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The disappearance of land use from UNFCCC decisions: A guided topic analysis

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ABSTRACT

The United Nations Framework Convention on Climate Change (UNFCCC) plays a pivotal role in shaping global environmental policies, yet a topic analysis of UNFCCC decisions reveals variations in the emphasis on distinct topics each year. This study critically examines all UNFCCC decisions from COP1 in 1995 to COP28 in 2023, along with decisions of the Kyoto Protocol and Paris Agreement. We utilize a form of Natural Language Processing called Guided Latent Dirichlet Allocation to examine how 16 topics that were predefined by the UNFCCC are represented within decisions. The results show how "Land Use", a topic critical for climate change mitigation, is prominently featured only in certain years. Through network analysis, we illustrate land use's limited cooccurrence with other topics within decisions and conferences. We draw on Punctuated Equilibrium and Policy Bubble theories to describe land uses's broader geopolitical trends.

1. Introduction

Approximately three-quarters of the Earth's land has been altered by human actions. Agriculture, Forestry, and other Land Use (AFOLU) is a major cause of climate destruction, accounting for 22% of greenhouse gas emissions globally (IPCC, 2022, WG3, Ch. 2). The IPCC concludes that land-use, land-cover change, and deforestation collectively weaken the resilience of humans and ecosystems to climate change (IPCC, 2023, AR6, Section B.2.1). Conversely, environmentally friendly land use can have a positive impact on the climate as a sink for carbon storage (UNEP, 2023). Properly addressing land use seems crucial in the global effort to mitigate climate change, but recognition of the interrelation between land use and climate change is an ongoing development. This study contributes to the theoretical goal of understanding the evolution of topics within The United Nations Framework Convention on Climate Change (UNFCCC).

The UNFCCC listed 16 topics on its website at the time of the 28th Conference of the Parties (COP28), one of which was "Land Use". Our main research question is how strongly the land use topic is represented within UNFCCC decisions and how that representation changes over time. Our corpus includes decisions from its first meeting (1995) to COP28 (2023), encompassing all three main governing bodies: COP, the Kyoto Protocol Conference (CMP), and The Paris Agreement Conference (CMA). We innovate on the plethora of studies about the UNFCCC by using novel computational methods to examine a large amount of text as data. Such methods allow us to identify patterns that would not be obvious to a human reader. Our analysis is based on a supervised Natural Language Processing (NLP) topic analysis method, known as Guided Latent Dirichlet Allocation (GLDA). We present three analyses: (1) word cooccurrences, (2) longitudinal distributions, and (3) topic networks. The word cooccurrence analysis reveals definitions of the topic, which words are more central or peripheral to the topic. The longitudinal analysis examines which topics are featured in the titles and texts of decisions each year. The network analysis utilizes three measures: (1) within conference cooccurrence, (2) within decision cooccurrence, and (3) topic similarity. We thus show the definition of land use, how the theme has increased and decreased annually, and its relation to other topics.

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This study traces the periodic resurgence and retreat of land use and its relation to other climate topics, offering valuable insights for policymakers. We identify cycles of policy focus that can inform future international negotiations. Our study offers a methodological approach for understanding the inclusion of topics in the UNFCCC decisions, providing policymakers with crucial insights for reinvigorating neglected issues in international climate negotiations.

2. Subtopics of land use within the UNFCCC

Several scholars highlight deficits of land use subtopics within transnational climate negotiations and decisions. Chigbu (2025) highlights how land tenure is absent from UNFCCC decisions. One reason that land tenure may be absent is that it is deeply connected to indigenous communities (Chigbu and Babalola, 2025). A substantial portion of the world's forest carbon is stored on indigenous land, which often lacks formal recognition. UNFCCC decisions have thus far inadequately incorporated indigenous rights despite the recognized importance of their traditional knowledge for successful climate mitigation and adaptation strategies (Carmona et al., 2023; Sauls et al., 2022). Franco and Borras (2021) highlight how this failure to address land issues of indigenous populations weakens the effectiveness of preserving such areas as carbon sinks. More generally, and beyond the question of indigenous communities, land tenure has not been a major focus of intergovernmental organizations and international agreements (Sikor et al., 2013). There is no global organization with comprehensive land governance authority and international attempts to regulate land tenure have remained voluntary rather than binding, as in the case of the Food and Agriculture Organization's Voluntary Guidelines on Responsible Governance of Tenure of Land, Fisheries and Forests (FAO, 2012). Attempts at global land governance touch on fundamental questions of state sovereignty, triggering national resistance to international commitments that might constrain countries' domestic policy space. Moreover, land use change is inherently contested among multiple users and objectives (Vidal et al., 2022). Consequently, global land use policies are often indirect and insufficiently coordinated with overlapping mandates, conflicting objectives, and a lack of formal mechanisms (Prestele et al., 2016; Sayer et al., 2013; Schulz et al., 2020). Land tenure insecurity thus intertwines with indigenous population issues, national sovereignty concerns, diverging policy goals, undermining restoration efforts and exacerbating conflicts.

Agriculture is another significant land use subtopic of global climate governance, as a leading cause of deforestation and its role in greenhouse gas emissions and removals. UNFCCC decisions historically exempt agriculture from rigorous emissions reduction obligations, primarily citing food security concerns, thus limiting the sector's contribution to climate mitigation efforts (Schlamadinger et al., 2007; Zahar, 2023). The Clean Development Mechanism (CDM) outlined in the Marrakech Accords at COP7 in 2001 excluded agricultural practices that could reduce greenhouse gas emissions. While the Kyoto Protocol permitted developed (Annex I) countries to optionally include cropland management and grazing land management in their national carbon accounting, these land management options were not available for CDM projects in developing countries during this period. The Warsaw Framework (Decision 15/CP.19) opened the door to include agriculture in the REDD+ (Reducing Emissions from Deforestation and Forest Degradation) negotiations. However, the need for flexible obligations, wider deployment of technologies, mechanisms to curb emission leakage, and measures addressing consumption-side drivers still hinder the full integration of agriculture into REDD+ and other global climate mitigation frameworks (Fellmann et al., 2018).

The global governance of forests is similarly problematic. While mechanisms like REDD+ were implemented, they faced substantial challenges. Many carbon-offset projects have not delivered the promised reductions in deforestation rates, significantly undermining their credibility as climate solutions (West et al., 2023). The Land Gap Report (Dooley et al., 2022) warned that many national pledges banking on afforestation and bioenergy would require vast land areas, and the changes needed would have unwanted legal and natural repercussions. Entrenched economic and political interests often complicate land tenure reforms, undermining project fidelity and effectiveness (Larson et al., 2013; Bustamante et al., 2014). Calls have emerged for a dedicated global treaty on forests to replace the existing patchwork of pledges (Burke, 2022). Nearly all the impacts of forestry mitigation efforts are context-specific, and countries' varying responses to sustainable forest management criteria showcase the difficulties in creating national implementations of international agreements (Duchelle et al., 2015).

The reliance on land-based carbon sinks and the offset markets built around them have also drawn extensive criticism. Land-based sinks are terrestrial ecosystems whose net uptake of carbon can be increased through land management practices, while offset markets are trading systems that let emitters meet reduction targets by purchasing credits generated by projects elsewhere. Both first entered the international climate policy agenda in the lead up to the Kyoto Protocol, as negotiations got highly technical and controversial (Boyd et al., 2008). Sinks were controversial because every country held different ideas on how to implement them. For some countries, high ambition targets were a risk that could be mitigated by manipulating the prior year to use as a benchmark. Countries that set a more recent date as a benchmark or those with natural high carbon capture sinks received easier carbon capture targets. The inclusion of sinks in the CDM was particularly divisive, with concerns over potential socio-economic impacts on indigenous communities relying on land tenure, as creating more sinks could lead to forcible displacement (Fry, 2002; Schlamadinger et al., 2007; Burleson, 2016). Some scholars cite the extensive disagreement on sinks as one of the reasons for the failure of COP6, which had to be extended by a year (Dooley and Gupta, 2016; Schlamadinger et al., 2007).

3. Longitudinal and topic analysis research about the transnational climate governance

The number of studies about the UNFCCC COP is growing substantially. The Elsevier Scopus database currently (July 23, 2025) identifies 3375 documents that include the search term "UNFCCC" and 2484 documents that also include "COP", yet only 32 of these documents also include the word "longitudinal". Few studies have conducted an actual longitudinal analysis of COP conferences. Thew et al. (2020) conducted a longitudinal ethnographic analysis of youth participation between COP21 and COP23, but their analysis did not examine the COP decisions. Chin-Yee et al. (2020) conducted interviews with leaders from the Africa Group of Negotiators between COPs 21 to 25, but their analysis was not longitudinal. Afionis and Chatzopoulos (2010) examined Russia's role in COP between 2001 and 2008, highlighting how the USA's failure to adopt the Kyoto Protocol enabled Russia to become a more prominent leader. Kolleck et al. (2017) longitudinally examined education-specific messages on Twitter associated with a range of 6 years of COP conferences, but these comments were not analyzed in relation to decisions. Ruiz-Campillo (2024) conducted a discourse analysis of how requests made by negotiation groups from developing countries translated into decisions between COPs 23 to 28.

Lesnikowski et al. (2019) conducted a longitudinal topic analysis based on a 200 word rectangular window of opening speeches at the UNFCCC, which is one of the closest comparisons to our current study. Since our current study examines decisions that have clear beginnings and endings, we did not limit the number of words in our analysis. Another study similar to the current one by Gupta and Singh (2023) conducted a scientometric analysis of publications related to the UNFCCC and UN Convention on Biodiversity (CBD) that reference climate change and biodiversity. However, they did not examine the actual decisions. Parks et al. (2019, 2023) used longitudinal analyses of CBD COP decisions associated with indigenous populations. Their analysis

was similar to the current study in that it examined how specific topics were represented annually in decisions, albeit focusing on a different convention.

Several recently published studies have utilized NLP to examine land use topics. Madu et al. (2018) use LDA to analyze data on oil spillages in Nigeria's Niger Delta. Holand et al. (2024) use LDA to examine literature associated with reindeer pastoralism. Music et al. (2021) conduct sentiment analysis of social media comments. Zhou et al. (2021) employ topic modeling to examine urban renewal mode decisions in China. Selles and Rissman (2020) use computer-aided content analysis and structural topic modeling to explore "resilience" in forest fire science and management documents. Hallberg-Sramek et al. (2024) apply topic modeling to analyze Swedish media coverage of forest conflicts. We are not aware of any studies that examined UNFCCC decisions with topic analysis.

4. Methods

To address our gap in understanding about how land use decisions evolved over time in transnational climate policy, we embarked on a comprehensive study of 28 years of UNFCCC decisions.

4.1. Sample

Our analysis is based on the publicly available English version of decisions that are published on the UNFCCC website: https://unfccc.int/decisions. We utilize the corpus of decisions, because they represent the final outcome of the conference. Each decision represents a legal accomplishment from a vast multilateral decision body. Some decisions are based on a single topic that is clearly identified in the title, while others amalgamate numerous topics or veer towards a topic that differs from the one expected by the title.

We analyzed 838 final decisions from 1995 to 2023. In total there were 28 COP conferences and 551 COP decisions between 1995 and 2023. The 194 decisions from the Parties to the Kyoto Protocol (CMP) from 2005 to 2023 and the 93 decisions from the Paris Agreement (CMA) from 2016 to 2023 were analyzed together and separately from the COP results.[1] The number of decisions varies annually. In COP6 there were just 6 decisions, the lowest count to date.[2] The max of 39 decisions appeared the following year (COP7). The average length of a COP decision was 1670 words. The average number of complex words in a decision (criteria of at least 3 characters and not included in the NLTK stopwords) was 854, and the average number of unique words in a decision was 372. The average length of decisions also fluctuates over the years with a max of 3227 words in 2011 and a minimum of 534 words in 2008.

Our analysis heuristic gave each decision and each conference equal weight, a limitation that we later discuss. Our time period is the concurrent COP number (1 to 28), which happened annually with a few minor exceptions.[3] We also created a separate list of just the decision titles, which we utilized for a simple keyword analysis of mentions of "land" and "forest". For each of the complete decision documents we removed the headers, table of contents, resolutions, and statements of gratitude.[4] The documents were preprocessed in line with common procedures in similar studies (e.g. Jagarlamudi et al., 2012; Nakai and Itoh, 2022; Venugopalan and Gupta, 2022a,b; Churchill and Singh, 2022; Schmiedel et al., 2018).[5] The unprocessed corpus includes 1,373,667 words, but this number is reduced to about half that size after preprocessing (removing stopwords, words less than 3 characters, numbers, and non-English words).

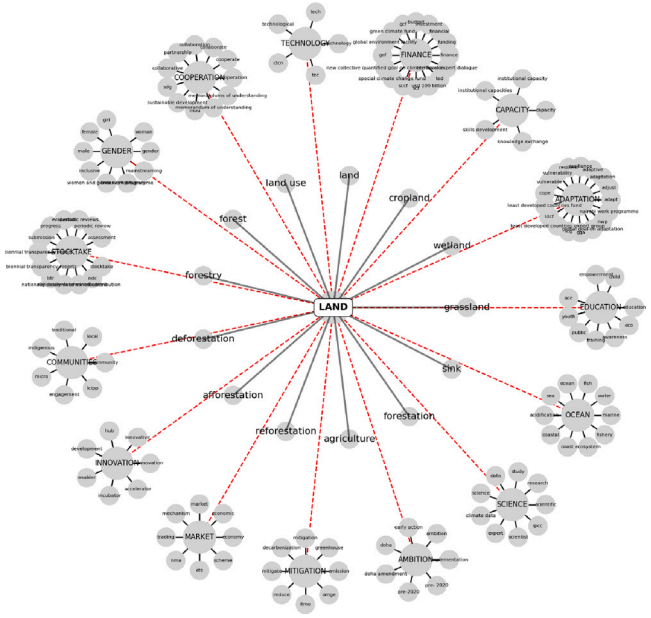


Fig. 1. Conceptual model.

4.2. Model

We utilize the 16 topics that the UNFCCC listed on its website as hypothesized topics for analysis. Hereinafter we refer to each latent topic by its abbreviated title (e.g. Land). The original list of seedwords is based on an NLP keyword analysis of the UNFCCC website's topic description texts with human review of relevant terms. Subsequently we conducted a manual search for additional key terms recognized in the Climate Negotiations Glossary (IISD, 2024). This provided us with an extensive list of seedwords to be analyzed within the corpus (Table 1).[6] While many of these terms can be used across different topics with distinct meanings according to the topic, as guiding words they provided us with a general way to ensure that the empirically deduced topics that we extracted from the texts somewhat matched the topics that the UNFCCC defined.

Fig. 1 displays the framework for our analyses, whereby Land and other topics are analyzed according to seedwords. We examine how words represent the inductively conceived topics identified by the UNFCCC, coherency, and cooccurrence of the latent Land topic with other latent topics.

4.3. Research questions

Since several IPCC reports (2000, 2003, 2019) have shown how Land is fundamental towards mitigating climate change, we questioned

[1] Owing to the cancellation of UNFCCC conferences in 2020, we ran regression analyses for year based on a scale of COP numbers 1 to 28.

[2] There were 6 decisions in both COP6 conferences combined.

[3] COP6 was extended into the following year. COP26 was delayed in 2020. The first CMA meeting was held in 3 parts over a period of 3 years (2016–2018). We included it as happening concurrently with the COP meeting of 2018.

[4] We removed resolutions despite them often being included as decisions, because their aim was to thank a host or recognize a region that is suffering from climate change.

[5] We utilized the NLTK toolkit to lemmatize the words and identify non-English words. We removed 2-letter words. We also manually removed the following words: "year", "unfccc", "english", "secretary", "page", "included", "decision", and "table". This clean text was used for frequency and LDA analyses.

[6] All combinations of plural and singular were examined, including irregulars (e.g. children and NGOs). We also manually added all plural combinations of phrases, as well as all combinations of upper and lower case.

Table 1
GLDA seedwords and the number of times they are mentioned within UNFCCC decisions.

Title (N)	Topics	Seedwords
Education	Action for Climate Empowerment Education and Youth	training (1024), public (900), awareness (224), youth (213), ace (208), education (182), empowerment (168), child (104), eco (1)
Adaptation	Adaptation and Resilience	adaptation (3890), vulnerable (336), least developed countries expert group (232), vulnerability (192), resilience (180), least developed countries fund (166), leg (144), resilient (113), global goal on adaptation (67), nairobi work programme (63), adaptive (45), ldcf (26), nwp (7), cope (2), gga (1)
Capacity	Capacity-building	capacity (2202), skills development (12), knowledge exchange (5)
Finance	Climate Finance	financial (2497), finance (2088), funding (966), budget (916), global environment facility (896), green climate fund (623), gef (387), investment (298), special climate change fund (135), gcf (135), scf (109), usd 100 billion (67), technical expert dialogue (28), new collective quantified goal on climate finance (27), sccf (25), ted (23)
Technology	Climate Technology	technology (2468), technological (660), tec (149), ctcn (73), tech (8)
Cooperation	Cooperative Activities and SDGs	cooperation (393), collaboration (359), sustainable development (357), partnership (187), mou (103), cooperate (89), collaborate (58), memorandum of understanding (56), collaborative (33), sdg (10), memorandums of understanding (1)
Gender	Gender	gender (699), woman (222), inclusive (89), mainstreaming (42), lima work programme (37), female (24), girl (9), male (5), women and gender constituency (3)
Stocktake	Global Stocktake	assessment (1613), submission (1164), progress (1043), nationally determined contribution (362), ndc (335), stocktake (322), evaluation (251), biennial transparency report (118), periodic review (62), btr (41)
Community	Local Communities and Indigenous Peoples Platform	local (437), engagement (318), indigenous (305), community (115), traditional (41), micro (9), lcipp (4)
Innovation	Innovation	development (2935), innovation (112), innovative (73), hub (24), accelerator (17), incubator (10), enabler (7)
Land	Land Use	land (1975), forest (1004), sink* (636), reforestation (551), forestry (539), afforestation (537), agriculture* (246), cropland (218), deforestation (143), wetland (127), grassland (115), forestation (10)
Market	Market and Non-Market Mechanisms	mechanism (2549), economic (604), market (270), economy (192), scheme (73), trading (43), nma (25), ets (1)
Mitigation	Mitigation	emission (3831), greenhouse (1434), mitigation (1339), reduce (146), itmo (90), mitigate (51), omge (11), decarbonization (2)
Ambition	Pre-2020 Ambition and Implementation	implementation (4819), ambition (187), doha (119), pre-2020 (33), early action (3), pre- 2020 (2), pre2020 (1), pre 2020 (0)
Science	Science	expert (2665), data (1401), scientific (743), ipcc (691), research (274), science (138), study (49), scientist (10)
Ocean	The Ocean	ecosystem (145), water (112), ocean (43), marine (35), coastal (32), sea (6), fishery (3), acidification (1)

whether its meaning and significance changed in UNFCCC decisions over time. To do so we examine three overarching research questions: (1) Which words represent Land? (2) How does Land change in frequency over time? and (3) How does Land coexist with other topics within decisions and within conferences? We further questioned whether decisions about Land at COP were equivalent to those in the CMP and CMA. First, we analyze word frequencies and cooccurrence measures. Second, we examine longitudinally the distribution of topics within each conference. Third, we visualize GLDA topic networks and examine correlations between topics.

The first question is exploratory and conceptual. We count the occurrence of Land seedwords and their cooccurrence with other seedwords within a ±10-word tokenized rectangular window within each decision. We then perform a network analysis that shows us topics that integrate with land. We also visualize word clouds based on the GLDA estimated weights of words in the Land topic and describe differences in the topic between conferences.

The second question is longitudinal and confirmatory. First, we examine a basic research question: Is the Land topic presented in equal proportions as the other 15 topics (1/16)? We then measure four competing hypotheses that Land is: (1) a prominent topic every year (uniform distribution, $\beta = 0$), (2) growing in prevalence (linear increase, $\beta = 1$), (3) decreasing in prevalence (linear decrease, $\beta = -1$), or (4) represents a quasi-normal distribution, whereby Land gradually became a prominent topic and has since faded from decisions. Since there are 16 hypothesized topics defined by the UNFCCC, the first hypothesis thus implies that the probability of Land in any given year is the same:

$$y = \frac{1}{16}$$

The second hypothesis presumes an increasing slope, where n is the number of topics, x is the COP number, and $\bar{x}$ is the total number of conferences (28):

$$y = \frac{1}{2n} + \frac{\left(\frac{1}{n/2} - \frac{1}{2n}\right)}{\bar{x} - 1}(x - 1)$$

This equation implies that Land began with half prevalence (1/32) and increased to double (1/8):

$$y = \frac{1}{32} + \frac{\left(\frac{1}{8} - \frac{1}{32}\right)}{28 - 1}(x - 1)$$

The third hypothesis is the opposite. Land begins with double prevalence, and we subtract from the intercept rather than adding to create a decreasing slope:

$$y = \frac{1}{n/2} - \frac{\left(\frac{1}{n/2} - \frac{1}{2n}\right)}{\bar{x} - 1}(x - 1)$$

While these are mathematical hypotheses, the fourth hypothesis recognizes literature that showed Land as an important topic following the implementation of REDD+ soon after 2007 (COP13). The mechanism served as a "win-win" opportunity (Gupta, 2012), whereby developing and developed countries could agree on Land issues due to its payments for environmental services scheme (Wunder et al., 2020). Our fourth hypothesis presumes that Land would thus achieve a pinnacle moment between COP14 and COP15: Land begins with half prevalence (1/32), increases to double prevalence (1/8) at the midpoint (14.5), and returns to half prevalence in the final year with a quasi-normal distribution, hence:

$$y = \frac{1}{2n} + \frac{1}{n\sqrt{8\pi}} \exp\left(-\frac{(x - \bar{x})^2}{8\,n^2\,\pi}\right)$$

For each hypothesis, we examined the model fit of COP and all three conferences (COP, CMA and CMP) combined using a chi-square test:

$$\chi^2 = \sum_{i=1}^{28} \frac{(\mathrm{obs}_i - \mathrm{exp}_i)^2}{\mathrm{exp}_i}.$$

Since calculation of the three latter hypotheses implies fluctuations between half and double prevalence over a period of time that represents the 28 COP conferences that took place prior to the research, the linear increase and decrease hypotheses presume a total prevalence of 7.8% (above uniform) and the quasi-normal hypothesis presumes a total prevalence of 5.0% (below uniform).

The third question is exploratory and relational. We do not make hypotheses that aim to predict results. We simply map the cooccurrence and similarity of topics and describe how Land is closer to or more distant from other topics, along with measures of centrality. Our network analyses are calculated based on three measures of distance: (1) within conference cooccurrence (topics occurring within the same year), (2) within document cooccurrence (topics occurring within the same decision), and (3) similarity (topics using similar words). Finally, to answer our question about the relation of Land with other topics, we show how the prevalence of Land correlates positively and negatively with other topics, in addition to the correlations of each topic over time.

4.4. NLP and GLDA

Our primary analysis tool is NLP text mining. Specifically, we make use of a semi-supervised version of LDA, GLDA (Jagarlamudi et al., 2012; Watanabe and Zhou, 2022). In GLDA, each document is considered a mixture of latent topics, similar to LDA. However, GLDA differs from LDA in that it enables us to predefine the topics of interest and the representative words associated with them. We gave the words and phrases shown in Table 1 a seed confidence of 25%, thereby encouraging the latent topics to closely mimic the seedwords. This method made the most sense for our goal to examine the 16 topics that were clearly defined by the organization itself.

We used the NLTK, SKLEARN, GENSIM, and GLDA toolkits in Python. In order to analyze texts quantitatively, we reduce words and phrases into numerical units. To make similar words equivalent we use lemmatization.[7] Each decision can represent more than one topic (e.g. Land and Mitigation) (see Mimno et al., 2011). Each conference contains numerous decisions and numerous topics. Using the topic distributions generated for each document, we calculated cumulative topic probabilities for each year (prevalence). This analysis presumes that a decision is entirely defined only by the 16 seeded topics, such that all topics combined equal 100% of each decision, and each conference is defined likewise as the cumulative sum of probabilities for each topic with equal weight to each decision.

We examine correlations, coherence, cosine similarity, and conditional probabilities of two topics existing within the same decision and the same conference. To capture relations between topics we utilize Normalized Point Mutual Information (NPMI), the joint probability of vector scores for two topics (A and B) appearing together in a document. NPMI tells us whether two topics cooccur more often than would be expected by chance:

$$\mathrm{NPMI} = \frac{\log\left(\frac{p(A,B)}{p(A)\cdot p(B)}\right)}{-\log\left(p(A,B)\right)}$$

Topic coherence (Cv) is computed as the average cosine similarity between the embedding vectors of the top representative words (W) and the embedding vector representing the entire topic, where N is the number of top words that represent the topic. Higher coherence indicates that the top words represent a cohesive semantic concept:

$$\mathrm{Cv} = \frac{1}{N}\sum_{i=1}^{N} W(A_i)$$

Topic similarity is measured by cosine similarity, showing the amount that similar words are being used in different topics. These measures were standardized to 0 to 1 for the network analyses.

The network edges were computed with a square root transformation to the scores to reduce the disproportionate impact of highly prevalent topics (Rahimi et al., 2023). In the networks, the nodes are colored by coherence (with darker being more coherent), and their size is based on their prevalence. We present measurements for weighted degree centrality (WDC: the sum of the weights of the edges connected to a topic divided by the number of neighbor topics $|\mathcal{N}(A)| - 1$) and inverted closeness centrality (C_{inv}: the speed with which a topic A can reach others B, inverted to give more weight to stronger connections):

$$\mathrm{WDC} = \frac{\sum w(A,B)}{|\mathcal{N}(A)| - 1}$$

$$C_{\mathrm{inv}}(A) = \frac{|\mathcal{N}(A)| - 1}{\sum\left(\frac{1}{w(A,B)}\right)}$$

5. Results

5.1. Which words represent land?

The Land topic is dominated by the words "land" (1975) and "forest" (1004), which appear far more than any other seedwords. Variance in mentions of forest each year is 58% explained by mentions of land, emphasizing further how these two concepts are closely connected. As a part of all UNFCCC decisions, "land" is used 2214 times and "forest" is used 1863 times. The lemmatized stems of land and forest feature slightly less than other lemmatized stems, such as technology (2884), climate (4703) and national (3534). The analysis of words in a 10-word window shows that the word "land" has its greatest common cooccurrence with a lemmatized stem of "forest" (1787), followed by "change" (648), "use" (585), and "convert" (430). After land, the lemmatized stem of "forest" has its greatest cooccurrence with "activity" (1246), "project" (986), and "change" (726). Words, such as "emission" (902) and "carbon" (450) feature in close proximity to either "land" or "forest". An analysis of all Land seedwords combined shows that the most frequently cooccurring words are "use" (4093), "change" (2108), "activities" (1541), "project" (1461), "management"

[7] Lemmatization was utilized rather than stemming, because we found that the latter equated many words incorrectly. We did not conduct smoothing by sentences or paragraphs (see Watanabe and Baturo, 2024), as the decisions were organized according to bullet points, some of the decisions were relatively short, and the decisions are supposed to represent concise topics.

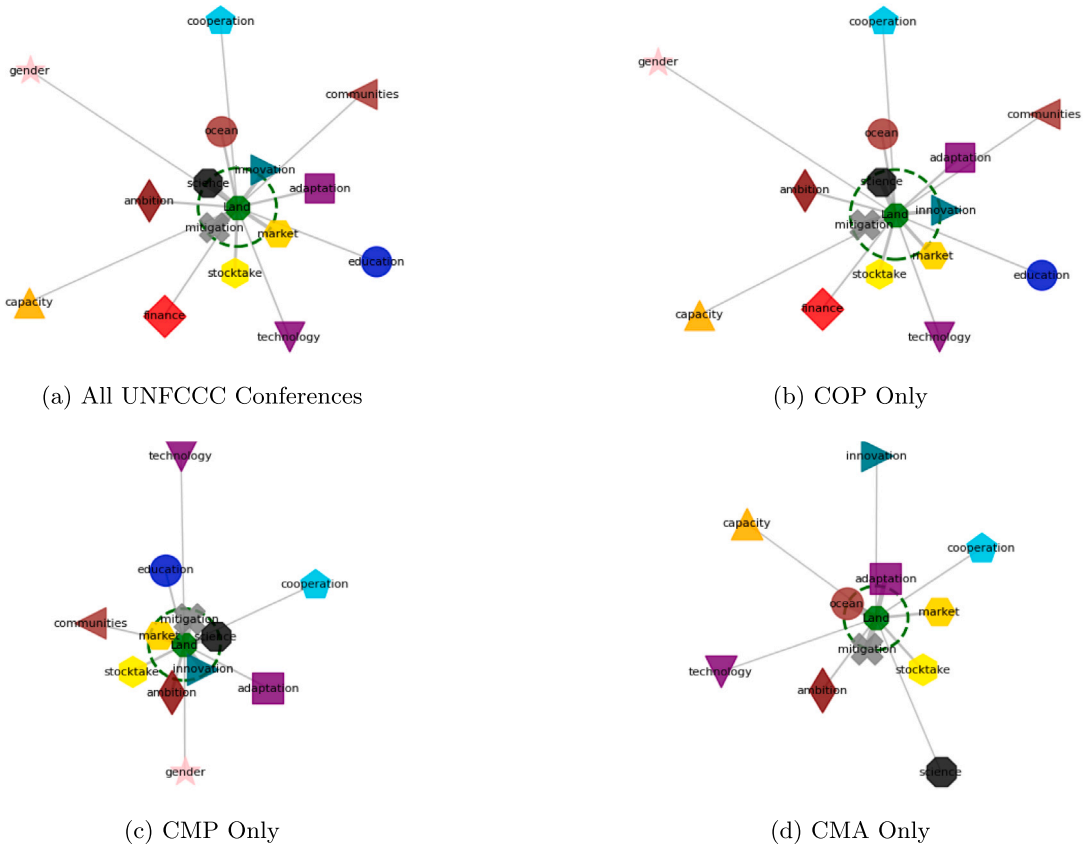


Fig. 2. Topic seedword cooccurrence networks.

(1039), "emissions" (1030), "carbon" (789), and "CDM" (781). Land appears to be intertwined with resource utilization.

In Fig. 2 we show cooccurrence networks based on all seedwords for each topic combined. In all UNFCCC decisions there is a relatively clear inner and outer circle based on the number of times that those topics cooccur. Land's inner circle includes Mitigation (556), Science (373), Innovation (238), Market (235), and Stocktake (148). Land's outer circle includes Finance (34), Education (28), Communities (20), Cooperation (15), Capacity (9), and Gender (7). The COP conference mirrors the overall results, as it represents the bulk of UNFCCC decisions. In the CMP conference, Land similarly cooccurs with Mitigation (90), Market (76), Innovation (61), and Science (61). In the CMA conference, while there is high proximity with Mitigation (28), Ocean (33) is actually Land's closest topic and Adaptation also features relatively frequently (20).

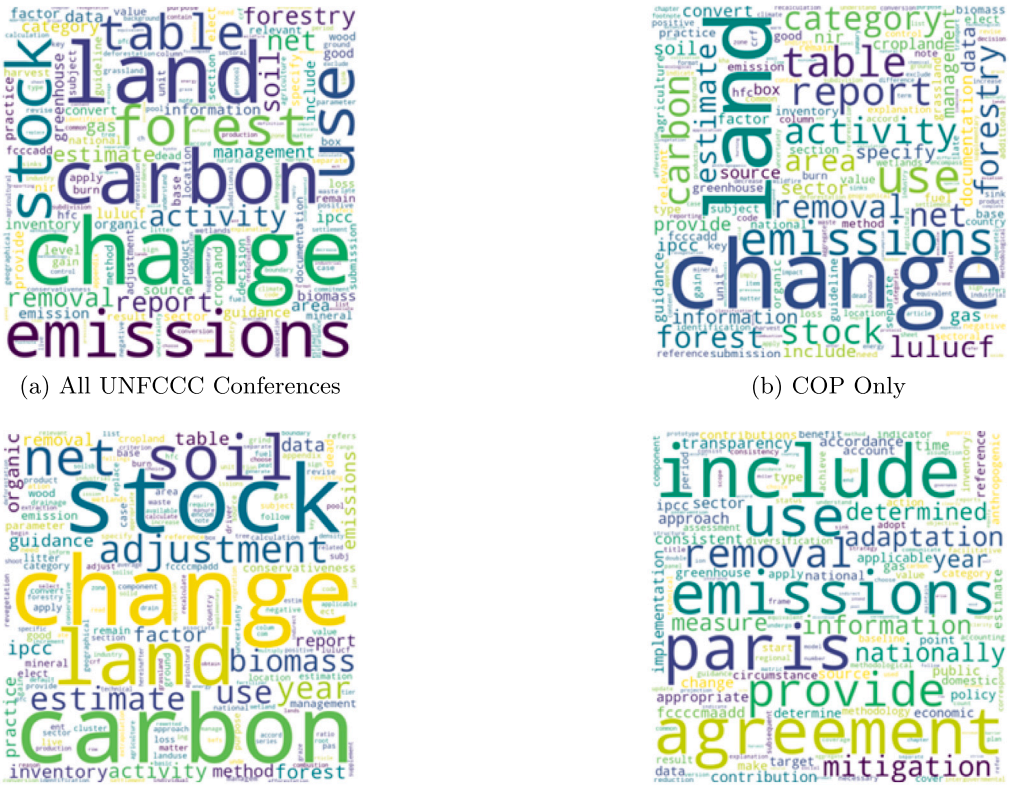
Certain topics are more coherent than others. Land obtained the highest coherence score of any topic (0.82). The other most coherent topics are Market (0.68), Mitigation (0.66), Finance (0.63), Adaptation (0.62), and Innovation (0.62). On the other hand, some topics had relatively poor coherence, specifically Ocean (0.47) and Stocktake (0.40). While the COP and CMP models provided sufficient coherence scores for Land (0.80 and 0.70 respectively), the CMA model gave much lower coherence for Land (.48) and most of the other topics. Land is a very coherent topic when looking at COP, CMP, or all UNFCCC decisions combined.

When we adjust the relevancy measure of the GLDA model to 0, we identify terms that are distinct to each topic. Specifically, we found that the bigrams for 'carbon stock', 'stock change', 'forest land', 'stock changes', 'change soils', 'ground biomass', 'land converted', 'mineral soils', 'per area', and 'biomass carbon' are the most unique terms associated with Land. CMP decisions place a strong emphasis on carbon management with higher frequencies of 'carbon' and 'stock'. Unique keywords in the CMP documents include 'commitment', 'biomass', 'organic', and 'wood'. Conversely, the extremely low coherence of land in the CMA indicates that Land might reflect a different topic meaning altogether. It should also be noted that the unsupervised model (LDA) provided satisfactory coherence levels for a Land topic (0.68). The seedwords assisted to create topics that more closely resembled the 16 topics that the UNFCCC defined.

Fig. 3 shows a word cloud of the Land topic based on the entire text of the decisions where word size corresponds to the GLDA weight (i.e. the relative importance of each term to the topic). In all conferences combined, the words "change" (0.04), "land" (0.03), "carbon" (0.02), "emissions" (0.02), and "use" (0.02) have the highest weights. A number of additional words appear that were not seedwords, such as "biomass" (.01), "greenhouse" (.01), and "IPCC" (.01). COP similarly features "land" (0.03), "use" (0.03), and "emissions" (0.03). The CMP Land topic focuses more on "carbon" (0.04), "stock" (0.04), and "soil" (0.02). As noted, the CMA is unique, owing to both the limited number of decisions in that conference and the relatively small role of Land within it. "Land" and "stock" have weights near zero in the CMA model, and the topic focuses on "include" (0.03), "agreement" (0.03), "paris" (0.03), and "emissions" (0.03).

5.2. How does land change in frequency over time?

In Fig. 4 we examine just the titles of the decisions. A lemmatized segment of "land" or "forest" is featured in 19 out of the 551 COP decisions. Land first appeared in a decision title in COP4. That first decision included more keywords in its title (4) than any decision since: "Methodological guidance for activities relating to reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries". Three separate COP decisions had the



(a) All UNFCCC Conferences (b) COP Only

(c) CMP Only (d) CMA Only

Fig. 3. Word clouds based on weights of the land topic in the GLDA models.

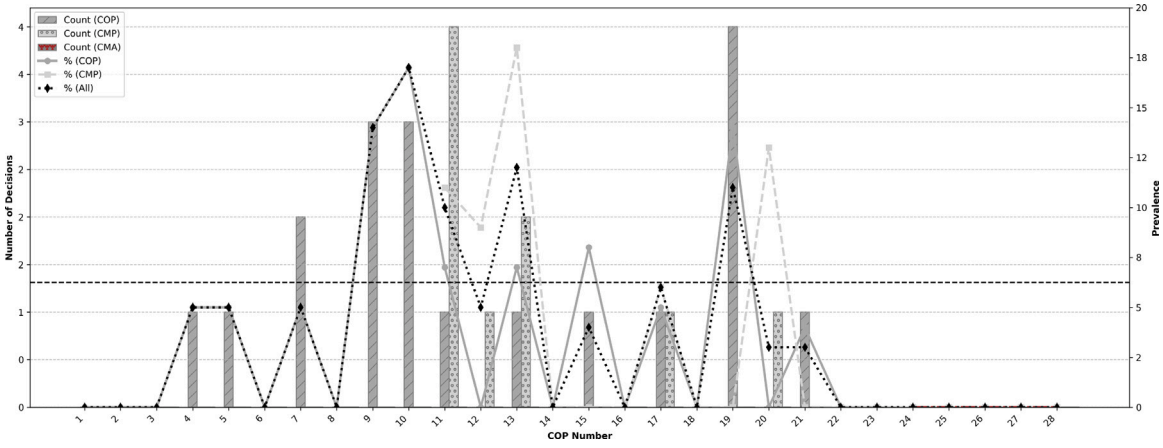


Fig. 4. Number of decisions that include land or forest in the title.

same title: "Land-use, land-use change and forestry" (9/CP.4, 16/CP.5, and 11/CP.7). Six additional titles included 2 keywords (e.g. "Addressing the drivers of deforestation and forest degradation" (15/CP.19). We calculate the title analysis as a binomial score for whether a lemmatized segment of "Land" or "Forest" appears in the title at least once.[8].

Fig. 4 shows that after one Land titled decision in COP4 (9/CP.4) and COP5 (16/CP.5), there were none in COP6. Then in COP7 there were two decisions (11/CP.7 and 12/CP.7). There were three Land decisions each in COP9 (13/CP.9, 19/CP.9, and 22/CP.9) and COP10 (13/CP.10, 14/CP.10, 15/CP.10). Starting in COP11 a pattern began with one decision one year and then one year without one. This trend continued until COP19 when there were a record four decisions (10/CP.19, 13/CP.19, 15/CP.19, and 11/CP.19). In COP21 there was again one decision (16/CP.21), and then after COP21 Land disappears from decision titles entirely. The most recent period in history thus represents an age of Land decisions' disappearance from COP decisions.

CMP1 included 4 Land titled decisions (5/CMP.1, 6/CMP.1, 16/CMP.1, 17/CMP.1), which was more than in any future conference. In CMP2 there was only one decision (8/CMP.2). In CMP3 there were

[8] Sink and agriculture were included as seedwords in the GLDA analysis, but we did not count them in the title keyword analysis. Specifically, one decision included sink in its title (7/CP.27) and one decision included agriculture (3/CP.27). The sink-titled decision focused on the atmosphere. The agriculture-titled decision focused on collaboration. Neither decision mentioned another Land seedword.

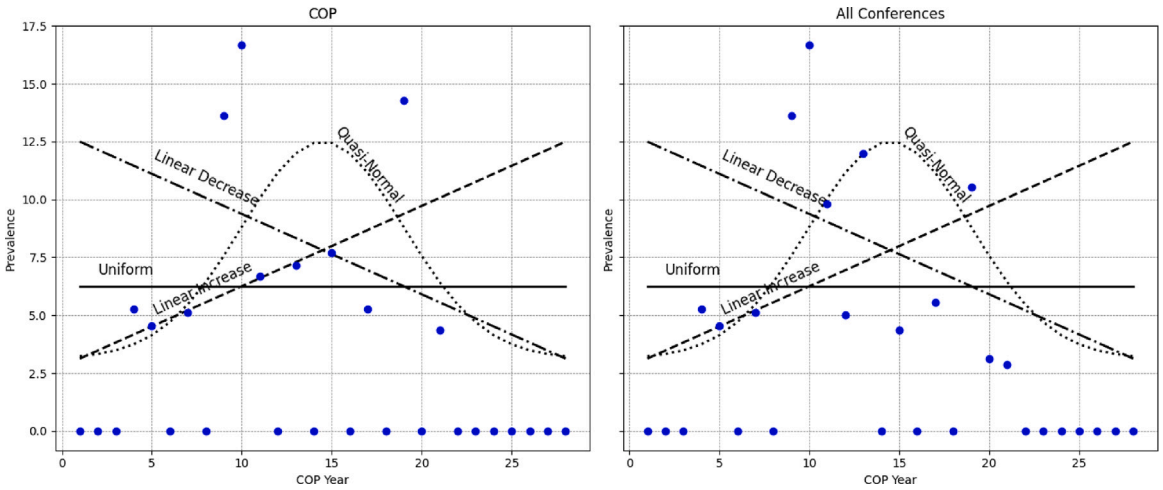


Fig. 5. Land titled decisions (dots) with hypothetical distributions (lines).

Table 2
Chi-square values for different hypotheses in COP and all conferences.

Hypothesis	χ^2 COP	χ^2 all conferences
Uniform	144.7	135.2
Linear Increase	177.7	171.5
Linear Decrease	151.9	135.8
Quasi-Normal	127.1	112.7

two (6/CMP.3, 6/CMP.3), followed by a 3-year pause from CMP4 to CMP6. In CMP7 there was one more Land decision (2/CMP.7), which was followed again by a 3 year pause from CMP8 to CMP10. Then, once again, there was one more Land decision (7/CMP.10), and then for the following 8 years there were not any CMP Land decisions. Of these prior 9 CMP Land decisions, there are 10 mentions of "land" and 12 mentions of "forest". Five of the decisions repeat the motif "Land use, land-use change and forestry". Another motif featured in two of the decisions is "afforestation and reforestation".

Several Land decisions were enacted in COP just as the first CMP started. An intermittent pattern developed thereafter where Land decisions were enacted in one year followed by a lull of one year at first and recently with complete absence. This lull has been carried over into the CMA where none of the decisions mention Land. In summary, no Land titled decisions were taken over a period of 7 years in any of the UNFCCC's three main conferences.

Fig. 5 shows the prevalence as the percentage of decisions out of all decision each conference that have at least one lemmatized stem of "land" or "forest" in the title compared to the four hypothetical distributions. Table 2 shows that the quasi-normal distribution fits the data best, and the combination of all conferences provides a better model fit. However, owing to the numerous COP conferences with zero Land decisions, the hypothesis has a number of errors. Land decisions grew and declined, but the pattern appears to bounce up and down from one year to the next. A simple average of all years shows that Land decisions overall are underrepresented compared to the expected uniform distribution of 6.25%, both in COP alone (3.24%) and overall (3.52%).

The GLDA model based on the complete texts, not just the titles as previously, reveals that Land is mentioned rather infrequently in UNFCCC decisions relative to other topics. Land represents only 1.9% of all decisions when it should represent 6.3%. Hence, while Land is included in the title of a decision, many other topics are seeping their way into those decisions and diluting its prevalence. The largest topics are Ambition (19.3%) and Cooperation (18.7%). Other significant topics include Education (12.5%) and Adaptation (10.0%). Finance (9.2%), Technology (6.9%), and Science (6.4%) are also more frequently discussed. Land receives considerably less attention in the decision-making processes of the UNFCCC. However, some topics are featured even less prominently, such as Innovation (1.0%), Mitigation (1.1%), and Market (1.2%).

Fig. 6 illustrates the likelihood of Land appearing as a topic based on the GLDA calculations of prevalence alongside the count of Land seedwords in each conference. The graph mirrors our initial frequency analysis of topics (Fig. 4). Scrutinizing these results, we discern waves of Land prevalence: a minor initial wave spanning COPs 6 to 7, a huge wave spanning COPs 9 to 11, a wave that was influenced by CMP3 decisions (at the time of COP13), followed by two additional waves influenced by CMP8 and CMP11, which extended across COPs 15 to 19. Corresponding with the analysis of titles, the Land topic virtually disappears in all three conferences following COP22.

Notably, in COP1, only 16 Land seedwords are mentioned. By COP7, the number increases to 401 (4.2% prevalence). Then, after a brief lull in COP8, there was a dramatic wave of Land infused decisions between COPs 9 to 11 (COP9: 778, 7.4%; COP10: 753, 5.7%; and COP11: 504, 6.8%). During this time, only Land's prevalence increases above the expected uniform distribution hypothesis (1/16). A closer inspection of the documents at this time shows that repeated references to LULUCF account for a large proportion of these mentions. This large wave was accentuated during COP11 with the concurrent rise in Land of CMP1 (950, 7.8%). Land during COP11 and CMP1 reaches a climax, not seen since, of 7.4% prevalence in all conferences combined. Land was noticeably absent during the following conference (COP12: 9, 2.5%; CMP2: 19, 2.3%). A brief resurgence of Land occurs with CMP3 (228, 5.9%). However, there are just two Land seedwords in COP14 and 13 seedwords in CMP4 (0.0%). COP14 had the lowest proportion of Land out of any conference (.0026%).

While it is tempting to measure Land's prevalence based on the number of seedwords, significant variations in the number of decisions in each conference alter the correlation between seedwords and topic prevalence. COP6 had only 6 decisions, and CMP14 had only 5. Furthermore, the length of decisions in certain conferences was much shorter than others. Certain text patterns related to Land remain, even though direct mentions to Land seedwords dissipate. After COP15 there is a gradual increase in Land prevalence, but most of this occurs due to mentions of "forest" within the CMP. During COP19 there is a resurgence of Land (208 seedwords), which aligns with the 4 Land titled decisions in that conference, but the following year in COP20 Land almost vanishes from both conferences (0.1% prevalence in COP and 1.0% prevalence overall). During CMP11, there is a final resurgence of Land (188 seedwords, 8.1% prevalence in CMP), but Land is largely absent from the concurrent COP21 (73 mentions, 0.7% prevalence

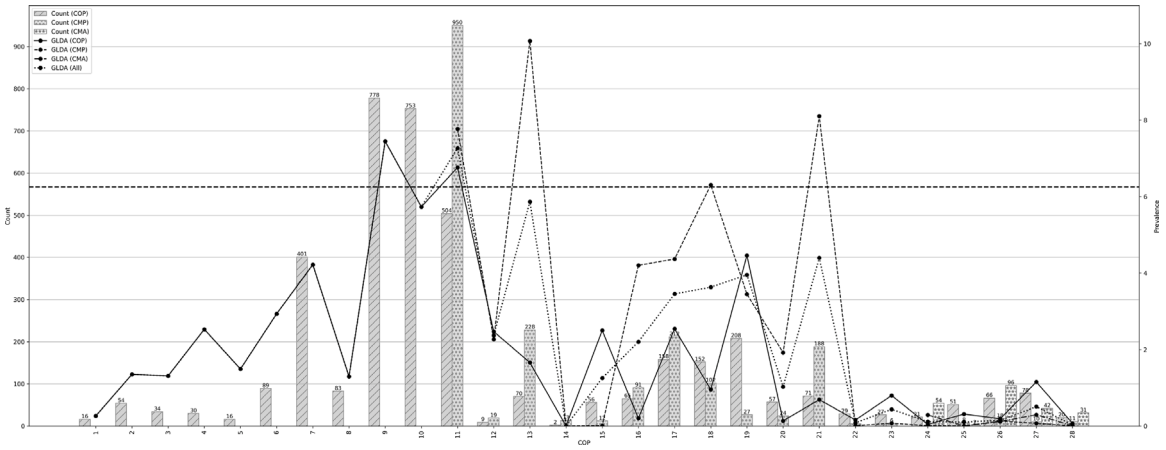


Fig. 6. GLDA prevalence of land topic (line) and frequency of land seedwords (bar).

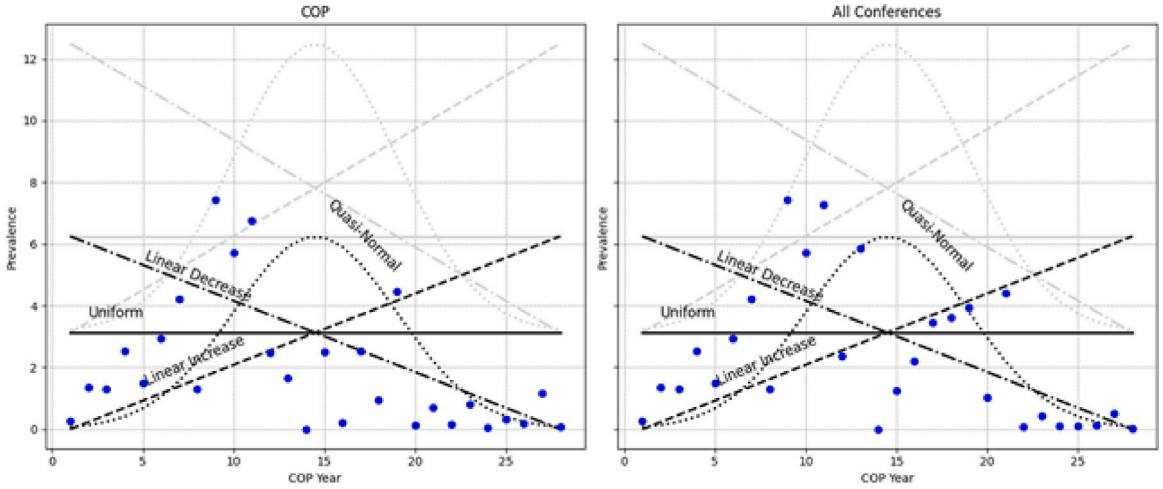


Fig. 7. Fit of GLDA land prevalence frequencies (dots) with initial (gray lines) and revised (black lines) hypothetical distributions.

in COP). Hence, COPs 17 to 19 represent the second wave of Land within UNFCCC decisions. During this wave Land fails to reach uniform proportional prevalence. Thus, we identify the period between COP9 and COP11 as the first great wave of Land in UNFCCC decisions, with resurgences in CMP3 (COP13), CMP8 (COP18), and CMP11 (COP21). Between COP22 and COP28 Land remains below 1% prevalence overall in each year.

The CMA begins concurrently with COP24, but Land is not a primary topic of those decisions. While Article 5 of the Paris Agreement emphasizes a commitment to land use, the topic is clearly absent from its decisions. The average prevalence of Land in the CMA is only 0.14%. During this same overlapping period in COP (COPs 24 to 28) Land's prevalence is only 0.04%, and within the CMP (CMPs 14 to 18), it is only 0.35%. Owing to the low prevalence of Land in the GLDA model, our hypotheses needed to be adjusted. Fig. 7 displays the GLDA estimated prevalence of Land in COP and all conferences combined alongside the hypothetical distribution (gray line). In order to better fit the results, we present revised hypotheses (black line). We reduced the hypothetical max from 1/8 (double prevalence) to 1/16 (equal prevalence). We also altered the uniform hypothesis to 1/16, meaning that we only expect Land to represent half the amount we would expect if all topics were equally represented.

Table 3 shows that the revised half proportional distribution hypotheses, based on the fit for all conferences combined, are more robust. While the quasi-normal distribution provided the best fit based on the titles, these results indicate that Land is experiencing a linear decrease ($\chi^2 = 44.6$). Owing to the large wave of Land from COP9 to COP11, the lesser wave from COP17 to COP19, and the dearth of Land from COP22 to COP28, there is a clear decrease in the prevalence of Land over time. Furthermore, the sudden lulls after a year where Land has high prevalence (e.g. COPs 7 to 8, 11 to 12, 13 to 14, 19 to 20, and 21 to 22) indicate that perhaps our hypotheses that envisioned gradual or no change do not properly address to the true dynamic of Land within the conferences, which takes on a jagged shape of a bouncing ball. Land has essentially been ignored from all UNFCCC decisions over the past 7 years, and unless that changes in the future the best fit line will remain a linear decrease).

5.3. How does land coexist with other topics within decisions and within conferences?

We present 3 topic network analyses that represent the total combination of all 3 conventions (COP, CMP, and CMA) with differing edges based on the following topic measures: (1) cooccurrence within conferences, (2) cooccurrence within decisions, and (3) cosine similarity. The darkness of the node shows the average coherence score for a topic, and the size of the node is based on the cumulative probability of each topic existing across all documents within that conference series.

Fig. 8 summarizes how topics cooccur within conferences. Land occupies an external coordinate in the graph, in a quadrant alongside mitigation, ocean, finance, and communities. Land has its highest cooccurrence with Market (.18), Ambition (.18), Stocktake (.13), and

Table 3
Chi-square statistics comparing expected topic distributions under various hypotheses.

	Hypothesis	χ^2 COP	χ^2 all conferences
Original Proportional Distribution Hypotheses (1/16)	Uniform	102.7	90.5
	Linear Increase	146.7	132.0
	Linear Decrease	136.1	122.3
	Quasi Normal	114.8	98.5
Revised Half Proportional Distribution Hypotheses (1/32)	Uniform	50.3	49.3
	Linear Increase	172.4	170.7
	Linear Decrease	48.9	44.6
	Quasi-Normal	82.1	68.1

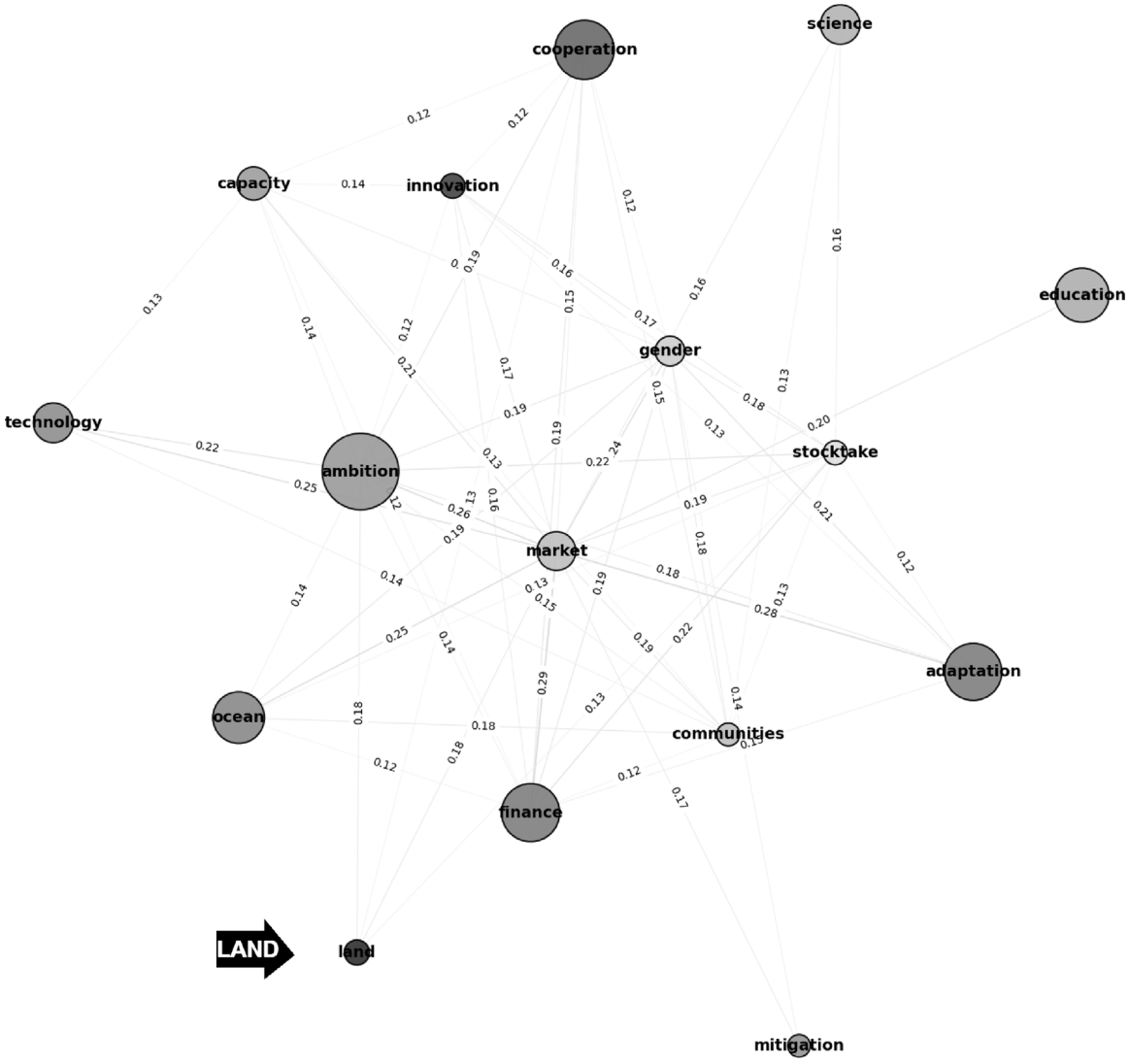


Fig. 8. UNFCCC within conference topic cooccurrence network.

Cooperation (.13). Land's WDC is moderate (1.53). Its connections are not as strong as more central topics like Market or Ambition. It rarely acts as a bridge between other topics. Its C_{inv} is low at 0.11. Land is relatively isolated. Cooccurrence measurements for all three conventions combined are substantially lower than when we examine COP on its own. Within COP there is a high cooccurrence of Land with Market (.24), Ambition (.19), Finance (.15), Cooperation (.15), Stocktake (.14), and Gender (.14). Analyzing just the CMP, we find that Land cooccurs more often with Mitigation (.15). In the CMP Land appears at opposite coordinates from Ocean. Analyzing the CMA, Land occupies a central position with high levels of cooccurrence with numerous topics. However, Land has low coherence in the CMA (.43), and there have only been 5 CMA conferences. We thus cannot make any conclusions about the limited amount of Land discussed there. The results for all three conferences combined show that Land occupies an external role, but it is a coherent topic. Ambition, Market, and Stocktake have higher centrality measures, and these topics are often included in the same conferences where Land policies appear.

Fig. 9 displays the extent that topics cooccur within the same decisions across all UNFCCC conferences. Land has low within-decision cooccurrence with most other topics, indicating that Land is often the dominant topic in a decision. In terms of centrality measures, Land has the lowest WDC (0.67) of any topic, reflecting its limited connections with other topics. Land does not act as a bridge between topics. C_{inv} is

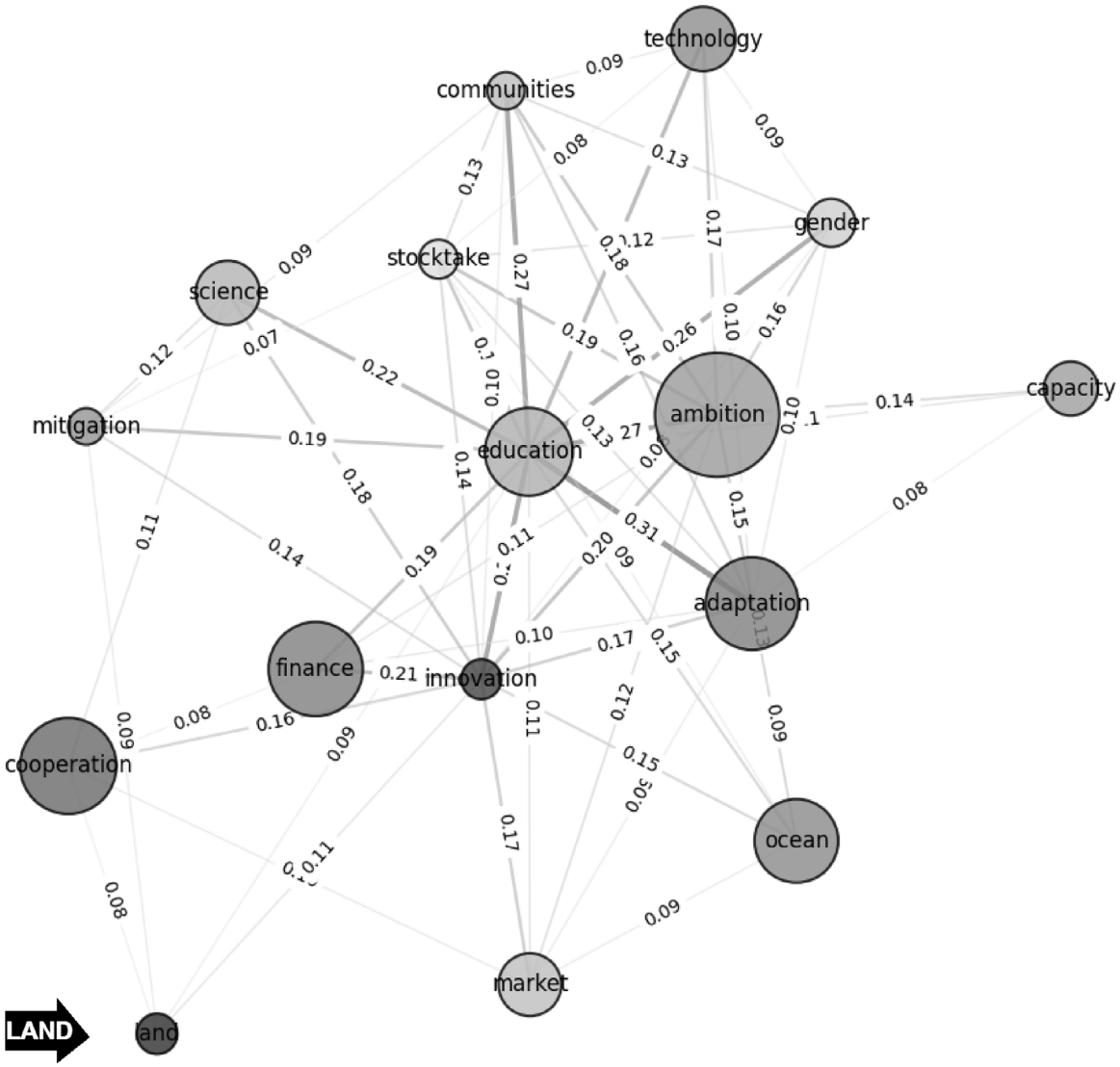


Fig. 9. UNFCCC within decision topic cooccurrence network.

also again low (0.07). Land occupies the same quadrant as Cooperation and Market, which also have low centrality. On the opposite side of the graph, furthest from Land, are Technology, Communities, Gender, and Capacity. It's highest within decision cooccurrences are with Innovation (.11), Mitigation (.09), Education (.09), and Cooperation (.08), but these levels barely breach uniform expectations (.06).

Looking just at COP, Land is further isolated from other decisions. It's highest within decision cooccurrence is with Ocean (.11), Adaptation (.09), and Mitigation (.09). Scores for Land within just COP are not especially higher than in the conferences combined. Land is a unique topic within the decisions it is featured and not a topic that is often combined with other decisions. Within just the CMP, Land still occupies an external position. It's highest cooccurrences are with Mitigation (.15), Communities (.10), Gender (.10), and Science (.09). These values are also not very high. Also, at the CMP when Land decisions are made, we find high levels of topic singularity where primarily only Land dominates a single decision. In the CMA Land occupies a very central role with high cooccurrence with other topics. Land has not obtained a high level of definition in the CMA, failing to dominate decisions as it does in the other conferences. Hence, the results are not robust.

The last network (Fig. 10) shows the similarity of topics within UNFCCC decisions in terms of the words that are used to describe them. Once again Land occupies an external coordinate on the graph. Its greatest similarities are with Mitigation (.17) and Ocean (.14). It has the least similarity with Technology, Communities, and Capacity. Examining just COP, Land is still similar to Mitigation (.15) and Ocean (.14), while staying on the outside of the graph. WDC is relatively weak (0.71). C_{inv} is also quite low (.06). Land has some similarity connections with other topics, but it is relatively isolated. The topics that share a community with Land are Cooperation, Innovation, Market, Mitigation, Science, and Ocean. In the CMP we find that Land continues to utilize a unique combination of words, existing on the edge of the graph. It has its highest similarity with Mitigation (.22) and Communities (.15). Its position in relation to Ocean and Finance especially is even further removed. Finally in the CMA, Land occupies a more central location with much higher levels of similarity with other topics. Since Land is such an incoherent and marginal topic in the CMA, it appears to be similar to major topics.

Utilizing the prevalence of each topic across the 28 years of COP conferences, we examined linear correlations for change over time and the correlations of Land with other topics. Fig. 11 displays the prevalence of each topic in each COP conference along with its correlation over time. There is a negative correlation of Land over time (R = −.38). Certain topics are decreasing even more profoundly: Cooperation (R = −.93), Ocean (R = −.54), Market (R = −.44), and Finance (R = −.41). Other topics are increasing: Capacity (R = .85), Technology (R

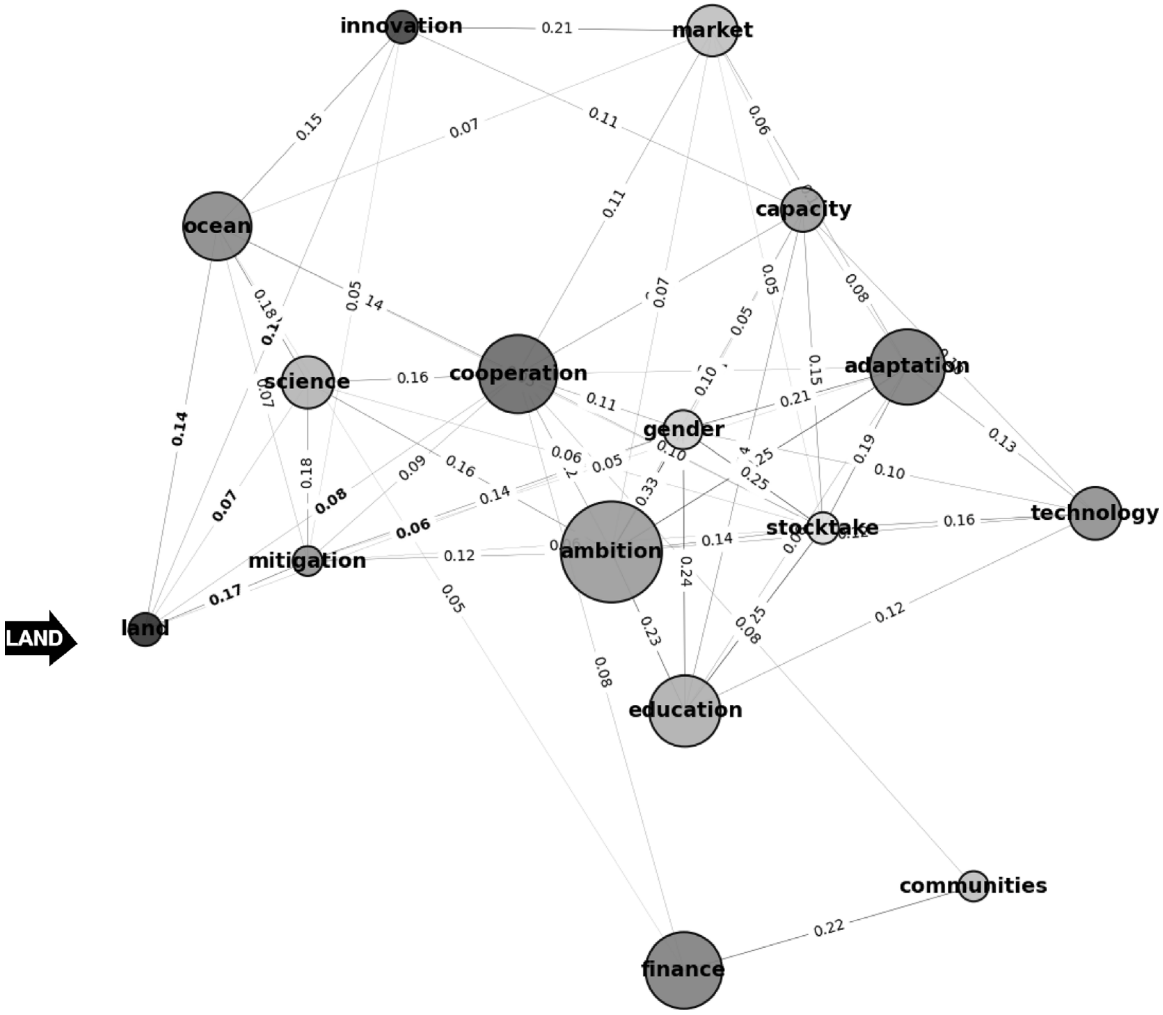


Fig. 10. UNFCCC topic cosine similarity network.

= .84), Education (R = .81), Community (R = .76), Innovation (R = .70), and Adaptation (R = .40). Logically, many of the topics that are increasing have negative correlations with Land: Ambition (R = −.52), Technology (R = −0.51), Capacity (R = −.43), and Community (R = −.38). Conversely, many of the topics that are decreasing have positive correlations with Land: Ocean (R = .67), Market (R = .64), Science (R = .51), and Mitigation (R = .50).

While Land has never been a prominent topic of the UNFCCC, it has clearly regressed in prominence from the words in the final decisions. Fig. 12 summarizes how COP policy decisions especially have become increasingly focused on Technology, while Land is included less. Within CMP decisions, Land is also clearly decreasing. However, it is not due to increasing Technology, which does not have a major role in that conference yet. While Land was featured in early CMPs, later conferences were dominated by Adaptation and Finance. The CMA only has five data points, and it does not appear to be a venue for Land. Technology, Education, Capacity, and Ambition are its main focuses.

6. Discussion

The goal of this study was to present a macro review about what Land represents in UNFCCC decisions that might help guide future policy development. We initially expected our analysis would uncover subtopics of Land, such as land tenure, agriculture, forestation, and sinks. However, we discovered that the language associated with Land decisions was centered on land and forest, such that we could not make intricate arguments about nuanced subtopics. Indeed, such findings reflect prior research that indicated land tenure is absent from UNFCCC decisions (Chigbu, 2025). Studies that incorporate future decisions and texts will hopefully provide a more nuanced vision of Land within climate negotiations. Such studies might also determine whether implementation of Land decisions occurs and whether ensuing policies reinforce or expand prior commitments.

This study taught us that Land has high coherence compared to other UNFCCC topics, owing to the high number of Land seedwords concentrated in certain decisions. A clear set of words help define the topic, such as carbon, stock, and emissions. Our longitudinal analysis showed that Land's prevalence comes in waves, often surging in one conference and then nearly vanishing the next. Land emerged as a major topic around COP9, but its prevalence has seesawed over time, and its inclusion appears to be dwindling. There has not been a primarily Land focused decision between COPs 22 and 28 in any of the UNFCCC's three conferences. The network analysis showed us that Land rarely overlaps with other topics, neither within the same decision, the same conference, nor the same words. Land is more closely associated with Mitigation and Market. Land is rarely discussed alongside Technology, which is becoming more prevalent in recent years as Land declines.

One explanation that we explored was that a REDD+ boom soon after COP13 inspired an increase in Land. While we found some evidence for this hypothesis based on the titles of the decisions, the GLDA analysis of the complete texts of the decisions indicates that the linear decrease hypothesis provides a better fit. An alternative hypothesis is that the emergence of Land may be attributable to the IPCC LULUCF reports in 2000 (COP6), 2003 (COP9), and 2019 (COP25). Prior waves

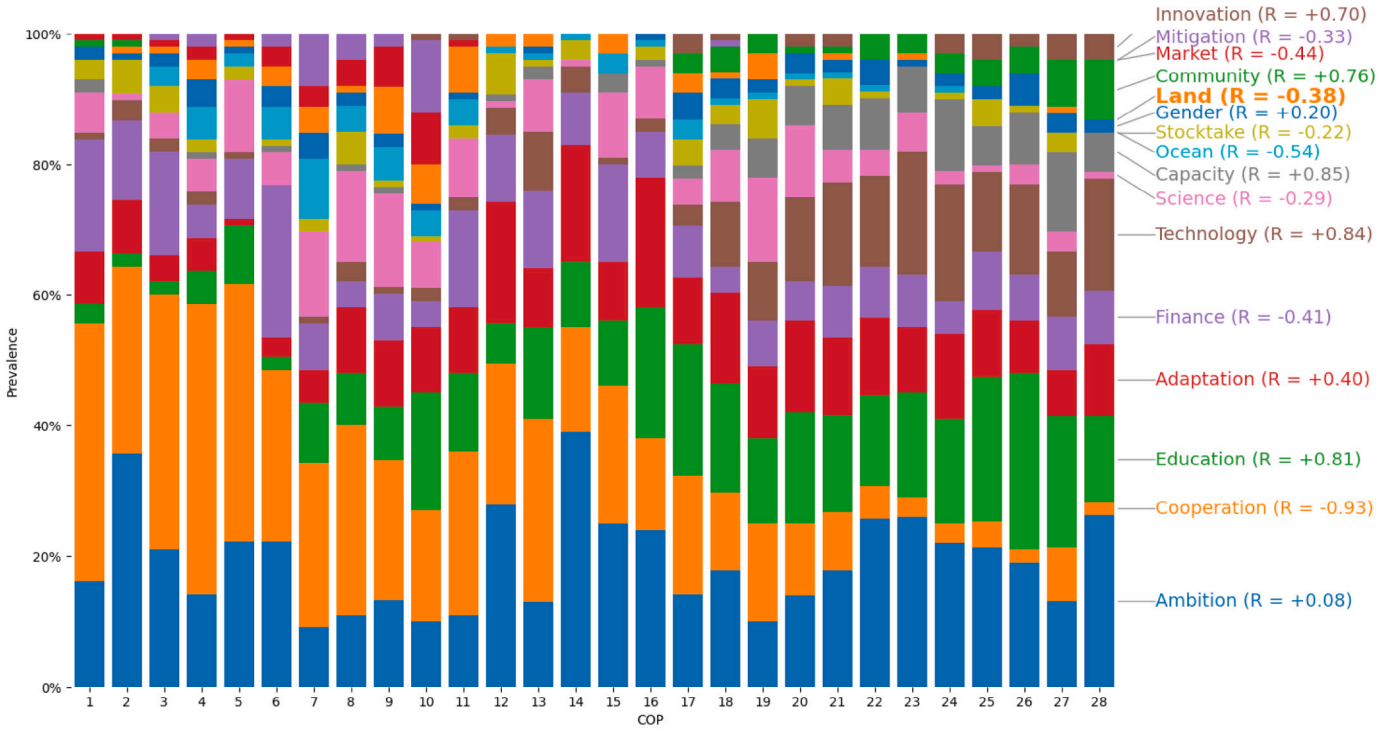


Fig. 11. GLDA prevalence of topics in COP with correlations over time.

of Land in UNFCCC decisions appear to follow the year after key IPCC publications (e.g., COP6, 2000 and COP9, 2003). The more recent IPCC special report on LULUCF (COP25, 2019) did not prompt a comparable surge in Land decisions. This could be attributed to the COVID-19 pandemic postponing COP26 negotiations, or perhaps it is a result of fossil fuel lobbyists gaining visibility at forest topic side events and steering discussions to energy (Xie et al., 2025).

The decline of Land may have to do with socio-economic factors. Winkler et al. (2021) observed a transition of global land use from an acceleration phase to a deceleration phase around the time of the 2007–08 global financial crisis. They argue that this shift aligns with changes in global food regimes and the transition from agrotechnological intensification to production for globalized markets. This transition reflects broader "teleconnections", where economic changes in one region led to far-reaching effects on land use elsewhere, underscoring the interconnected nature of global land-use dynamics. Perhaps it is not coincidental that at the same time that land use decelerated, the number of policies that refer to Land also dissipated. Other scholars emphasize misconceptions in understanding land use. Interpretations are often subjective and may lead to conflicting views (Li, 2014). Developed and developing countries maintain distinct interpretations about how their land use contributes negatively to climate change (Meyfroidt et al., 2022), which makes it very difficult to agree on binding commitments (Blaxekjær et al., 2020; Leinaweaver and Thomson, 2021; Ruiz-Campillo, 2024).

Although the UNFCCC is celebrated for showcasing the world's ability to collaborate, many observe that the conference falls short of its goals. Some scholars argue that failures of the UNFCCC to adequately tackle climate change have led to the emergence of alternative political spaces and transnational governance models (Chatterton et al., 2013; de Moor, 2023). This theory of "independent globality" suggests that new frameworks, beyond the UNFCCC, may be necessary to address the complexities of land use and climate change. Alternative spaces may also be necessary due to challenges of reaching consensus between developed and developing nations. Despite being a platform for global collaboration, the UNFCCC often fails to meet its commitments to the developing world and excludes meaningful participation from civil society and indigenous communities (Kinley et al., 2021; Maslin et al., 2023).

The reason that decisions about Land are disappearing from the UNFCCC may also have to do with the way that it makes decisions. Each decision creates new arenas to deal with climate policy issues, especially within REDD+ and LULUCF. Indeed, many of the Land decisions reference such mechanisms. An hypothesis that this study did not explore is whether external bodies that deal with Land are becoming more efficient, and thus the UNFCCC did not require further decisions to deal with Land topics. Additionally, the United Nations Convention to Combat Desertification, The UN Department of Economic and Social Affairs, FAO, CBD, and other UN bodies address Land issues within their own mandates, possibly diminishing the need for the UNFCCC to do so. While Land may be disappearing from UNFCCC decisions, it appears to still be a critical topic in global environmental policies.

A methodological concern of this study is the evaluation of a decision. It makes sense that decisions are enacted to tackle urgent problems. If a prior decision is efficiently tackling a problem, then we would expect decisions on that topic to decrease. An additional limitation of the current study is that we do not examine cause and effect between policy proposals and decisions. Aside from examining just decisions, we encourage researchers to further question how policy debates about Land have failed and succeeded to reach transnational climate agreements. Our analysis heuristic gave each decision and each conference equal weight in their respective analyses, but we must recognize that the impact of each conference and each decision is not equal. Rather than examining the texts in a vacuum, researchers should ask deeper research questions: What is the impact of each decision? What gaps occur between policies and the actual implementation of decisions?

Future researchers should explore the outcomes on the ground, as well as backstage dynamics that influence these decisions, such as the role of side events, advocacy, and informal discussions. Weights could be calculated and other empirical scaling methods could be devised. We also did not analyze the references to prior decisions. Such a network analysis would allow us to examine the intersection of decisions,

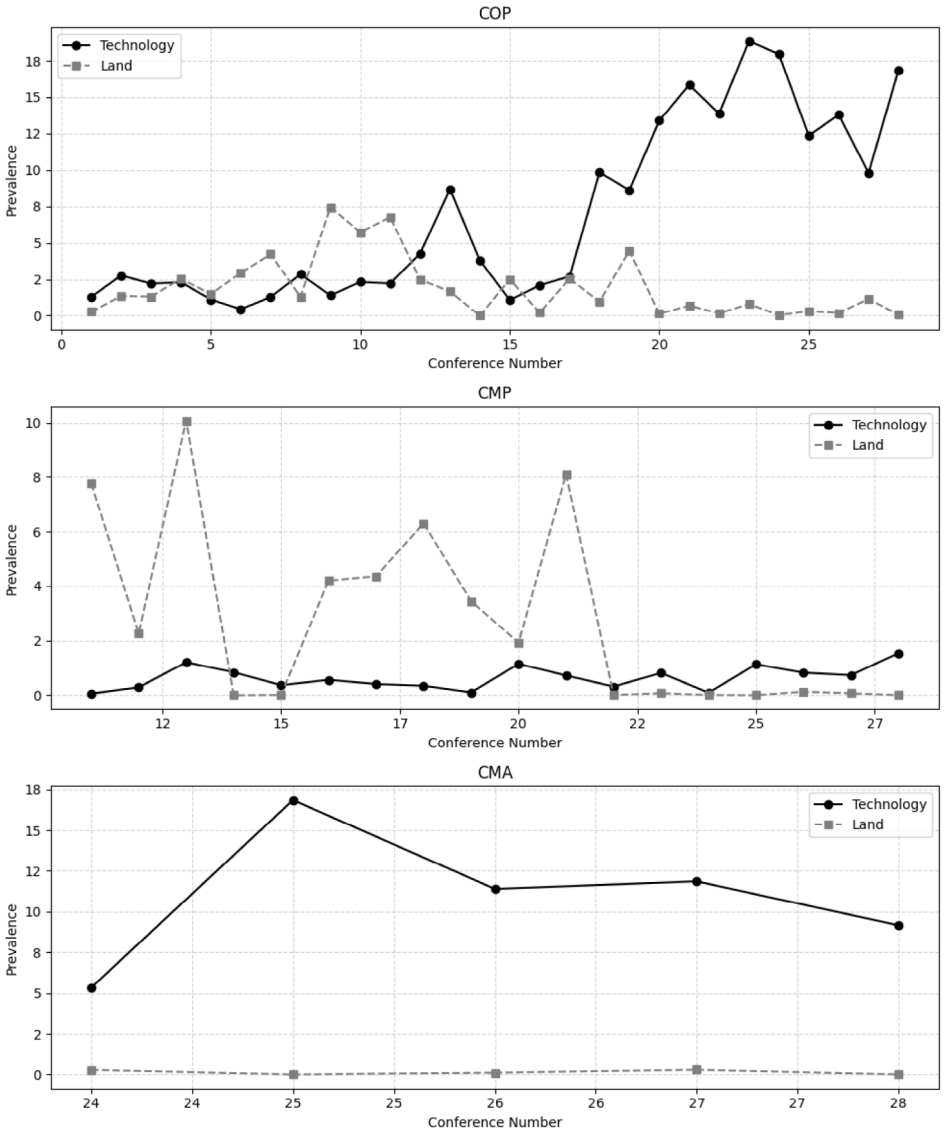


Fig. 12. GLDA prevalence of Land and Technology in each conference.

whereby a prior decision is invoked over time. Future NLP research on UNFCCC decision texts should employ other types of topic models: regular LDA, Dynamic LDA, Semantic LDA, BERT, and other methods. The current study relied on GLDA, because we wanted to replicate the 16 topics that the UNFCCC defined as its goals. Since beginning this study, the UNFCCC added 2 new topics for COP29 ("Just Transition" and "Climate Weeks") and another topic for COP30 ("Budget"). Land likewise was absent from the titles of COP29, and it remains to be seen whether another resurgence may happen in COP30 and beyond. In addition to incorporating these new topics, studies might attempt to focus on only those documents or phrase windows that specifically discuss Land to uncover its subtopics. Fortunately, future researchers will have the added benefit of more years of decisions and discourse to analyze.

7. Conclusions

We expected the topic analysis of UNFCCC decisions to show a clear pattern where Land rises, falls, rises and falls, or has a constant rate of prevalence. The results indicate that all of our hypotheses were wrong. UNFCCC decisions exhibit waves of Land inclusion, where Land appears in decisions one year and then disappears the next. These peaks and lulls might be explained by Punctuated Equilibrium Theory (PET, Gould and Eldredge, 1977). This theory has expanded to explanations of environmental policies (Baumgartner, 2008) and international organizations (Lundgren, 2018; Joly and Richter, 2020). Does the UNFCCC implement a Land decision and then wait a period of time before initiating a new decision on the same topic? The current period may represent the stasis phase of punctuated equilibrium, and we might witness another punctuated wave of Land decisions. Another competing theory is that Land experienced a policy bubble (Jones et al., 2014; Maor, 2014, 2025), whereby there was an overgrowth of political attention to REDD+ and LULUCF but unsustainable commitments. Unlike PET, which anticipates repeated waves, policy bubbles theory expects policy abandonment. Considering the disappearance of Land from more recent UNFCCC decisions, our most empirical conclusion is that Land experienced a policy bubble.

Since land use is still considered fundamental to mitigating climate change (Pongratz et al., 2021; Searchinger et al., 2018), it stands to reason that it should be included in UNFCCC decisions. Policy makers may be experiencing difficulties combining Land with other topics. Land occupies a peripheral location in topic networks. It occurs within the same conferences as other marginal topics. It is isolated within decisions. Land is a unique topic that dominates decisions, with

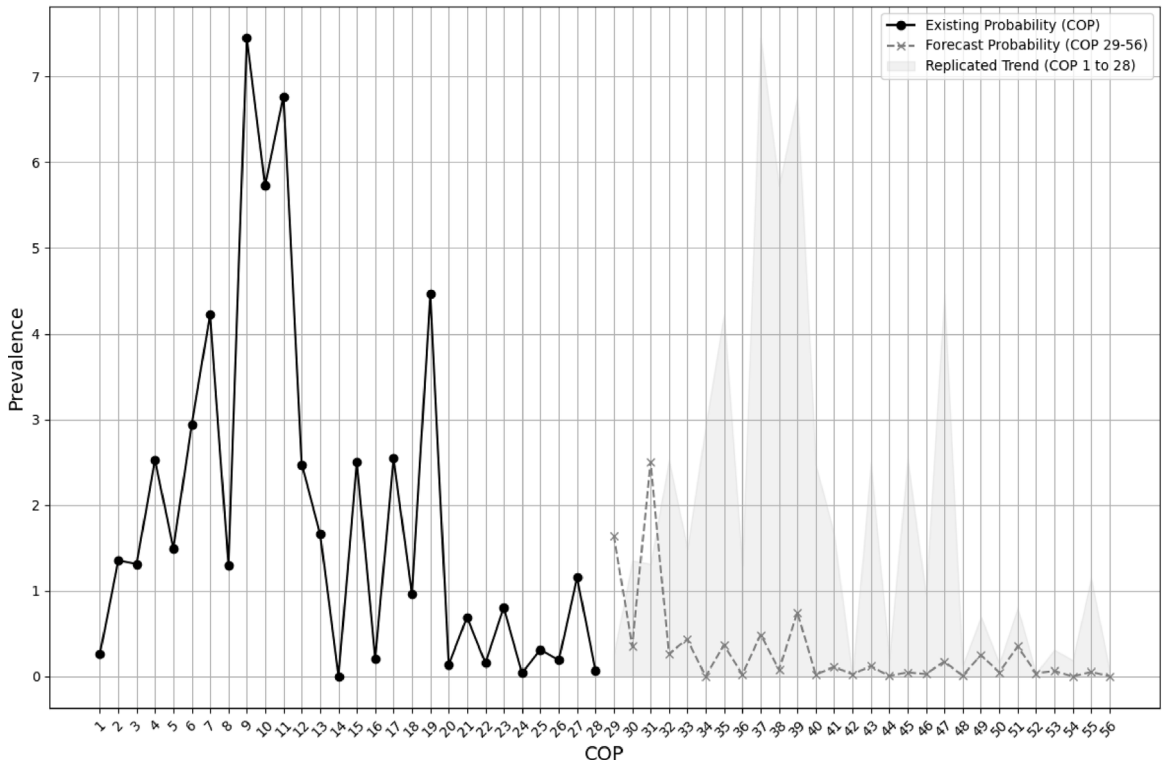


Fig. 13. SARIMA forecast probability and replicated trends of Land in COP.

numerous land decisions in one conference and then none in the next. It runs the risk of sputtering out entirely of the UNFCCC. Proponents of multilateral land use policy reforms should consider how to incorporate Land with other topics, especially central ones, such as Technology, Finance, Education, Adaptation, Ambition, and Innovation. Such strategies might help ensure that Land remains a central component of global climate action.

We conclude this study with a question: What will happen to Land in future UNFCCC decisions? In Fig. 13 we visualize two possibilities for Land's future inclusion in COP conferences. One possible future, based on a SARIMA forecast, depicts Land as a policy bubble. Land might increase slightly in the short term, but it will continue to sputter out of the conference. The other possible future, based on PET theory, presumes that we are at the end of a cycle and will once again see repeated waves (a replicated trend) of Land inclusion within COP decisions.

CRediT authorship contribution statement

Keith Goldstein: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Bruna Rodrigues:** Writing – review & editing, Validation, Investigation. **Pedro Jacobetty:** Software, Formal analysis. **Kathryn Hahn-Madole:** Software. **Helge Jörgens:** Writing – review & editing, Supervision, Project administration, Conceptualization. **Nina Kolleck:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Nina Kolleck, Helge Jörgens, Keith Goldstein, and Bruna Rodrigues report financial support was provided by the German Research Foundation through Nina Kolleck as Principal Investigator. The other authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors have nothing else to declare. The funders had no role in the study design, collection, analysis and interpretation of data, writing of the report and decision to submit the article for publication.

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Data availability

Data will be made available on request.

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