Social network and contact analysis of the North American Carbon Program as a scientific community of practice

Objectives:

- This investigation uses a conceptual framework from social science to explore the role that the North American Carbon Program (NACP) has played in connecting researchers into a carbon cycle knowledge network and in enabling them to conduct physical science that includes ideas from social science.
- The conceptual framework used is a community of practice (CoP) model in which a CoP is defined as "a group of people who share a common set of problems, a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis".
- A CoP has three structural elements: domain (knowledge concerns and issues); community (people and relationships); and practice (rituals, systems of meanings, and communication).
- The domain of the NACP is defined as: "to study the sources and sinks of carbon with the expectation that the resulting knowledge should ultimately be accessible and salient to stakeholders at a variety of levels".
- The CoP model also identifies distribution of participants in three groups corresponding to investment in the community: core members who attend meetings and oversee tasks; active members who regularly attend; and peripheral members who participate occasionally.
- The authors use keyword analysis in order to derive the topics of research being produced by the NACP and to compare them to the knowledge goals (domain) of the program.
- The authors also conduct a co-authorship social network analysis derived from publications of core NACP members to describe the structure and social pathways within the community.
- Two datasets are used this study: the NACP Project database and a bibliographic dataset from the Multidisciplinary ISI Web of Science.
- For the keyword analysis, abstracts of articles published by NACP members were compared to a list of dictionary terms and phrases that referenced different aspects of human processes and experiences relevant to integration with carbon cycle science.
- The products of the network analysis on both the NACP database and the bibliographic database were network graphs that illustrated connectivity and co-authorship ties.
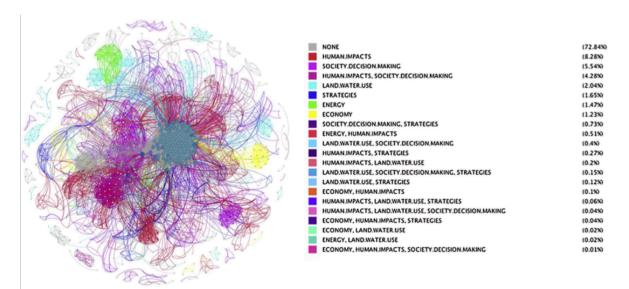
New Science:

- This study found an increase in the use of social and economic topics in interdisciplinary carbon cycle science research associated with the NACP members and the papers they have published from 2007 – 2013.
- Results of the co-authorship social network analysis demonstrate that the NACP has formed a tightly connected community with many social pathways through which knowledge may flow, and that it has expanded its network of institutions involved in carbon cycle research over the past 7 years.
- Of 2447 articles written by at least one core member, 57% contained at least one human-related carbon cycle keyword, with keywords reflecting society and decision making, land and water-use and human impacts most prevalent.
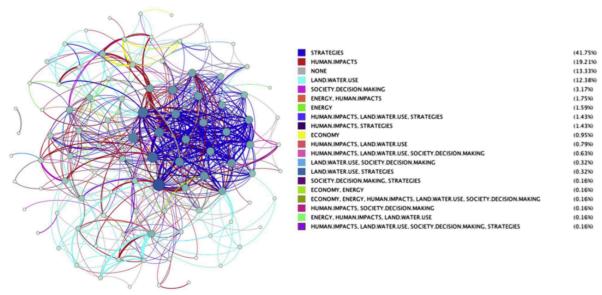
- Of 408 total project abstracts analyzed, 66% contained at least one human related carbon keyword, and the distribution of topics was similar to that found for the article abstracts.
- There was a 29% increase in the bibliographic journal articles referencing a human-related carbon cycle science keyword for articles co-authored by more than two NACP-core members from 2007-2013.
- The co-authorship network graphs show that in 2007 only about one third of the NACP scientists were connected to each other and the connections were fragmented; over time, however, a highly interconnected network has emerged.
- The tightly clustered network of the of the core NACP co-authorships supports the hypothesis that the NACP is a community both in name and in practice, and that myriad social pathways exist for knowledge sharing and collaboration across the majority of members.
- The summary statistics and the network analysis suggest that different institutions within the NACP community are becoming more interconnected. However, the tightly clustered network may also suggest that the community is fairly insular, working more with each other than with those on the periphery.

Significance:

- Central to the NACP's science agenda is the engagement of social, economic and policy-relevant research in order to improve how carbon cycle science is conducted to ensure policy-relevant findings.
- The challenges facing the NACP bring to light larger issues as to how organizations, agencies, and nations at any level can cultivate the development of interorganizational and interdisciplinary networks targeted toward creation of specific kinds of knowledge resources.
- This research demonstrates the value of content analysis and social network analysis using publication data for assessing a CoP's knowledge production against its professed knowledge domain, and this has implication for the ability of the community to realign itself with goals.
- Future research is suggested that focuses on analyzing the attributes of individuals within community to identify insights into influences and motivations for change within a community, as well as an understanding of which individuals tend to drive change and how they do so.
- Cause and effect cannot be clearly connected by network analysis and it is noted that the analysis presented in this paper cannot determine the reasons why the NACP network has changed over time.
- It is not clear from this analysis that the process of connecting science and decision makers is being undertaken; previous research has shown that just because research is policy-relevant it does not mean that policy makers will use it.

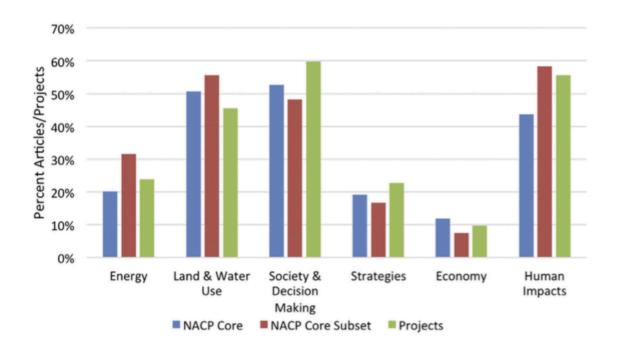| NONE | (72.84%) |
HUMAN.IMPACTS	(8.28%)
SOCIETY.DECISION.MAKING	(5.54%)
HUMAN.IMPACTS, SOCIETY.DECISION.MAKING	(4.28%)
LAND.WATER.USE	(2.04%)
STRATEGIES	(1.65%)
ENERGY	(1.47%)
ECONOMY	(1.23%)
SOCIETY.DECISION.MAKING, STRATEGIES	(0.73%)
ENERGY, HUMAN.IMPACTS	(0.51%)
LAND.WATER.USE, SOCIETY.DECISION.MAKING	(0.4%)
HUMAN.IMPACTS, STRATEGIES	(0.27%)
HUMAN.IMPACTS, LAND.WATER.USE	(0.2%)
LAND.WATER.USE, SOCIETY.DECISION.MAKING, STRATEGIES	(0.15%)
LAND.WATER.USE, STRATEGIES	(0.12%)
ECONOMY, HUMAN.IMPACTS	(0.1%)
HUMAN.IMPACTS, LAND.WATER.USE, STRATEGIES	(0.06%)
HUMAN.IMPACTS, LAND.WATER.USE, SOCIETY.DECISION.MAKING	(0.04%)
ECONOMY, HUMAN.IMPACTS, STRATEGIES	(0.04%)
ECONOMY, LAND.WATER.USE	(0.02%)
ENERGY, LAND.WATER.USE	(0.02%)
ECONOMY, HUMAN.IMPACTS, SOCIETY.DECISION.MAKING	(0.01%)

Co-authorship network using project data from all NACP members. The network has 1007 people with 16,518 connections and 15,716 unique edges. The nodes of the graph are colored by the degrees of connection, so that a darker blue represents the degree of connectedness of nodes. The node sizes are also categorized by the degree of connections. The edges are colored by the keywords associated between two pairs of nodes, the meaning of which is provided in the legend.

STRATEGIES	(41.75%)
HUMAN.IMPACTS	(19.21%)
NONE	(13.33%)
LAND.WATER.USE	(12.38%)
SOCIETY.DECISION.MAKING	(3.17%)
ENERGY, HUMAN.IMPACTS	(1.75%)
ENERGY	(1.59%)
HUMAN.IMPACTS, LAND.WATER.USE, STRATEGIES	(1.43%)
HUMAN.IMPACTS, STRATEGIES	(1.43%)
ECONOMY	(0.95%)
HUMAN.IMPACTS, LAND.WATER.USE	(0.79%)
HUMAN.IMPACTS, LAND.WATER.USE, SOCIETY.DECISION.MAKING	(0.63%)
LAND.WATER.USE, SOCIETY.DECISION.MAKING	(0.32%)
LAND.WATER.USE, STRATEGIES	(0.32%)
SOCIETY.DECISION.MAKING, STRATEGIES	(0.16%)
ECONOMY, ENERGY	(0.16%)
ECONOMY, ENERGY, HUMAN.IMPACTS, LAND.WATER.USE, SOCIETY.DECISION.MAKING	(0.16%)
HUMAN.IMPACTS, SOCIETY.DECISION.MAKING	(0.16%)
ENERGY, HUMAN.IMPACTS, LAND.WATER.USE	(0.16%)
HUMAN.IMPACTS, LAND.WATER.USE, SOCIETY.DECISION.MAKING, STRATEGIES	(0.16%)

Co-authorship network using article database of 1555 connections resulting in 630 unique edges between 99 core NACP scientists. The nodes of the graph are colored by the degree of connection so that a darker blue represents the degree of connectedness of nodes. The node sizes are also categorized by the degree of connections. The edges are colored by the keywords associated between two pairs of nodes, the meaning of which is provided in the legend.

(a) CoP model proposed distribution		(b) Observed attendance distribution (n=808)	
Core	10–15%	3–4 Meetings	14.7%
Active	15–20%	2 Meetings	22.8%
Periphery	65–75%	1 Meeting	62.5%

Theoretical and observed participation distributions. The theoretical model for CoP (a) proposes three levels of community involvement and suggests distribution ranges for the proportion of the community which will fall into each level; (b) summarizes the attendance frequency distribution for individuals (n=808) who attended the most recent four NACP meetings between 2007 and 2013.

Results from content assessment for articles and projects by human-related carbon cycle keyword category.