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Modelling Research Topic Trends in Community Forestry

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Abstract

How is community forestry (CF) research changing as CF policies mature around the world? In this research note we use bibliometrics and topic modelling to display trends in the geographic foci and research topics mentioned in the abstracts of CF-related research papers published between 1990 and 2017. We find that studies of CF in South Asia make up a substantial proportion of the literature, although CF research in Africa, Southeast Asia, and Latin America has also developed. Using a structural topic model, we identify four major research areas and 20 topics latent in the text of the abstracts analyzed. The trends of topic proportions over time offer evidence of a shift in research focus from broad policy analysis to local outcomes and growing interest in carbon sequestration. Results identify the most prominent CF research topics and demonstrate the potential of topic models to analyze large amounts of scientific literature.

Keywords Community-based forestry · Sustainable natural resource management · Bibliometrics · Topic modelling · Research gaps

Introduction

How has community forestry (CF) research been changing as CF policies mature around the world? CF, defined as policies, programs, or practices that seek to increase the role of local people in forest management planning and implementation (Center for People and Forests 2013), has become a "major modality" of global forest governance (Gilmour 2016). Budget reductions, pressure from researchers and international organizations, and 'grassroot' campaigns led by communities have helped motivate many governments to devolve forest

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management rights to local communities (Charnley and Poe 2007; Agrawal et al. 2008; Tole 2010). More than 732 million hectares of forest around the world are now managed under CF regimes (Food and Agriculture Organization 2015).

Although CF policies and programs have the potential to allow local communities to secure their tenure rights and achieve more sustainable outcomes, issues related to the equitable devolution of management authority and the long-term economic viability of operations in different contexts have often been significant obstacles (Tole 2010; Bowler et al. 2012; Gilmour 2016). As research has played an important role in shaping CF policies and realizing their adoption (Charnley and Poe 2007), CF's underperformance has led to calls for researchers to shift from "promotion to critical analysis" of these policies (Arnold 2001). In this research note, we investigate how the topics of CF research have changed since 1990. We apply bibliometric analysis and statistical topic modeling to a database comprising the abstracts of 1112 CF-related research papers published between 1990 and 2017 to explore trends in the geographic foci and identify prominent topics of research.

Methods

Data Collection

We developed a database of all abstracts returned by searches on Scopus and Web of Science (WoS) using the terms "community forestry", "community forest management", or "community-based forestry", resulting in 1481 unique entries. We then removed abstracts addressing "urban" forestry and those abstracts which did not mention "communities," "decentralization," "smallholders," or "local management", resulting in a final database (corpus) of 1112 entries. These entries were largely limited to abstracts of articles published in English and excluded most books and government reports as they are generally not indexed by WoS or Scopus. Nevertheless, the volume of data returned by our search includes most CF-related research publications over the study period and was deemed adequate to reflect the general trends of CF research. A list of all articles included in the database, as well as a breakdown by journal, can be found in the Supplemental Materials.

Once the corpus was finalized, each abstract was reviewed and manually coded with location data. For each abstract that used data from a single country, the country was recorded. Abstracts that compared multiple countries were coded as "Multiple." Abstracts that presented meta-analyses or literature reviews were coded as "Review." All other abstracts, i.e. those from studies lacking a specific geographic focus but presenting original research, were coded as "Theory." Finally, a "Region" variable was recorded for each abstract, grouping the different countries into larger geographic regions. Abstracts addressing CF in Mexico were coded as "Latin America" as many articles compare CF in Mexico to other countries across South and Central America.

Data Analysis

Data were analyzed using a computational linguistics technique called probabilistic topic modelling. The method assumes that a set of latent topics was used to generate the words observed in the documents. Those topics are identified by first considering documents in the corpus as collections of words. Sets of co-occurring words are then assumed to express the underlying topics that structure each document. We used Roberts et al.'s (2018) Structural Topic Model (STM) package for R. STM employs a Latent Dirichlet allocation (LDA) model where each document in a corpus is represented as a multinomial distribution across the set of topics in the corpus, and each topic as a multinomial distribution over the set of words in the corpus (Roberts et al. 2018). Words that are highly associated with a topic indicate its theme (Mohr and Bogdanov 2013). The frequency of those words in the corpus overall give an indication of that topic's prevalence relative to the other topics; we call this the topic's *expected proportion* because it is the algorithm's estimate of this unobserved information.

The STM package is particularly useful for topic modelling because it assumes that topics can be correlated with each other and that their distribution over the documents is structured by some observed covariates (Roberts et al. 2016). Several studies have previously used LDA to analyze the prevalence, distribution, and relationships of ideas or topics in a scientific field (Griffiths and Steyvers 2004; Hall et al. 2008; Bohr and Dunlap 2017). Blei (2012) gives a deeper, but still accessible, overview of topic modelling.

Our data were organized in a comma separated values file with each row recording an article's abstract, publication data, and location data. The STM package was used to process data. The *textProcessor* function, for example, removes punctuation and words appearing in fewer than five articles and "stems" words. Stemming ensures, for example, that terms like "manage," "management," "manager," and "managing" are all contained in the token "manag". After processing, the corpus comprised 2358 terms and 81,563 tokens. Since STM is capable of processing millions of words at a time, this is a relatively small database. However, other authors have presented meaningful findings from databases of similar size. Bohr and Dunlap (2017), for example, built a topic model for the environmental sociology literature using 815 abstracts.

Finally, a model was estimated using the *stm* function. STM requires the analyst to specify a certain number of topics (K) before model estimation. Although there is no "best" number of topics for a given corpus, several metrics exist to guide K specification. A semantic coherence score approximates topic interpretability. When the most probable words for each topic often occur together within documents, the model will score highly on semantic coherence. Topic exclusivity scores, which identify models in which highly-frequent words are divided across multiple topics, were also considered. In practice, model selection is an iterative process. Multiple models are estimated and the most sensibly interpretable one is then chosen by the researcher (Bohr and Dunlap 2017). Semantic coherence and topic exclusivity suggested a model of approximately 20 topics for our corpus. After running models for Ks of 16 through 24, the 20-topic model was selected for additional analysis.

Assumptions and Limitations

The data export capabilities of Scopus and WoS make it easy to construct a comprehensive database of research abstracts but cannot be used to gather full research papers. Our analysis therefore assumes that useful information about a paper's research topics is present in its research abstract. Although previous research has used the abstracts of papers to construct topic models (e.g. Griffiths and Steyvers 2004; Bohr and Dunlap 2017), we recognize that abstracts may be inconsistent with the text of the full paper (Pitkin et al. 1999). However, Griffiths and Steyvers (2004) note that one of the main purposes of an abstract is to inform readers of the topics addressed in a paper, and there is evidence that research topics are usually presented in abstracts (Dos Santos 1996). Nevertheless it should be noted that the model presented here strictly represents topics present in the abstracts of the papers gathered through database searches.

It is also important to keep in mind the nature of the topics generated by topic models. In these models a topic is defined as a "distribution over a fixed vocabulary" (Blei 2012). Mohr and Bogdanov (2013) describe it as the "constellation of words that tend to come up in a discussion." Topics represent "hidden structure" in documents, which are assumed to have been generated by selecting topics to write about and then selecting words associated with those topics (Blei 2012). The reliability of these models depends on the concordance between the hidden linguistic structure they represent and the thematic patterns in which we are interested (Blei 2012). To enhance validity, models are generated iteratively and models with "substantive interpretability" are selected for further analysis (DiMaggio et al. 2013). Model selection is also guided by metrics such as a semantic coherence score, which has been shown to reflect human judgements of topic quality (Chang et al. 2009; Mimno et al. 2011). However, Roberts et al. (2014) caution that such models do not replace human judgement. The insight provided by the model is maximized for readers who are already familiar with the literature under examination. The value of a topic model is the ability to quickly analyze large sets of documents and compare the results against a researcher's theoretical expectations (Blei 2012; Roberts et al. 2014).

In this paper, the topics are presented and then labelled. Those labels, meant to enhance data visualization, are our thematic interpretations of the words that were highly associated with each topic and were not generated by the model itself.

Results

Growth of CF Research

Based on our results, CF research has expanded greatly around the globe, especially since 2000 (Fig. 1). South Asia, the focus of 360 papers, or 32% of the database, is the most-studied region (Fig. 2). The gap between CF research in South Asia and the other regions has continually widened, with a noticeable increase in the rate of publications since 2013. Both Latin America and Africa have been the focus of more

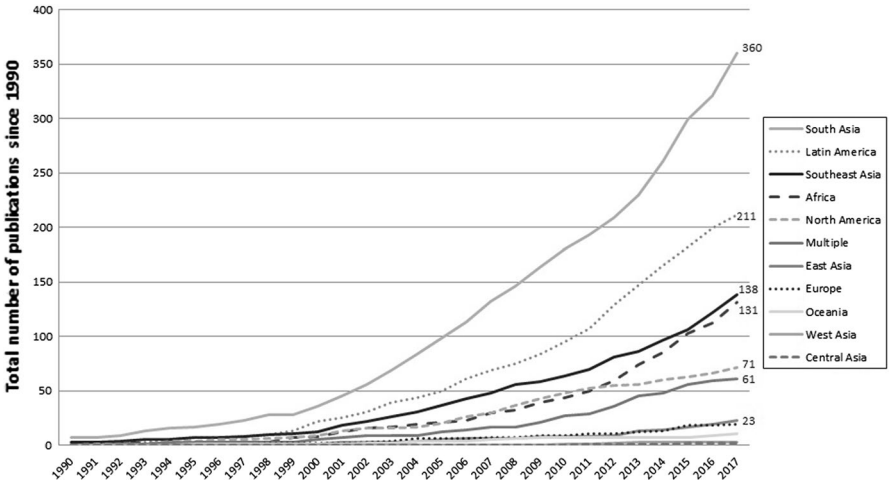

Fig. 1 Total number of CF articles published by region, 1990–2017

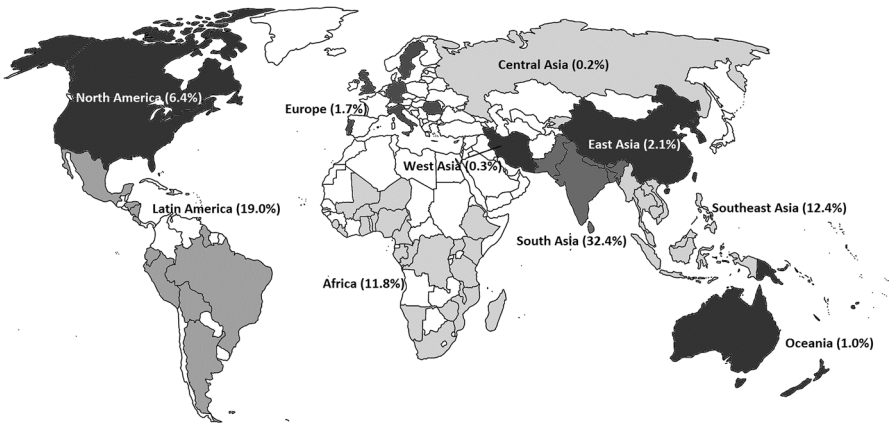

Fig. 2 Countries for which CF studies have been published, shaded by region. Percentages indicate what percent of the CF studies in the database focused on a country in this region

articles in the last five years, with, respectively, 211 (19%) and 131 (12%) total studies published as of 2017. Southeast Asia is the only other region in which more than 100 CF studies have been conducted. 71 studies have been conducted in North America (excluding Mexico), but just 16 of these have been published since 2012. Relatively few publications have analyzed CF in East Asia, Europe, Oceania, West Asia, or Central Asia. A description of how these regions are defined can be seen in Fig. 2 and in the Supplemental Materials.

The number of published articles without a geographic focus has also consistently increased since 1990 (Fig. 3). These articles are mainly reviews or economic models. The publication rate of reviews, especially, has increased in recent years. Overall, annual CF research, as measured by articles published per year, has been

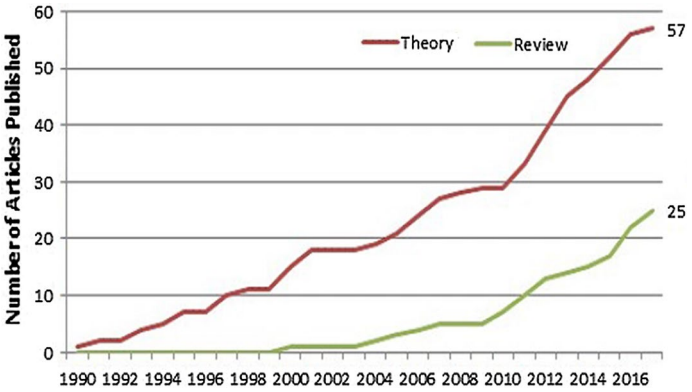

Fig. 3 Number of CF articles without a geographic focus published per year, 1990–2017

increasing consistently since 1990 (Fig. 4). 2015 and 2017 were the most productive years.

Our database draws on articles from 281 different journals, but the distribution of publications by journal is highly unequal. The top five journals by publication count are *Forest Policy and Economics* (87 studies), *International Forestry Review* (76), *Small-scale Forestry* (46), the *Journal of Sustainable Forestry* (42), and *Society and Natural Resources* (39); together, they contributed 26% of the CF studies we analyzed. The Supplemental Materials include a full list of publication count by journal.

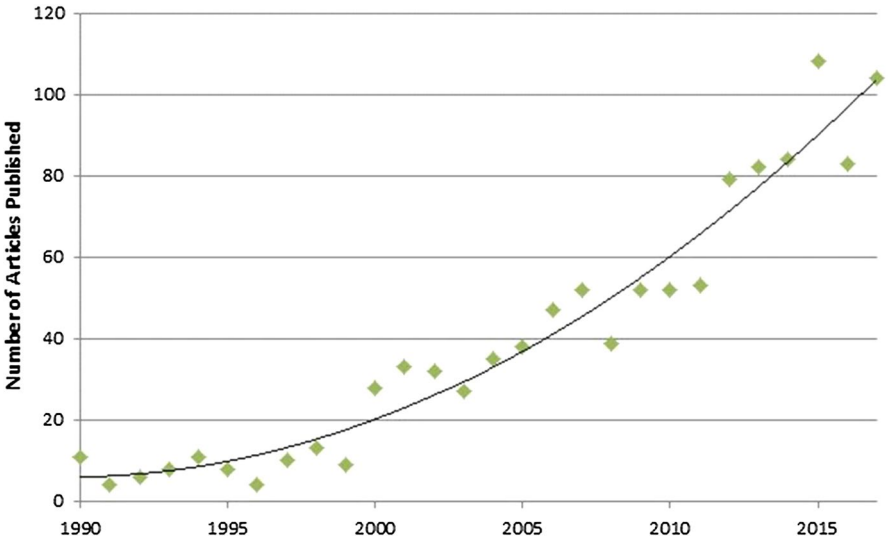

Fig. 4 Number of CF studies published per year, 1990–2017

Topic Proportions

The most prevalent topics in the corpus focus on policy questions (Fig. 5). Topic 1, "CF Policies," makes up almost 8% of the total discussion. It is highly associated with words including "policies," "reform," "govern," "programme." This indicates that abstracts associated with this topic tend to discuss policy changes and government programs. Other prevalent topics focus on management arrangements and community involvement. For example, Topic 3, "Joint Management," is associated with words like "institutions," "arrangements," "state," and "rights," while Topic 13, "Local Management," focuses on words like "use," "stakeholder," "knowledge," and "plan." Topic 9, "Resource Users," is the second-most prevalent topic in the corpus and includes terms like "household," "benefits," "income," and "poor."

Topics related to more specific domains of research within the CF literature are less prevalent. Topic 20, "CFEs and Certification," accounts for only about 2.5% of the corpus and associates with technical terms like "certify," "logging," and "costs." Topics 15 and 14 are similarly technical. Topic 15, "Land Cover Change," associates

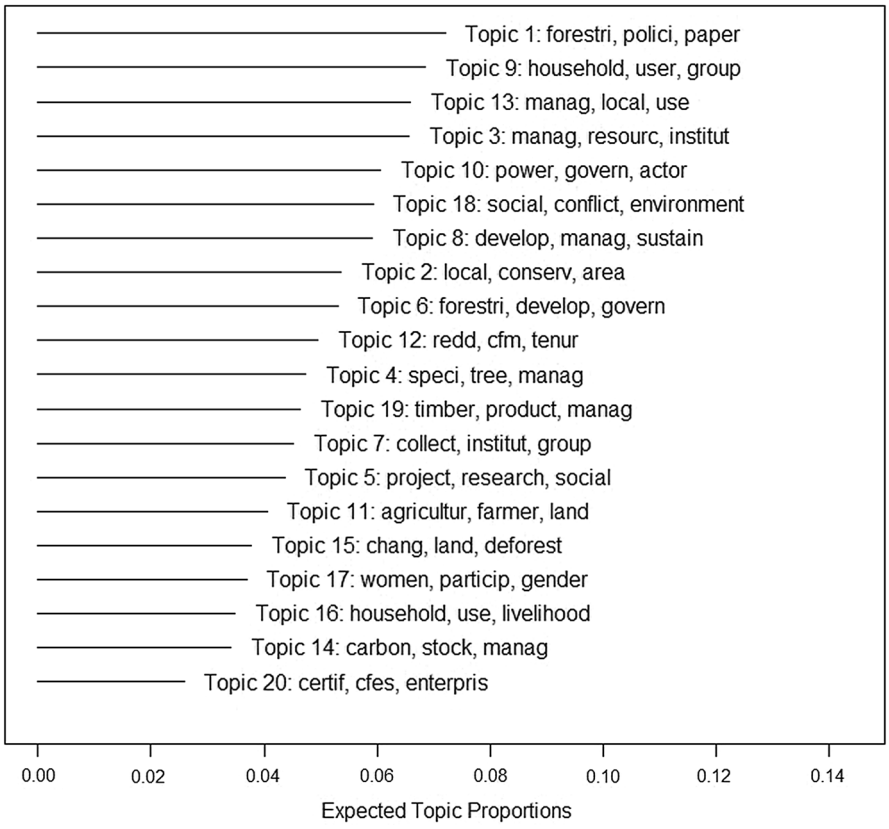

Fig. 5 Expected proportion over entire corpus for all topics

with the tokens "chang," "land," and "deforest." Topic 14, "Carbon Sequestration," relates to carbon accounting and includes the term REDD, a reference to the United Nations' "Reducing Emissions from Deforestation and Forest Degradation" program (REDD+).

The labels introduced above are meant to clarify the meanings of the topics. They are not output by the model, but instead are our interpretations based on the words that the model associates frequently and exclusively with that topic. A list of all the topic labels can be found in the Supplemental Materials.

Topic Correlations

The STM package can also analyze how often topics co-occur within the same document to discover correlated topics. When pairs of topics with covariance > 0.01 are mapped, four distinct groups of correlated topics emerge (Fig. 6). The topics separate into a "policy and power" group (1), a "community institutions and outcomes"

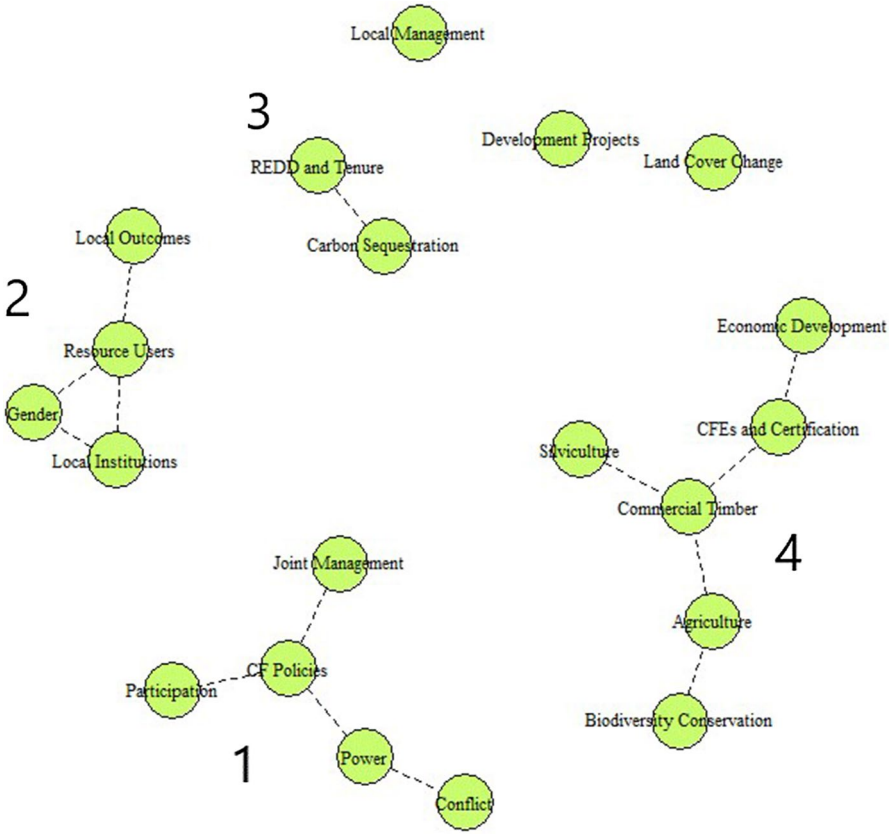

Fig. 6 Topic correlation map. Dashed lines indicate topic pairs with covariance > 0.01. Four main groups of correlated topics are identified

group (2), a "carbon sequestration and tenure" group (3) that includes REDD + discussion, and a large group of topics related to "economic activities" like logging and agriculture (4). Discussion of community forest enterprises (CFEs) is also part of this group. CFEs are the small businesses usually created by community members under CF policies to organize forest management and business activities. They are the most common mechanism by which communities may obtain and distribute economic benefits (Butterfield et al. 2005).

"CF Policies," "Local Institutions," and "Resource Users" are the three most prevalent topics in the corpus and are all correlated with multiple other topics. This may indicate that these are core CF topics, as they are often discussed in abstracts and are more likely to be connected to other topics. In contrast, "Local Management," "Development Projects," and "Land Cover Change" are not correlated with any other topics. Article abstracts that reference these topics tend not to use language associated with other topics.

Changes in Topic Prevalence

By including each abstract's year of publication in the topic model, changes in expected topic proportion over time can be assessed. The model uses the word frequencies in abstracts published in a given year to estimate the topic proportions for that year. In this section, we use these trends to assess how CF research has changed since 1990.

Abstracts have become much more likely to mention REDD + and carbon sequestration (Fig. 7). This increase is unsurprising since the UN-REDD program started in 2008 (Cotula and Mayers 2009). However, the extent to which these issues have grown in importance is striking. Despite its recent emergence, the "REDD + and Tenure" topic is the tenth most prevalent in the entire corpus. For the past two years, "REDD and Tenure" has been one of the most commonly discussed topics in the corpus.

"Resource Users" and "Local Outcomes" are the other topics which display marked increases in proportions. The rise of these topics, which share highly associated words like "households," "users," and "benefits," may show that research has become more likely to investigate the effects of CF policies in terms of local participation and benefits.

Topic changes are assessed according to their relative proportion in the corpus, so rising discussion of some topics must come at the expense of certain other topics. The "CF Policies" and "Participation" topics have declined the most (Fig. 8). The language associated with these topics generally references policies and policy processes. The stems "polici" and "reform" are related frequently and exclusively to "CF Policies" and "coopera" and "collabor" are related frequently and exclusively to "Participation." The decline of these topics in research abstracts, therefore, may reflect movement in the CF literature away from broad, policy-oriented research and towards local outcomes and technical research, as described in the previous section. This would align with Arnold's (2001) call for CF research to move from "promotion to critical analysis" (p. 113).

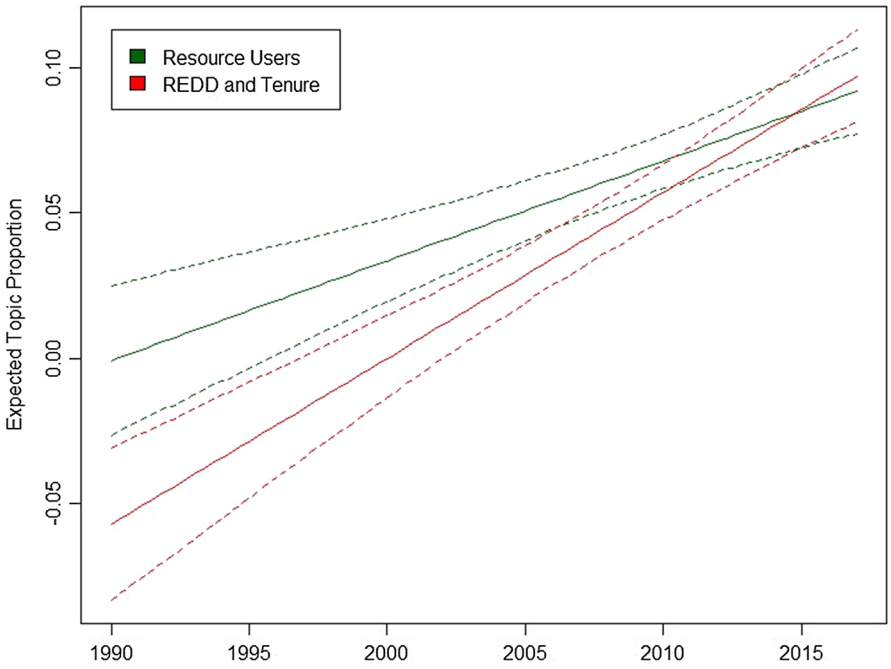

Fig. 7 Expected topic proportion trends for "Resource Users" and "REDD and Tenure" topics from 1990 to 2017, 90% confidence intervals

However, since these topic trends are measured in terms of their *expected proportion*, it should be noted that, given the large overall increase in the number of CF articles published between 1990 and 2017, these topics are not necessarily discussed less often today. Rather, their relative decline could just reflect the pursuit of more research topics over time. Most topics do not reflect a clear increase or decrease in relative proportion over time (Fig. 9).

Discussion

Trends in the Geography and Topics of Research

The results of this study highlight several important trends in the evolution of CF research. First, they describe the geographic trends in CF research since 1990. South Asia, Southeast Asia, Africa, and Latin America are well represented in the literature. Countries in those regions are mentioned in 863 of the studies in the database with a geographic basis (87%).

South Asia is important in CF research. Out of a total 994 studies with a geographic focus, 360 (36%) discuss CF in South Asian countries. More than a quarter of the abstracts focus on Nepalese CF (254 studies). These data corroborate the findings of Mai et al. (2011) who, in a review of gender analysis in forestry research,

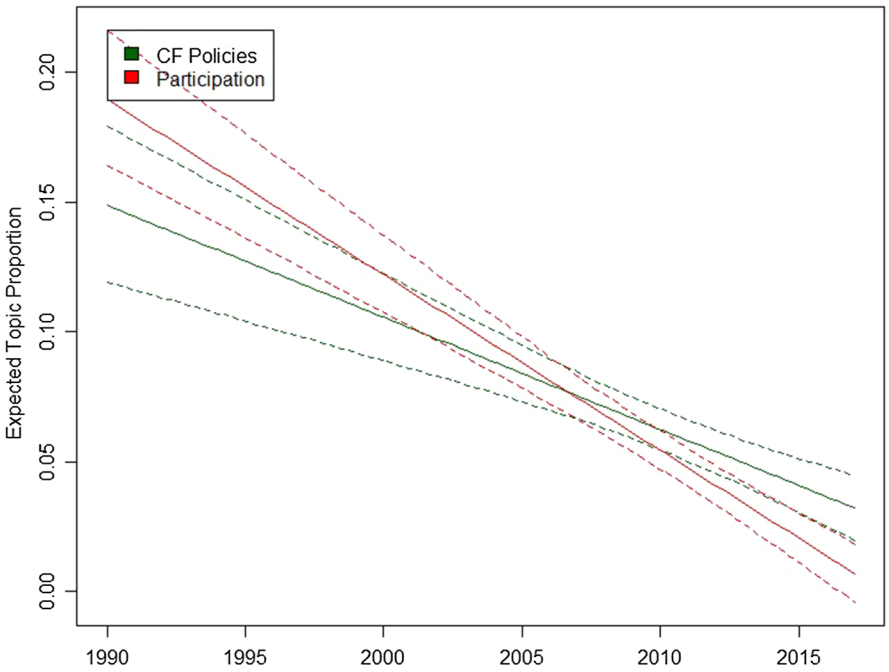

Fig. 8 Expected topic proportion trends for "CF Policies" and "Participation" topics from 1990 to 2017, 90% confidence intervals

found that CF studies were most often conducted in South Asia. They attribute the geographical concentration of CF research in South Asia to the region's longer history in forest management devolution. However, our data show the research gap between South Asia and the rest of the world has continued to widen even in recent years. The gap in output between South Asia and all other regions may raise questions concerning generalizability. CF outcomes are influenced by a wide variety of contextual variables (Cox et al. 2010). These include the biophysical environment, community institutions, national legal frameworks, and political context (Pagdee et al. 2006). Policy recommendations suitable for one set of institutional and biophysical conditions may not succeed when adopted in a different context (Ostrom and Cox 2010). Therefore research on CF would benefit from further description and analysis of CF experiences across a greater diversity of contexts. Many countries in Southeast Asia, Latin America, and Africa now have decades of experience with CF from which researchers may draw (see e.g. de Jong et al. 2010; Tole 2010; Poffenberger 2006).

Our analysis also shows the influence of a growing interest in carbon sequestration, especially REDD+. The "REDD and Tenure" topic has grown to be one of the most prevalent topics in the corpus in recent years. It is noteworthy that words relating to tenure and words relating to REDD + co-occur so frequently that the model combines them into one topic. To illustrate, the highest probability words for this topic are "redd," "cfm," "tenure," "local," and "rights."

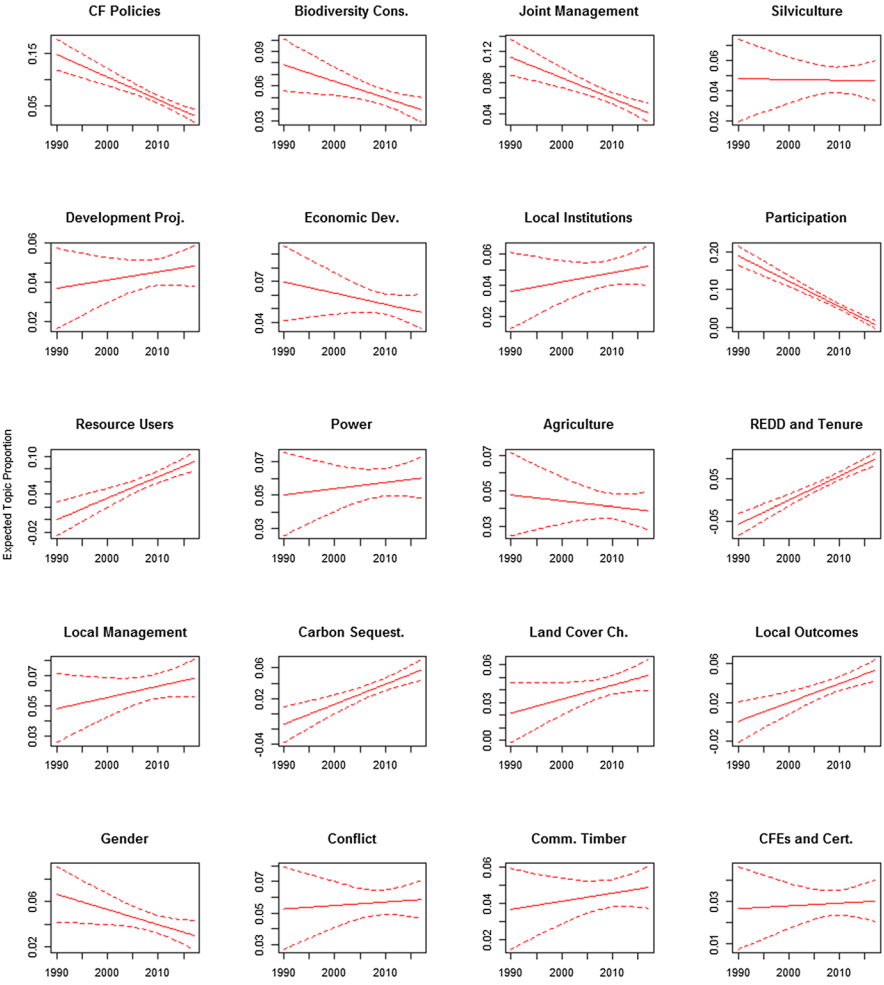

Fig. 9 Expected topic proportions for all topics from 1990 to 2017, 90% confidence intervals

Furthermore, the model associates the words "tenure," "climate," and "emissions" frequently and exclusively with this topic. REDD+, first launched in 2008, is a United Nations Framework Convention on Climate Change program meant to enhance forest carbon stocks. It allows developed countries to partially offset CO_2 emissions by financing efforts to reduce deforestation and forest degradation in developing countries (Mateo-Vega et al. 2018). REDD+ and CF policies may be complementary (Agrawal and Angelsen 2009). However, several authors have noted that tenure concerns are one of the most controversial aspects of the REDD+ (Larson 2011; Cotula and Mayers 2009) and the model indicates that one is rarely discussed without referencing the other. CF has often been seen by communities as a way to strengthen their tenure claims (Larson et al. 2008). The model's combination of REDD+ and tenure issues into a single topic supports

claims made by other authors that this process is carrying over into the REDD+ process (e.g. Larson et al. 2013).

Several topics that relate to measuring local outcomes have risen in expected proportion over time. "Resource Users" has increased significantly and is the second-most prevalent topic across all abstracts. The "Local Outcomes" topic also shows an increase. This means that words like "users," "benefits," "income," "livelihoods," and "surveys" have become more common in CF research abstracts. This shift could represent a tightening of research focus from foundational research to more localized analyses. It could also be evidence of a change in research objectives from promotion to evaluation of outcomes for resource users and communities. Both cases would be consistent with Arnold (2001)'s call for more critical analysis of CF. Research into CF should continue broadening the geographic distribution of analyses to document the performance of such policies in different contexts.

Topic Models and Natural Resource Sciences

This study adds to a growing body of research using topic models to understand trends in scientific fields (e.g. Griffiths and Steyvers 2004; Hall et al. 2008; Bohr and Dunlap 2017). We are not aware of any previous studies that have extended these techniques to natural resource management issues. Considering the ability of topic models to quickly analyze very large sets of textual data and use language to compare topics across disciplines, it may be helpful to apply them more widely in the natural resource management literature. Such methods can help researchers understand trends, disciplinary breakdowns, and common themes for much larger literatures than could be manually reviewed.

The limitations of the model are also displayed in this paper. First, it requires a degree of previous familiarity with the literature to interpret the significance of the topic proportions and highly-associated words. Second, it is difficult to judge why topic proportions change over time. Topic modelling is most useful as an exploratory technique to examine changes in scientific topics, quickly identify prominent topics, and compare the results of the model to the researcher's expectations (Blei 2012).

Conclusion

Using abstracts of CF studies indexed by Scopus and WoS between 1990 and 2017, we have shown a striking growth of CF research around the globe and especially in Asia, Latin America, and Africa. We then modeled the topics addressed in the text of these abstracts using Roberts et al. (2018)'s STM package for R. Increases in language discussing the effects of CF policies on local users and research about REDD+ and tenure issues are the most remarkable trends shown by the topic modelling data. Overall there is some evidence that CF research is changing to address new issues like REDD+ and focus more on local outcomes. Although strict conclusions are difficult to draw from topic models alone, analysts interested in understanding

overall trends in scientific fields stand to benefit from using the impressive information-processing capabilities of these models.

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