ford et al. 2021; Wilson et al. 2020; Termeer et al. 2016; Gillard et al. 2016; Pelling 2010). Despite the growing interest in, and attention on, theories and practices of transformation, persistent barriers and a lack of action for implementation remain (Berrang-Ford et al. 2021; Leiter 2021).

Bridging the gap between climate change planning and adaptive action requires greater attention to how adaptation is communicated (Artega et al. 2023; Perga et al. 2023). We use Natural Language Processing (NLP), computational linguistic method, to analyse language through statistical patterns and relation extraction, an innovative approach to climate change adaptation which identifies meaningful patterns in text (Gil-Clavel et al. 2025). Our comprehensive comparative linguistic analysis of five purpose-built corpora explores how changes related to the effects of climate change are framed in A-NZ across groups that have an influence on agricultural decision-making. We used NLP tools to analyse language across the texts, focusing on tone, meaning, and how key terms are framed. After removing common words, we applied methods like TF-IDF, BERT-tiny embeddings, and sentiment analysis with TextBlob. Collocation networks helped identify how words are connected, while FastText models trained for each corpus showed related terms based on meaning.

To understand the potential for change in the primary sector, we use NLP to explore framing of the terms change, transitions, and transformation. These terms describe complex processes that entail shifts at personal, cultural, organizational, institutional, and systems levels (O'Brien & Sygna 2013). Change has been described as a dynamic interplay between persistence and alteration(s) at multiple levels, recognising and responding to multi-scale and cross-scale dynamics (Meadowcroft 2009; Geels & Schot 2007). The term transition is mostly used in the context of intentional, directive processes, that can be more gradual in their dynamic, and happen in higher-level, higher-scale developments (e.g. whole sector transitions to renewable energy sources, cf. Biresselioglu et al. 2020). The term transformation is used to describe more drastic, non-linear, large-scale changes (Pelling et al. 2015; Goepel 2016; Hoelscher et al. 2018; Folke et al. 2010). Distinctions between the terms and concepts are not always clear-cut, and there are several overlaps (Hoelscher et al. 2018). Those overlaps are one of the reasons why measuring progress or the status quo of reactions to climate change, be it adaptation or resilience building or even transformation, is challenging (Sietsma et al. 2024).

Depending on the framing of such terminology, communication can either influence the willingness to act in response to climate change or diminish its likelihood of success (Perga et al. 2023; Hornsey et al. 2022; de Vries 2020; Holmes & McEwen 2020). Framing emphasises specific attributes of an issue while downplaying others (Badullovich et al. 2020), which can impact how an issue is perceived and understood. This influence extends to how people think and reason about environmental issues. Various studies in behavioural, neurophysiological, and linguistic domains contribute to our understanding of climate adaptation and transformation (Flusberg et al. 2017). Examining how groups that affect agricultural decisions communicate about change, how they frame it in their conversations and texts can reveal some of the underlying principles that guide priorities and policies (Fløttum et al. 2014).

Improving reactions to climate change is particularly relevant for Aotearoa New Zealand (A-NZ), a small, developed economy in the Pacific. Here, climate-sensitive primary industries provide an outsized contribution to GDP (relative to other developed nations), as well has having a complicated—and increasingly contested—history of colonisation and European settlement. Contemporary A-NZ, with its economic, social, and cultural prominence of agriculture, and dynamic social, and cultural milieu, provides a rich, empirical context for examining the context for change (Spector et al. 2019; Cradock-Henry 2021). To remain viable, its primary sector must adapt, transition, and transform (Kirk & Cradock-Henry 2022; Renwick et al. 2019; Vermeulen et al. 2018; Rickards & Howden 2012). Transformation of agriculture is unlikely to happen without interventions (Renwick et al. 2019). However, unlike the European Union or the USA, A-NZ does not incentivise land-use changes through subsidies but rather attempts to influence it through channels such as resource management framework, global market trends, consumer preferences, and behavioural and psychological factors (Renwick et al. 2019).

Our analysis showcases differences between the public, government, an advisory body organisation, research, and Māori (indigenous population of A-NZ), in how they communicate change within A-NZ's primary sector. Communication is one factor in a complex web of contributors to resilience and transformation (Han & Niles 2023). Our study contributes to that broader conversation by using NLP to indicate where there is potential for agreement on a change in the primary sector's direction. It is organised as follows. Next, we introduce our methods and materials. This is followed by results of our comparative study. Results contribute to a clarification similarities and differences in the usage of these concepts across five groups that have an influence agricultural change and have the potential to assist in navigating uncertainties stemming from differences in definitions. We discuss potential objectives, preferences, and values that have the power to shape individual and collective attempts to change, transitions, or transform (Pelling et al. 2015; Patterson et al. 2016). We close with reflections on the influence of communicating change in relation to adaptation strategies

within the primary sector more generally, and its implications in other domains.

Using natural language processing to understand change potential

Machine learning and Natural Language Processing (NLP) approaches are increasingly used to analyse reactions to climate change by categorising and comparing language (Sietsma et al. 2024; Schäfer & Hase 2023). NLP helps researchers manage and understand the vast amount of textual data on climate change (Sietsma et al. 2024). However, critics argue that overreliance on empiricism and biases in data selection and interpretation can undermine research. They emphasise the need to integrate computational methods with theoretical perspectives to improve climate change research (Schäfer & Hase 2023; Lahsen 2022; Grundmann 2021).

NLP has been used in climate change research to analyse the significance of climate change relative to other concerns and identify key actors in public discourse (Schäfer & Hase 2023). Climate change research benefits from NLP due to its rapid growth and diverse perspectives. Studies have used NLP to track public opinion over time (Dahal et al. 2019), analyse social media communities (Kaushal et al. 2022), understand audience behaviour (Yan et al. 2021), compare arguments (Schaefer & Stede 2022), examine interdependencies between science and policy discourse (Smith et al. 2021), and explore positions in climate change debates (Biesbroek et al. 2020; Adam et al. 2020). Additionally, NLP is well suited to the study of adaptation to climate change, for assessing the status of adaptation progress or its potential (Berrang-Ford et al. 2021). NLP is valuable for studying climate adaptation by assessing its progress and potential (Berrang-Ford et al. 2021). Although NLP does not measure adaptation outcomes, it provides insights into adaptation processes (i.e. "where and how is adaptation occurring?") (Sietsma et al. 2024).

We use NLP to situate and compare the discourse of five influential groups in A-NZ's primary sector. We expect communication on change in reaction to climate change challenges to differ between these groups. The degree and complexity of differences allow us to discuss more or less likely pathways to cohesively approach the challenges the primary sector experiences today and in the future. Understanding where and under what conditions influential stake- and rightsholders (dis)agree can affect the degree of change we see in the primary sector. For example, contradictory positions and a lack of consensus among governments and publics on the existence and impacts of climate change have been a challenge for implementation and action in the past (Bertana et al. 2022). We draw on this in our conceptualisation and discussion.

Methods and material

We created five corpora to compare the framing of change, transition, and transformation in A-NZ's primary sector across media, government, advisory bodies, researchers, and Māori (Table 1). Several actors influence A-NZ's agricultural change dynamics (Kirk 2025; Driver et al. 2023). A-NZ's government increasingly implements regulations, incentives, and programs to tackle environmental challenges in agriculture, shaping how farmers engage with knowledge and interact with their advisors (Kirk et al. 2022). He Waka Eke Noa, included as an advisory body voice, is described as representing dominant activities, focused on optimisation of existing systems (Klerkx et al. 2022). Māori interests are deeply embedded in climate-sensitive sectors such as agriculture, forestry, horticulture, and tourism (Awatere et al. 2021). The effects of the climate crisis are being felt across Aotearoa and will intensify over time, with disproportionate impacts on communities already affected by colonisation and systemic injustices, including Māori (Cretney et al. 2024). Te ao Māori (Māori world view) provides a major opportunity to transform climate adaptation, introducing innovative perspectives that can reshape existing approaches, such as valuing reciprocity over profit, recognising the role of guardianship, and centring collective well-being (Lawrence et al. 2023). Māori have unique responsibilities and ownership structures under a long-standing agreement with the Crown. Through direct tribal affiliations, trusts, and companies, iwi (Māori tribes) manage approximately 6% of A-NZ's total land area, and have interests in several primary industries, including dairying, horticulture, and viticulture. Indigenous knowledge also plays a vital role in guiding infrastructure decisions that incorporate nature-based solutions, supporting both climate adaptation and cultural revitalisation (Reid et al. 2024).

To analyse how public discourse on agricultural change has evolved over time, we used broad search terms in the Factiva database (Agriculture AND Resilience, Agriculture AND Transformation, Agriculture AND Climate Change, and Agriculture AND Cyclone Gabrielle), retrieving 3983 media items, including television, radio, blogs, and

Table 1 Text dataset summary: raw and cleaned word totals

	Word count before cleaning	Word count after cleaning
RES	2,400,367	1,490,922
WAI	587,903	314,282
ADV	69,308	40,425
GOV	2,436,111	1,252,456
PUB	4,111,458	2,329,796

newspaper articles, published between 1990 and 2023.[1] This corpus reflects shifts in societal attitudes and the framing of issues by journalists, influencing public perception.[2] We downloaded 48 policies, acts, strategies, and plans relevant to farming to understand the regulatory and policy landscape affecting the primary sector (see supplementary material). These documents offer insights into government priorities, responses to environmental and economic challenges, and the evolution of policy frameworks.

We downloaded all reports and guidance documents from He Waka Eke Noa, a partnership between the New Zealand Government, the primary sector, and iwi/Māori. This program aims to reduce agricultural greenhouse gases and improve water quality. Analysing these documents offers insights into collaborative efforts, attitudes toward voluntary versus regulatory approaches, and the integration of traditional knowledge with contemporary environmental management. We chose to include this to look into communication by an advisory body that sits between farmers and government.

To include Māori perspectives, we built a corpus consisting of the 2011 Waitangi Tribunal[3] report, Ko Aotearoa Tēnei, into the Wai 262 claim. The Wai 262 claim, commonly known as the Fauna, Flora, and Intellectual Property Rights claim was presented to the Waitangi Tribunal in 1991 by six claimants on behalf of themselves and their iwi (tribe) and sought the protection of taonga Māori (treasured possession) by tāngata Māori.[4] As the first whole-of-government inquiry, the Wai 262 claim is one of the most complex and far-reaching in the Tribunal's history. Ko Aotearoa Tēnei suggests changes to laws, policies, or practices in various sectors, including inter alia, the protection of indigenous plants and animals. It also touches on resource management and conservation. These proposals call for modifications in legislation and the creation of new collaborative entities. Analysing responses to this claim can illuminate discussions around indigenous rights, biodiversity, and cultural heritage in the context of primary sector changes. This corpus is key to understanding the intersection of cultural, environmental, and economic considerations.

We conducted a Scopus search for publications on agriculture, resilience, and agricultural change/transformation/adaptation (see supplementary material for search strings). This research offers insights into the scientific, technological, and economic aspects of change in the primary sector. The corpus highlights emerging trends, innovations, and the academic community's response to sector challenges. Comparative analysis may reveal gaps between research recommendations and public discourse or policy action.

"RES" refers to a corpus of Scopus titles and abstract. "WAI" refers to a corpus of Wai262 claim documents. "ADV" refers to a corpus of He Waka Eke Noa reports. "GOV" refers to a corpus of government documents. Finally, "PUB" refers to a corpus of 3983 media outputs downloaded from Factiva, which we analyse to reflect on public discourse.

Several methods were applied to understand the corpora and compare how they frame change, transition, and transformation as well as related terms and concepts. We pre-processed the corpora by removing common function words using NLTK's stop words Corpus. We used TextBlob, Scikit-learn, PyTorch, Transformers, and the online tool LancsBoxX (Brezina and Platt 2023; Brezina et al. 2020) for collocation network analyses. Descriptive methods were applied to understand lexical and semantic similarities, tone, and subjectivity.

Lexical similarity was calculated using the cosine similarity of TF-IDF matrices, while semantic similarity was determined using BERT-tiny word embeddings and cosine similarity of their average meanings. To generalise scores for each corpus, we averaged the pairwise comparisons across the other four corpora. We used TextBlob's PatternAnalyzer for word-level sentiment analysis, scoring polarity from -1 (most negative) to 1 (most positive) and subjectivity from 0 to 1 (most subjective).

We conducted specific searches, including collocation analysis and word embeddings, to understand terminology framing across corpora. Collocation graphs display (i) shared collocates and (ii) cross-associations between nodes, expandable as networks. The associated table (see supplementary material) provides information on each collocate: (i) distribution, (ii) collocation frequency, (iii) overall corpus frequency, and (iv) statistical measures. For each corpus, we trained a separate Gensim FastText model (Bojanowski et al. 2017), thereby making the FastText word embeddings specific to each corpus and not comparable with our other corpora. For each model, we calculated a list of 10 words that have the shortest cosine distance to a given search term's word embedding.

Results

The next subsection presents the results of our lexical and semantic comparison.

[1] Please refer to our supplementary material for a year-by-year overview of the media items.

[2] This approach may entail a selection bias, as relevant narratives or framings of agricultural change not captured by the chosen search terms could be underrepresented.

[3] The Waitangi Tribunal is a quasi-judicial forum for hearing claims regarding violations of Māori treaty rights, referring to property and resource rights guaranteed to Māori under the 1840 Treaty of Waitangi (cf. Levine 2010).

[4] Including protection, conservation, management, treatment, propagation, sale, dispersal, utilisation, and restriction on the use of and transmission of the knowledge of New Zealand Indigenous Flora and Fauna and their resources.

Table 2 Top 20 distinctive words for each text collection, based on TF-IDF scores (out of 5,000 total terms analysed). TF-IDF stands for Term Frequency–Inverse Document Frequency. It's a common method in text analysis used to identify how important a word is in a specific document compared to a collection (or "corpus") of documents

RES	"climate", "change", "study", "adaptation", "vulnerability", "resilience", "risk", "system", "impact", "community", "adaptive", "management", "water", "result", "forest", "area", "capacity", "author", "social", "model"
WAI	"māori", "te", "new", "taonga", "zealand", "crown", "downloaded", "kaitiaki", "mātauranga", "also", "work", "ngāti", "interest", "reo", "act", "treaty", "right", "claimant", "policy", "conservation"
ADV	"farm", "emission", "ghg", "farmer", "model", "milestone", "plan", "eke", "gas", "programme", "change", "greenhouse", "waka", "climate", "noa", "increase", "dairy", "new", "tool", "total"
GOV	"section", "act", "may", "person", "land", "must", "amendment", "authority", "new", "plan", "management", "part", "resource", "amended", "change", "notice", "inserted", "zealand", "environment", "area"
PUB	"new", "zealand", "said", "year", "farmer", "government", "right", "million", "emission", "change", "climate", "also", "say", "inc", "would", "agriculture", "farm", "need", "business"

General overview, descriptive statistics

We looked at the most frequently occurring words across all corpora, where we see little overlap apart from change, climate, and new. Next, we continued by comparing Term Frequency Inverse Document Frequencies (TF-IDF), a calculation of how relevant a word is in a corpus relative to its relevancy to all corpora, for each corpus's 5000 most frequent words (Table 2). This insight into characteristic words for each of our corpora provides an initial assessment for the framing of terms.

While each group of texts focuses on distinct themes and topics, there are some commonalities and overarching connections that can be identified based on these top 20 words: Most groups (RES, ADV, GOV, PUB) show a dominant concern related to climate change, including its impacts, adaptation strategies, greenhouse gas emissions, and government policies. The ADV and PUB corpus highlight the significance of agriculture, particularly in terms of emissions, mitigation plans, and the impact of climate change on the farming sector. RES and WAI groups touch on community-related aspects, with RES emphasising community response and social models, while WAI focuses on Māori rights, cultural heritage, and relationships.

We checked for lexical and semantic similarities in corpus pairs and used those to calculate the mean lexical and semantic similarities for each corpus. These scores in Table 3 show that lexically, the PUB corpus is the most like the other four corpora, followed by RES, ADV ~ WAI, and GOV. Semantically, RES and ADV are respectively equally like the other four corpora, followed by PUB, GOV, and WAI. Taking both scores together, we observe that PUB is the most central corpus, followed by RES, ADV, and GOV; WAI stands out the most from the rest of the corpora.

As Table 4 shows, our sentiment analysis suggests that RES contains more objective and less positive words than the other frameworks, while ADV contains more subjective words than the other frameworks.

Table 3 Mean lexical and semantic similarities for each corpus

Corpus	Mean lexical similarity	Mean semantic similarity	Combined lexical and semantic similarity
RES	0.35	0.90	0.63
WAI	0.32	0.82	0.57
ADV	0.32	0.90	0.61
GOV	0.30	0.86	0.58
PUB	0.42	0.89	0.66

Table 4 Polarity and subjectivity of corpora

Corpus	Polarity (− 1 to 1)	Subjectivity (0 to 1)
RES	0.08	0.40
WAI	0.11	0.44
ADV	0.10	0.47
GOV	0.07	0.44
PUB	0.11	0.42

Our descriptive statistics reinforce the observation that the WAI and GOV corpora are the most divergent out of our corpora, and that PUB is the most central.

Specific searches

Concordances and context across our corpora

We plotted collocation graphs and networks to explore the contexts in which transformation, change, and transitions are framed within the corpora. Collocation analysis of the use of terminology and presence of related concepts shows (a) differences in presence and relevance of the terms/concepts and (b) differences in how the terms/concepts are situated and contextualised. We used log Dice and a frequency filter for a clearer display. Edge length indicates collocation strength,

with closer collocates showing stronger associations. Collocate circle size reflects collocation frequency, while colour indicates corpus frequency. The graph positions collocations based on text positions, spreading out overlapping collocates for clarity.

There are no shared collocations between transition and transformation in our GOV corpus (Fig. 1), but they both share collocates with change. Transition and change share collocations that reflect "where" (environment, economy, energy, department, district, country, state, local), "why" (environment, economy, need, effect, clause, time, part), and "how" (developing, planning, response, process, commencement, support, minister, new, national, act, notice, clause) shifts are discussed in A-NZ governmental documents. In this context, transitions are strongly connected to lowering emissions, and the response is again connected to authoritative decision-making (force, manager, authorises, declared) as a response to urgency (emergency, termination, recovery, end, immediately). On its own, collocations with transitions reflect a top-down, authoritative decision space, with a high prevalence of timelines and temporality associated with transitions (period, end, immediately, appear, terminate, extension, come, gradient, developing), local and national scales, roles, and contexts (pm, rma, manager, authorises, emergency, arrangements, force, declared), and effects (equitable, low emissions).

We performed more in-depth exploration of the relevance of transformation and find the term appears most frequently in the context of sector and agency (cf. supplements). Plotted as a network in connection with agriculture and new, we see that transformation appears in the context of departmental units and tasks (ministry, secretary, portfolio, mpi, director general, minister, subpart, amendment, act, new section, council).

Figure 2 shows the collocation network between change, transition, and transformation for the RES corpus. Here, there is a more nuanced connection between terms. Transformation and change in the research corpus share the collocates impact, vulnerability, and effect. Transition and change share the collocates risk and economy. All three share several collocates that describe different scales/systems (global, system, societal, environmental), directions and classification of change (pathway, forward, towards, adaptation, transition, change, transformation), classic research terminology (study, theory, concept, insight), and characteristics/implications of changes (innovation, sustainable, sustainability). Collocations around change occurrences show the highest overall frequencies in collocations. Change mostly co-occurs with the terms vulnerable (453 collocations, 1979 overall corpus), variability (425 collocations, 1613 overall corpus), and climatic (425 collocations, 1519 overall corpus). Transformation mostly co-occurs with digital (63 collocations, 318 overall corpus) and agrifood (22 collocations, 97 overall corpus). Transition with low_carbon (9 collocations, 38 overall corpus) and agrarian (8 collocations, 62 overall corpus).

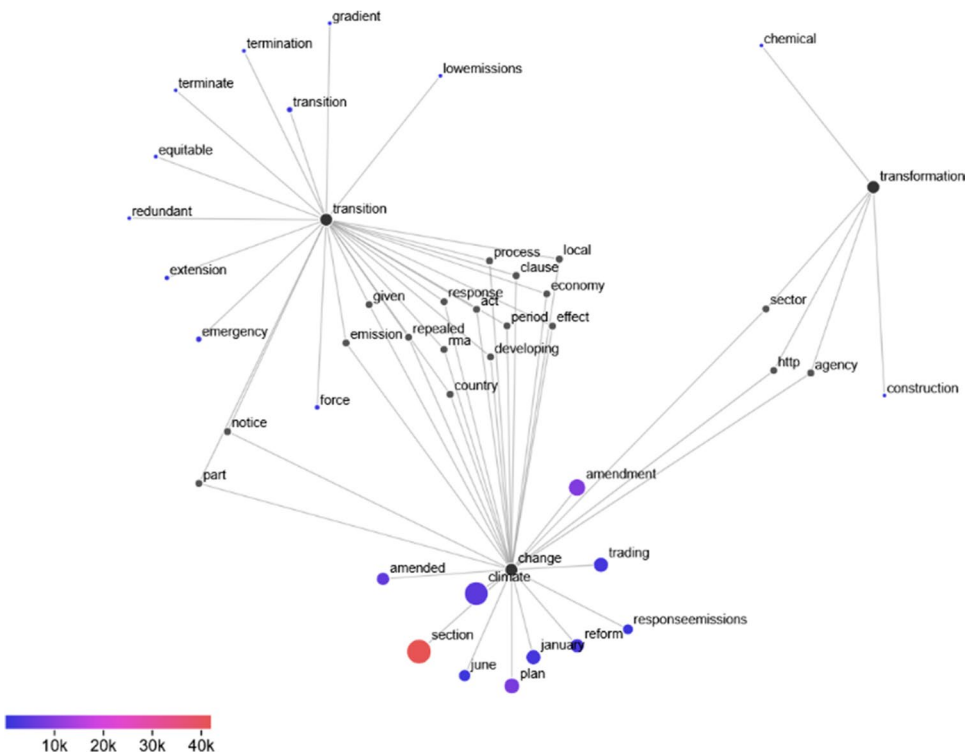

Fig. 1 Collocation network for the governance corpus, showing shared and non-shared collocations between the terms change, transition and transformation

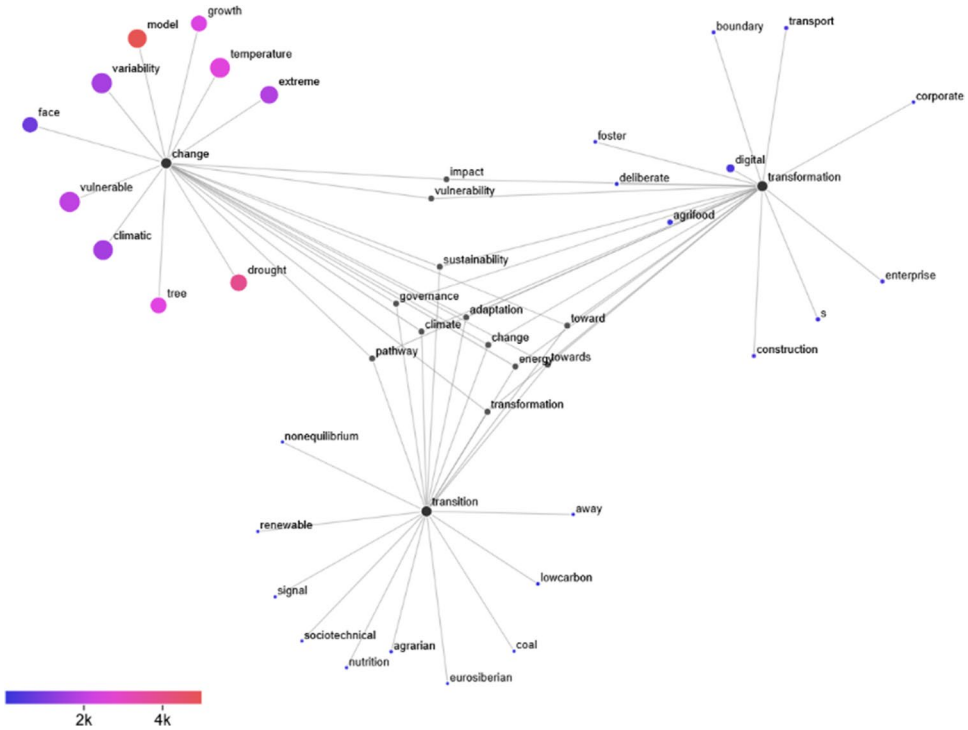

Fig. 2 Collocation network for the research corpus, showing shared and non-shared collocations between the terms change, transition and transformation

When plotting the connection between agriculture and transformation (cf. supplements), we find agriculture in the context of climate-smart, regenerative, diversified, smallholder, conservation practices, and respective vulnerability. Transformation is framed around who, where, and why: who is involved (lead, political, agency, enterprise, corporate), where transformation takes place (cross-scale, boundary, societal, socio-ecological, corporate, systemic, transport), and how it takes effect (rapid, deliberate, similarly, learning, lead, profound).

As can be seen in Fig. 3, the terms transition and transformation are less present in WAI262. Change is mostly associated with environment, recommend, and land.

We mapped out the collocations for land and change, future, and water to situate the framing of change in a resource use context.

This mapping provides valuable insight into the relational view on change, as exemplified through the shared collocations connecting the words change and water: māori, relationship, land. This relationship is reiterated through some of the collocations and contexts land and change share: mātauranga (knowledge), taonga (treasure), environmental, culture. The external codification of this relationship through the settler state is part of this context too (crown, act). The importance of guarding future developments against the background of the relationship between humans and the environment is visible in the collocation contexts of the words change and future; they share the collocations kaitiaki (guardian), past, generation, reo, and work.

To look at the framing of transformation in WAI, we decided to also map the collocations for environment and food, to clarify against which background transformation can be discussed (Fig. 4). We then performed additional searches to clarify the background to conversations about change, environment, transitions, and transformation (cf. supplements).

The words ministry and relationship show the highest frequencies and strongest statistical relationship of co-occurrences with environment, followed by environment, natural, kaitiakitanga, court, and management. As the size of the circles show, relationship is a word that is frequently discussed in the corpus, as are the words ministry, kaitiaki, and management. A further search on relationship shows the following collocations with highest frequency and statistical values: kaitiaki, species, taonga, environment, mātauranga, and protect (cf. supplementary material).

Next, we mapped collocations for He Waka Eke Noa documents in our ADV corpus. The term transformation does not appear in the corpus and is unrelated to change and transition (Fig. 5). Transition and change share the collocations farm and plan. The term change is mostly discussed in the context of climate, rainfall, regional, and opportunity. The collocation network shows one additional, unshared, collocate for transition, namely end.

A more specific search on transitions, farm, and end shows a clear association with emissions planning and quantifying (documented, milestone, model, type, programme, manage, measure, reporting, report, sector, my_imprint,

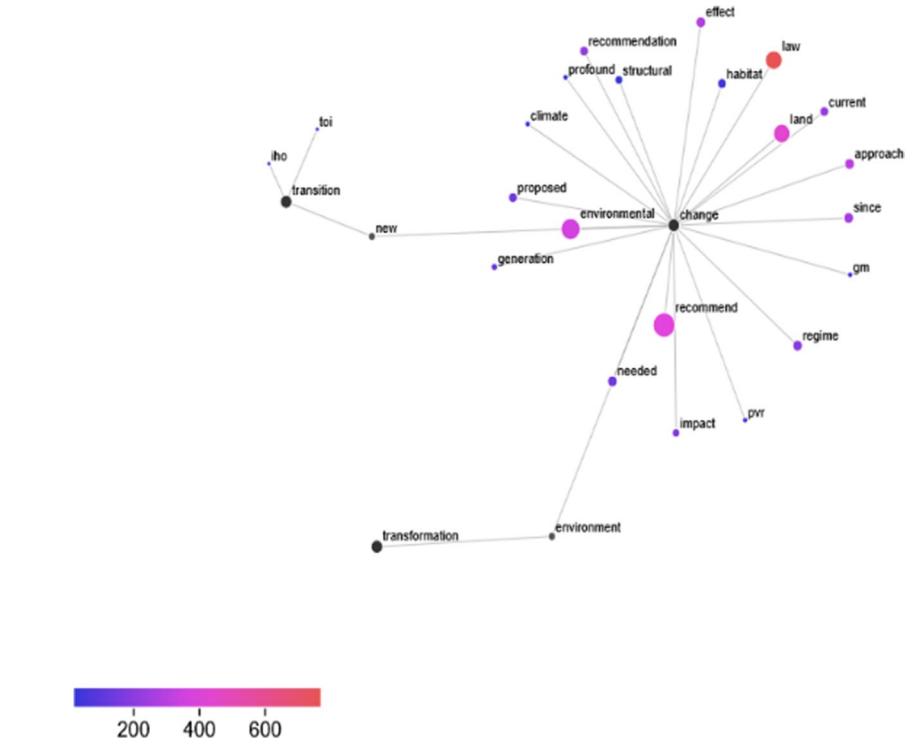

Fig. 3 Collocation network for the WAI 262 corpus, showing shared and non-shared collocations between the terms change, transition and transformation

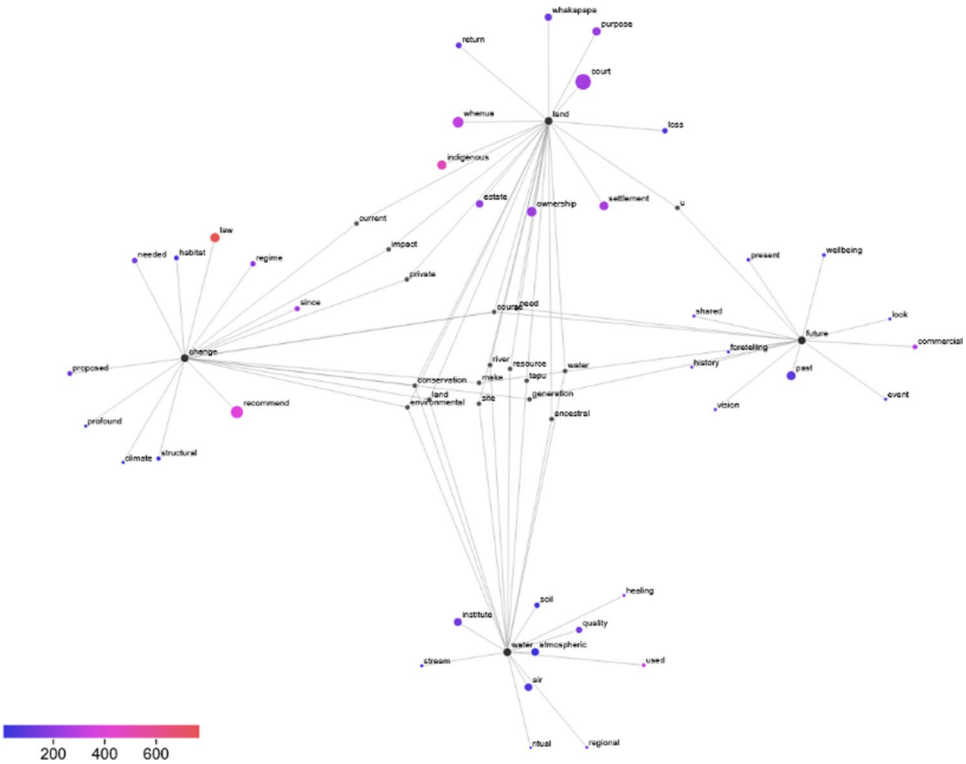

Fig. 4 Collocation network for the WAI 262 corpus, showing shared and non-shared collocations between the terms land, change, water and future

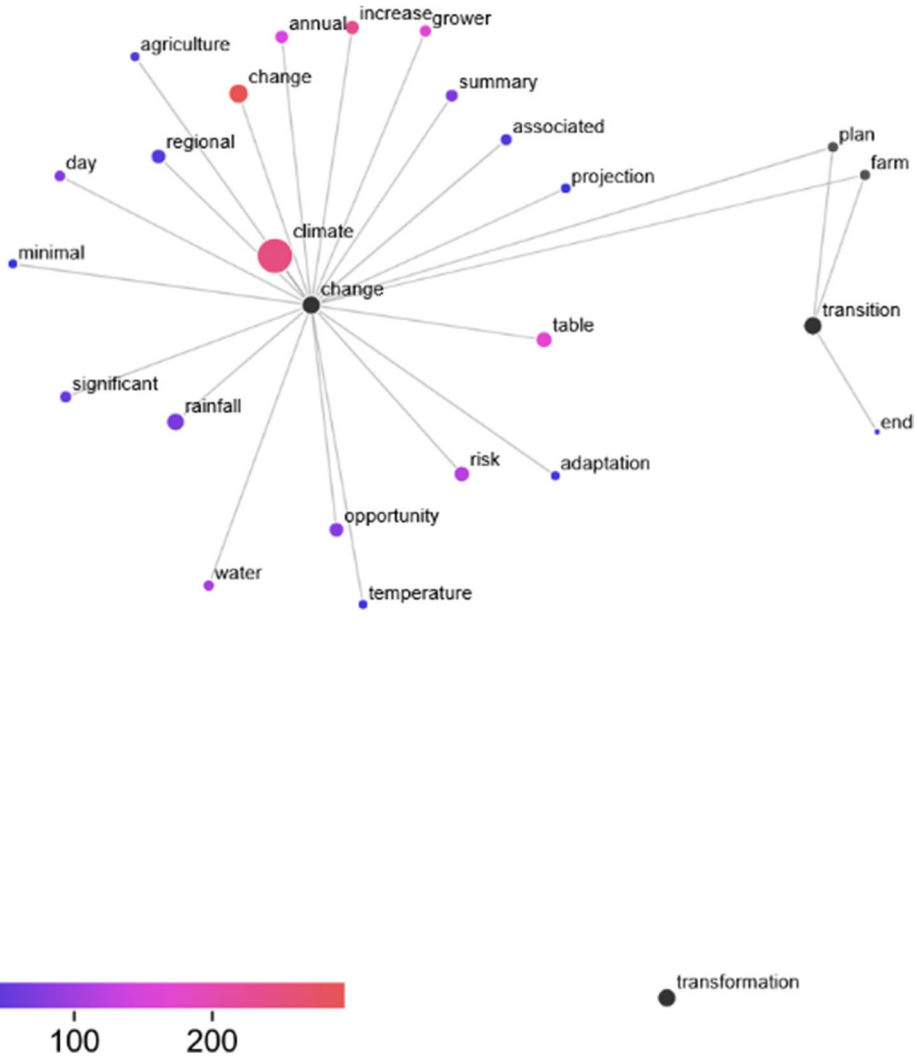

Fig. 5 Collocation network for the Advisory Body corpus (He Waka Eke Noa), showing shared and non-shared collocations between the terms change, transition and transformation

written), particularly in the context of sheep and dairy farming, which is not surprising given the characteristics of the group as supporting emissions reduction in the sector (cf. supplements).

We analysed the PUB corpus using a subsample of 100,000 random paragraphs (1,125,748 words before cleaning; 638,769 words after cleaning). Results show (Fig. 6) the position of change in the context of climate, impact, commission, and government. The most frequent collocations of transition are hybrid, low_emissions, economy, helping, and european. Most frequent collocations with transformation include biopesticide, agrarquest, subsequently, digital, and agritec. In this subsample, the three terms share the collocates plan, new, need, farmer, zealand, and government. Transformation and change share collocations that reflect on added value (innovation, growth, value, leading). Transition and change share collocations reflecting on direction of change and where/how change takes effect (economy, energy, sustainable, fuel), while underscoring the need for support (help, support, helping).

Overall, the collocation networks show that PUB and RES most comprehensively connect change, transition, and transformation. PUB links change to specific events and people, involving national, European, and global governmental actors. GOV emphasises a task-oriented framing around change and transitions. ADV does not connect transformation with the other terms but discusses specific pathways for transitions and change. WAI shares collocations but also includes context on other terms like environment and land, relating to the three key terms within their respective group discourses.

Word embeddings

Finally, we compared the word embeddings of the following search terms in each of the corpora. Table 5 shows the

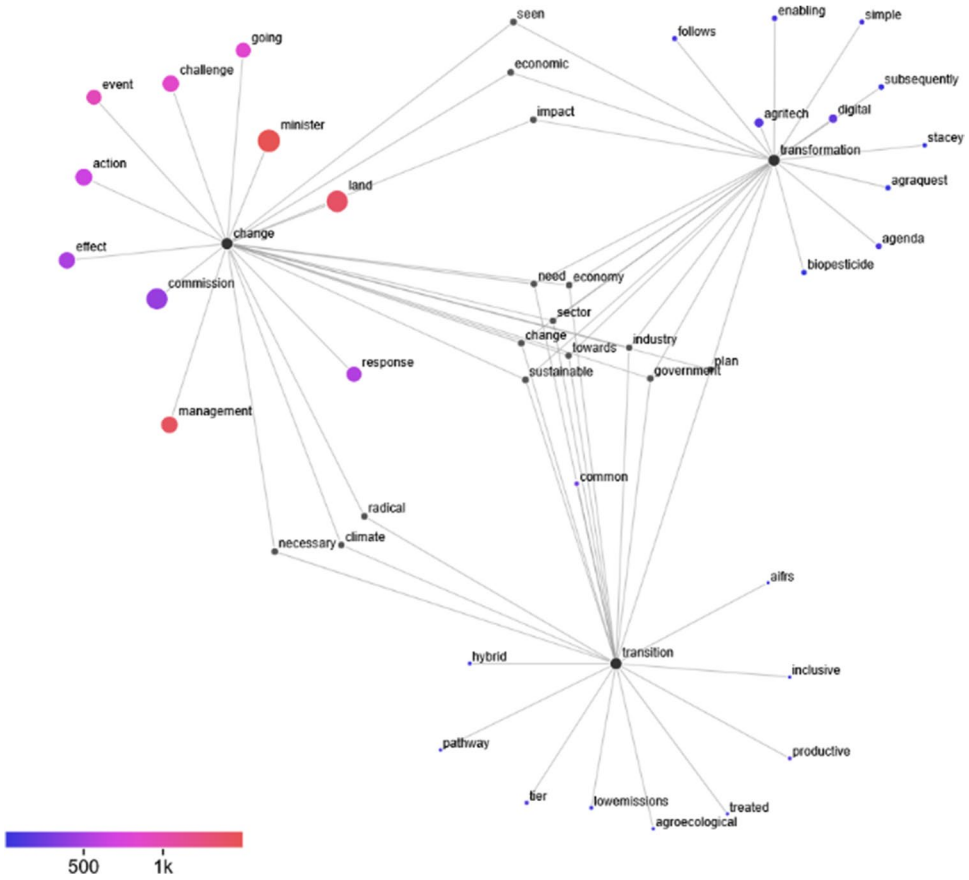

Fig. 6 Collocation network for the media publications corpus, showing shared and non-shared collocations between the terms change, transition and transformation

closest words to search term, its semantic meaning in the specific corpus the model was trained upon.

Change is predominantly discussed in the context of climate effects. While there is some overlap in terms across all groups, each group has its unique focus and emphasis. RES puts emphasis on projective aspects, anticipating future environmental changes, while WAI contextualises change with structural considerations, mitigating endangerment and proactive approaches. ADV is focused on adaptable strategies, diverse outcomes, and tools for emission reduction. GOV shows emphasis on legislative responses, addressing environmental impact and vulnerabilities, while PUB talks about real-world actions, adaptive patterns, and addressing public needs.

Climate co-occurs with terms like "change" and "impact" across all groups, but each group maintains its unique emphasis. RES focuses on projective assessments, current impacts, and unanticipated events. WAI on conditions, cultivation, catastrophic events, and environmental ambiguity. ADV on adaptable strategies and practical approaches. GOV on legislative responses in the context of vulnerability, and hazard mitigation. PUB on public discourse and amelioration efforts.

Transformation. RES focuses on institutional and systemic transformation, WAI more specifically on transportation and various forms of information. ADV has limited mentions of "transformation". GOV puts emphasis on processes related to governance, including institutional transition, innovation, systemic approaches, and reflexive pluralisation for actualisation, and PUB on innovation and realignment in the public discourse.

Key terms associated with transition highlight the diverse perspectives and emphases of each group. RES focuses on fundamental transformation and renovation, decarbonization, and progressive reorientation in the context of climate resilience and adaptation. WAI on language-related concepts (transliteration, translation), transportation, and transactions. ADV on transformative changes, and gradual changes in the agricultural emission reduction programme. GOV on transient provisions, continuation, and commencement in the context of environmental management legislation, and PUB on generational plans and acting in the public discourse.

Table 5 Word embeddings model results

Model results change	
RES	climate, impact, unanticipated, future, variability, forthcoming, current, global, projective, environmental
WAI	structurally, prosaically, endangerment, midrange, really, reap, mitigate, outset, sparingly, impoverishment
ADV	climate, adaptable, bell, chance, outcome, toolbox, storminess, clip, projection, box
GOV	climate, pressure, climax, impact, decimate, severity, variability, vulnerability, catastrophic, imperative
PUB	climate, real, action, adaption, pattern, need, irrational, reverse, commiseration, causation
Model results climate	
RES	change, future, current, forthcoming, projective, impact, presently, variability, potential, unanticipated
WAI	climbing, cultivate, catastrophic, cooler, pest, countless, ambiguous, sparse, pollutant, plus
ADV	change, adaptable, bell, outcome, mary, tackle, viable, toolbox, opportunity, chance
GOV	change, impact, vulnerability, hazard, pressure, decimate, adapter, magnitude, mimic, climbing
PUB	change, adaption, action, combative, disaster, tackling, amelioration, real, mitigation, scalping
Model results transformation	
RES	transition, transilience, institutionalism, innovation, systemic, preconception, reflexively, pluralization, actualization, unlocking
WAI	transportation, transplantation, transduction, decimation, totipotent, affirmation, fermentation, conjugation, segregation, information
ADV	TRANSFORMATION appeared in ADV less than 10 times
GOV	prefabrication, formation, information, indication, augmentation, compilation, desiccation, sophistication, multiplication, production
PUB	innovation, visionary, underdevelopment, realignment, scalping, renovation, digitally, deceleration, shaper, realizing
Model results transition	
RES	transformation, transilient, fundamentally, decarbonization, renovation, preconception, socialization, pluralization, progressive, reorientation
WAI	transliteration, transduction, translation, transportation, transgression, nutrition, tuition, motion, radiation, transaction
ADV	transferred, transparent, transformative, transportation, trait, trend, gradual, unplanned, trade, edition
GOV	transient, provision, mansion, redemption, saving, continuation, relinquishment, proclamation, germination, commencement
PUB	transient, recommitment, regeneratively, need, action, generational, plan, supporting, moving, taking

Discussion

Climate change and its impacts and implications evolve dynamically—and the way we conceptualise, act on, and talk about adaptation, transitions, and change must be equally flexible and accommodating of complexity (see e.g. Artega et al. 2023; Dilling et al. 2023). Our comparison of corpora reveals varied emphasis on future impacts, strategies, and perceptions, illustrating the multi-dimensional nature of change. We observe differences in narratives and framing of change, e.g. between government and He Waka Eke Noa, who place higher value on economic concerns, and the WAI corpus, that places higher value on relational concerns. Regarding future impacts, each corpus emphasises different aspects: Research (RES) focuses on climate projections (consistent with the prevailing top-down, outcome-oriented approach to assessing climate impacts), while He Waka Eke Noa (WAI) on intuitive responses and potential loss. Sustainable agriculture and legislative responses are emphasised in Advocacy (ADV) and Government (GOV) respectively. Despite these variations, common themes like "action", "innovation", and "outcome" are evident across all corpora, indicating a shared interest in practical results and government involvement in addressing climate change and environmental management. In a recent analysis of submissions to A-NZ's National Adaptation Plan, Cretney et al. (2024) find a similar breadth of framing when analysing adaptive futures.

Communication on climate change effects and reaction tends to be uncoordinated; potential synergies in communication remain underexplored and -used (Schwarzinger et al. 2019). Based on the diversity shown in our results, there is an opportunity to improve the integration of scientific, indigenous, practical, and policy perspectives as part of comprehensive primary sector strategies. Providing holistic information can support planning and is itself an implicit acknowledgement of the complex decision contexts facing farmers. There is, however, no silver bullet for communicating climate change (Troy 2025; Ranney &

Velautham 2021). Although there is evidence that communication influences behaviour, research climate framing and its effects are still emerging (Badullovich 2022). Adaptation, involving behavioural changes to navigate climate challenges, requires complex decisions (Cradock-Henry et al. 2019). Individuals are more likely to make adaptation decisions when they are influenced by experiences and historical knowledge (Lie et al. 2023; Koerth et al. 2016), incentivised by policy (Buelow & Brower 2023), and have the capacity for making changes or are surrounded by others who are starting to implement change (Cismaru et al. 2011). Perceptions of communication are influenced by prior beliefs, values, and heuristics that influence decision-making (Quick et al. 2011). Thus, while our analysis cannot lead to a single solution, we highlight the following takeaways, each written with the aim of strengthening the connection between the five message "senders" analysed here and farmers as their intended audience: inclusive communication for a changing sector, bridging narratives, and diverse engagement with different perspectives.

Inclusive communication for a changing sector The way we talk about change plays a pivotal role in shaping adaptation strategies within the primary sector (Vulturius et al. 2020; Yorgey et al. 2017). Understanding the discourse around change between groups provides critical insights for policymaking, industry planning, and societal response. Comparing the ways change is understood and discussed by different groups can illuminate their priorities, concerns, and openness to innovation or conservation efforts. It might allow communication strategists to address the structure and root causes of vulnerabilities embedded in different exposure and capability as well as perceived responsibility to act on climate change, and offer rationales for action (Griffin et al. 2023). Inclusive communication can foster collaboration among relevant stakeholders, including farmers, researchers, policymakers, and extension agents (Bolden et al. 2018). Such collaborative efforts can lead to the development of innovative adaptation strategies and the pooling of resources to address common challenges. While the groups we analyse exhibit diverse perspectives and emphases, they are generally aligned with respect to the need for change and innovation. The diversity we observe provides an opportunity for tailored, yet complementary approaches, with each corpus making a unique contribution to understanding and driving change in the primary sector. Climate change communicators therefore should aim to unite audiences by promoting a shared ambition with respect to climate resilience and sustainability while tailoring messages to specific groups (Hine et al. 2014). Primary producers want to be sustainable and cope with adverse climatic shocks, regardless of any trust or belief in the science of climate change (Yletyinen et al. 2024). Recognising the broader political, social, and cultural contexts of transformation acknowledges its "vital complexities" (Stirling et al. 2023), requiring deeper engagement with diverse knowledges and openness to different perspectives on change and transformation (Pérez-Hämmerle et al. 2024). Crafting meta-narratives or meta-visions could potentially reconcile disparate viewpoints, bridging the differences we see between our corpora, to foster more inclusive discussions on change, transitions, and transformation (Rout et al. 2021; Fage-Butler et al. 2022; Wong et al. 2013; Greenhalgh et al. 2005).

Bridging narratives We find that the Public (PUB) corpus demonstrates the highest lexical overlap with other corpora, particularly with He Waka Eke Noa documents (ADV), indicating a resonance with public discourse. Conversely, Government (GOV) texts exhibit a more neutral tone and high subjectivity, due to legal jargon. The distinctiveness of the GOV corpus therefore suggests a potential gap in communications strategies between the government and other stakeholders, emphasising the need for more engaging and accessible approaches. Because broad public support is crucial for driving the changes needed to tackle climate change (Geiger et al. 2021), aligning government communication with public discourse may help bring stakeholders' perspectives closer together and improve policy implementation. However, communication does not occur in isolation: knowledge brokers including media, think tanks, and advocacy groups are more effective at influencing policy when they align ideologically with policymakers (García-Hombrados et al. 2024). Futures are also influenced by factors beyond climate change, including rising political polarisation, growing authoritarianism, and the actions of those who hold or can access power (Cretney et al. 2024). The challenge, therefore, is to strengthen communication channels that work across ideological divides. Creating transformative adaptive futures requires governance that moves beyond consultation to actively build capacity, support, and partnerships, fostering relationships, empowerment, and diverse collective and individual identities (Cretney et al. 2024).

Diverse engagement with different perspectives Knowledge sharing can increase social learning in agriculture (Harvey et al. 2012). One challenge to consider regarding the potential non-engagement across groups is attributed to the formation of "echo chambers", where like-minded individuals reinforce their beliefs, hindering collaboration and consensus-building (Sakieh 2024). Groups that share similar dialogues often employ similar rhetorical strategies as part of their efforts to advance their interests and values in the management of specific resources and locations, which may involve conflict and consensus-building (Maclean et al. 2014). The stories we tell ourselves about transformation

in scientific writing as well as in policy documents are "(to varying degrees) […] unduly singular, deterministic, categorical" (Stirling et al. 2023, p.2). This is where discourse carries power; the way we talk about an issue, the way we tell a story, holds methodological, analytical, political, and transformative potential (Harris 2022). Such discourse, such as storytelling, is used by individuals and groups to (re)create meaning, including sense of self, and how they relate to others, reinforce identities (Elliott 2005). By identifying how different stakeholders frame climate adaptation through tone and terminology, our study reveals where views align or differ. This insight can help inform messaging that unites audiences, emphasising collective responsibility and shared values, rather than compounding divisions. Additional research could explore how storylines based on different framings of change are perceived across groups. Based on our results, framing change, transitions, and transformation around innovation appears to be the least confronting approach across the groups whose communication we analysed. This framing could therefore serve as a useful starting point for communicating pathways toward general change, specific transitions, and/or broader transformation. This is very much in line with exploration of positive and encouraging messaging, which can affect behaviour (Baden et al. 2019). However, considering the diversity of framings regarding change, transitions, and transformation in the corpora, it is important to consider if and how messages with "dissonant" information challenge farmers' world views and values, which could decrease the likelihood of change intentions and actions (Nisbet et al. 2015). This is also affected by attitudes toward the sender of messages, e.g. their perceived trustworthiness (Kerr et al. 2022; Brick et al. 2018; Pornpitakpan 2004), and the framing of information, e.g. how persuasively it is worded (Buelow and Brower 2023; Waedegaard et al. 2024). If the aim is to encourage behaviour change, audience segmentation, which involves dividing the audience into groups based on key characteristics, could focus on the main drivers and obstacles related to the desired actions (Hine et al. 2014).

Finally, it is important to note that NLP and ML identify patterns and trends but interpreting these results in A-NZ's unique socio-political and cultural context requires additional insights. Future work could involve more detailed analysis of corpora and exploration of stakeholder perceptions. Engaging with A-NZ primary sector stakeholders can validate findings and uncover new insights. Given the unique position of the WAI corpus, in particular, further research could explore how indigenous knowledge and perspectives on environmental management and change can be more fully integrated into national strategies and discussions. Research could also explore integrating Māori knowledge into national strategies, particularly through engagement with Māori communities and concepts. Additionally, examining how the five groups describe change and how these descriptions are perceived by farmers compared to the public or decision-makers could highlight differing adaptation preferences.

Conclusion

The accelerating impacts of climate change have significant implications for productive systems, including agriculture, and adaptation is urgently needed. To gain insight into the potential for transformational change within primary industries, using A-NZ as a case study, the findings underscore the critical need for drafting more inclusive and multi-dimensional communication strategies. Based on the analysis of five different corpora of textual material, the results of the application of NLP tools highlight the diversity in communication across different groups, the complexity of the discourse, and the potential for constructive engagement and learning. By acknowledging the varied priorities and concerns of different stakeholders, there is an opportunity to foster tailored and integrated approaches to managing change, one that leverages the strengths and insights of each group.

The potential for complementary narratives among the different corpora suggests a pathway toward a more collaborative and cohesive strategy for environmental management and innovation in the primary sector. The emphasis on innovation as a common ground across different groups provides a promising starting point for facilitating broader conversations about change, transitions, and transformation.

Future research should focus on further dissecting these communication patterns, exploring the perceptions of different stakeholders, and investigating the impact of these communications on policy and practice. Engaging with indigenous knowledge and perspectives offers a valuable dimension to this discourse, promising richer, more inclusive strategies for managing environmental change that are urgently needed. Ultimately, this study not only highlights the diversity of perspectives on change within A-NZ's primary sector but also points toward the potential for these varied conversations to contribute to more sustainable and resilient futures.

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Declarations

Conflict of interest The authors declare no competing interests.

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