RESEARCH ARTICLE

People and Nature

What constitutes sustainable agriculture for different audiences in Germany? A comparative analysis of large-scale text data

Bartosz Bartkowski[1,2] | Marieke Cornelia Baaken[3] | Mansi Nagpal[1] | Jan Sodoge[4,5] | Mariana Madruga de Brito[4]

[1]Department of Economics, Helmholtz Centre for Environmental Research–UFZ, Leipzig, Germany

[2]Department of Economics, Martin Luther University Halle-Wittenberg, Halle, Germany

[3]Department of Environmental Economics, Institute of Environmental Systems Research and Faculty of Economics and Business Administration, Osnabrück University, Osnabrück, Germany

[4]Department of Urban and Environmental Sociology, Helmholtz Centre for Environmental Research–UFZ, Leipzig, Germany

[5]Institute of Environmental Science and Geography, University of Potsdam, Potsdam-Golm, Germany

Correspondence
Bartosz Bartkowski
Email: bartosz.bartkowski@ufz.de

Handling Editor: Mollie Chapman

Abstract

1. Agriculture contributes in several ways to achieving sustainability objectives. However, there is no agreement among different societal groups, such as farmers, consumers and scientists, on what constitutes 'sustainable agriculture'. These differences affect how the impacts of agricultural production on sustainability objectives is perceived, which solutions are considered and implemented.

2. In this paper, we investigate the topics discussed under the heading 'sustainable agriculture' in German newspapers and agricultural magazines. To this end, we apply topic modelling to extract topics discussed in these two large-scale text corpora. We complement these with scientific articles as a contrast case. We run separate topic models for each corpus and use the identified topics to compare the patterns qualitatively.

3. Results reveal heterogeneity in the topics across the three corpora with limited overlaps restricted to topics such as agricultural policy. This supports the assumption that farmers and the broader society in Germany have very different perceptions of sustainable agriculture. A surprising result is the absence of topics related to climate change from the agricultural magazine corpus.

4. These disparities may create challenges for designing and implementing democratically legitimized policies to promote sustainable agriculture.

KEYWORDS
agriculture, farming, natural language processing, sustainability, topic modelling

1 | INTRODUCTION

Agriculture is a prominent topic in sustainability debates, given its significant contribution to biodiversity loss, nonpoint-source pollution and climate change (Campbell et al., 2017; Clark et al., 2020; Pe'er et al., 2020). At the same time, it stands out as one of the sectors most strongly affected by environmental change, especially climate change (Yang et al., 2024). Consequently, agriculture features prominently in sustainability policy debates at various levels (e.g. Schebesta & Candel, 2020; Scown & Nicholas, 2020;

SPD, Bündnis 90/Die Grünen, FDP, 2021), in which explicit or implicit pictures of sustainable agriculture are drawn. However, given the complexity of the relationship between agriculture and sustainability challenges, it remains ambiguous what constitutes sustainable agriculture (Baaken, 2022; Garibaldi et al., 2017; Velten et al., 2015).

Agriculture or, more broadly, agri-food systems include complex actor and power networks (Williams et al., 2023). At the same time, sustainable agriculture is a normatively charged topic (see Korthals, 2001). Different actors emphasize different aspects, which may result in conflicts of interest and a stalemate in policy reform. For instance, substantial discrepancies exist in the discourses around sustainable agriculture between science and policy (Janker et al., 2018). Also, it has been observed that in an era of increasing urbanization, there is growing detachment, particularly of the urban population, from the realities of farming, often leading to the romanticization of the past and demonization of modern 'industrial' agriculture (Sumberg & Giller, 2022; Sutherland et al., 2020). At the same time, it is sometimes argued that a transformation towards sustainable agriculture requires taking seriously the perspectives of and barriers faced by the farming community (Baaken & Vollan, 2024; Bohan et al., 2022; Gütschow et al., 2021). The conflict between these two perspectives—societal sustainability demands versus farmers' preferences and priorities—is increasingly played out in the political arena, for example in the context of bottom-up initiatives such as referenda (Huber & Finger, 2019) or farmers' protests (van der Ploeg, 2020). Understanding what the relevant aspects are for different actors—including farmers and the non-farming public—can help align their perspectives, facilitating the development of comprehensive policy frameworks to affectively address the challenge of sustainability in agriculture (Oliver et al., 2018). This paper contributes to generating such understanding by analysing topics discussed in different media in the context of sustainable agriculture.

Media are an important platform for societal debates, including sustainability-related ones. Different media channels discuss and represent such debates differently based on the interests of different societal groups (Sindermann et al., 2024), their ideologies and ongoing political events (Carvalho & Burgess, 2005; McHenry, 1996; Rust et al., 2021). Print media have been shown to affect public attitudes and behaviours related to sustainability (Happer & Philo, 2015; Happer & Wellesley, 2019). This makes them important in shaping societal debates on sustainability and a potential lens into these debates. Understanding how sustainable agriculture is represented and discussed in media with different audiences can help identify sources of contention, conflict and common concerns across the involved groups. Such knowledge could facilitate more informed public discourses and inclusive dialogues on sustainable agricultural practices and beyond (Velten et al., 2018).

In this paper, we investigate the topics discussed under the heading 'sustainable agriculture' in different German print and online media. We use large-scale automated text analysis to compare three different text sources (hereafter referred to as corpora) on sustainable agriculture: German newspaper articles, representing the topics discussed by the general public; articles from German agricultural magazines, representing the perceptions and opinions of the farming community; and, as a complementing contrast case, abstracts from international peer-reviewed publications on the topic. We apply topic modelling to identify topics that emerge from these three corpora and compare them in terms of prevalence and with respect to temporal development. The overarching question is: What is being discussed under the heading 'sustainable agriculture' in German print and online media? Moreover, we contribute to the understanding of differences in perception across major societal groups (particularly farmers vis-à-vis the broader society) by investigating the differences between the three corpora.

With 50% of its terrestrial area covered by agriculture (Statistisches Bundesamt, 2023), Germany serves as our case study because of its contentious sustainability issues (Schaub, 2021; Schüßler et al., 2024). As one of the largest member states of the European Union (EU), it also greatly influences the shape of the EU's Common Agricultural Policy (CAP). For these reasons, the debates around sustainable agriculture in Germany are of particular interest. Newspaper and print media still attract the broadest user group in Germany alongside radio (Statista, 2023). Their analysis involves dealing with large amounts of text. Traditional approaches to investigating text-based data include content analysis, interviews and focus groups, also in the context of sustainable agriculture (e.g. Asplund et al., 2013; Happer & Wellesley, 2019; McHenry, 1996; Rust et al., 2021; Schüßler et al., 2024). While providing rich and deep insights, these traditional approaches have important limitations. First, they can only capture a limited subset of relevant documents or actors. Second, interviews and focus groups only provide snapshot insights at a given point in time. An alternative approach is large-scale text analyses using natural language processing, text mining and machine-learning modelling tools (e.g. Dehler-Holland et al., 2021; Otto et al., 2022; Reber et al., 2022; Sodoge et al., 2023; von Nordheim et al., 2019). While not offering as deep insights as conventional analyses, this approach offers unprecedented breadth, allowing for the analyses of thousands of text documents and uncovering implicit semantic patterns (Gentzkow et al., 2019; Roberts et al., 2016). Our study follows this breadth-focused approach.

2 | DATA AND METHODS

An overview of the methodological steps is provided in Figure 1. Web scraping, data cleaning and pre-processing were conducted in the statistical software R, version 4.2 (R Core Team, 2022). The topic model was implemented in Python (Python Software Foundation, 2022). All data cleaning and processing code, including a full list of used packages, can be found at https://github.com/BartoszBartk/sust_ag_discourses.

2.1 | Data

We collected three sets of data for the topic modelling analyses: agricultural magazine articles (full texts), newspaper articles (full texts) and scientific articles (abstracts).

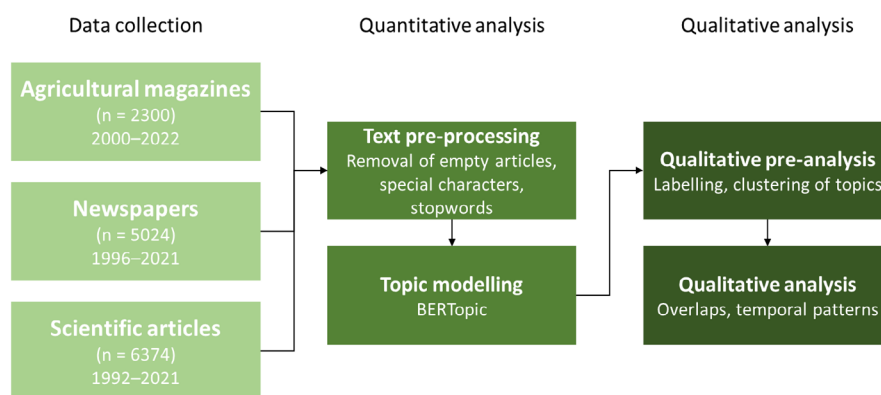### 2.1.1 | Agricultural magazines

Germany has a range of professional magazines addressing farmers. Many focus on a specific type of farming or a specific region. To analyse what is discussed under the heading 'sustainable agriculture' in the German farming community, we used a web scraping approach to download articles from three major agricultural magazines: Top Agrar, AgrarHeute and DLG Mitteilungen. For the former two, we used the search string "nachhaltige landwirtschaft" ("sustainable agriculture"); for DLG Mitteilungen, we used "nachhaltigkeit" ("sustainability"), because the search function of its archive did not allow for fixed multi-word phrases. The selection of magazines was based on circulation, Germany-wide coverage, accessibility and the number of articles found by applying the search string (minimum 100). The articles were retrieved on 19 October 2021 (Top Agrar), 16 December 2021 (DLG Mitteilungen) and 28 April 2022 (AgrarHeute) (The search was updated in April 2022, but for DLG Mitteilungen, no new relevant articles were found at that time, while for Top Agrar, the new search returned a significantly lower number of articles, which seems to have been due to changes in the magazine's website, so we decided to keep the original sample of articles and only updated AgrarHeute). Table 1 offers an overview of the three agricultural magazines. The final dataset consisted of 2300 articles.

2.1.2 | Newspapers

Germany has a complex newspaper publishing landscape, with both national and regional newspapers being read widely (see Table 2 below). We used the newspaper database wiso-net.de (part of genios.de) to retrieve newspaper articles, as it is the most comprehensive German-language newspaper database available. We applied the search phrase "nachhaltige landwirtschaft" on 15 July 2021, which returned 8064 entries. All the entries were downloaded manually as PDFs. In the next step, they were converted into plain text and reformatted for further analysis. While the wiso-net.de database does not cover all existing media outlets, our sample included major national and regional German newspapers, including some of the most widely circulated ones according to the German Audit Bureau of Circulation (IVW): Der Spiegel, Die Zeit, Stern, Focus, Nürnberger Nachrichten, Neue Osnabrücker Zeitung, Rheinische Post, Sächsische Zeitung—all with a circulation of more than 200,000 copies in the fourth quarter of 2020 (see Table 2 for newspapers with most included articles). The temporal coverage of the newspapers in the database varies strongly; nonetheless, we included all relevant articles without restricting the time frame (see Section 2.2.1 for further explanations).

Given that some articles are reprinted almost verbatim in multiple newspapers (e.g. if they belong to the same publisher), we calculated a similarity score (based on Jaccard similarity) and removed all articles that exceeded 90% similarity with an already included article (nonetheless, some duplicates may have remained in the corpus due to minor differences among the versions from the individual newspapers). Furthermore, some articles were removed because their text field was empty due to technical issues within the newspaper database. The final dataset used for the analysis consisted of 5024 newspaper articles.

FIGURE 1 Overview of methodological steps in the analysis of sustainable agriculture discourses in Germany.

TABLE 1 Agricultural magazines used for the analysis.

Magazine	Circulation Q1/2021	Article count	Temporal coverage
Top Agrar	93,600	1301	2001–2021
DLG Mitteilungen	20,433	827	2000–2021
AgrarHeute	49,897	172	2010–2022

Note: Circulation based on data from German Audit Bureau of Circulation (ivw.de); search phrases applied: Top Agrar and AgrarHeute "nachhaltige landwirtschaft", DLG Mitteilungen "nachhaltigkeit".

TABLE 2 Article counts for 10 regional newspapers with most articles in our sample and all national newspapers.

Newspaper	Federal state	Circulation Q4/2020	Wiso coverage	Article count
Regional newspapers				
Passauer Neue Presse	BY	154,656	1996	214
Rheinische Post	NW	251,708	2001	182
Märkische Allgemeine	BB	101,233	2006	132
Mitteldeutsche Zeitung	ST	148,412	1990	131
Schweriner Volkszeitung	MV	67,697	2004	128
Südkurier	BW	103,209	1999	106
Neue Westfälische	NW	122,013	2003	103
Nordkurier	MV	63,903	1999	88
Badische Zeitung	BW	133,141	2003	81
Rhein-Zeitung	RP	155,368	1997	76
National newspapers				
Frankfurter Rundschau		NA	1995	121
Handelsblatt		136,558	1986	52
Die Welt		76,224	1999	40
Die Zeit		574,492	1946	23
Der Spiegel		655,371	1993	20
Focus		254,823	1993	11
Stern		373,889	1996	6

Note: Assignment to federal state based on name and/or headquarters; circulation based on data from the German Audit Bureau of Circulation (ivw.de). NA—no circulation data available from IVW. Wiso coverage: start of coverage in the Wiso database. Number of articles included after removing duplicate and empty articles. Federal state codes: BB—Brandenburg, BW—Baden-Württemberg, BY—Bavaria, HH—Hamburg, HE—Hesse, MV—Mecklenburg-Vorpommern, NI—Lower Saxony, NW—North Rhine-Westphalia, RP—Rhineland-Palatinate, SH—Schleswig-Holstein, SL—Saarland, SN—Saxony, ST—Saxony-Anhalt, TH—Thuringia.

2.1.3 | Scientific articles

Scientific articles form a complementary corpus to serve as a 'contrast case', whose primary purpose is to investigate whether the breadth of topics discussed in science concerning sustainable agriculture is reflected in the other two corpora. Since scientific discourses are seldom nationally specific, we decided not to apply any geographical restrictions on the included articles. To retrieve these, we applied a simple search string "TITLE: sustainab* AND (farm* OR agricultur*)" to Scopus and Web of Science (Core Collection) databases, restricted to publications from 1992 onwards. The search was conducted on 2 August 2021 and returned 10,295 entries from Scopus and 4699 from WoS. For all entries, we downloaded basic bibliographic information (i.e. title, authors, keywords, publication year, outlet, DOI etc.) and the abstracts, which were to be used in the topic modelling analysis. Using only abstracts is common practice in topic modelling analyses of the scientific literature (e.g. Berrang-Ford et al., 2021; Callaghan et al., 2021; Droste et al., 2018), as the use of full texts is restricted by practicability, copyright issues and potential biases introduced for example, by reference lists or methodology sections. Before subjecting this dataset to analysis, we merged the two sub-datasets (from Scopus and from WoS) while also removing

duplicates and entries without DOI or with empty abstracts. The final dataset consisted of 6374 entries.

2.2 | Methods

We used a mixed-method approach to analyse the data, combining quantitative topic modelling with qualitative interpretation.

2.2.1 | Topic modelling

We subjected the three corpora of text data—agricultural magazine articles (full texts), newspaper articles (full texts), and scientific articles (abstracts)—to a topic modelling analysis. First, the textual data have undergone pre-processing to decrease noise in the data, thereby enhancing the identification of meaningful and comprehensible topics. Initially, special characters and numerical values were removed from the corpora. This was followed by the removal of stop words, which are words that lack a specific meaning (e.g. "and" or "thus"). Both steps are commonly applied throughout similar applications of topic models (see Maier et al., 2018; Nunes Carvalho et al., 2024).

For the topic modelling, we used BERTopic, which uses a deep-learning approach (Grootendorst, 2022). It is based on the Bidirectional Encoder Representations from Transformers (BERT) algorithm, a pre-trained language model (Devlin et al., 2019). This foundation allows BERTopic to understand the context and meaning of words within a sentence, allowing it to identify topics and themes more accurately and efficiently than traditional topic modelling techniques (Egger & Yu, 2022; Grootendorst, 2022). When applying BERTopic, careful consideration was given to selecting the appropriate specifications for each text corpus. For the two German text corpora, a multilingual model was chosen for BERTopic, with the sentence transformer being paraphrase-multilingual-MiniLM-L12-v2. For the academic abstracts, an English-specific model was selected, with the sentence transformer being all-MiniLM-L6-v2. The sentence transformer converts text inputs into a high-dimensional space or embedding, representing the text in a numerical format that the model can process. Based on these embeddings, BERTopic identifies topics and themes within the text data. Additionally, the model was allowed to integrate n-grams of up to three words, which enables the identification of typical word sequences related to an individual topic. This allows for more detailed descriptions of topics, which can be identified by word combinations rather than individual words alone.

About half of all articles from each corpus could not be assigned to any larger topic (i.e. they could not be associated with any other texts in the corpus, being either too specific, e.g. covering a topic no other text covered, or too generic, e.g. covering a high number of different topics at once). These were classified as outlier topics, which were not included in the further analysis. Other evaluations and case studies that employed BERTopic also found large fractions of observations categorized as outliers (Egger & Yu, 2022; Grootendorst, 2022). Such behaviour has been attributed to the density-based clustering of the text embeddings. Also, selecting text documents based on particular keywords could introduce a share of articles without a clear association to clusters because their content might not be completely reflected in the keywords.

We estimated a separate topic model for each corpus. Any analyses comparing the corpora were done afterwards, mostly qualitatively. The output of each topic model consisted of a list of topics, including the 10 most common keywords and the articles associated with each topic (see Supplementary Material S1). The association of articles with topics is binary—each article can belong to only one topic. We used the number of articles assigned to a topic to measure their prevalence, that is the *relative* predominance of a topic within the corpus. This allowed us to study the development of each topic over time (in terms of its prevalence relative to other topics in the sample), which is based on simple counts of articles assigned to a given topic in a given year, divided by the number of articles in the corpus in that year. We used prevalence as an indicator of the relative importance of the analysed topics—the assumption being that if a topic is considered relatively important, it is written about more often than other topics. Furthermore, dendrograms were created to visualize a hierarchical clustering of the topics and thus to identify relationships among topics (see Supplementary Material S2, Figures SM2.1–SM2.3).

2.2.2 | Qualitative analysis and interpretation

Having identified the topics for all three corpora separately, we proceeded with a qualitative analysis and interpretation of the results (see Figure 1 above). First, we manually labelled the topics by considering the most frequently occurring words, which is a common approach in topic modelling (e.g. Droste et al., 2018; Russell et al., 2023). To ensure accuracy and reliability, two authors independently labelled the topics for each corpus and later discussed their results to reach a consensus on the topic labels. In most cases, there was agreement on the labels; exceptions were topics that seemingly covered two interrelated topics (e.g. topic 22 in agricultural magazines [see Supplementary Material S1] with links to both organic farming and precision farming). To resolve such cases and further validate our labelling approach, we examined a randomly drawn sample of two articles per topic and assessed whether these articles matched the topic. The two responsible authors then jointly agreed on a final label. Throughout the labelling process, some topics were found to be irrelevant to our focus (see Supplementary Material S1 for a complete list of labelled topics and reasons for exclusion), often because they were related to politics, regional or non-agricultural issues. Notably, the newspaper corpus contained many irrelevant topics that had to be excluded due to their lack of relevance to the context of sustainable agriculture.

In some cases, the topics identified by the BERTopic model were qualitatively similar enough that they were given identical labels. In those cases, we checked whether we can meaningfully distinguish their focus. If not, we merged them; otherwise, we relabelled them. This was done during the labelling process. For example, in the agricultural magazines and newspapers corpora, there are multiple topics related to the Common Agricultural Policy; these were ultimately all labelled as 'CAP' and merged. The individual topics (before merging) can be found in Supplementary Material S1.

Given the still large number of topics in each corpus (27 in agricultural magazines, 69 in newspapers, 73 in scientific articles), we proceeded by identifying clusters of similar topics. To this end, we used qualitative judgement in combination with the topic dendrograms generated by the model. We then looked for overlaps across corpora at the level of clusters. The similarities and differences were subjected to a qualitative analysis using information about the relative prevalence of the clusters and topics within each corpus and its temporal development. Furthermore, we derived temporal trends in the relative prevalence of topics and clusters within each corpus separately, based on the assignment of individual articles to a topic. It is important to note that both the number of articles per corpus and the number and Shannon diversity of topics for each corpus increased over time (see Figures SM2.7 and SM2.8), which should be taken into account when interpreting the temporal trends in relative topic prevalence. To support the interpretation, we created

a timeline (Figure 3b) of the major developments related to agri-environmental policy in the EU since 1992 (the first year for which we have text data). This follows the hypothesis that such political events will likely affect discussions related to sustainable agriculture, as they are often associated with large-scale political consultations and debates between politics and lobbying groups. While we are not able to identify causal relationships with our methodology, we qualitatively investigated the presence of the expected correlations. The timeline delineates the four CAP programming periods (1993–1999, 2000–2004, 2005–2013, 2014–2022), which correspond to EU budgetary periods and usually go along with reforms or reformulations of the CAP, which makes up the largest part of the EU budget. In addition, we highlight five major reforms or strategically important events (Cunha & Swinbank, 2011; Pe'er et al., 2017, 2020):

- MacSharry reform in 1992, which first introduced agri-environmental payments.
- Agenda 2000 in 1999, which led to the introduction of the so-called 2nd pillar of the CAP, devoted to rural development and including agri-environmental schemes, and also prepared for the EU enlargement in 2004.
- Fischler reform in 2003, which included a decoupling of direct payments from production and further strengthening of the rural development programmes.
- Health check in 2008, which led to increases in the budget devoted to agri-environmental payments.
- European Green Deal in 2020, which prepared the ground for multiple strategies related to agriculture, including especially the Farm to Fork strategy, and was generally an attempt to redirect the EU economy towards sustainability and carbon neutrality.

3 | RESULTS

The original model output consisted of 27 topics for agricultural magazines, 69 for newspapers and 73 for scientific articles. After removing irrelevant topics and merging similar ones, the numbers were reduced to 16, 27 and 50, respectively. To draw comparisons between the different corpora, these were grouped into 8, 11 and 17 clusters, respectively. In what follows, we first focus on comparing agricultural magazines and newspapers (sometimes calling them the 'German corpora'), before then briefly turning to scientific articles.
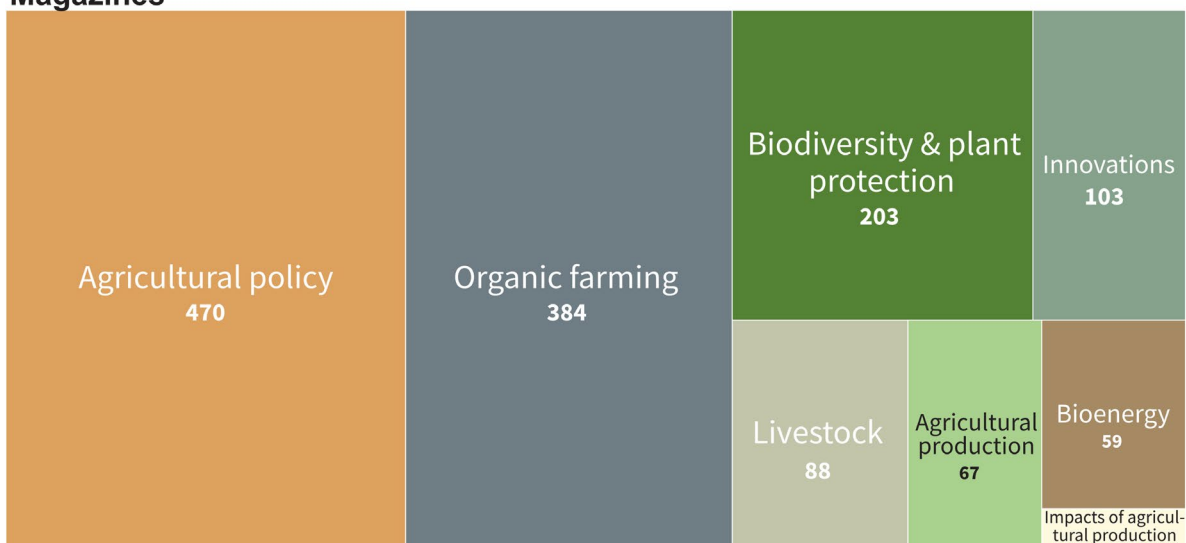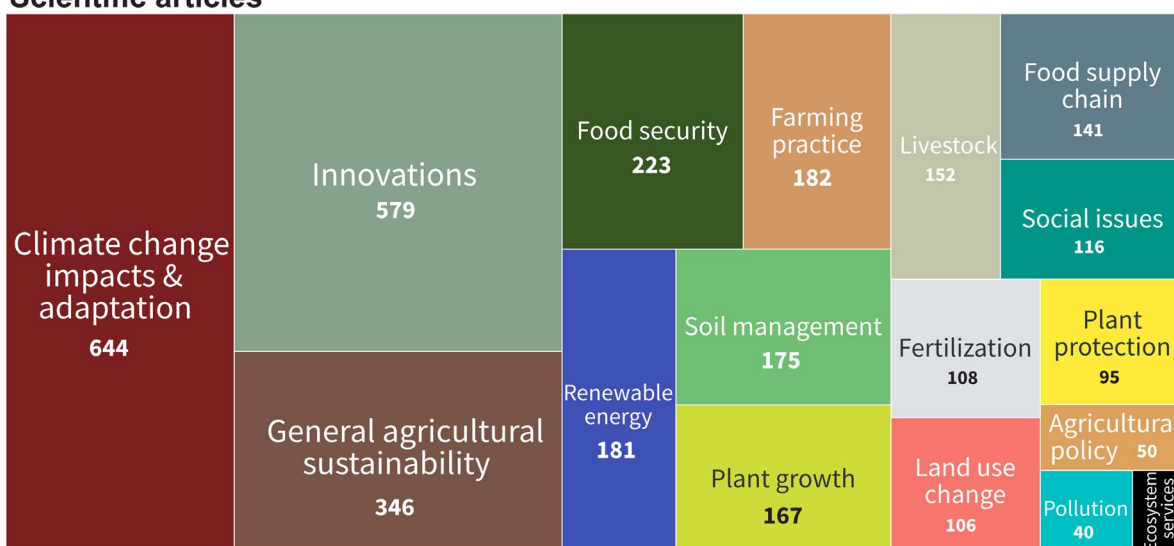
Figure 2 shows the relative shares of clusters in the corpora (see Table 3 for the number of topics in each cluster). One striking result is the absence of topics related to climate change in the agricultural magazines corpus. Conversely, 'Organic farming' is only prominently discussed in that corpus. Five clusters are present in both German corpora: 'Agricultural policy', 'Innovations', 'Livestock', 'Bioenergy' and 'Impacts of agricultural production'. 'Agricultural policy' is the dominant cluster in both corpora, demonstrating the prominence of this topic in the German debates around sustainable agriculture. The majority of the topics included in it across corpora are closely interrelated and discuss the different aspects of the CAP. One exception

is a topic on glyphosate regulation that is included in the 'Agricultural policy' cluster of the newspaper corpus. Also, 'Innovations' and 'Bioenergy' are similar in terms of their relative prevalence, while 'Livestock' and 'Impacts of agricultural production' are more prevalent in the newspaper corpus. The other clusters are specific to only one of the two corpora, with the most prominent being 'Biodiversity and plant protection' in agricultural magazines and 'Civil protests', 'Climate change policy & impacts' and 'Retail & food' in newspapers.

While the two German corpora share some topics and clusters, the scientific article corpus stands apart in many respects, especially in the prominence of climate change ('Climate change impacts & adaptation'). Also, likely due to its size, it exhibits a substantially larger number of topics and clusters. The only clusters shared by all three corpora are 'Agricultural policy' (much less prevalent here), 'Innovations' (more prevalent here) and 'Livestock' (relatively low prevalence). Also, the cluster 'Renewable energy' is related to 'Bioenergy' in the other two corpora, though its focus is much broader than in the German texts. Furthermore there are a few clusters that scientific articles share with the other two corpora: 'Food security' (scientific articles with newspapers), 'Plant protection' (related to 'Biodiversity & plant protection' in agricultural magazines), 'Climate change impacts & adaptation' (related to 'Climate change policy & impacts' in newspapers).

Some patterns are discernible in the temporal development of the relative prevalence of the clusters in each corpus (Figures 3–6). We focus here on patterns at the level of clusters—first, because there are many topics, and second, because the number of topics increases over time in each corpus, so virtually all temporal trends in relative prevalence are negative (see Figures SM2.4–SM2.6). While the latter is also partly the case for the clusters (see Figures 4–6), the effect is not as pronounced.

In agricultural magazines, 'Agricultural policy', 'Innovations' and 'Organic farming' exhibit upward trends over time (Figure 4). 'Agricultural production' and 'Biodiversity & plant protection' exhibit negative trends, while the other clusters in this corpus have remained relatively stable in terms of their relative prevalence over time. It should be noted, however, that in some cases individual topics comprising a cluster exhibit different trends. For instance, the negative trend of the cluster 'Biodiversity & plant protection' is mainly due to the topic 'Plant protection', whereas the prevalence of 'Biodiversity protection' is relatively stable over time (Figure SM2.4). The overall trends at the cluster level demonstrate that 'Agricultural policy' has come to dominate the sustainable agriculture discussions in this corpus, confirming the visual impression from Figures 2 and 3. The spikes in the relative prevalence of the 'Agricultural policy' cluster (mainly driven by CAP debates) correspond to periods shortly preceding CAP reforms (2005, 2013 and 2020–2022, with many discussions also centring around publication of the European Green Deal and the Russian invasion of Ukraine in 2022; Figure 3). The impacts of agricultural production seem almost only to have been discussed around the 2003 Fischler reform that came into place in 2005 and is considered one of the most radical CAP reforms, whose main element was the decoupling
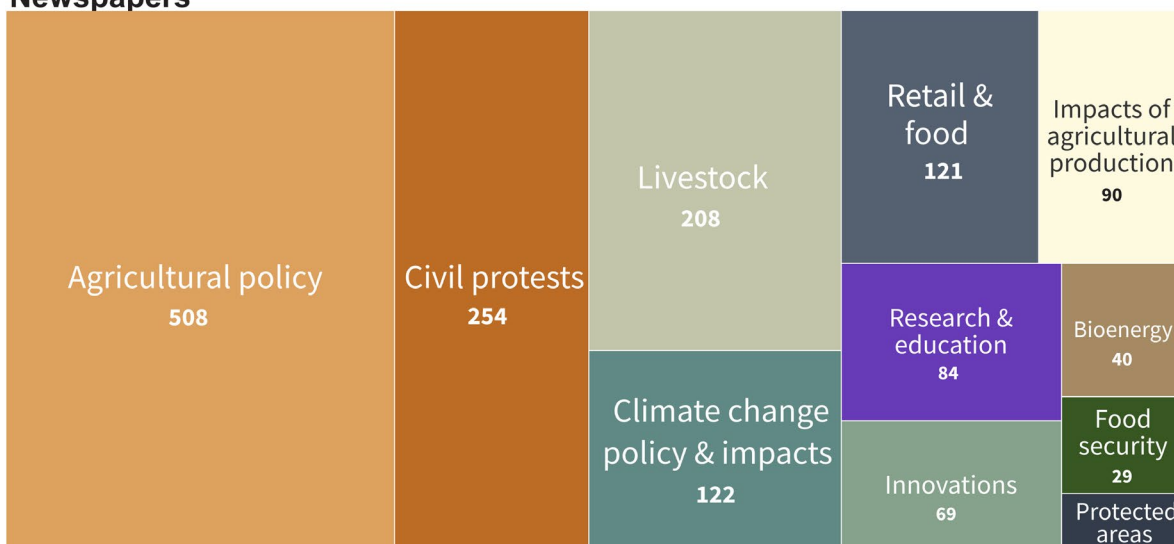
FIGURE 2 Tree-map plots showing the relative prevalence of topic clusters for each corpus. Numbers indicate the number of articles assigned to a given corpus; missing numbers: Impacts of agricultural production (Magazines) 13, protected areas (Newspapers) 17, ecosystem services (Scientific articles) 23.

Agricultural magazines	Newspapers	Scientific articles
Innovations (4)	Research & education (5)	General agricultural sustainability (6)
Biodiversity & plant protection (3)	Retail & food (4)	Innovations (6)
Agricultural production (2)	Civil protests (3)	Social issues (5)
Bioenergy (2)	Climate change policy & impacts (3)	Soil management (5)
Livestock (2)	Impacts of agricultural production (3)	Plant growth (4)
Agricultural policy (1)	Agricultural policy (2)	Fertilization (3)
Impacts of agricultural production (1)	Innovations (2)	Food supply chain (3)
Organic farming (1)	Livestock (2)	Land use change (3)
	Bioenergy (1)	Agricultural policy (2)
	Food security (1)	Climate change impacts & adaptation (2)
	Protected areas (1)	Farming practice (2)
		Food security (2)
		Plant protection (2)
		Pollution (2)
		Ecosystem services (1)
		Livestock (1)
		Renewable energy (1)
Total topics: 16	Total topics: 27	Total topics: 50

TABLE 3 Clusters of topics related to sustainable agriculture across three text corpora.

Note: Numbers in parentheses indicate the number of topics for each cluster. Note that these may not reflect the relative prevalence of the clusters within a corpus. The total number of topics at the bottom refers only to relevant topics.

of payments to farmers (Cunha & Swinbank, 2011). Also, the peak in the prevalence of the 'Bioenergy' cluster (2006–2010) seems to correspond to a policy change—the introduction of biofuel quotas in 2007. Further notable patterns are the spikes in 'Biodiversity & plant protection' around 2002 and in 2006. However, the patterns until 2010 should be treated with caution, given that there are few data points for this period.

Contrary to agricultural magazines, the topic 'Agricultural policy' in newspapers does not exhibit a clear trend (Figure 5). Pronounced temporal trends are visible for 'Climate change policy & impacts' (positive trend), 'Impacts of agricultural production' (positive) and 'Innovations' (negative). The other clusters do not exhibit clear temporal patterns. The spikes in the relative prevalence of the 'Agricultural policy' cluster follow similar patterns to those in agricultural magazines. However, the most recent high is more prolonged, with an onset around 2016. The 'Civil protests' cluster also seems to be associated with the CAP reforms and related events (2001, 2004, 2014, 2019), only recently being complemented by climate-related protests that also address agriculture (see the 'Climate activism' topic in Figure SM2.5). Documents associated with the 'Civil protests' cluster mentioned agricultural policy ('Agrarpolitik') on average 0.7 times, while other documents mentioned CAP only 0.1 times. Innovation-related topics have essentially ceased being discussed by 2001, much in contrast with the scientific articles (see below). 'Impacts of agricultural production' exhibit peaks around 2006 and 2015, while 'Climate change policy & impacts' has gained a more prolonged prominence since 2017 after previous short-lived peaks in 2001, 2005 and 2009 (the latter possibly being related to the Copenhagen Conference of the UNFCCC).

In the scientific articles, which we use as a 'contrast case' for the other two corpora, multiple clusters exhibit clear temporal trends (see Figure 6): 'Agricultural policy' (positive), 'Climate change impacts & adaptation' (positive), 'Food supply chain' (positive), 'General agricultural sustainability' (negative), 'Innovations' (positive), 'Plant growth' (positive), 'Pollution' (positive), 'Renewable energy' (positive) and 'Soil management' (negative). As indicated above, the Germany-specific patterns in agricultural magazines and newspapers show little overlap with the patterns of sustainable agriculture discussions in the scientific articles. In contrast with the German corpora, climate change is a permanently prevalent topic in this corpus. Meanwhile, even in the newspapers, the 'Drought impacts' topic has only spiked in 2018, the first year of the recent multi-year drought in Germany (Figure SM2.5).

4 | DISCUSSION

The results of our comparative analysis of large-scale text data from three different corpora (agricultural magazines, newspapers and scientific articles, the latter serving as a 'contrast case') discussing sustainable agriculture show restricted overlaps across the corpora. This holds both in terms of the identified topics and their temporal dynamics. Probably the most surprising result is the limited coverage of climate change in the two German corpora (also in contrast to the scientific articles; see below): this topic is limited to a short-lived spike in 2018 in the newspaper corpus and is absent from the agricultural magazines. Of course, the latter does not imply that climate change impacts are not discussed in German agricultural
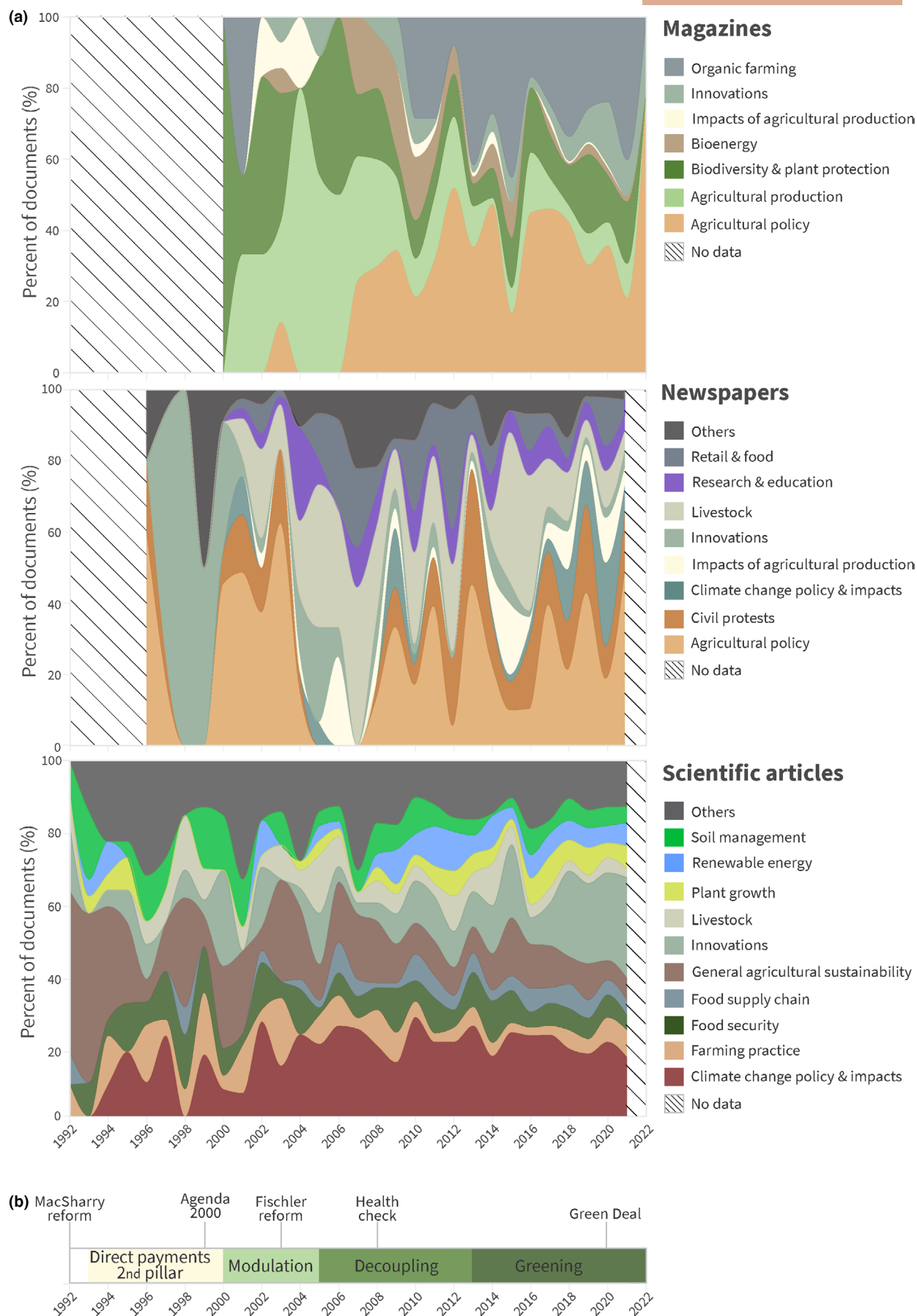
FIGURE 3 Temporal development of the relative prevalence of topic clusters across the three corpora.
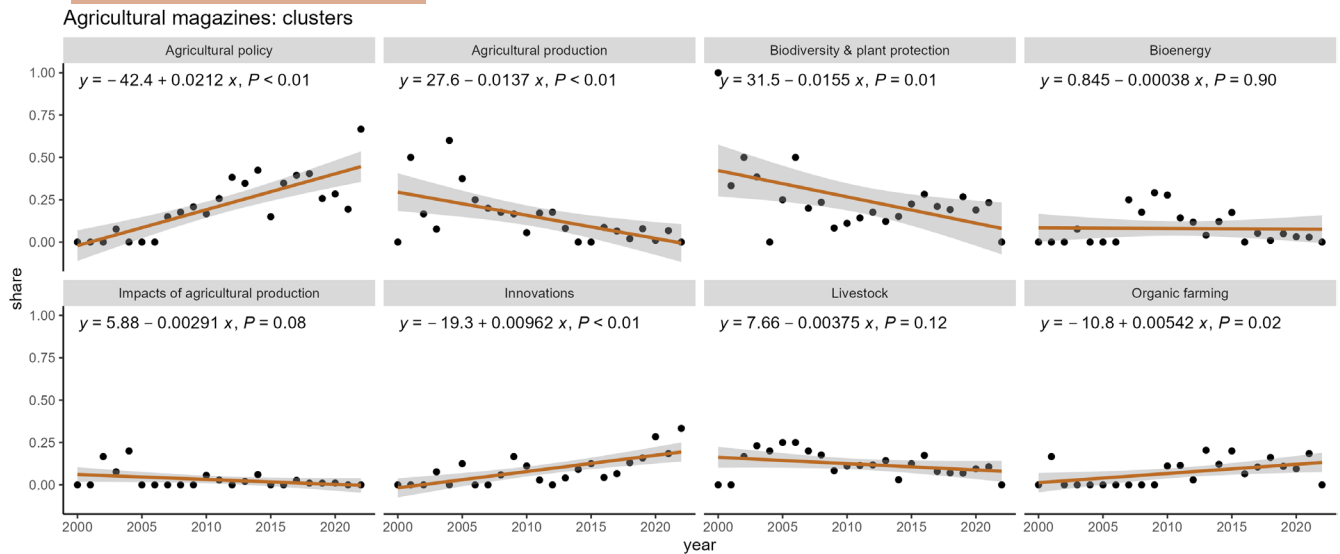
Agricultural magazines: clusters

FIGURE 4 Temporal trends of clusters in the agricultural magazine corpus.
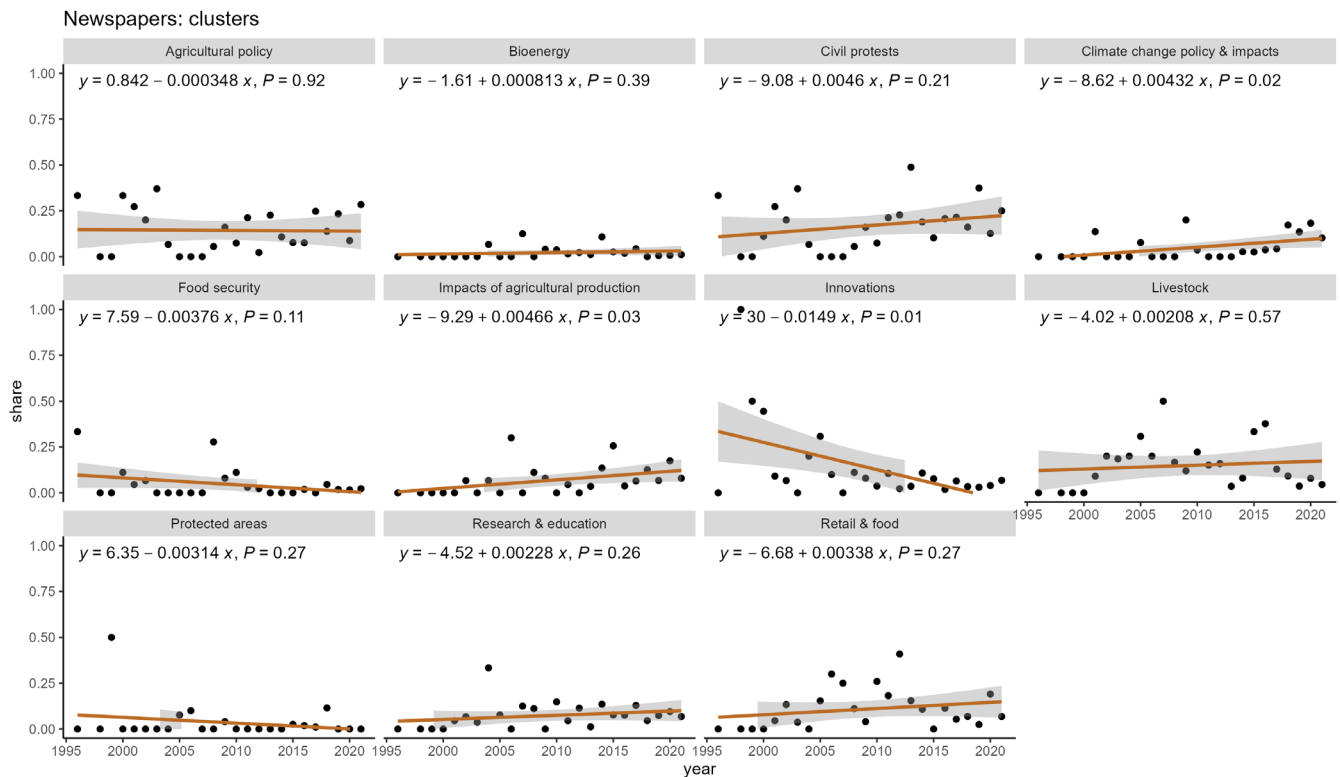
Newspapers: clusters

FIGURE 5 Temporal trends of clusters in the newspaper corpus.

magazines—they may be discussed but are not linked to sustainable agriculture. If anything, they constitute a separate debate stream.

In some cases, the temporal trends are opposite—for instance, in agricultural magazines, the cluster 'Biodiversity & plant protection' has declined in relative prevalence (mainly due to a decline of the plant protection topic in this cluster), while the related cluster 'Impacts of agricultural production' in newspapers has become more prevalent over time. This shows that the two arguably biggest sustainability challenges—climate change and biodiversity (Pörtner

et al., 2021)—are not visible in the discussions around sustainable agriculture in German professional farming magazines. This is in contrast with the scientific evidence pertaining to the impacts of agriculture on climate change and biodiversity as well as the consequences of climate change for agriculture, including in Germany (Clark et al., 2020; Nagpal et al., 2024; Peichl et al., 2019; Yang et al., 2024). This is also reflected by the high prevalence of the 'Climate change impacts & adaptation' cluster in our scientific article corpus.
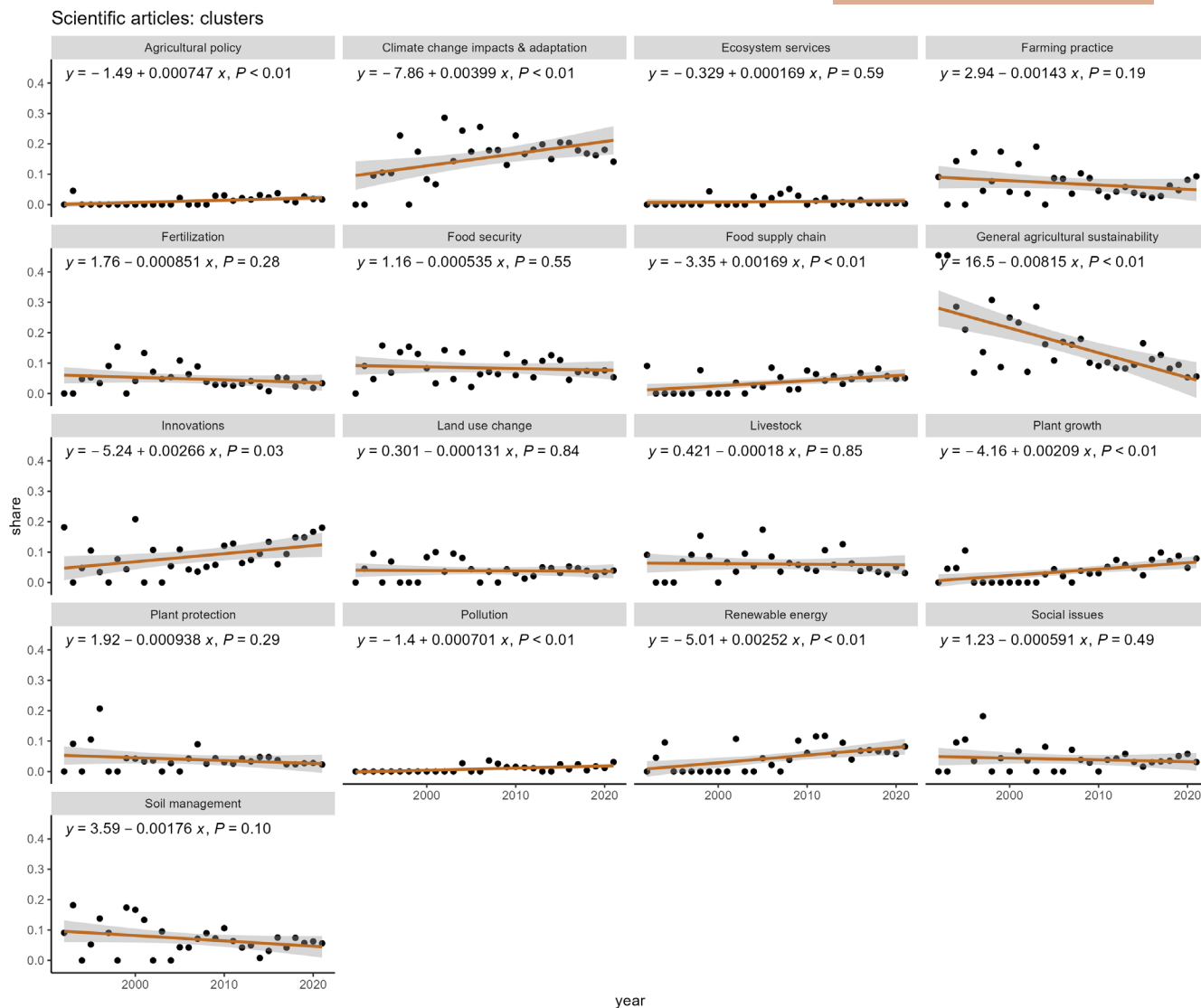
Scientific articles: clusters

FIGURE 6 Temporal trends of clusters in the scientific article corpus.

The most substantial overlap—thematically and temporally—between agricultural magazines and newspapers is related to debates about agricultural policy. These are strongly associated with ongoing events such as CAP reforms. The associated cluster dominates both corpora, even though it fluctuates heavily over time in both cases. This could also be viewed as creating windows of opportunity for science communication—which, however, is challenging because of the short-lived nature of the popular media's increased interest in the topic. While in the scientific literature, opinion pieces are sometimes published that react to such ongoing events (e.g. Candel et al., 2023; Pe'er et al., 2020), the lag times between research/submission and publication are usually too long for such short-term spikes that we see in the two non-scientific corpora to be easily matched by scientific literature. The recent publication of the Faktencheck Artenvielfalt, a comprehensive biodiversity assessment for Germany (Wirth et al., 2024), which addresses agriculture as a major driver of biodiversity change and has received broad media coverage, might be an exception from this trend—future studies are needed to verify its impact (especially in terms of termporal persistence).

The high relative prevalence and temporal development of 'Agricultural policy' in both newspaper and agricultural magazines corpora likely reflects the gradual shift in the focus on the European Union's CAP towards sustainability objectives (Dupraz & Guyomard, 2019; Erjavec & Erjavec, 2021; Pe'er et al., 2019), creating strong links between agricultural policy and the question what constitutes sustainable agriculture. A cursory reading of selected articles suggests, however, that agricultural policy and its relevance for sustainable agriculture are discussed differently in the two corpora, with more critical interpretations voiced in the agricultural magazines. The controversies may make it difficult for science communication to be heard in the ensuing debates. While information alone does not change mindsets or leads to action (Toomey, 2023), careful communication strategies have the potential to reduce conflict and increase the uptake of scientific evidence in public and policy debates (Legagneux et al., 2018).

Irrespectively, the high relative prevalence of this cluster demonstrates the importance of policy decisions for shaping the future of sustainable agriculture in Germany. At the same time, the divergence in what is discussed in the context of sustainable agriculture between farmers (approximated by our agricultural magazine corpus) and the general public (newspapers) suggests a major challenge for formulating democratically legitimate agri-environmental policy (Pickering et al., 2022). The lack of a common understanding of the problem may undermine the legitimacy of any policy targeting sustainable agriculture and impede its implementation. Here, dialogue and possibly the involvement of stakeholders in the co-design of policies may be helpful (Hölting et al., 2022), as well as involving farmers as citizen scientists (Ebitu et al., 2021).

Beyond the topic clusters related to agricultural policy developments, we qualitatively linked some temporal changes in the two short-lived, non-scientific corpora to policy events, including the CAP reforms and funding periods that we considered more systematically. For all the events, the suggested links are associations at best; establishing causal claims requires a different methodological approach, including linking topic modelling with causal inference techniques (Sridhar & Blei, 2022). In many cases, it is unclear in which direction the causal effect might work (Sridhar & Blei, 2022). In our explorative, qualitative analysis, we did not assume any direction of causality (and do not want to claim causality)—instead, we only focused on a visual interpretation of temporal correlations. For the identified links between the prevalence of certain topics and CAP-related events, the causality may likely go both ways. The (expected) policy changes are likely to trigger debates on their potential effects, sensibility etc. However, the opposite direction of causality is also thinkable, as has been studied by Huber and Finger (2019) in the context of Swiss referenda and the surrounding debates as drivers of policy change. The study of causal links between the corpora characterized using topic modelling and real-world events, including policy change, is another important avenue for future research.

As already indicated above, we did not find any obvious signs of scientific debates influencing the other two corpora. The discrepancy between the topics identified in the two non-science corpora and what is discussed in science concerning sustainable agriculture may indicate a deficiency in science communication efforts—or, framed differently, it may signify a lack of public receptiveness for research results on the importance of climate change for sustainable agriculture. At the same time, the opposite reasoning is also possible—that science does not pay sufficient attention to what the public and those directly affected (i.e. farmers) consider important (Bohan et al., 2022). It should be noted, though, that because we have not restricted the coverage of scientific literature to German publications, it is challenging to ascertain, based on our data, whether and how public debates influence research.

5 | LIMITATIONS AND WAYS FORWARD

Given its exploratory nature, our methodological approach exhibits some limitations. First, we have chosen a specific topic model

(BERTopic) among many. Other applications have used different models, but since the topic modelling methodology is developing fast, it is unclear which model should be used for a given purpose (see Churchill & Singh, 2022; Egger & Yu, 2022). Also, some applications have used probabilistic assignment of individual texts to topics as an alternative to the binary assignment by BERTopic (e.g. Droste et al., 2021). A key limitation of BERTopic is the varying quality of underlying language models, which can affect their ability to effectively capture semantics and content across different languages. Particularly for languages with lower available digitalized training data and lower research interest, models are performing worse (Bender et al., 2021; Wu & Dredze, 2020). However, we did not notice differences while evaluating the resulting topics, as they demonstrated meaningful word associations that supported our interpretations. In the absence of clear guidelines about which models and model settings to use in a given topic modelling context, some methodological choices are made intuitively and are thus arbitrary to some extent.

A second limitation is related to the data used—as mentioned above, while wiso-net.de can be considered the best available German newspaper database, the data from it exhibits some qualitative deficiencies that impact their large-scale analysis (e.g. missing texts). As for the agricultural magazines, we used web scraped articles and thus relied on the efficiency of the search options on the magazines' websites. For both corpora, the rather unbalanced temporal coverage can be seen as a weakness–our analysis relies on the assumption that each corpus is relatively homogenous and thus, variable coverage is not a large source of bias. At the same time, in our qualitative analysis, we focused particularly on patterns in the periods for which we have the most data. Our sample of agricultural magazine articles is restricted to three broad-spectrum magazines for pragmatic reasons, thus obscuring to some extent the diversity of views within German agriculture (Bethge & Lakner, 2023). Moreover, we extracted the agricultural magazine articles from online websites of the magazines—while for DLG Mitteilungen, this does not constitute a difference to the print version, for the other two magazines, it does. We assumed that there is no substantial difference in the topics discussed in printed vis-à-vis online articles. For the scientific articles, we restricted ourselves to using abstracts, as using full texts was impractical, may have introduced biases of its own, for example due to reference lists and methodology sections, and because only open-access publications could have been considered due to legal reasons. While abstracts are supposed to convey the gist of the article, they offer rather few data points each for the kind of analysis that we applied and may include 'buzzwords' that do not reflect the actual content of the reported research well. While we used the scientific literature mainly as a 'contrast case', its very different publishing pace makes it difficult to view it together with the other corpora, especially when contrasting temporal developments in topic prevalence.

Lastly, we acknowledge the limitations of only listing broad topics, which may potentially overlook the richness of debates within the text. Topic modelling is inherently broad, providing a "bird's eye

view" of the main themes rather than providing detailed nuances within each topic. Our qualitative analysis was exploratory and meant to augment the topic modelling rather than constituting an equally systematic counterpart. Future applications might consider a more vital role for the qualitative analysis to capture a wider range of discussions and highlight the nuances within these overarching categories. For example, a close reading of the documents could reveal how specific aspects of agricultural policy intersect with other topics, such as 'Impacts of agricultural production' or 'Innovations'.

Beyond what has been already mentioned concerning causal inference and our methodological choices, we see further fruitful avenues for future research. First, it would be interesting to compare how certain topics were discussed in the different corpora—for example, have they been discussed positively or negatively across newspapers and agricultural magazines? Future studies might focus more on this aspect, for example using qualitative content or sentiment analysis. However, given that many of the texts in our three corpora mention sustainable agriculture without having it as their main focus, a sentiment analysis could also be misleading, as it would not be clear whether the identified sentiments are related to sustainable agriculture or some other aspects addressed in the texts (see e.g. Dehler-Holland et al., 2021). This could also help improve how the relative importance of topics is measured (beyond the simple quantitative indicator of relative prevalence that we used). Second, conducting the same analysis in different (EU) countries would allow to verify our findings' cultural robustness and generalizability. A cross-country comparison could yield an in-depth understanding of the temporal patterns in relative prevalence. Third, given the declining importance of traditional media, it might be interesting to contrast the results of our or similar analyses with analogous analyses focusing on non-traditional media, including social media, online discussion fora, messenger chat groups and so forth. This would illuminate how representative traditional media are of actual societal discourses on sustainable agriculture. Fourth, it would be of high policy relevance to investigate how the apparent divergence of discourses could be reduced, thus sparking a more compromise-oriented debate that would allow for a democratically legitimate, effective transformation of agriculture towards sustainability.

6 | CONCLUSIONS

In this paper, we used a mixed-methods approach combining natural language processing and topic modelling with a qualitative analysis to exploratively investigate topics discussed in relation to sustainable agriculture in Germany in three large-scale text corpora: newspapers, agriculture magazines and scientific articles, the latter serving as a 'contrast case'. We found very limited thematical or temporal overlaps between these corpora. An exception is related to discussions of agricultural policy, which is the dominant cluster of topics in both newspapers and agricultural magazines. Temporal trends within the topics in the cluster 'Agricultural policy' are associated with major policy developments, particularly reforms of the

European Union's Common Agricultural Policy. With respect to the temporal patterns, the disparity in the topics discussed in relation to sustainable agriculture across the three corpora is striking. Given the urgency of transforming the sector towards sustainability and climate resilience, this lack of a common understanding of sustainable agriculture is worrying. Diverging perspectives on sustainable agriculture to the point of lacking overlap in the topics discussed implies challenges for formulating and implementing democratically legitimized policies to promote sustainable agriculture.

AUTHOR CONTRIBUTIONS

Bartosz Bartkowski: conceptualization, methodology, data collection, qualitative analysis, quantitative analysis, writing—original draft preparation, supervision. Marieke Cornelia Baaken: conceptualization, data collection, qualitative analysis, writing—reviewing and editing. Mansi Nagpal: conceptualization, data collection, qualitative analysis, writing—reviewing and editing. Jan Sodoge: methodology and quantitative analysis. Mariana Madruga de Brito: quantitative analysis, visualization, writing—reviewing and editing, supervision.

CONFLICT OF INTEREST STATEMENT

The authors do not have any conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

The text data used in this publication are proprietary and not owned by the authors. Therefore, they are not freely available, but require an access to the wiso-net.de database.

ORCID

Bartosz Bartkowski https://orcid.org/0000-0001-5938-1221

REFERENCES

Asplund, T., Hjerpe, M., & Wibeck, V. (2013). Framings and coverage of climate change in Swedish specialized farming magazines. *Climatic Change*, *117*, 197–209. https://doi.org/10.1007/s10584-012-0535-0

Baaken, M. C. (2022). Sustainability of agricultural practices in Germany: A literature review along multiple environmental domains. *Regional Environmental Change*, *22*, 39. https://doi.org/10.1007/s10113-022-01892-5

Baaken, M. C., & Vollan, B. (2024). Identifying behavior change interventions with deep leverage: A conceptual and qualitative case study with farmers from Germany. *Sustainability Science*, *19*, 2171–2186. https://doi.org/10.1007/s11625-024-01540-3

Bender, E. M., Gebru, T., McMillan-Major, A., & Shmitchell, S. (2021). On the dangers of stochastic parrots: Can language models be too big? In *Proceedings of the 2021 ACM Conference on Fairness, Accountability, and Transparency, FAccT '21* (pp. 610–623). Association for Computing Machinery. https://doi.org/10.1145/3442188.3445922

Berrang-Ford, L., Siders, A. R., Lesnikowski, A., Fischer, A. P., Callaghan, M. W., Haddaway, N. R., Mach, K. J., Araos, M., Shah, M. A. R., Wannewitz, M., Doshi, D., Leiter, T., Matavel, C., Musah-Surugu, J. I., Wong-Parodi, G., Antwi-Agyei, P., Ajibade, I., Chauhan, N., Kakenmaster, W., … Abu, T. Z. (2021). A systematic global stock-take of evidence on human adaptation to climate change. *Nature Climate Change*, *11*, 989–1000. https://doi.org/10.1038/s41558-021-01170-y

Bethge, S., & Lakner, S. (2023). Farmers' attitudes toward the future of direct payments: An empirical study from Germany. *German Journal of Agricultural Economics*, *72*, 34–46. https://doi.org/10.30430/gjae.2023.0268

Bohan, D. A., Richter, A., Bane, M., Therond, O., & Pocock, M. J. O. (2022). Farmer-led agroecology for biodiversity with climate change. *Trends in Ecology & Evolution*, *37*, 927–930. https://doi.org/10.1016/j.tree.2022.07.006

Callaghan, M., Schleussner, C.-F., Nath, S., Lejeune, Q., Knutson, T. R., Reichstein, M., Hansen, G., Theokritoff, E., Andrijevic, M., Brecha, R. J., Hegarty, M., Jones, C., Lee, K., Lucas, A., van Maanen, N., Menke, I., Pfleiderer, P., Yesil, B., & Minx, J. C. (2021). Machine-learning-based evidence and attribution mapping of 100,000 climate impact studies. *Nature Climate Change*, *11*, 966–972. https://doi.org/10.1038/s41558-021-01168-6

Campbell, B., Beare, D., Bennett, E., Hall-Spencer, J., Ingram, J., Jaramillo, F., Ortiz, R., Ramankutty, N., Sayer, J., & Shindell, D. (2017). Agriculture production as a major driver of the earth system exceeding planetary boundaries. *Ecology and Society*, *22*, 8. https://doi.org/10.5751/ES-09595-220408

Candel, J., Pe'er, G., & Finger, R. (2023). Science calls for ambitious European pesticide policies. *Nature Food*, *4*, 272. https://doi.org/10.1038/s43016-023-00727-8

Carvalho, A., & Burgess, J. (2005). Cultural circuits of climate change in U.K. broadsheet newspapers, 1985–2003. *Risk Analysis*, *25*, 1457–1469. https://doi.org/10.1111/j.1539-6924.2005.00692.x

Churchill, R., & Singh, L. (2022). The evolution of topic modeling. *ACM Computing Surveys*, *54*, 215:1–215:35. https://doi.org/10.1145/3507900

Clark, M. A., Domingo, N. G. G., Colgan, K., Thakrar, S. K., Tilman, D., Lynch, J., Azevedo, I. L., & Hill, J. D. (2020). Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets. *Science*, *370*, 705–708. https://doi.org/10.1126/science.aba7357

Cunha, A., & Swinbank, A. (2011). *An inside view of the CAP reform process: Explaining the MacSharry, Agenda 2000, and Fischler reforms*. Oxford University Press.

Dehler-Holland, J., Schumacher, K., & Fichtner, W. (2021). Topic modeling uncovers shifts in media framing of the German renewable energy act. *Patterns*, *2*, 100169. https://doi.org/10.1016/j.patter.2020.100169

Devlin, J., Chang, M.-W., Lee, K., & Toutanova, K. (2019). BERT: Pre-training of deep bidirectional transformers for language understanding. https://doi.org/10.48550/arXiv.1810.04805

Droste, N., Bartkowski, B., & Finger, R. (2021). Hot topics in agricultural and environmental economics—A large-scale bibliometric analysis. LSR Working Papers Series.

Droste, N., D'Amato, D., & Goddard, J. J. (2018). Where communities intermingle, diversity grows – The evolution of topics in ecosystem service research. *PLoS One*, *13*, e0204749. https://doi.org/10.1371/journal.pone.0204749

Dupraz, P., & Guyomard, H. (2019). Environment and climate in the common agricultural policy. *EuroChoices*, *18*, 18–25. https://doi.org/10.1111/1746-692X.12219

Ebitu, L., Avery, H., Mourad, K. A., & Enyetu, J. (2021). Citizen science for sustainable agriculture—A systematic literature review. *Land Use Policy*, *103*, 105326. https://doi.org/10.1016/j.landusepol.2021.105326

Egger, R., & Yu, J. (2022). A topic modeling comparison between LDA, NMF, Top2Vec, and BERTopic to demystify twitter posts. *Frontiers in Sociology*, *7*, 886498. https://doi.org/10.3389/fsoc.2022.886498

Erjavec, K., & Erjavec, E. (2021). Framing agricultural policy through the EC's strategies on CAP reforms (1992–2017). *Agricultural and Food Economics*, *9*, 5. https://doi.org/10.1186/s40100-021-00178-4

Garibaldi, L. A., Gemmill-Herren, B., D'Annolfo, R., Graeub, B. E., Cunningham, S. A., & Breeze, T. D. (2017). Farming approaches for greater biodiversity, livelihoods, and food security. *Trends in Ecology & Evolution*, *32*, 68–80. https://doi.org/10.1016/j.tree.2016.10.001

Gentzkow, M., Kelly, B., & Taddy, M. (2019). Text as data. *Journal of Economic Literature*, *57*, 535–574. https://doi.org/10.1257/jel.20181020

Grootendorst, M. (2022). BERTopic: Neural topic modeling with a class-based TF-IDF procedure. https://doi.org/10.48550/arXiv.2203.05794

Gütschow, M., Bartkowski, B., & Felipe-Lucia, M. R. (2021). Farmers' action space to adopt sustainable practices: A study of arable farming in Saxony. *Regional Environmental Change*, *21*, 103. https://doi.org/10.1007/s10113-021-01848-1

Happer, C., & Philo, G. (2015). New approaches to understanding the role of the news media in the formation of public attitudes and behaviours on climate change. *European Journal of Communication*, *31*(2), 136–151. https://doi.org/10.1177/0267323115612213

Happer, C., & Wellesley, L. (2019). Meat consumption, behaviour and the media environment: A focus group analysis across four countries. *Food Security*, *11*, 123–139. https://doi.org/10.1007/s12571-018-0877-1

Hölting, L., Busse, M., Bülow, S., Engler, J. O., Hagemann, N., Joormann, I., Kernecker, M. L., Larondelle, N., Sturm, A., Turkelboom, F., Wätzold, F., & Cord, A. F. (2022). Co-design: Working with farmers in Europe to halt the loss of biological diversity. *Ecological Solutions and Evidence*, *3*, e12169. https://doi.org/10.1002/2688-8319.12169

Huber, R., & Finger, R. (2019). Popular initiatives increasingly stimulate agricultural policy in Switzerland. *EuroChoices*, *18*, 38–39. https://doi.org/10.1111/1746-692X.12209

Janker, J., Mann, S., & Rist, S. (2018). What is sustainable agriculture? Critical analysis of the international political discourse. *Sustainability*, *10*(12), 4707. https://doi.org/10.3390/su10124707

Korthals, M. (2001). Ethical dilemmas in sustainable agriculture. *International Journal of Food Science and Technology*, *36*, 813–820. https://doi.org/10.1046/j.1365-2621.2001.00533.x

Legagneux, P., Casajus, N., Cazelles, K., Chevallier, C., Chevrinais, M., Guéry, L., Jacquet, C., Jaffré, M., Naud, M.-J., Noisette, F., Ropars, P., Vissault, S., Archambault, P., Bêty, J., Berteaux, D., & Gravel, D. (2018). Our house is burning: Discrepancy in climate change vs. biodiversity coverage in the media as compared to scientific literature. *Frontiers in Ecology and Evolution*, *5*, 175. https://doi.org/10.3389/fevo.2017.00175

Maier, D., Waldherr, A., Miltner, P., Wiedemann, G., Niekler, A., Keinert, A., Pfetsch, B., Heyer, G., Reber, U., Häussler, T., Schmid-Petri, H., & Adam, S. (2018). Applying LDA topic modeling in communication research: Toward a valid and reliable methodology. *Communication Methods and Measures*, *12*, 93–118. https://doi.org/10.1080/19312458.2018.1430754

McHenry, H. (1996). Farming and environmental discourses: A study of the depiction of environmental issues in a German farming newspaper. *Journal of Rural Studies*, *12*, 375–386. https://doi.org/10.1016/S0743-0167(96)00050-2

Nagpal, M., Heilemann, J., Samaniego, L., Klauer, B., Gawel, E., & Klassert, C. (2024). Measuring extremes-driven direct biophysical impacts in agricultural drought damages. *EGUsphere*, 1–20. https://doi.org/10.5194/egusphere-2024-2585

Nunes Carvalho, T. M., Souza Filho, F. D. A. D., & Madruga De Brito, M. (2024). Unveiling water allocation dynamics: A text analysis of

25 years of stakeholder meetings. *Environmental Research Letters*, *19*, 044066. https://doi.org/10.1088/1748-9326/ad37cd

Oliver, T. H., Boyd, E., Balcombe, K., Benton, T. G., Bullock, J. M., Donovan, D., Feola, G., Heard, M., Mace, G. M., Mortimer, S. R., Nunes, R. J., Pywell, R. F., & Zaum, D. (2018). Overcoming undesirable resilience in the global food system. *Global Sustainability*, *1*, e9. https://doi.org/10.1017/sus.2018.9

Otto, D., Pfeiffer, M., de Brito, M. M., & Gross, M. (2022). Fixed amidst change: 20 years of media coverage on carbon capture and storage in Germany. *Sustainability*, *14*, 7342. https://doi.org/10.3390/su14127342

Pe'er, G., Bonn, A., Bruelheide, H., Dieker, P., Eisenhauer, N., Feindt, P. H., Hagedorn, G., Hansjürgens, B., Herzon, I., Lomba, Â., Marquard, E., Moreira, F., Nitsch, H., Oppermann, R., Perino, A., Röder, N., Schleyer, C., Schindler, S., Wolf, C., … Lakner, S. (2020). Action needed for the EU common agricultural policy to address sustainability challenges. *People and Nature*, *2*, 305–316. https://doi.org/10.1002/pan3.10080

Pe'er, G., Lakner, S., Müller, R., Passoni, G., Bontzorlos, V., Clough, D., Moreira, F., Azam, C., Berger, J., Bezak, P., Bonn, A., Hansjürgens, B., Hartmann, L., Kleemann, J., Lomba, A., Sahrbacher, A., Schindler, S., Schleyer, C., Schmidt, J., … Zinngrebe, Y. (2017). *Is the CAP fit for purpose? An evidence-based fitness check assessment*. German Centre for Integrative Biodiversity Research (iDiv).

Pe'er, G., Zinngrebe, Y., Moreira, F., Sirami, C., Schindler, S., Müller, R., Bontzorlos, V., Clough, D., Bezák, P., Bonn, A., Hansjürgens, B., Lomba, A., Möckel, S., Passoni, G., Schleyer, C., Schmidt, J., & Lakner, S. (2019). A greener path for the EU common agricultural policy. *Science*, *365*, 449–451. https://doi.org/10.1126/science.aax3146

Peichl, M., Thober, S., Samaniego, L., Hansjürgens, B., & Marx, A. (2019). Climate impacts on long-term silage maize yield in Germany. *Scientific Reports*, *9*, 7674. https://doi.org/10.1038/s41598-019-44126-1

Pickering, J., Hickmann, T., Bäckstrand, K., Kalfagianni, A., Bloomfield, M., Mert, A., Ransan-Cooper, H., & Lo, A. Y. (2022). Democratising sustainability transformations: Assessing the transformative potential of democratic practices in environmental governance. *Earth System Governance*, *11*, 100131. https://doi.org/10.1016/j.esg.2021.100131

Pörtner, H.-O., Scholes, R. J., Agard, J., Archer, E., Bai, X., Barnes, D., Burrows, M., Chan, L., Cheung, W. L., Diamond, S., Donatti, C., Duarte, C., Eisenhauer, N., Foden, W., Gasalla, M. A., Handa, C., Hickler, T., Hoegh-Guldberg, O., Ichii, K., … Ngo, H. (2021). IPBES-IPCC co-sponsored workshop report on biodiversity and climate change. *Zenodo*. https://doi.org/10.5281/zenodo.5101133

Python Software Foundation. (2022). *Python*.

R Core Team. (2022). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing.

Reber, U., Fischer, M., Ingold, K., Kienast, F., Hersperger, A. M., Grütter, R., & Benz, R. (2022). Integrating biodiversity: A longitudinal and cross-sectoral analysis of Swiss politics. *Policy Sciences*, *55*, 311–335. https://doi.org/10.1007/s11077-022-09456-4

Roberts, M. E., Stewart, B. M., & Airoldi, E. M. (2016). A model of text for experimentation in the social sciences. *Journal of the American Statistical Association*, *111*, 988–1003. https://doi.org/10.1080/01621459.2016.1141684

Russell, K., Fryirs, K., Reid, D., Miller, A., Vietz, G., Rutherfurd, I., Pearson, B., Wood, A., Gregor, S., Walker, J., & Slijkerman, J. (2023). Evolution of a river management industry in Australia reveals meandering pathway to 2030 UN goals. *Communications Earth & Environment*, *4*, 1–13. https://doi.org/10.1038/s43247-023-00748-y

Rust, N. A., Jarvis, R. M., Reed, M. S., & Cooper, J. (2021). Framing of sustainable agricultural practices by the farming press and its effect on adoption. *Agriculture and Human Values*, *38*, 753–765. https://doi.org/10.1007/s10460-020-10186-7

Schaub, S. (2021). Public contestation over agricultural pollution: A discourse network analysis on narrative strategies in the policy process. *Policy Sciences*, *54*, 783–821. https://doi.org/10.1007/s11077-021-09439-x

Schebesta, H., & Candel, J. J. L. (2020). Game-changing potential of the EU's farm to fork strategy. *Nature Food*, *1*, 586–588. https://doi.org/10.1038/s43016-020-00166-9

Schüßler, C., Nicolai, S., Stoll-Kleemann, S., & Bartkowski, B. (2024). Moral disengagement in the media discourses on meat and dairy production systems. *Appetite*, *196*, 107269. https://doi.org/10.1016/j.appet.2024.107269

Scown, M. W., & Nicholas, K. A. (2020). European agricultural policy requires a stronger performance framework to achieve the Sustainable Development Goals. *Global Sustainability*, *3*, e11. https://doi.org/10.1017/sus.2020.5

Sindermann, C., Kannen, C., & Montag, C. (2024). The degree of heterogeneity of news consumption in Germany—Descriptive statistics and relations with individual differences in personality, ideological attitudes, and voting intentions. *New Media & Society*, *26*, 711–731. https://doi.org/10.1177/14614448211061729

Sodoge, J., Kuhlicke, C., & de Brito, M. M. (2023). Automated spatio-temporal detection of drought impacts from newspaper articles using natural language processing and machine learning. *Weather and Climate Extremes*, *41*, 100574. https://doi.org/10.1016/j.wace.2023.100574

SPD, Bündnis 90/Die Grünen, FDP. (2021). *Mehr Fortschritt wagen: Bündnis für Freiheit, Gerechtigkeit und Nachhaltigkeit*. Koalitionsvertrag 2021–2025 zwischen der Sozialdemokratischen Partei Deutschlands (SPD), BÜNDNIS 90/DIE GRÜNEN und den Freien Demokraten (FDP).

Sridhar, D., & Blei, D. M. (2022). Causal inference from text: A commentary. *Science Advances*, *8*, eade6585. https://doi.org/10.1126/sciadv.ade6585

Statista. (2023). *Topic: Media usage in Germany* [WWW Document]. Statista. https://www.statista.com/topics/5053/media-usage-in-germany/

Statistisches Bundesamt. (2023). *Bodenfläche insgesamt nach Nutzungsarten in Deutschland*. [WWW Document]. https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Flaechennutzung/Tabellen/bodenflaeche-insgesamt.html

Sumberg, J., & Giller, K. E. (2022). What is 'conventional' agriculture? *Global Food Security*, *32*, 100617. https://doi.org/10.1016/j.gfs.2022.100617

Sutherland, C., Sim, C., Gleim, S., & Smyth, S. J. (2020). Canadian consumer insights on agriculture: Addressing the knowledge-gap. *Journal of Agricultural & Food Information*, *21*, 50–72. https://doi.org/10.1080/10496505.2020.1724114

Toomey, A. H. (2023). Why facts don't change minds: Insights from cognitive science for the improved communication of conservation research. *Biological Conservation*, *278*, 109886. https://doi.org/10.1016/j.biocon.2022.109886

van der Ploeg, J. D. (2020). Farmers' upheaval, climate crisis and populism. *Journal of Peasant Studies*, *47*, 589–605. https://doi.org/10.1080/03066150.2020.1725490

Velten, S., Leventon, J., Jager, N., Newig, J., Velten, S., Leventon, J., Jager, N., & Newig, J. (2015). What is sustainable agriculture? A systematic review. *Sustainability*, *7*, 7833–7865. https://doi.org/10.3390/su7067833

Velten, S., Schaal, T., Leventon, J., Hanspach, J., Fischer, J., & Newig, J. (2018). Rethinking biodiversity governance in European agricultural landscapes: Acceptability of alternative governance scenarios. *Land Use Policy*, *77*, 84–93. https://doi.org/10.1016/j.landusepol.2018.05.032

von Nordheim, G., Müller, H., & Scheppe, M. (2019). Young, free and biased: A comparison of mainstream and right-wing media coverage of the 201516 refugee crisis in German newspapers. *Journal of Alternative & Community Media*, *4*, 38–56. https://doi.org/10.1386/joacm_00042_1

Williams, T. G., Bui, S., Conti, C., Debonne, N., Levers, C., Swart, R., & Verburg, P. H. (2023). Synthesising the diversity of European agri-food networks: A meta-study of actors and power-laden interactions. *Global Environmental Change*, 83, 102746. https://doi.org/10.1016/j.gloenvcha.2023.102746

Wirth, C., Bruelheide, H., Farwig, N., Maylin Marx, J., & Settele, J. (Eds.). (2024). Faktencheck Artenvielfalt. oekom Verlag. https://doi.org/10.14512/9783987263361

Wu, S., & Dredze, M. (2020). Are all languages created equal in multilingual BERT?

Yang, Y., Tilman, D., Jin, Z., Smith, P., Barrett, C. B., Zhu, Y.-G., Burney, J., D'Odorico, P., Fantke, P., Fargione, J., Finlay, J. C., Rulli, M. C., Sloat, L., van Groenigen, K., West, P. C., Ziska, L., Michalak, A. M., THE CLIM-AG TEAM, & Lobell, D. B. (2024). Climate change exacerbates the environmental impacts of agriculture. *Science*, 385, eadn3747. https://doi.org/10.1126/science.adn3747

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Supplementary Material S1. Topics labelled selection clusters.

Supplementary Material S2. Figure SM2.1. Dendrogram of agricultural magazine topics.

Figure SM2.2. Dendrogram of newspaper topics.

Figure SM2.3. Dendrogram of scientific article topics.

Figure SM2.4. Temporal trends of topics in agricultural magazines.

Figure SM2.5. Temporal trends in topics in newspapers.

Figure SM2.6. Temporal trends in topics in scientific articles.

Figure SM2.7. Temporal development of Shannon diversity of clusters across corpora.

Figure SM2.8. Temporal development of absolute numbers of articles discussing 'sustainable agriculture' across the three corpora after removal of duplicates.