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Executive Summary of Activities

The Aspen Global Change Institute (AGCI) convened a week-long interdisciplinary science workshop from September 15-20, 2019 entitled, "Impacts of Land Use and Land Management on Earth System Evolution, Biogeochemical Cycles, Extremes, and Inter-Sectoral Dynamics." The purpose of the workshop was to advance research on the impacts of land use and land management on climate, carbon emissions, and extremes, as well as the impact of land-use change on important societal issues such as food, water, and energy security. The workshop was co-chaired by Kate Calvin (PNNL), George Hurtt (University of Maryland), and Dave Lawrence (National Center for Atmospheric Research). Co-funders of the workshop included NASA, NOAA, and travel support for European colleagues through CRESCENDO.

This workshop brought together 31 professionals with expertise across biogeochemistry, climate impacts, mitigation, land use datasets, and societal impacts to coordinate on upcoming research and publications on the role of biogeochemical and biophysical properties of the Earth surface

and their implications for climate, as conducted through the Land Use model Intercomparison Project (LUMIP), which is part of Phase 6 of the Coupled Model Intercomparison Project (CMIP6).

A primary outcome of the meeting was the definition and planning of a series of LUMIP papers that will rely on the LUMIP and CMIP6 simulations. By the end of the meeting more than twenty papers and paper lead authors had been identified and scoped out. Around ten of these papers were submitted by the December 31, 2019 IPCC deadline.

Accomplishments

Workshop Context and Goals

Human land-use activities have resulted in large changes to the Earth surface, with resulting implications for climate, carbon cycling, and society. In the future, land-use activities are likely to expand and intensify further to meet growing demands for food, fiber, and energy. Broadly, the biogeophysical impacts of land-use and land-cover change (LULCC) on climate are relatively well-understood with observational and modeling studies agreeing that deforestation has a cooling effect at high latitudes and a warming effect in the tropics with more uncertain changes in the mid-latitudes.

Despite this growing consensus of understanding, substantial disagreement remains across models in terms of their simulated regional climate response to LULCC with some observed effects not captured by models, contributing to a lack of confidence in projections of regional climate change. Furthermore, projections of future land-use change differ substantially depending on emissions pathway with lower emission projections requiring large-scale adoption of either afforestation or biofuel policies. These different projected land-use trajectories are an additional source of uncertainty that has not been examined systematically.

The biogeochemical impact of LULCC relates to emissions of greenhouse gases (GHGs) in response to LULCC. Models estimate that the net LULCC carbon flux accounts for ~25% of the historic increase in atmospheric CO_2 concentration, but this LULCC-driven carbon emissions remains one of the most uncertain aspects of the global carbon budget. Models exhibit a broad range for LULCC-driven historic and future emissions.

There is growing recognition that it is not just land-cover change that is important to model, but that the details of land use matter greatly and that land management or land-use intensification can have as large of an impact on climate as land-cover change itself. Only about 18-29% of the ice-free land surface has undergone land-cover change while a much larger fraction of the planet (42-58%) has not experienced land-cover change per se, but is nonetheless managed, sometimes intensively, to satisfy human demands for food and fiber. Recent studies have found that the temperature impacts can be equivalent for land-management change and land-cover change.

For example, irrigation, which has increased substantially over the 20th century, can directly impact local and regional climate. Explicit representation of the crop phenology is also important Representing harvest, grazing, and tillage resulted in cumulative land-use related carbon loss that was 70% greater than in simulations without these processes. Furthermore, agricultural practices can mitigate heat extremes through the cooling effects of irrigation, due to enhanced evapotranspiration associated with cropland intensification, or by increasing surface albedo by transitioning to no-till farming. Recognition that land management impacts climate and the carbon cycle leads to questions about whether or not specific land management can be employed as a tool for climate mitigation.

Human population and affluence is expected to increase which, in combination with the increasing importance of bioenergy, will drive surging demands for food and fiber. Expansion of land-use into relatively untouched parts of the world may be able to satisfy some of the growing demand, but intensification is also likely to play a strong role. Therefore, we anticipate an increasing contribution from land-management changes to the overall impacts of LULCC on the climate system. The requirement of negative emissions to achieve low radiative forcing targets also highlights the need for better understanding of the impacts and sustainability of carbon removal strategies requiring land-use or land management change such as bioenergy carbon capture and storage.

This workshop utilized new CMIP6 Earth System Model simulations designed to provide the most advanced assessment to date of the potential impacts of land use change and land management on climate. The Land Use Model Intercomparison Project (LUMIP) of CMIP6 aims to further advance understanding of the impacts of land-use and land-cover change on climate, specifically addressing the questions:

(1) What are the effects of land-use and land-cover change on climate and biogeochemical cycling in past and future? and
(2) What are the impacts of land management on surface fluxes of carbon, water, and energy, and are there regional land management strategies with promise to help mitigate against climate change?

In addressing these questions, LUMIP is addressing a range of more detailed science questions to get at process-level attribution, uncertainty, data requirements, and other related issues in more depth and sophistication than possible in a multi-model context to date. There was a particular focus on the separation and quantification of the effects on climate from land-use and land-cover change relative to all forcings, separation of biogeochemical from biogeophysical effects of land-use, the unique impacts of land-cover change versus land management change, modulation of land-use impact on climate by land-atmosphere coupling strength, and the extent that impacts of enhanced CO_2 concentrations on plant photosynthesis are modulated by past and future land use. Participants discussed broader impacts of these land use and land management options, including their implications for energy systems, security, water scarcity, water quality, biodiversity, and adaptation.

Workshop goals included:

- Assess the state of understanding and analysis with respect to the above science questions and planning additional analysis in the context of IPCC AR6.
- Clarify focus of the LUMIP community on the societal impacts of land use and land management, especially at low emission scenarios. Several recent studies and the IPCC special report on 1.5 degrees highlighted the potential role of land use in deep mitigation studies. However, these studies also identified potential trade-offs between land uses and other sustainable development goals. For example, a number of studies indicate that large-scale use of bioenergy and BECCS can increase food prices, with negative consequences for food security.
- Examine impacts of different forms of land management (e.g., agriculture, forestry, irrigation, urbanization) on climate and discussion of broader impacts of these land use and land management options, including their implications for energy systems, food security, water scarcity, water quality, biodiversity, and adaptation.
- Present and develop metrics, based on satellite data and bookkeeping approaches, that classify the fidelity of Earth System Model-simulated land use change impacts on climate and carbon cycling.
- Advance analysis of CMIP6 LUMIP experiments and make plans for critical research for IPCC AR6 with a special emphasis on low emission scenarios (1.5^{o} and 2^{o} targets) where land use change and land management are expected to have large relative impact.

Major Activities

The Aspen Global Change Institute (AGCI) convened a week-long interdisciplinary science workshop from September 15-20, 2019 entitled, “Impacts of Land Use and Land Management on Earth System Evolution, Biogeochemical Cycles, Extremes, and Inter-Sectoral Dynamics.” The purpose of the workshop was to advance research on the impacts of land use and land management on climate, carbon emissions, and extremes, as well as the impact of land-use change on important societal issues such as food, water, and energy security. The workshop was co-chaired by Kate Calvin (PNNL), George Hurtt (University of Maryland), and Dave Lawrence (National Center for Atmospheric Research). Co-funders of the workshop included NASA, NOAA, and travel support for European colleagues through CRESCENDO.

This workshop brought together 31 professionals with expertise across biogeochemistry, climate impacts, mitigation, land use datasets, and societal impacts to coordinate on upcoming research

and publications on the role of biogeochemical and biophysical properties of the Earth surface and their implications for climate, as conducted through the Land Use model Intercomparison Project (LUMIP), which is part of Phase 6 of the Coupled Model Intercomparison Project (CMIP6).

Workshop Approach

AGCI employed its unique interdisciplinary approach to workshop organization. Scholars and scientists from *across* backgrounds and disciplines engaged with one another for the full duration of a week-long program. AGCI supported volunteer co-chairs from the research community in designing the program and roster. Each invited participant had an active role in the workshop, spanning a mixture of technical presentations, plenary discussions, and breakout group facilitation. This provided the structure for building common languages and frameworks for ideas across scientific disciplines.

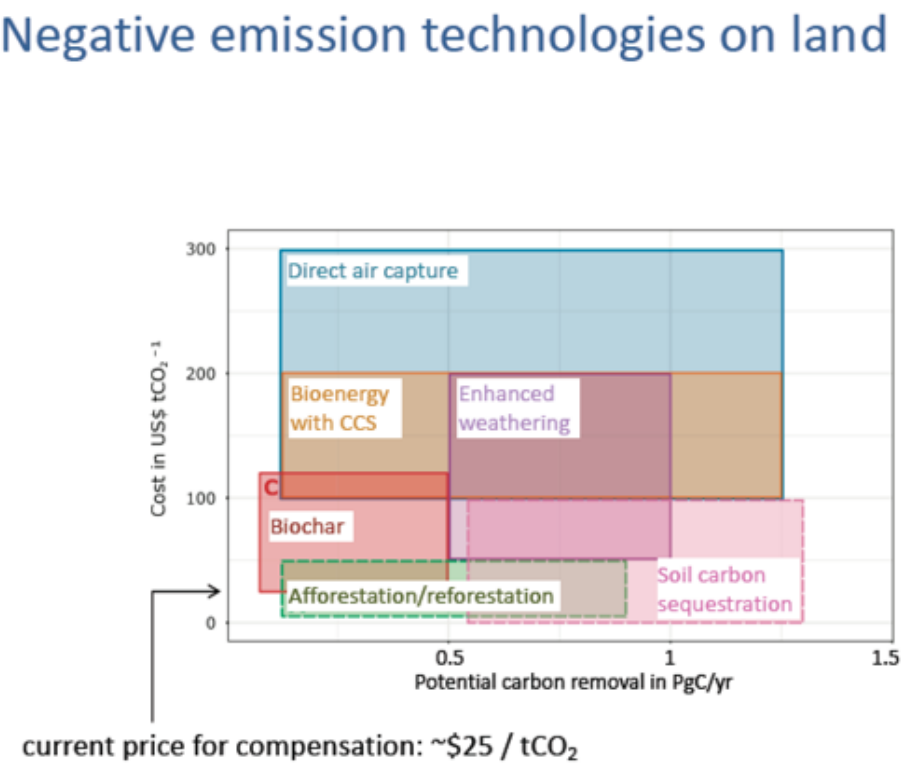
This workshop was held in Snowmass Village, CO from September 15-20, 2019. The timing of this workshop was particularly opportune, capitalizing on not only the release of initial LUMIP model results, but allowing for enough time for modelers to run additional analyses and submit their findings for publication in advance of the December 2019 deadline for papers to be considered in the IPCC AR6 process.

AGCI workshop participants were recruited through a careful invitation process designed to maximize a diversity of perspectives, expertise, career stages, and backgrounds within the relatively small group of 30 participants that attended (see Appendix for full roster).

Specific Objectives

To achieve the workshop goals and objectives, the meeting consisted of four main sessions (see Appendix for complete Agenda).

Session 1: Presentations and discussion on the state of knowledge of land use history and land use change and land management impacts on climate, water, biogeochemistry. A second focal topic, following on the heels of the recent IPCC Special Report on LULUC, was the extent to which land management can help mitigate climate change such as through carbon uptake and storage through re- or afforestation (see figure below).



Examples of land management negative emissions technologies for climate mitigation. Shared in a public lecture presented by Dr. Julia Pongratz (Max-Planck Institute for Meteorology) Credit: Minx et al. 2018.

Session 2: Modeling centers provided updates on the representation of land use in their respective ESMs as well as updates on the status and results from LUMIP and CMIP6 model simulations. Nine different modeling centers were represented and, as expected, there was considerable diversity across models in terms of the representation of land use and land management.

Session 3: Preliminary results and plans for LUMIP papers were presented, followed by breakout group discussions where these and additional paper plans were discussed in greater detail.

Session 4: The final set of presentations and breakouts focused on connections between LUMIP model results and the multi-sectoral dynamics and societal impacts community.

Significant Results and Key Outcomes

A primary outcome of the meeting was the definition and planning of a series of LUMIP papers that will rely on the LUMIP and CMIP6 simulations. By the end of the meeting more than 20 papers and paper lead authors had been identified and scoped out. All authors are being

encouraged to keep their analysis plans up-to-date on the LUMIP Analysis Planning page (https://docs.google.com/document/d/1YWmSJqg5bGG7Q VdEUfqolFQkJ6SjK2nXABXyteQv_yU/edit#heading=h.vr1pz6hygmin). Around ten of these papers were submitted by the December 31, 2019 IPCC deadline. Key papers were prioritized that covered:

(1) climate and carbon response to idealized deforestation,
(2) evaluation of the consistency of re/afforestation carbon gains in ESMs vs IAMs for SSP1-2.6,
(3) historical reconstruction and benchmarking of land-uses and land-cover changes (LULCC) impacts on surface temperature, albedo, and evapotranspiration fluxes,
(4) mitigation potential from LULCC at different CO2 levels,
(5) assessment of coupled versus uncoupled impacts of LULCC, and
(6) assessment of the impacts of LULCC on global soil carbon stocks.

A secondary outcome involved longer term planning. In particular, three new sets of numerical experiments were identified that would continue to advance LULCC science. Due to the relative importance of LULCC at low emissions, ambitious climate change target levels, it was determined that it is critical to run ESMs with alternative land use scenarios for the SSP1-2.6 scenario. Existing IAMs simulate different LULCC pathways to achieve the low emission targets, which would have differing implications for climate and the carbon cycle. This is a critical uncertainty that is currently not properly considered within the context of these low emissions scenarios. The group also saw a strong benefit from utilizing the Simple Land Interface Model (SLIM) to disentangle the relative contributions of albedo, ET, and roughness changes due to deforestation. Finally, there was strong consensus that a next important step for LULCC science is better consideration of conservation and biodiversity issues. Ambitious targets for wildland conservation are being proposed by the scientific community to help ensure biodiversity and the general health of the planet. Consideration of conservation factors would strongly affect projections of land use.

As part of the workshop, in the interest of connecting broader audiences with the cutting edge research of the workshop, a public lecture was delivered by Julia Pongratz of the Max Planck Institute for Meteorology. The talk was entitled, “Climate Consequences of Land Management,” and reviewed the biogeophysical variables of different land use strategies that could indicate LULCC as either a net sink or source of carbon. The talk, as well as many of the workshop proceedings, were live-streamed to extended audiences. The public lecture is available on AGCI’s website: agci.org/event/19s4wor

Opportunities for Professional Development

AGCI workshops have a long history of advancing the careers of participants, and this can be especially formative for those early in their careers. The knowledge-building, connections, inspiration, and influence of AGCI workshops has been documented formally and informally for early career participants in particular. Therefore, AGCI has continually advocated for decades

that early career participants be well-represented in roster development. Over the last several years AGCI has re-doubled these efforts and has seen a steady increase in early career representation. In 2016-17 workshops, 22% of participants had received their terminal degrees within the last ten years. The figure rose to 27% on average in 2018 workshops, and to 34% in 2019 workshops, including this workshop.

A follow-up survey on the anniversary of this workshop confirmed that the workshop inspired new thinking and connections for participants of all career stages. It also confirmed that early career participants, specifically, formed new connections at this workshop that have led to new publications, working groups, and collaborations that are advancing their careers.

Dissemination of Findings

As noted above in Key Outcomes, workshop co-chairs coordinated with workshop participants to share progress on their analysis plans not only with one another, but with the broader LUMIP community, in a shared google document. This document was used to coordinate submission of papers in advance of the December 31, 2019 IPCC deadline. Workshop findings were also shared with the broader LUMIP community on the LUMIP website (ee Products section for links to the google document and LUMIP website).

AGCI made the workshop description, roster, and agenda available on the official AGCI workshop website. Videos of publicly approved workshop presentations and the public lecture are available on the workshop website: agci.org/event/19s4.

Products/Outcomes

Journal Publications

So far a number of papers discussed and coordinated through this workshop have been successfully published, including:

LUMIP Papers

Lawrence, D.M., G.C. Hurtt, A. Arneth, V. Brovkin, K.V. Calvin, A.D. Jones, C.D. Jones, P.J. Lawrence, N. de Noblet-Ducoudre, J. Pongratz, S.I. Seneviratne, and E. Shevliakova, 2016. The Land Use Model Intercomparison Project (LUMIP) contribution to CMIP6: Rationale and experimental design. *GMD*, 9, doi.org/10.5194/gmd-9-2973-2016.

Hurtt, G.C., L. Chini. R. Sahajpal, S. Frolking, B.L. Bodirsky, K. Calvin, J.C. Doelman, J. Fisk, S. Fujimori, K.K. Goldewijk, T. Hasegawa, P. Havlik, A. Henimann, F. Humpnoder, J. Jungclaus, J. Kaplan, J. Kennedy, T. Kristzin, D. Lawrence, P. Lawrence, L. Ma, O. Mertz, J. Pongratz, A. Popp, B. Poulter, K. Riahi, E. Shevliakova, E. Stehfest, P. Thornton, F.N. Tubiello, D.P. Van Vuuren, and X. Zhang, 2020. Harmonization of Global Land-Use Change and Management for the Period 850-2100 (LUH2) for CMIP6. *GMD*, 13, 5425-5464, doi.org/10.5194/gmd-13-5425-2020.

Boysen, L., V. Brovkin, J. Pongratz, D. Lawrence, P. Lawrence, N. Vuichard, P. Peylin, S. Liddicoat, T. Hamima, Y. Zhang, M. Rocher, C. Delire, R. Seferian, V.K. Arora, L. Nieradzik, P. Anthoni, W. Thiery, M. Lague, D. Lawrence, M.-H. Lo, 2020. Global climate response to idealized deforestation in CMIP6 models. *Biogeosciences*, doi.org/10.5194/bg-17-5615-2020.

Singh, A., S. Kumar, S. Akula, D.M. Lawrence, and D. Lombardozzi, 2020. Plant growth nullifies the effect of increasing water use efficiency under elevated CO2 in the Southeastern United States. *GRL*, doi.org/10.1029/2019GL086940.

Ito, A., T. Hajima, D.M. Lawrence, V. Brovkin, C. Delire, B. Guenet, C.D. Jones, S. Malyshev, S. Materia, S.P. McDermid, D. Peano, J. Pongratz, E. Robertson, E. Shevliakova, N. Vuichard, D. Wårlind, A. Wiltshire, and T. Ziehn, 2020. Soil carbon sequestration in CMIP6-LUMIP models: Implications for climate mitigation. *Accepted to ERL*.

Lombardozzi, D.L., Y. Lu, P.J. Lawrence, D.iM. Lawrence, S. Swenson, K.W. Oleson, W.R. Wieder, and E.A. Ainsworth, 2020. Simulating agriculture in the Community Land Model version 5. *JGR-Biogeosciences*, doi.org/10.1029/2019JG005529.

Papers that utilize LUH2 data

Devanand, A., M. Huang, D.M. Lawrence, C. Zarzycki, Z. Feng, P. Lawrence, Y. Qian, and Z. Yang, 2020. Land use and land cover change strongly modulates land-atmosphere coupling and warm-season precipitation over the Central United States in CESM2-VR. *JAMES*, doi.org/10.1029/2019MS001925.

Websites

Analysis Plans discussed at the AGCI workshop were coordinated through a shared google doc within the LUMIP community: https://docs.google.com/document/d/1YWmSJqg5bGG7QVdEUfqolFQkJ6SjK2nXABXyteQv_yU/edit#heading=h.vr1pz6hygmin

In addition, workshop findings and publications informed by the workshop were shared on the new LUMIP webpage: https://www.cesm.ucar.edu/projects/CMIP6/LUMIP/.

Finally, AGCI created a workshop website that makes videos of publicly approved workshop presentations and public lecture available to the public: agci.org/event/19s4.

Personnel and Other Collaborators

Personnel

The execution of this work was made possible by a small, experienced team of staff with more than four decades of combined experience in convening interdisciplinary science sessions at AGCI.

As Principal Investigator, AGCI Executive Director James Arnott was responsible for the overall administration and direction of this project. Dr. Arnott has worked at AGCI for nearly 11 years and has served as PI for previous DOE-supported workshops.

Projection Co-Investigator, AGCI Program Director Emily Jack-Scott, was the lead implementer of workshop programming. Ms. Jack-Scott's contribution included program planning and roster development with workshop co-chairs, general coordination of the meeting, support of pre- and post-workshops development of products and outputs, workshop inclusivity initiatives, as well as oversight of post-workshop development and dissemination of education and outreach materials on the AGCI workshop website.

AGCI's Co-Founder John Katzenberger served as Senior Scientific Advisor to this project and, along with AGCI staff, conducted follow-up briefings with agency program managers.

Project management was provided by AGCI Finance Director, Alyson Wright. This task involved a year-round cycle of logistical support, such as negotiating contracts with third parties for services related to the meetings such as lodging, travel, food service, and reimbursement procedures.

Personnel Name	Role	Nearest Whole Person-Month (calendar)
James Arnott	PI	0
Emily Jack-Scott	Co-I	1
John Katzenberger	Senior Scientific Advisor	0
Alyson Wright	Finance Director	1

Voluntary Co-Chairs

Workshop co-chairs Dave Lawrence (National Center for Atmospheric Research), Kate Calvin (Pacific Northwest National Laboratory), and George Hurtt (University of Maryland) were instrumental in the workshop roster and agenda development. They also spearheaded all follow-on activities to coordinate and support publications informed by workshop findings. They served in these roles voluntarily, and no part of the award went towards compensation for their time. Likewise, no workshop participants were provided stipends or speaker fees. Workshop participant costs (such as lodging, per diem, and travel) were supported for co-chairs and most participants.

Impacts & Evaluation

Results from post-workshop evaluations confirm that the workshop led to highly substantive collaborations and idea sharing. Workshop participants produced publications informed by workshop presentations and discussions, new research collaborations and partnerships, and

incorporated insights from their participation into their respective research and home institutions. These impacts were demonstrated within and across disciplines.

Specific examples cited by participants include:

- formation of a new transdisciplinary effort coordinating research on irrigation in the Earth system;
- incorporation of connections between global land modeling and biodiversity policy assessments into an individual's research;
- one participant serving on a Master's committee for a student advised by another workshop participant;
- submission of a new research proposal among several participants;
- paper ideas originated from the workshop that have since been realized/are progressing;
- initiation of a working group on human-Earth system coupling, which picks up on topics (and includes participants) from the AGCI workshop.

The impacts cited by participants reinforce the role the workshop played in enriching human resources and broadening institutional ties within and beyond the LUMIP research community.

The various publications that were informed by the workshop, and in particular those submitted for publication in advance of the IPCC AR6 deadline, will also have impacts on how workshop topics and focus areas are characterized within the next IPCC report. The IPCC report in turn obviously has broad readership and impacts on how research institutions, the public, and decision makers conceive of the drivers of climate change.

Dozens of members of the general public were also engaged through the public lecture given by Julia Pongratz on "Climate Consequences of Land Management," which reviewed the biogeophysical variables of different land use strategies that could indicate LULCC as either a net sink or source of carbon. The public lecture continues to gain views, published for educational and archival purposes on AGCI's website.

While the participants of this workshop come from institutions within the U.S. and abroad, no part of this budget was spent in foreign countries.

Workshop Evaluation

At the closing of the workshop, participants were asked to complete a workshop evaluation form to give anonymous feedback to AGCI staff on how to continually improve the AGCI workshop process including: topic selection, presentation formats, logistical support, and communication of science to the public. In addition to initial evaluation efforts, AGCI sent a follow-on evaluation survey to participants on the one-year anniversary of the workshop and to track outputs, collaborations, and research agendas catalyzed by workshops.

Quantitative Evaluation Results for Interdisciplinary Workshop on the Impacts of Land Use and Land Management on Earth System Evolution, Biogeochemical Cycles, Extremes, and Inter-Sectoral Dynamics

	Poor	Fair	Good	Very Good	Excellent	Totals
Session Theme Selection	0	0	1	5	18	**24**
	0%	**0%**	**4%**	**21%**	**75%**	
Quality of Presentations	0	0	1	11	12	**24**
	0%	**0%**	**4%**	**46%**	**50%**	
Logistical Support	0	0	0	0	24	**24**
	0%	**0%**	**0%**	**0%**	**100%**	
Personal Value	0	0	0	4	20	**24**
	0%	**0%**	**0%**	**17%**	**83%**	

The following selected comments are from the written evaluation forms filled out at the close of the workshop in September 2019, and from the anniversary survey circulated to participants in September 2020. The selections are intended here to provide a qualitative sense of the workshop and specifically what about the format of the sessions, topic selection, etc., they found particularly useful.

Session Theme Selection:

- *LUMIP was the focus point to which all participants came, involved and/or interesting in. The theme was perfect for bringing expertise of people with different backgrounds. The session themes cover all aspects relevant to LULCC. I learned a lot.*
- *Very relevant theme for my research area. Timely workshop as we prepare for CMIP6 deadlines.*
- *Very comprehensive from biophysical modeling to policy implications. The topic is very timely.*

Quality of Presentations/Discussions:

- *Speakers are mostly world renown experts in their field.*
- *There was a good balance between presentation and discussion, and both of them have been very useful.*
- *Quality was top. I'm not used to join many workshops or conferences but I should say I learned a lot from the presentations.*
- *[The co-chairs] are amazing. Great speakers/very interesting presentations. Maybe a slight bias towards US-based topics/speakers. Cuts probably difficult to avoid.*

Logistical Support:

- *This is the best in all workshops I attended.*
- *Excellent support! Very supportive of the science.*
- *It was perfect from the invitation to join this meeting up to the "minors" logistic case of all us during the meeting.*

- *Really, really well done. Many of my questions were anticipated and taken care of before I could ask.*

Personal Value to You:

- *The workshop is eye opening. The AGCI staff members are professional and know how to bring the scientists closer by adding team building activities.*
- *Amazing for networking, ideas and connections. I've got both papers and proposals coming out of this!*
- *This workshop gave me the possibility to better connect with the community and to improve my understanding of land use studies.*
- *Highly valuable. Lots of these people are the people who's papers I "grew up" reading in grad school—meeting them and talking to them in person is amazing!*
- *Very useful to hear first hand about the various models- it's a lot to keep track of.*
- *Met a lot of people I'd admired through their publications for a long time. Have hopefully begun a couple of new collaborations too.*
- *It was great to have a broader connection to the global land change modeling community, encouraging me to connect my work more to this community*

General Comments:

- *This was excellent- truly. Very well run and highly productive.*
- *Thanks for the amazing organizational support and meeting facilitation. You all added a lot of great energy.*
- *Very useful for early career scientists.*

Workshop Diversity, Equity, & Inclusion

AGCI adapted the Guide to Organizing Inclusive Scientific Meetings: Where to Start for our own workshop context during the 2019 workshop season. New protocols were implemented in workshop topical selection, leadership selection, participant selection, invitation language, registration process, workshop environment and participants roles in the agenda. AGCI emphasized to the workshop co-chairs the organization's commitment to diverse participation and inclusive workshop atmosphere, and reinforced the importance of advancing diversity, equity, and inclusion throughout the workshop planning and execution.

One specific measure at the outset of each workshop was AGCI's opening introductory talk, which was designed to set an inclusive tone. AGCI's introduction underscored that every individual in the room came with unique and valuable experience and expertise that was key in identifying and advancing solutions to the workshop topic at hand. AGCI actively discouraged "imposter syndrome," encouraging participants to instead ask questions and volunteer their perspective. AGCI introduced workshop-specific methods for engaging in discussion (e.g., raising hands to engage in discussion instead of over-talking one another).

AGCI also presented its code of conduct, with the basic tenants, which was also printed and inserted into each participant's name tag sleeve for easy access:

1. Share our time & space together. Actively listen, contribute, and learn.
2. Find ways to support the work & ideas of others.
3. Respect differences – disagreements should be based exclusively on professional differences.
4. Practice self-care.
5. AGCI adheres to the same guidelines of expected and unacceptable behavior, including sexual harassment, other forms of harassment, and sexual assault, as the American Geophysical Union. (with links to resources and point of contact information in case of violations)

The effectiveness of various strategies at broadening participation were evaluated by analyzing demographic data, and the inclusivity of the workshop was gauged from informal feedback and written evaluations collected at the close of the workshop.

Demographic data revealed that:

- 34% of participants were early career (within ten years of their terminal degree)
- 38% of participants identified as women, 59% identified as men, with 3% preferring not to respond
- 66% were White, 14% Non-White, with 21% preferring not to respond
- 36% of all participants had primary caretaking responsibilities

Numerous participants (especially women) gave informal verbal feedback that the workshop was significantly more inclusive than most in their fields. Others commented on feeling more comfortable and included as a result of the opening presentation made by AGCI leadership. This feedback was reinforced by anonymous evaluation forms, as indicated by select comments:

"This was the best representation of women I have ever experienced and it felt really good."
"Love the rules of engagement (self-care, respect for others, contact info for help)."
"Very conscientious and accommodating."
"Good mix of established and early career scientists."
"I particularly appreciate the few words expressed by [AGCI] at the start of the workshop on the expected atmosphere during the meeting. I'm not fluent in English and this is not always easy to take part to some discussions. This words were welcome and helpful to me a lot to participate actively."

One area of difficulty implementing diversity, equity, and inclusion strategies in 2019 was diversifying roster development. Due to the small size of AGCI workshops it was at times difficult for co-organizers to continually prioritize searching for diverse candidates outside their established networks. Sometimes strategic considerations about how to most effectively advance research agendas or anticipated follow-on efforts would steer co-organizers towards senior heads of departments or research agendas, rather than towards early career individuals.

An unanticipated dimension of access and equity came when a handful of invitees declined invitations to the workshop due to new policies at their institution(s) that limit travel to workshops abroad due to concerns about greenhouse gas emissions, even when emissions were being offset. To accommodate these participants, we opted to live-stream the vast majority of the workshop to them and other members of the LUMIP community, but these individuals were limited from full participation due to the extended duration of AGCI workshops and informal discussion times and activities outside the formal agenda. AGCI also repeatedly observed intersectionality of early career participants being disproportionately from underrepresented groups, which carried its own set of power dynamics during discussions in particular. AGCI continues to work to incorporate formal and informal feedback to make its workshop series more diverse, equitable, and inclusive.

Changes/Problems

There were some variations in the final budget to actual. One staff member left AGCI to pursue other opportunities and her time was re-allocated to the rest of the team. James ended up spending more time than budgeted after he finished his PhD and was able to dedicate more time to the meeting. Staff travel costs were lower than expected as staff who traveled in were able to share expenses with an AGCI staff meeting after the workshop. Finding a time for the meeting that worked for everyone and that was affordable was difficult for this meeting. The price availability made holding the meeting in Snowmass, a first for AGCI, the best option. The participant costs varied with more being spent on subsistence and less on travel, but overall participant costs were $650 above what was budgeted. More was spent on materials as a few participants could only join remotely so we upgraded our online access and purchased a solid state drive to back up the video recordings. We spent more on publication costs to support some website upgrades specific to the workshop materials being displayed and for outsourcing the processing of the videos to be uploaded to the website. Less was spent on facilities than budgeted. As we've encountered with some other hotels, they reduce the facility costs by having a food minimum so some of the savings in that line item were accounted for under subsistence.

Appendix: Roster and Topical Agenda

Roster

Impacts of Land Use and Land Management on Earth System Evolution, Biogeochemical Cycles, Extremes and Inter-Sectoral Dynamics

ROSTER

September 16-20, 2019
Snowmass, CO

Co-Chairs: Dave Lawrence (NCAR), George Hurtt (U Maryland), Katherine Calvin (PNNL)

Justin Baker
RTI International

Victor Brovkin
Max Planck Institute (MPI) for Meteorology

Katherine Calvin
Pacific Northwest National Laboratory (PNNL)

Louise Chini
University of Maryland

Edouard Davin
ETH Zürich

Alan Di Vittorio
Lawrence Berkeley National Laboratory (LBNL)

Erle Ellis
University of Maryland, Baltimore County (UMBC)

Luke Grant
Katholieke Universiteit (KU) Leuven

Petr Havlik

International Institute for Applied Systems Analysis (IIASA)

Peter Hess
Cornell University

Kathleen Hibbard
National Aeronautics and Space Administration (NASA)

Maoyi Huang
Pacific Northwest National Laboratory (PNNL)

George Hurtt (in absentia)
University of Maryland

Akihiko Ito
National Institute for Environmental Studies (NIES)

Andy Jones
Lawrence Berkeley National Laboratory (LBNL)

Marysa Lague
University of Washington

David Lawrence
National Center for Atmospheric Research (NCAR)

Deborah Lawrence
University of Virginia

Peter Lawrence
National Center for Atmospheric Research (NCAR)

Spencer Liddicoat
Met Office

Danica Lombardozzi
National Center for Atmospheric Research (NCAR)

Sergey Malyshev
Geophysical Fluid Dynamics Laboratory (GFDL)

Sonali McDermid
New York University

Sara Ohrel
Environmental Protection Agency

Daniele Peano
Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC)

Julia Pongratz
University of Munich

Ben Poulter
National Aeronautics and Space Administration (NASA)

Sam Rabin
Karlsruhe Institute of Technology (KIT)

Natalie Schultz
Yale University

Elena Shevliakova
Geophysical Fluid Dynamics Laboratory (GFDL)

Nicolas Vuichard
Institut Pierre Simon Laplace (IPSL)

Yoshihide Wada
International Institute for Applied Systems Analysis (IIASA)

Agenda

Impacts of Land Use and Land Management on Earth System Evolution, Biogeochemical Cycles, Extremes and Inter-Sectoral Dynamics

AGENDA

September 16-20, 2019
Snowmass, CO

Co-Chairs: Dave Lawrence (NCAR), George Hurtt (U Maryland), Katherine Calvin (PNNL)

Please note: Unless stated otherwise, all presentation slots are 15 minutes. Extended discussion will follow each set of presentations. Specified sessions will be webcast to the greater LUMIP community; register online: https://zoom.us/webinar/register/WN_mHYjAeaVTqeyvkL4kxN4gw

MONDAY, SEPTEMBER 16

Session 1. Welcome & Introductions (to be webcast to extended LUMIP community)

9:00 AM Welcome from AGCI staff – **James Arnott, Emily Jack-Scott**

9:15 AM Participant introductions

9:45 AM Introduction to workshop goals, LUMIP, LUH2, SSPs – **Dave Lawrence**

10:10 AM Report on IPCC Special Report on Climate Change and Land – **Elena Shevliakova**, **Kate Calvin**

Session 2. State of knowledge of historic and projected land use change (to be webcast to extended LUMIP community)
Session Moderator: Dave Lawrence

11:00 AM **Erle Ellis**
Kate Calvin
Louise Chini

11:45 AM *Discussion*

Session 3. State of knowledge of land use impacts on climate and extremes (to be webcast to extended LUMIP community)
Session Moderator: Kate Calvin

2:00 PM **Marysa Lague** (Idealized)
Edouard Davin (Extremes)
Natalie Schultz (subgrid)
Alan Di Vittorio (land cover change impacts)

3:00 PM *Discussion*

Session 4. State of knowledge of land use impacts on biogeochemical fluxes (to be webcast to extended LUMIP community)
Session Moderator: Louise Chini

4:15 PM **Julia Pongratz** (Land use change carbon)
Ben Poulter (TRENDY)
Peter Hess (N2O emissions)

5:00 PM *Discussion*

5:30 PM ADJOURN

TUESDAY, SEPTEMBER 17

Session 5. State of knowledge of land management impacts on climate, water, and biogeochemistry (to be webcast to extended LUMIP community)
Session Moderator: Kate Calvin

9:00 AM **Danica Lombardozzi** (cover crops and tillage)
Yoshihide Wada (water)
Maoyi Huang (logging)

9:45 AM *Discussion*

Session 6. Modeling center reports on representation of land use in their models and initial results (to be webcast to extended LUMIP community)
Session Moderator: Dave Lawrence

10:45 AM Modeling center reports (10 mins each max, followed by 5 minutes for clarifying questions)
Charge: provide details of land use representation in models including gross vs net, implementation of LUH2, land management processes, including a few evocative initial land use change related results, and information on any 'gotchas' that those doing model analysis should be aware of

CESM – **David Lawrence** (NCAR)
CMCC – **Daniele Peano** (Italy)
E3SM – **Kate Calvin** (PNNL)

GISS – **Ben Poulter** (NASA)
GFDL – **Elena Shevliakova** (NOAA) **and Sergey Malyshev** (GFDL)

12:00 PM *Discussion*

Session 6 cont. Modeling center reports on representation of land use in their models and initial results (to be webcast to extended LUMIP community)
Session Moderator: Dave Lawrence

2:00 PM Modeling center reports (10 mins each max, followed by 5 minutes for clarifying questions)
Charge: provide details of land use representation in models including gross vs net, implementation of LUH2, land management processes, including a few evocative initial land use change related results, and information on any 'gotchas' that those doing model analysis should be aware of

IPSL – **Nicholas Vuichard** (IPSL)
MIROC – **Akihiko Ito** (NIES)
MPI – **Victor Brovkin** (MPI)
UKESM – **Spencer Liddicoat** (Met Office)

3:00 PM *Discussion*

Session 7. Introductions to LUMIP papers on idealized deforestation, historical land use impacts, benchmarking, and extremes (not webcast)
Session Moderator: Louise Chini

4:00 PM Idealized deforestation: **Victor Brovkin**
Benchmarking: **Edouard Davin**
Land Management: **Danica Lombardozzi**
Extremes: **Luke Grant**

5:00 PM *Discussion*

5:30 PM ADJOURN

WEDNESDAY, SEPTEMBER 18

Session 8. Breakouts to work on papers (not to be webcast)

Breakout groups to discuss priority scientific questions, additional analyses needed for papers, and timeline/responsibilities

9:00 AM Breakout Group 1: Idealized Deforestation
Breakout Group 2: Land Management
Breakout Group 3: Benchmarking

10:30 AM *Report Back & Group Discussion*

Session 9. Preliminary Results of LUMIP papers on projections, carbon, and LULCC as mitigation tool (not webcast)

11:30 AM Projections and mitigation: **Dave Lawrence**
Historical land use impacts: **Peter Lawrence**
Carbon: **Julia Pongratz, Spencer Liddicoat, Akihiko Ito**

12:30 PM *Group Discussion*

6:00 PM **Walter Orr Roberts Public Lecture (Guests Welcome)**

Julia Pongratz - Climate Consequences of Land Management
Location: Aspen Center for Environmental Studies (ACES) at Hallam Lake
100 Puppy Smith St., **Aspen, CO** (hotel shuttles from Viceroy Snowmass to Aspen are available)
Also live-streaming on Facebook: facebook.com/aspenglobal

THURSDAY, SEPTEMBER 19

Session 10. Breakouts to work on papers (not webcast)

Breakout groups to discuss priority scientific questions, additional analyses needed for papers, and timeline/responsibilities

9:00 AM Breakout Group 1: Projections
Breakout Group 2: Historical Land Use Impacts
Breakout Group 3: Biogeochemistry

10:30 AM *Report Back & Group Discussion*

Session 11. Connecting with multi-sector dynamics and societal impacts community, including implications of land use/land management options for water and food security (to be webcast to extended LUMIP community)
Session Moderator: Kate Calvin

11:30 AM BECCS: **Sara Ohrel**
Land-based mitigation: **Petr Havlik**
Agriculture and food security: **Sonali McDermid**
Bioenergy vs forest as mitigation policy and/or making ESM output relevant for impacts community: **Andy Jones**

12:30 PM *Discussion*

Session 11 cont. Connecting with multi-sector dynamics and societal impacts community, including implications of land use/land management options for water and food security (to be webcast to extended LUMIP community)
Session Moderator: Kate Calvin

2:00 PM Regional impacts (Asia): **Deborah Lawrence**
Regional impacts (Northern Eurasia/Southern and SE Asia): **Kathy Hibbard**
Forestry and logging (ecosystem services): **Justin Baker**
Human-Earth system feedbacks: **Sam Rabin**

3:00 PM *Discussion*

Session 12. Breakout discussions on societal impacts and multi-sector dynamics research (not webcast)

4:00 PM Breakout Group 1: Impacts on Water
Breakout Group 2: Impacts on Food Security
Breakout Group 3: Other Impacts TBD

5:30 PM ADJOURN

FRIDAY, SEPTEMBER 20

Session 12 cont. Breakout discussions on societal impacts and multi-sector dynamics research

9:00 AM Report Back & Group Discussion

Session 13. Synthesis & Follow-On Research Needs

9:45 AM Extended Discussion of follow-on research needs including new reconstructions, scenarios, iESM, model simulations

11:00 AM Summary & Coordination on new papers to be published in advance of IPCC timeline

12:00 PM ADJOURN

Afternoon Departures