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Drought Research Exhibits Shifting Priorities, Trends and Geographic Patterns

Roland Baatz[1,*], Gohar Ghazaryan[1,2], Michael Hagenlocher[3], Claas Nendel[1,4], Andrea Toreti[5] and Ehsan Eyshi Rezaei[1]

[1] Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany
[2] Geography Department, Humboldt-Universität zu Berlin , Unter den Linden 6, 10099 Berlin, Germany
[3] United Nations University, Institute for Environment and Human Security (UNU-EHS), Platz der Vereinten Nationen 1, 53113 Bonn, Germany
[4] Institute of Biochemistry and Biology, University of Potsdam, Germany
[5] European Commission, Joint Research Centre, Ispra, Italy

Correspondence to: Roland Baatz roland.baatz@zalf.de

Abstract. Drought research addresses a major natural hazard with adverse impacts towards achieving the sustainable development goals. Here, we analyzed more than 130,000 peer-reviewed articles indexed in Scopus, spanning from 1901 to 2022 using a generative model. The results delineate distinct shifts in research priorities. Plant genetic research for drought-tolerant genotypes and methods in drought forecasting are the major topics with highest and still increasing relative contribution to drought research. Importance of ecology, groundwater and forest research decreases in relative terms. Until 1983, interdisciplinarity of drought research was steadily decreasing, marking a pivotal shift, followed by a consistent rise in interdisciplinarity from 2007 onwards. Geospatial patterns reveal a focus on forecasting methods in all regions, and particular focus on policy and society in Africa and Oceania. In future, we recommend research and funding agencies to strengthen the track of more interdisciplinary and systemic cross-topic drought research in order to cope with drought as a multi-sectoral risk requiring multi-sectoral response frameworks.

1 Introduction

Drought is one of the socio-economically most damaging natural hazards (Yin et al., 2023; Esha Zaveri et al., 2023). Contrary to other climate extremes, drought manifests on a vast spatiotemporal scale, extending up to thousands of kilometers, and can persist for periods lasting up to years (Mondal et al., 2023). Drought episodes are becoming increasingly frequent, extreme, and prolonged driven by climate change (Hoylman et al., 2022; IPCC, 2021). Drought is significantly tied with other climate-driven hazards, particularly heatwaves, which can amplify drought impacts (Lesk et al., 2022). The emergence of frequent flash droughts in over 74% of the globe during the last 64 years has been also recently revealed (Yuan et al., 2023). This pattern

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is largely linked to elevated anomalies in evapotranspiration and precipitation deficits which are confirmed consequences of human-induced climate change (Yuan et al., 2023). Drought as the state of water shortage is exacerbated by anthropogenic activities such as unsustainable water use, allocation and water extraction (van Loon et al., 2022; van Loon et al., 2016; Chiang et al., 2021). This led to the reconsideration of the definition of drought as rather a being a process than a system state (van Loon et al., 2016; AghaKouchak et al., 2021). Drought poses therefore a substantial risk for and across sectors and systems (Voosen, 2020; Walker and van Loon, 2023; Hagenlocher et al., 2023), including agriculture, water supply, health, the energy sector, ecosystem services, and socio-political stability.

Drought impacts ecosystems by modifying ecological processes, altering of community structures and composition (Canarini et al., 2021). These changes can lead to adaptations such as improved water use efficiency in response to water storage(Poppe Terán et al., 2023). The total land area and population affected by severe terrestrial water storage drought could more than double by the end of the twenty-first century (Pokhrel et al., 2021). Over the first twenty years of the 21st century, extreme drought and drinking water shortages have plagued more than 80 major cities worldwide (Savelli et al., 2023). Food production and security have already been largely compromised by drought (Spinoni et al., 2020; Rossi L et al., 2023). For instance, the size of the dry zones across the global grain production area increased by 1.1 % per decade in the period from 1951 to 2011 (Wang et al., 2018). Globally, the average national cereal production shrank by 10 % over the period 1964 to 2007 as a result of extreme drought and heat (Lesk et al., 2016). In Europe, the adverse impacts of droughts and heatwaves on crop production tripled in the last 50 years (Brás et al., 2021).

Without climate action, annual drought damages for the EU and the UK could escalate from €9 billion to over €65 billion per year by 2100, doubling in terms of financial impact (Naumann et al., 2021). Given the potential damage caused by drought, it is crucial to conceptualize, develop, plan, implement, monitor, and assess effective sustainable adaptation strategies for the benefit of society at large. Exploring the long-term research timeline for drought enables the research community, funding bodies, and policymakers to more effectively align their efforts, prioritize resources, and design strategies aimed at mitigating adverse impacts, enhancing resilience, and supporting sustainable adaptation to escalating drought events.

2 Methods

We based the analysis on 131,748 abstracts curated in the licensed Scopus database under the search term drought on March 22, 2023. Data on title, keywords, language, abstract and publication year were retrieved from the Scopus database via the Scopus Search API and the elsapy search library. We removed duplicates, copyright information and non-English abstracts. Scopus provides the largest curated database of scientific literature and grants access to data- and text mining to licensed users for academic purpose. To discern pertinent topics and subtopics within the dataset, we used the latent Dirichlet Allocation

(LDA) (Blei et al., 2003; Radim Rehurek and Petr Sojka, 2010) method. LDA, an iterative Bayesian method of unsupervised machine learning, identifies multiple topic clusters within documents based on keyword distribution, co-occurrence, and frequency. Depending on the chosen granularity, classification can yield either broad or highly-specific topics. Remarkably, while LDA is a well-established method (Eker et al., 2018; Ewert et al., 2023; Cebral-Loureda et al., 2023; Rahman et al., 2022), its application to vast scientific abstract corpora is rare. To explore the drought research areas, we identified rather general topics and mores specific topics. This was done by pre-defining the number of topics to the algorithm and LDA did cluster the documents based on keywords into the given number of topics. We assessed coherence scores for a consecutively increasing number of topics, found that coherence increases until fifty topics, and decided to cap granularity at fifty topics, which would still yield 2634 documents on average per topic. We then selected five topics as a reasonable number for the general classification level, and twelve topics for a median level of granularity and fifty topics for the finest level granularity. Naming conventions for topics were derived from pivotal keywords within the context of drought research. To evaluate the evolving significance of research themes over time, we charted relative shares of each topic annually. For topic congruence, we calculated the cosine similarity between topic pairs. Cosine similarity normalizes the similarity score by the overall share of the two topics. This allows for a better direct comparison for topics with high shares and those with low shares. Here, a high similarity score indicates that two topics appear more frequently together in the same document. A low similarity score indicates lesser joint appearance. Topical overall similarity index is calculated as mean cosine similarity of a topic for the other n-1 topics. Heat maps of cosine similarity are ranked by overall similarity score of a topic starting with the highest to lowest. We visualized the topic trajectory using a Sankey diagram to highlight how general topics with coarse granularity narrow down to more specific topics. Consistent with Sankey diagrams, the width of the connecting lines is proportional to the document counts they represent. The geographic reference of drought research to individual continents was identified by keyword search. Abstracts were associated to a region i.e. continent if a specific continent, or country (for the US also the states) was mentioned in the title, keyword or abstract. One document could be associated with several regions in case several mentions. Topical shares by region were then calculated based on the documents found.

3 Results

3.1 Major and specific topics in drought research

Here, we employed a generative statistical model (Latent Dirichlet Allocation (Blei et al., 2003; Radim Rehurek and Petr Sojka, 2010) [LDA]), to assess 131,748 peer-reviewed articles revealing changes in the patterns of drought-related topics indexed in Scopus from 1901 up to the present. LDA enabled us to capture heterogeneity within research topics, using an unsupervised machine learning approach to reveal latent topics from linguistic data (Eker et al., 2018; Ewert et al., 2023). The number of drought-related peer-reviewed publications has increased exponentially adding 12,338 articles in 2022 alone (Figure 1). We let the LDA identify five major topics across the document pool (tier 1), twelve more focused yet still rather general topics (tier 2) and fifty even more specific topics (tier 3, Figure 2). While keyword frequency and co-occurrence generate topic clusters, they also allow domain experts to name the topics according to their context. A list of publications with the highest share of each topic (i.e. topical relevance > 98%) confirms the topic naming.

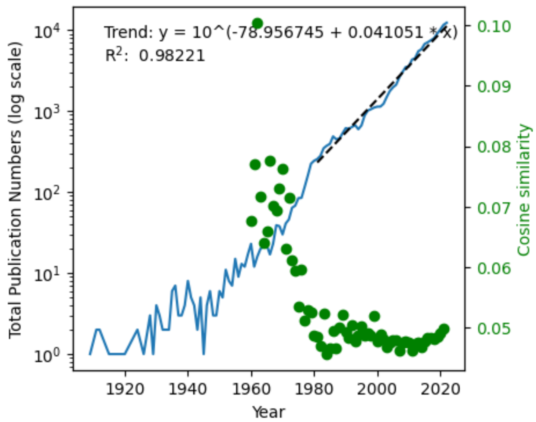

Figure 1: Publications by year in drought research. Research abstracts listed in Scopus and analyzed over the past century with regard to interdisciplinarity. Drought research exhibits an exponential trend (R2 = 0.98). Focus on range of specific topics increased until 1980s when plant genetics took a rise. From 2007 onwards inter-disciplinary rose again consistently.

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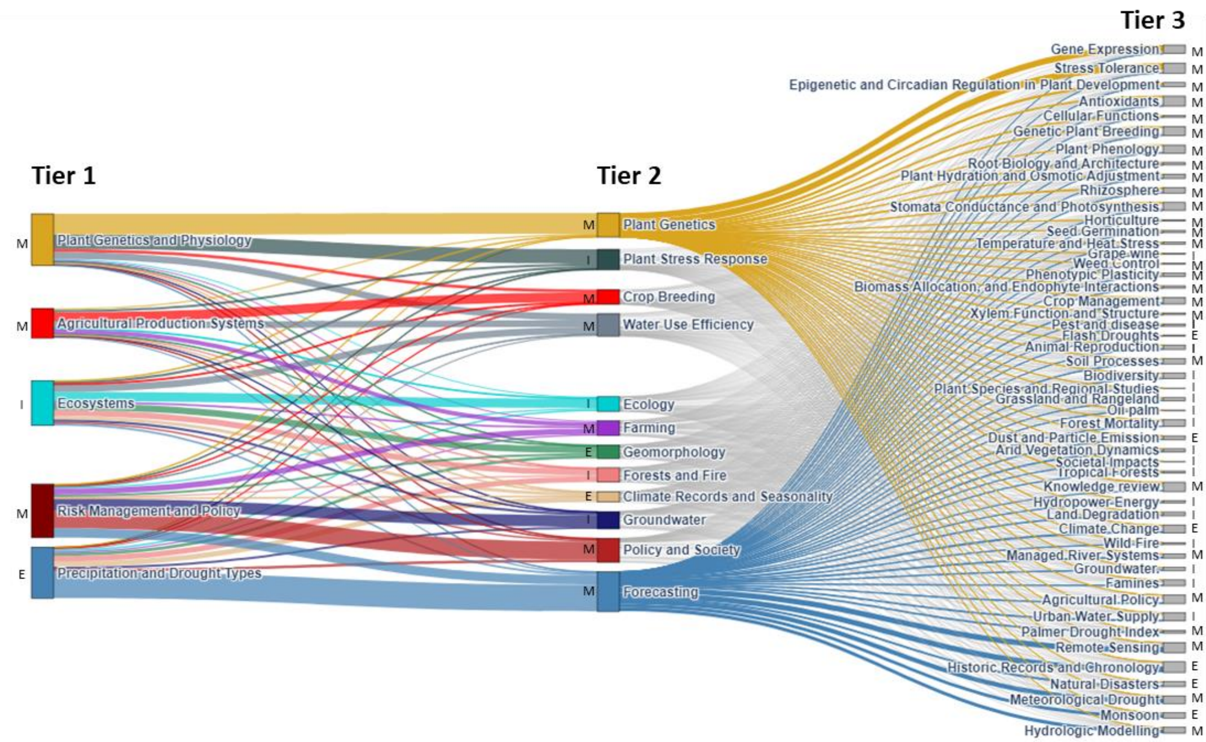

Figure 2 Hierarchical Depth of Research Topics in Drought Research. The breadth of drought research encompasses a diverse array of subjects. Each column represents the entire research corpus, encompassing 131,748 articles. This figure displays the share of each topic against the whole corpus. Three levels of specificity are distinguished: five broad topics (left), twelve intermediate topics (center), and fifty highly specialized topics (right). Visual emphasis is placed on the flows of plant genetics and forecasting, given their upward trends and dominance in the research field. Line width and width of bars is proportional to the share per topic. Topics are categorized into methods and processes (M), events and historical analysis (E), and impacts on socio-ecosystem compartments (I). For high resolution interactive Figure, please see the Supplement Figure S1.

The five general topics were categorized as *plant genetics and physiology*, *agricultural production systems*, *ecosystems*, *risk management and policy*, and *precipitation and drought types*. At the medium granularity with 12-topic classification, we identified *forecasting* methods including drought types and events on the one end and *plant genetics* at the other end as most dominant research topics. For the twelve topic classification, a network graph visualizes the connections of topics and keywords (Figure 3). Here, the dataset's structure is visualized with limited number of most important keywords in two dimensional space. As a result of the LDA, and topical distribution, *forecasting* is mainly associated to *risk management and policy* and *precipitation and drought types* from tier 1, with lesser association to the other three topics of tier 1 (Figure 2). This reflects how *forecasting* focuses on answering questions on risk using quantitative methods. In contrast, *water use efficiency* is strongly associated with three topics of tier 1, reflecting a higher transdisciplinarity and positioning it at the intersection of natural *ecosystems*, *agriculture* and *plant physiology*. *Farming*, as tier 2 topic, is particularly interesting as it bridges the gap

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through its strong association to *risk* and *agricultural production systems* (Figure 2). Other topics at level two are *geomorphology*, *forests and fire*, *climate records and seasonality*, *groundwater*, and *policy and society* (Figure 3). Topic identification and naming at the finest granularity reveal 50 specialized, potentially emerging topics, with an average of 2634 papers per topic. In the Sankey diagram, the association of Tier 3 topics with Tier 2 topics is indicated by a) their vertical alignment and b) the strength of the links. The topics *gene expression* and *stress tolerance* are at the top, with a strong link to *plant genetics*. At the bottom of Figure 2, the topics m*onsoon* and *hydrologic modelling* have a strong link to *forecasting*. These results quantify the extent, importance and the role of specific research topics with respect to drought research. The results demonstrate the importance to render and limit the topical scopes of reviews.

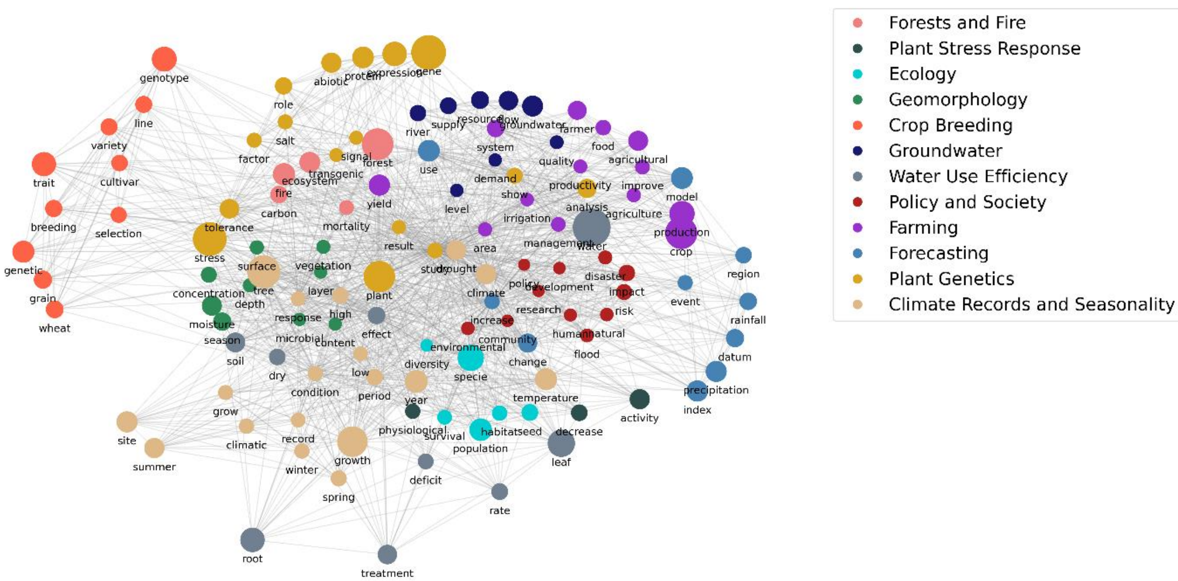

Figure 3: Network graph of drought research. Visualizes the network of the twelve drought research topics. Colors denote topics with strongest association, bubble size identifies abundance of keywords, keywords are located below the bubbles, links between keywords identify strongest co-occurrences, and keywords are located in order to minimize connection lengths. For high resolution Figure, please see the Supplement Figure S2.

Topics for instances strongly associated to forecasting methods can be grouped into studies with a focus on methods (e.g. *remote sensing*, *hydrologic modelling*, *meteorological drought*) and on events (e.g. *historic drought records and chronology*, *monsoon* (Figure 2). Here, method related research focuses on processes, tools, and methods for adaptation and mitigation of drought. Event studies focus on specific event types and historical analysis to guide development of methods. In addition, many topics focus on impacts of drought on a specific socio-ecosystem compartment. Following this categorization, within the tier 3 specific topics in the lower half of the Sankey diagram method related topics are *hydrologic modelling*, *remote sensing*, *agricultural policy*, *managed river systems* and *knowledge review* (Figure 2). In the upper half, tier 3 topics that focus on methods are e.g. improving *gene expression*, *stress tolerance*, *epigenetic and circadian regulation in plant development*, *genetic plant breeding*, adapting *plant phenology*. Impact-related topics, from top to bottom, include *grape wine*, *pest and disease*, *animal reproduction*, *biodiversity*, *grassland and rangeland*, *oil palms*, *forest mortality* (Figure 2). Event-type tier 3 topics, from top to bottom, include *flash droughts*, *dust and particle emission*, *natural disasters.* The density of method-related topics is much higher in the areas of plant genetics, physiology, and agricultural management than in forecasting-related topics. Impact-related topics for tier 3 are mostly found in the center, while topics related to events are predominantly situated in the lower section. This categorization was assessed for tier 1 and tier 2 topics. The results highlight a significant interconnection between research on events, impacts, and methods. This interplay, however, sometimes leads to challenges in distinctly categorizing topics, as evidenced by occasional overlaps and blurred boundaries among these areas (Figure 2).

Despite the rise in machine learning approaches being applied for drought forecasting (Al Mamun et al., 2024; Prodhan et al., 2022), in this analysis machine learning and artificial intelligence were not identified as individual topics. In addition, early warning systems and compound events were not identified as distinctive topics although urgency for progress in these topics is perceived as high (FAO-WFP early warning analysis of acute food insecurity hotspots, 2020; Yin et al., 2023; Ridder et al., 2022). There are two possible reasons for this. Firstly, these topics have not emerged as distinct individual topics within drought research and are potentially well-distributed across the research domain. Secondly, the fraction of research on these topics was too small to result in an individual cluster.

3.2 General and emerging trends

Interest in research topics fluctuates over time. Shifts in research priorities are influenced by societal interest and advancements in technological capabilities. We explored the development over time for drought-related research topics and their relative contributions over the past four decades and more recently, referring to the years 2012-2022. *Plant genetics* and *forecasting* as well as *crop breeding* are getting an increasing relative share of the research over the last four decades (Figure 4 and Supplement Fig. A). *Ecology* and *water use efficiency* have received comparatively less attention with declining shares. Surprisingly, *water use efficiency* is not the specific aim of *plant genetics* and *crop breeding* efforts but rather stands next to these in tier 2. Crop scientists have long targeted drought-tolerant crops to tackle food production challenges in dry regions. The introduction of new genomic technologies has greatly enhanced this effort (Anders et al., 2021), a trend reflected in our analysis. Amongst *plant genetic* and *plant breeding*, specific research on cellular and molecular functions exhibit positive trends for recent years such as the *epigenetic and circadian regulation in plant development* or the role of *antioxidants* that may reduce oxidative damage during drought stress (Bailey-Serres et al., 2019). Plant physiological processes such as *plant phenology* and *stomata conductance* and *photosynthesis* recently became less relevant although strongly related to *plant genetics* and *plant breeding*. Hence, future yield projections under climate change scenarios for food security should expect and incorporate biological advances in plant's genetic and molecular functions to become more drought tolerant.

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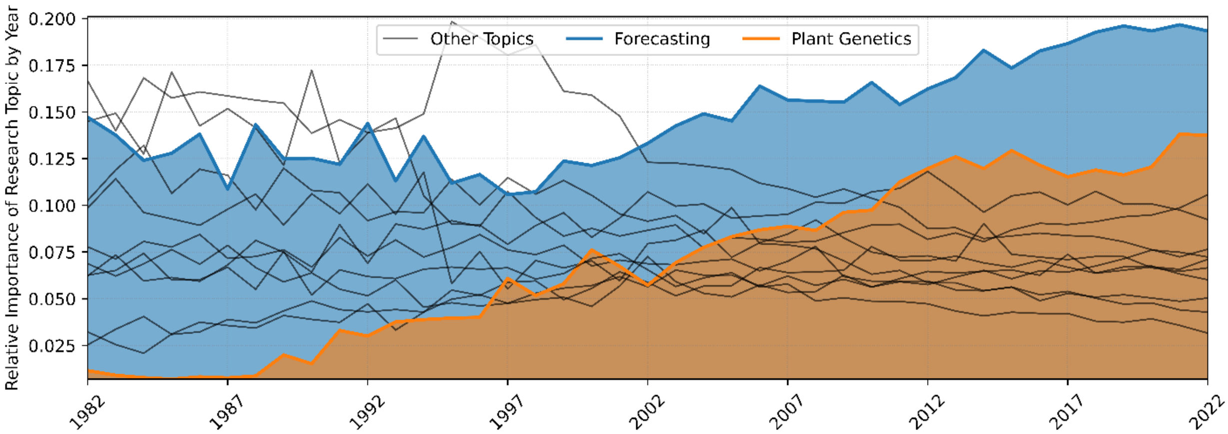

Figure 4: Temporal Dynamics of Research Topics. The evolution of research topics and their proportionate dominance from 1982 onwards, highlighting the ascendance of plant genetics and forecasting as dominant trending topics. For high resolution Figure, please see the Supplement Figure S3.

Other tier 2 topics, such as *groundwater*, *geomorphology*, *policy and society*, have also demonstrated a generally declining relative contribution to drought research over the last 40 years (Figure 4 and Supplementary Fig. A). It is vital to clarify that the decrease in relative share for e.g. *ecology* or *groundwater* topics does not imply a decrease in the absolute number of research studies on these subjects. Instead, the number of documents on these topics continues to grow, but the rate of growth was comparatively slower (Supplement Fig. B). In tier 2, *forecasting* methods and events represented the largest contribution among all topics across the study period (Figure 3). The urgent need for better drought preparedness through accurate forecasting based on mechanism understanding, coupled with the pressing demand to maintain food security for a growing population under more frequent drought conditions, may be the primary reason for the increase in the share of drought-related research in these domains (Krishnamurthy R et al., 2022). The emergence of fast developing drought events may also be another factor to explain such increase together with the occurrence of temporally persistent and large scale events (e.g. in the La Plata basin in South America, in west Africa) (Geirinhas et al., 2023). *Meteorological drought*, *remote sensing*, *climate change*, *natural disasters* and *palmer drought index* are emerging topics with strong association to *forecasting*. Given the stark data requirement, need for data integration platforms, environmental monitoring systems and artificial intelligence as method for generating indices, these may be important factors behind the growing importance of drought *forecasting* (Wardlow et al., 2017; Pasteris et al., 2005).

3.3 Interdisciplinarity of drought research

Each document consists of a variety of topics expressed as percentage i.e. share with the total sum of one for each document. While the algorithm for topic identification aims to discern individual topics within the corpus, the major share of a specific

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topic may dominate a specific document. In another case the topical shares may be dispersed across many topics. We measure interdisciplinarity by cosine similarity, a measure for similarity between two topics and a measure that scales well with the size of the two topics. We find for tier 2 topics (Figure 5) several robust thematic overlaps. *Plant stress response* and *water use efficiency* showed the highest thematic overlap. *Climate records and seasonality* are strongly manifested in sedimentary records and tree ring records, which causes a strong similarity of both tier 2 topics. Also pronounced similarity is found between *policy and society* with the topics *farming* and *groundwater* (Figure 5). Here, groundwater which is crucial for fresh water supply and energy systems (Jasechko et al., 2024) as well as for irrigation and food security has strong impact and link to *policy and society* (Figure 5). In contrast, forecasting is rather focusing on short-term responses with less pronounced similarities. Surprisingly, *geomorphology* and *water use efficiency* possess highest interdisciplinarity, indicating that these are generally important topics with impact across most drought research topics (Figure 5 and Figure 2). In contrast, *plant genetics* and *crop breeding*, jointly with *plant stress response* are less interdisciplinary with some similarities amongst each other. In this context, *forecasting* is only marginally linked to these three topics (Figure 5 and Figure 2).

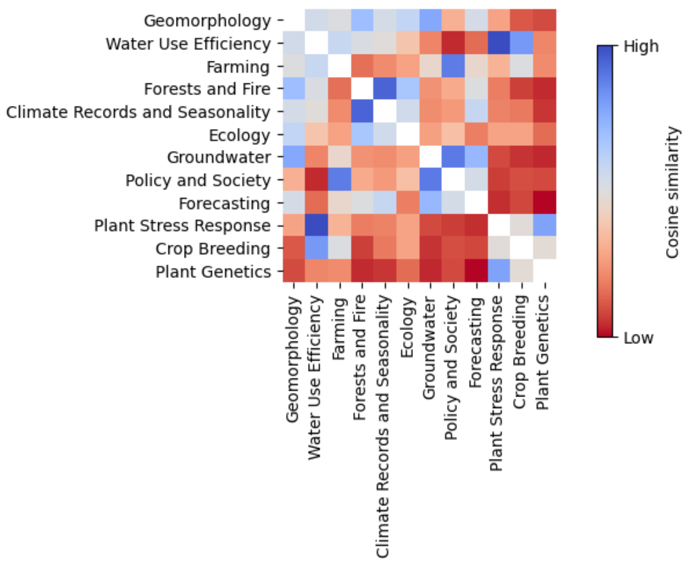

Figure 5: Thematic Overlap of Research Topics. Cosine similarity shows strength of overlaps between topics. It is the topic-wise similarity score that is the numerical value for cross-topic intersection. Stronger thematic overlaps (e.g., plant genetics and plant stress response) are identified by higher similarity, while minimal similarity score also stands for minimal intersections between two topics (e.g., plant genetics and forests and fire). Topics are sorted from highest overall similarity score (geomorphology) to lowest overall similarity score (plant genetics).

More specific topics of tier 3 reveal a different picture regarding inter-disciplinarity (Figure 6). These topics are more specific than the tier 2 topics. Here, *climate change*, *knowledge review*, *remote sensing* and *soil processes* lead the field in terms of overall interdisciplinarity (Figure 6). We note that these topics are highly inter-disciplinary based on the topical analysis results.

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Knowledge reviews seems to not only review a specific topic but make inter-connections beyond single topics. *Climate change* does relate to several topics e.g. through cause and impact. *Soil processes* affect a large number of fields apart from the mere research topic of its own. The same for *remote sensing* albeit here, with emphasis on two specific topics: *Meteorological* and *Palmer drought index* which themselves also possess a high similarity index (Figure 6). In contrast to interdisciplinary topics, *flash droughts*, *oil palm*, and *plant species and regional studies* are rather narrow in scope with low overall interdisciplinarity within drought research (Figure 6). Cosine similarity highlights further topics with strong similarity while for other topics we identify major difference and little overlap in terms of content. Here, interdisciplinarity appears to be more challenging rather than an opportunity to form larger content clusters. We urge researchers who work on narrow, very specific topics albeit important topics such as *flash droughts* and *plant species and regional studies* to expand on interdisciplinarity, and outline impacts in and relations to other areas.

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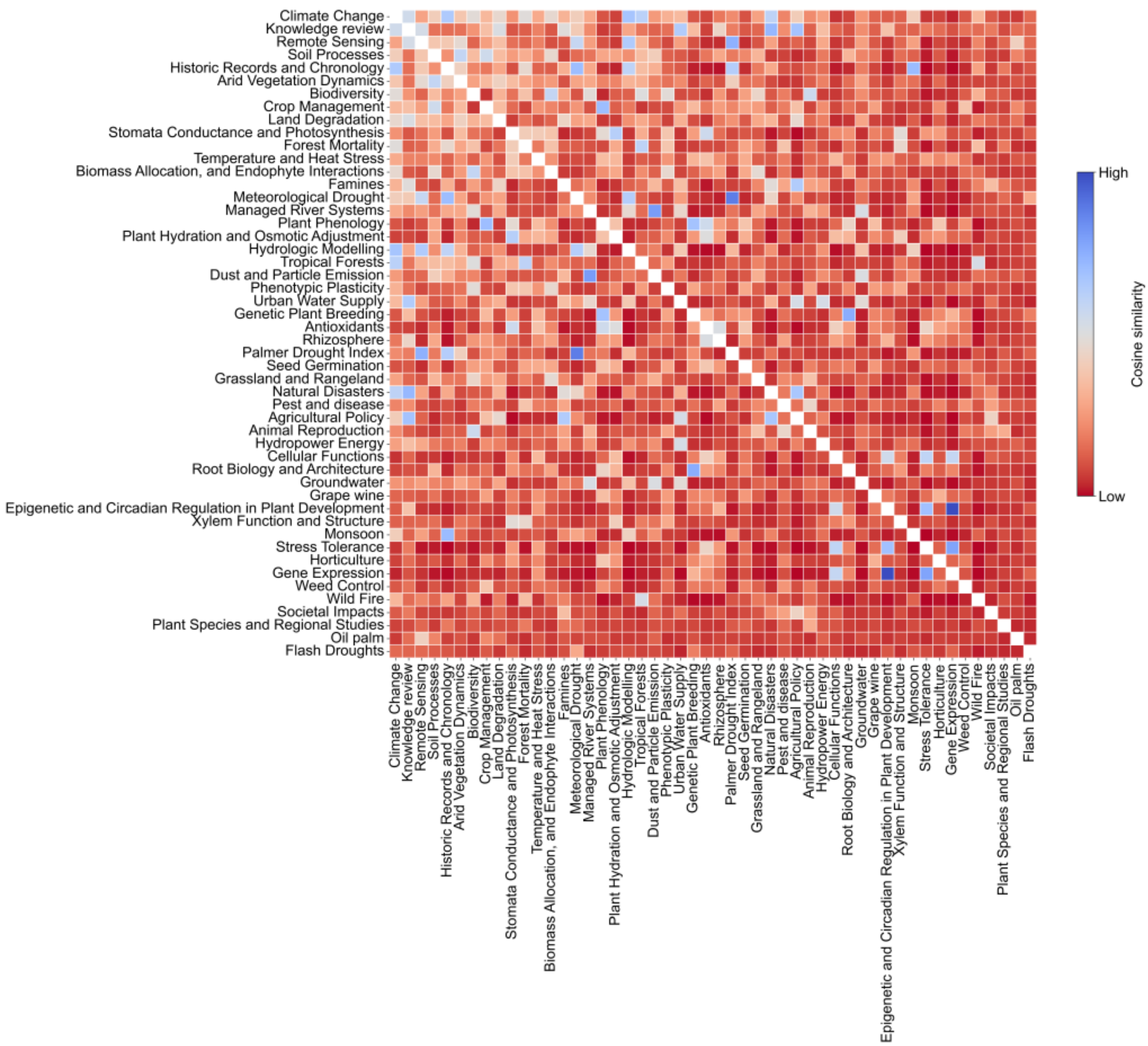

Figure 6: Thematic Overlap of Research Topics. Overlap of the 50-topic clustering results is based on the cosine similarity between topics as metric for similarity and inter-disciplinarity (high to low). The vertical axis is sorted for highest to lowest overall similarity score. Highest overall similarity score was calculated for climate change and knowledge review. Some topics such as gene expression exhibit very low overall similarity score marked by mostly dark red although there can be at times a strong relation to individual topics (dark blue) for instance gene expression and epigenetic and circadian regulation in plant development.

The multi-system impact of drought as natural hazard challenges the often topic specific approach of research projects by requiring a multi-system response. The trend-shift in 2007 towards drought research becoming more systemic again may acknowledge this multi-system property of drought hazard, exposure and vulnerability. Until 2007, drought research evolved

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to become more disciplinary as explained by the annual similarity index (Figure 1). Notable trend shifts occurred in the 1980s when genetics was introduced into drought research and started to become a major topic in the 30 years following. This led to a first trend shift from becoming more disciplinary by 1983 to again becoming more interdisciplinary with high volatility throughout. The second trend shift happened in the years around 2007, when similarity was lowest and succeeded again from a stable upward trend. Noting the systemic impact of drought, we welcome the trend of drought research to become more interdisciplinary because only systemic approaches can properly enhance drought impact resilience across systems.

3.4 Geographic patterns and priorities

Research priorities vary with regard to geographic context. We analyzed continent specific topical signatures in drought research (Figure 7). The largest number of studies refers to Asian (18.0%) and African countries (11.2%) although research budgets in Europe and North America are generally higher than in Africa. This indicates that drought is well recognized as challenge to many African countries, even more so in Asia. As major pattern, forecasting dominates drought research in geospatial context in all regions. In Africa and Oceania, forecasting is closely followed by research on policy and society. This pattern is less pronounced for Europe, Asia and South America (Figure 7). In Africa, farming is the third largest topic with still 12.5 percent and the other topics are less relevant. North American drought research prioritizes groundwater, ecology and forests and fire, just after forecasting with less weight on policy and society as compared to the other regions. In Oceania and Antarctica, ecology is the third major topic. Although there are distinct regional differences amongst the geographic regions, the Southern and Northern hemisphere do not show distinct topical patterns (Figure 7). Forecasting, and policy and society are the two major topics with geospatial context. Plant genetics is the major topic for research with no geospatial context, just before plant stress response and water use efficiency, due to the focus on biological, physiological, genetic and molecular scales.

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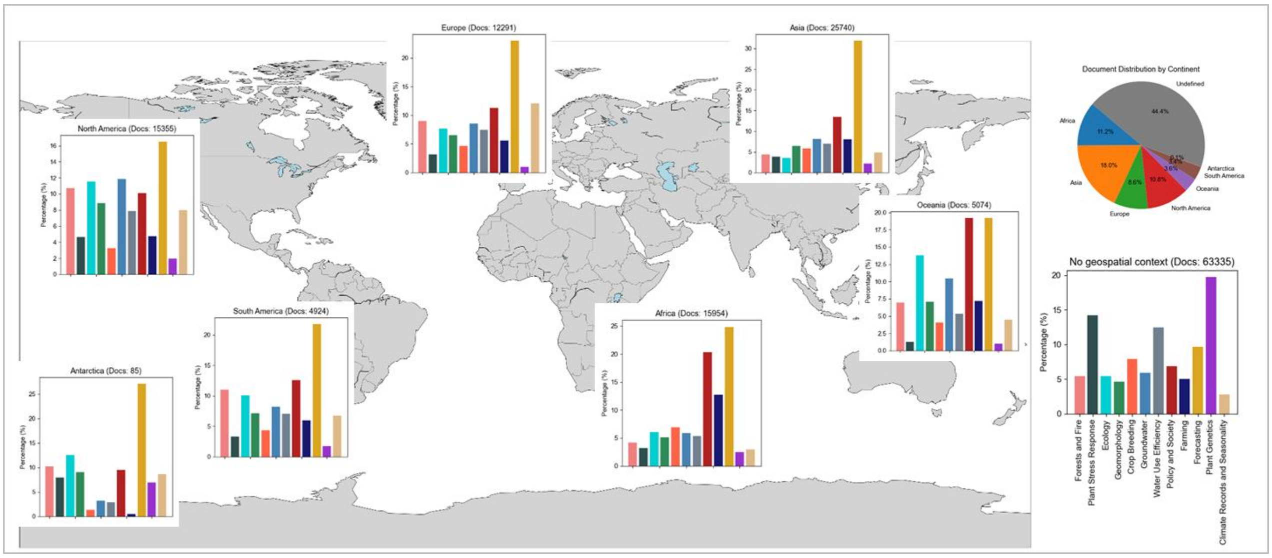

Figure 7: Geospatial Distribution of Drought Research Focii. Distribution of the twelve research topics differs depending on region of the world. Distributions were calculated based on mentioning the name of continents or states. Oceania and Africa exhibit a remarkably high share of policy and society related research. Europe and Asia have strong weight on forecasting, while in North America forests and fire, ecology and geomorphology are closely almost at level of forecasting. Plant genetics dominates research of no geospatial reference. For high resolution Figure, please see the Supplement Figure S4.

4 Discussion and Future Directions

4.1 Implications for research, policy and institutions

These findings have significant implications for scientific community, policymakers and institutions addressing drought issues. The current topical research emphasis lies on drought forecasting methods and plant genetics (Figure 4). Both topics guard food security and imply food security as human priority for funding and research interest. Plant genetics provides methods to identify genes and produce variants with higher drought tolerance by altering a variety of physiologic processes (Figure 2). Forecasting explores methods to forecast drought with regard to risk monitoring often related to agricultural impacts and indicators, and for specific events (Figure 2). In contrast, topics that address drought impact on socio-ecosystem compartments such as ecology and groundwater held greater importance in the past compared to their current relevance. Policy and funding agencies must decide based on their priorities whether this is a desirable trend or not, and align funding strategies accordingly.

It is now the time to bridge the gap between forecasting drought impacts under climate change and the consideration of genetic advances in crop traits albeit it is particularly challenging, considering the arch of drought research and current similarity between these topics. Some projects already address this challenge by aiming to include genetic variability of plants in crop models or use crop growth models for identification of climate adapted varieties (Parent and Tardieu, 2014; Chenu et al., 2017). Given our results, we urge that crop yield forecasts under climate change scenarios must give stronger consideration to genetic advances and plant molecular processes than currently is explored (Stella et al., 2023). Growing computational resources will provide sufficient technical hardware required. In addition, knowledge reviews as are required to bridge interdisciplinarity which they already do (Figure 6).

Surprisingly, several more recently advocated topics of interest were not fully perceived as emerging topics by our data-driven analysis. Although we identified for example remote sensing and drought indices as emerging topics, machine learning (Al Mamun et al., 2024; Prodhan et al., 2022), compound events (Yin et al., 2023; Lesk et al., 2022) and early warning systems (Funk et al., 2019; FAO-WFP early warning analysis of acute food insecurity hotspots, 2020) were not amongst the emerging topics. Here, topics that should make a meaningful contribution to drought research must gain more momentum and more substance through publication numbers, research focus and funding mechanisms.

Finally, we inform the development of systemic drought resilience frameworks by identifying the breadth of and quantifying connection strength between topics in drought research. The trend of increasing interdisciplinarity since 2007 must be consolidated and embraced by building drought resilience frameworks that are more systemic in character (Hagenlocher et al., 2023). Central components of drought research such as groundwater, a resource for drinking water supply, cooling and irrigation (Jasechko et al., 2024), and ecosystems, a critical component of the Earth's life support system (IPCC, 2021) must be included in drought resilience frameworks as well as climate change impacts (Hagenlocher et al., 2019), the topic with highest interdisciplinarity amongst topics of comparable size. Decision makers, policy institutes and researchers working on response strategies to address drought issues must consider the full breadth of outlined topics.

Code availability

Supporting information and code availability is available upon reasonable request from the corresponding author.

Data availability

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Author contribution

Conceptualization, formal analysis and writing – original draft preparation::RB, EER. Writing – review and editing: RB, GG, MH, CN, AT, and EER. All authors have read and agreed to the submitted version of the paper.

Competing interests

The authors declare that they have no conflict of interest.

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5 Appendix

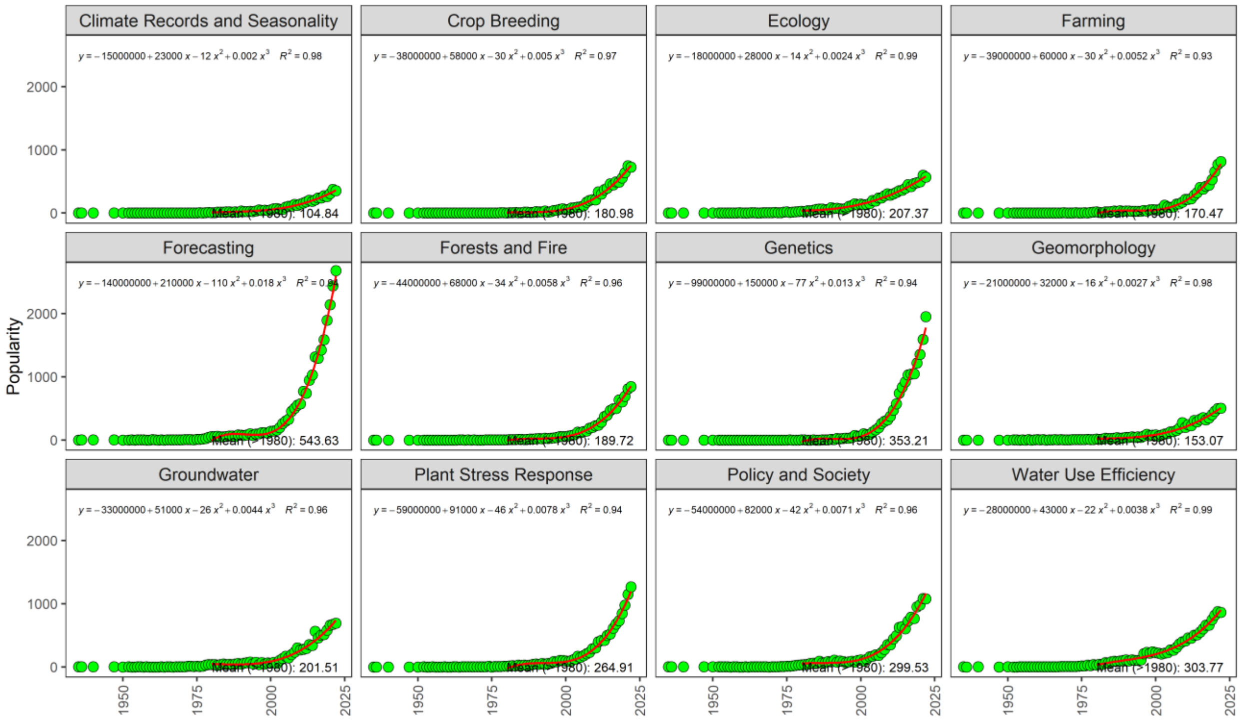

Figure A: Data and trends of total annual publications. Data and polynomial trends of annual publications by major topics per document. Popularity is the number of publication on the particular topic with the polynomial fitted function to indicate the trend since 1980 to 2022 and the mean for this period is given.

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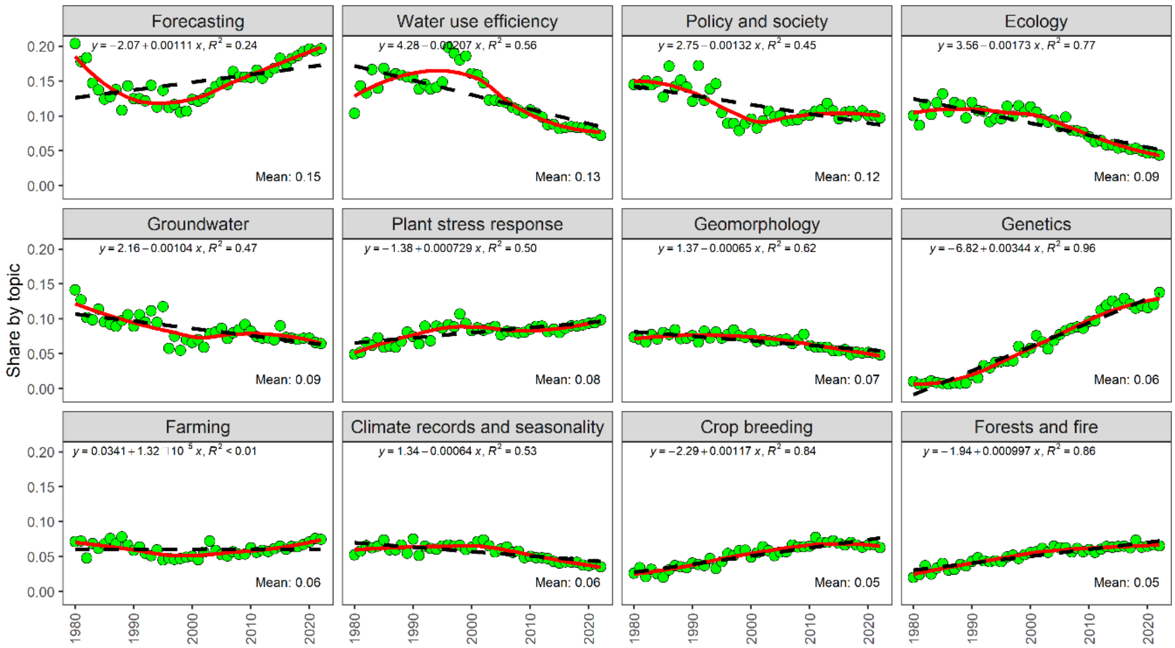

Figure B: Annual share of topics to drought research. Annual shares of research topics ranked by mean annual share. The formula for linear regression provides the trend over the last four decades (black dashed line). Genetics has the highest positive trend with highest Pearson correlation coefficient. Total publication growth is exponential while annual share refers to the single year, which leads to forecasting and genetics as the topics with highest overall share.