FINAL REPORT

LCLUC Synthesis: Ecosystem-Society Interactions on a Changing Mongolian Plateau
NNX14AD85G

Project Webpage: http://lees.geo.msu.edu/research/lcluc.html
Study Period: 8/19/2014 – 8/19/2017

Principal Investigators
   Jiquan Chen, Landscape & Ecosystem Science Lab, Michigan State University;
   jqchen@msu.edu; 517-884-1884 (phone); 517-353-2932 (fax)
   Daniel G. Brown, University of Michigan; danbrown@umich.edu; 734-763-5803 (phone);
   734-936-2195 (fax)

Graduate students & Postdocs (partially supported)
   Ginger Allington, postdoc research Associate, University of Michigan
   Munkhbayar Galbadrakh, PhD student—Mongolian, Beijing Forestry University
   Liping Gao, PhD student - completed, Auburn University
   Wei Ge, PhD Student, Auburn University
   Vincenzo Giannico, PhD student, University of Bari, Italy
   Ranjeet John, postdoc research Associate, Michigan State University
   Elliott Kurtz, MS student, University of Michigan
   Cheyenne Lei, PhD student, University of Michigan
   Wei Li, PhD student, University of Michigan
   Yaling Liu, PhD Purdue University
   Enkhjargal Natsagdorj, PhD student, National University of Mongolia
   Zutao Ouyang, postdoc research Associate, Michigan State University
   Hogeun Park, PD Student, Michigan State University
   Changliang Shao, postdoc research Associate, Michigan State University
   Gabriela Shirkey, MS student, Michigan State University
   Ki'Amber Thompson, undergraduate student, Doris Duke Conservation Scholars Program
   Ganzorig Ulgiichimeg, PhD Student, Institute of Geography, Mongolia
   Yecheng Xu, PhD student, Auburn University

Collaborators (via publications & data sharing)
   Arun Agrawal, University of Michigan
   Amartuvshin Amarjargal, University of the Humanities, Ulaanbaatar, Mongolia
   Ochirbat Batkhishig, Mongolian Academy of Sciences, Mongolia
   Kathleen Bergen, University of Michigan
   Maria Fernandez-Gimenez, Colorado State University
   Falk Huettmann, University of Alaska
   Peilei Fan, Michigan State University
   Martin Kappas, Georg-August University Goettingen, Germany
   Raffaele Lafortezza, University of Bari, Italy
   Jiaguo Qi, Michigan State University
   Song Qian, University of Toledo
   Tsolmon Renchin, National University of Mongolia
   Ge Sun, SGCP of the USDA Forest Service

Robert A. Washington-Allen, University of Tennessee
Jingfeng Xiao, University of New Hampshire
Yichun Xie, Eastern Michigan University
Yaoqi Zhang, Auburn University
Qianglai Zhuang, Purdue University

Team Summary (including support through data-knowledge-model sharing)

- 2 principal investigators
- 14 graduate students
- 4 postdoctoral research associates
- 18 collaborators (excluding some of the workshop participants)

OBJECTIVES & RESEARCH TASKS

The overall **objective** of this project is to synthesize our data, knowledge, and quantitative models on ecosystem and social resilience to the changing climate and dynamic socioeconomic pressures placed on these fragile ecosystems. This will be accomplished through modeling natural system (NS) and human system (HS) processes and dynamics as well as the interactions and feedbacks among them. We will use multiple data sources to document human and natural dynamics at multiple temporal and spatial scales for the plateau, where Inner Mongolia (IM) and Mongolia (MG) have had similar climates, ecosystems, cultures, and traditions, but different governments, land uses, economic development, and demographic changes in the past. Three **specific tasks** will be performed to achieve this objective: **1)** seamless integration of the datasets (i.e., data synthesis); **2)** analysis to achieve knowledge synthesis; and **3)** forecast synthesis following sound scenario development (i.e., modeling synthesis).

ACHIEVEMENTS

1) ***Collaborators*** *(Task 1, 2):* One of the research plans of this project is to build a consortium of additional collaborations with teams conducting relevant research on the Mongolian Plateau. The following researchers have contributed data or insights toward the synthesis:

Drs. Ranjeet John and Changliang Shao were primary convener and co-convener, respectively, of a session titled, "Climate-vegetation interaction and land cover/land use change in semi-arid Grassland Ecosystems (GC017)" at the American Geophysical Union (AGU) 2015. Drs. John and Shao were also invited to present at the "Building Resilience of Mongolian Rangelands Conference", on June 9 and 10, Blue Sky Hotel, Ulaanbaatar, (http://mongolia.usembassy.gov/pr_060815.html). This was one of the very first interdisciplinary and international scientific conferences on rangeland science ever to be organized in Mongolia.

An edited book for the "Landscape Studies" series. The following book proposal is being developed for Springer:

Kappas, Martin, Jiquan Chen, Garik Gutman, and Geoff Henebry. Landscape dynamics across the drylands of Eurasia: People, societies, and ecosystems. *Springer*.

2) ***Group Meetings in East Lansing and Ann Arbor, Michigan***

   MSU-UM Project Meeting (East Lansing): September 30, 2014, Participants: Jiquan Chen, Dan Brown, Ranjeet John, Changliang Shao, Ginger Allington, Peilei Fan, Hogeun Park, Wei Li, Yaoqi Zhang (Skype).

   MSU-UM Project Meeting (Ann Arbor): October 27, 2014; participants include:
   UM: Dan Brown, Ginger Allington, Wei Li;
   MSU: Jiquan Chen, Ranjeet John, Changliang Shao, Peilei Fan, Hogeun Park, Zutao Yang;
   Eastern Michigan University: Siyu Fan

3) ***Synthesis Workshop 2016*** - *2014:* We organized a workshop entitled "LCLUC Synthesis: Ecosystem-Society Interactions on a Changing Mongolian Plateau" in Ulaanbaatar, Mongolia, June 18-21, 2014. The goal of the workshop was to understand how social and ecological systems respond to changing climatic and socio-political conditions. One of the key objectives was to aim to develop and test possible future scenarios for the Mongolian Plateau and identify knowledge gaps for future research. Building on the expertise and experience of workshop attendees, which included high-level policymakers (e.g., Dr. Chuluun Togtokh, advisor to the Environment Ministry & Otgontugs, Banzragch Dean, Graduate School, National University of

Mongolia and Monetary Policy Board of the Central Bank of Mongolia) as well as *soum* (county) and *Bag* (block-level) leaders from the provinces of Bulgan, Bayan-Ulgii, Govi-altai, and Umnovgovi, we were able to identify key social and ecological stressors and available data and models to support the synthesis activities. We also expect that this workshop serves as a platform for forming new collaborations for future research. The workshop will serve to organize our collaborative research efforts for the next 3-5 years on the Plateau.

4) ***Synthesis Workshop 2016 – Ann Arbor***
We organized a workshop entitled "Mongolian Plateau: Research Synthesis & Innovation" in Ann Arbor, Michigan at University of Michigan May 12-13, 2016. Collaborators and PIs met to discuss synthesizing the collected ecological and sociological data on the Mongolian Plateau. The meeting agenda included: outline of goals and objectives, presentations of key research findings, breakout sessions to discuss state of knowledge and gaps, discussion of next research steps, and new questions to outline a new manuscript that synthesizes research findings across

the participating groups. Discussions at this meeting contributed a final step in an iterative approach to simulation and expert narrative to understand possible future scenarios for the Mongolian Plateau. The manuscript has been revised and resubmitted to the journal *Ecology and Society*, and describes new synthetic knowledge that has emerged from this iterative process about the role of urbanization on the plateau in affecting rural labor and livelihoods.

Participants:
(*funding for the participation by these individuals was provided by internal University of Michigan grants, not from NASA funds).*

> University of Michigan: Ginger Allington, Dan Brown (Co-I), Chuan Liao
> Michigan State University: Jiquan Chen (PI), Ranjeet John, Changliang Shao, Gabriela Shirkey, Peilei Fan, Hogeun Park, Zutao Ouyang
> Colorado State University: Maria Fernandez-Gimenez
> Auburn University: Henry Kinnucan, Yaoqi Zhang, Yecheng Xu, Jiaxuan Gao, Wei Ge
> Eastern Michigan University: Siyu Fan
> Mongolian University of the Humanities: Amarjargal Amartuvshin*
> Mongolian Ministry of Science: Tungaa Ulambayar*

5) *Synthesis Workshop 2017- Ulaanbaatar*

We organized a workshop entitled "Ulaanbaatar2017 Data Synthesis Workshop" in Ulaanbaatar, Mongolia, June 2-5, 2017. UB2017 was a product-focused workshop that aimed to connect collaborators with data and resources from two NASA projects lead by Drs. Jiquan Chen and Peilei Fan.

Participants were encouraged to lead as first authors, submit a synthesis proposal, and find co-authors with the necessary expertise and data to develop their manuscripts. Further data and resources were made available in our online database and our reference library, both of which were pooled together from attendees. The meeting included outlines of goals and objectives, presentations of key research findings, breakout

© Nguyen Dinh Duong

sessions to discuss state of knowledge and gaps, discussion of next research steps, and new questions to outline new manuscripts (total=18) that synthesizes research findings across the participating groups. Five two researchers from 17 countries attended the workshop.

Participants (and affiliation):
(*funding for the participation by these individuals is not from NASA funds as they were either local to Ulaanbaatar or self funded).

Jana Albrechtová, Charles University in Prague
Ginger Allington, SESYNC, University of Maryland, USA
Amarjargal Amartuvshin, University of the Humanities, Mongolia
Gang Bao, Nanjing University, China*
Ochirbat Batkhishig, Institute of Geography, Mongolian Academy of Sciences*
Jiquan Chen, Michigan State University, USA
Guangqing Chi, Pennsylvania State University, USA
Gang Dong, Shanxi University, China*
Peilei Fan, Michigan State University, USA
Maria Fernandez-Gimenez, Colorado State University, USA
Garik Gutman, NASA
Geoffrey Michael Henebry, South Dakota State University, USA
Ranjeet John, Michigan State University, USA
Zhe Kong, APNet*
Leisz, Stephen, Colorado State University, USA
Mingliang Liu, Washington State University, USA
Yong Liu, Southwest University, China*
Tatiana Loboda, University of Maryland, College Park, USA
Chao Long, Asian Pacific Network*
Dengsheng Lu, Michigan State University, USA
Elizabeth Mack, Michigan State University, USA
Tep Makathy, Cambodian Institute for Urban Studies, Cambodia
Win Soe Myint, Arizona State University, USA
Zin Nwe Myint, Yangon University, Myanmar
Zaw Naing, Mandalay Technology Co., Ltd, Myanmar
Dinh Duong Nguyen, Vietnam Academy of Science and Technology
Pham Thi Mai Thy, Vietnam Academy of Science and Technology
Hogeun Park, Michigan State University, USA
Pavel Groisman, NOAA
Jiaguo Qi, Michigan State University, USA
Huangquang Qiu, Renmin University, China
Changliang Shao, Michigan State University, USA
Outhailak Souphanthalop, Ministry of Natural Resources & Environment, Lao PDR
Tunga Ulambayar, Saruul Khuduu Environmental Research & Consulting (SKERC), Mongolia*
Baorui Wang, CAAS, China*
Xu Wang, CAAS, China*
Robert Washington-Allen, University of Tennessee, USA
Jingle Wu, Arizona State University, USA
Xiaoping Xin, CAAS, China*

5

Zutao Yang, Michigan State University, USA
Wenze Yue, Zhejiang University, China*
Yaoqi Zhang, Auburn University, USA

6) ***Databases for open access*** *(Task 1):* Michigan State University and University of Michigan upload bio-physical and socioeconomic data on a public webpage, which is available for download without request. The webpage is hosted on: lees.geo.msu.edu/data_web/index.asp. Regular updates assure that the most recent data is accessible to the public. The hyperlinks were also made through the LCLUC's data portal (supported by Sumalika Biswas, University of Maryland). A manuscript for publishing all data collected from this project is in progress for a data-publication at ESSD (Huettmann et al. in preparation).

7) ***Fieldwork: data collection for filling the gaps***
   a. Dr. Ranjeet John conducted an intensive ground survey [6/21/16–7/07/16] of the grasslands in the Khangai Mountains of Western Mongolia with the help of the Institute of Geography/Mongolian Academy of Sciences (MAS) soil scientists Dr. Ochirbat
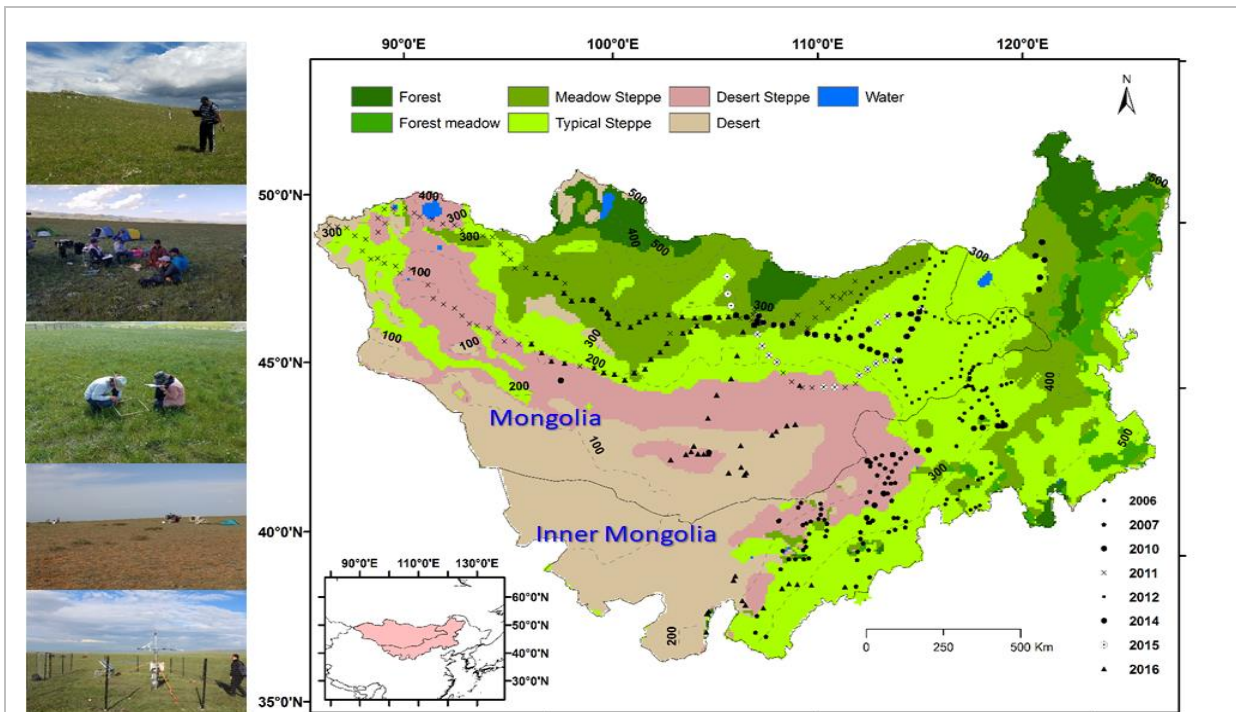

Fig. 1. Distribution of vegetation on the Mongolian plateau overlaid on isohyets (dashed lines) derived from CRU TS323 mean annual precipitation (1981-2014). The thick line denotes the border between the Republic of Mongolia and the province of Inner Mongolia, China. Multiple field teams were organized to collect vegetation, spectral reflections, LAI, and microclimate using the line-quadrat methods (John et al. *in review*). The inter-annual variability of CC and AGB varied across steppe types but was more pronounced in MG than in IM. We estimated CC of 0-70% and AGB of 0.42 PgC. We found that our scaled-up estimates were significantly related with inter-annual climatic variability and anthropogenic drivers of change, especially with the Euclidean distance to urban/built-up areas and livestock density.

Batkhishig and PhD. Student Ganzoo Ulgiichimeg. The survey covered a distance of >2500 km sampling in the several Khangai provinces including Tov, Bulgan, Arkhangai,Zavkhan, Bayankhongor, and Ovorkhangai. In addition to the western steppe transect described above, the survey team also established/revisited sites representative of the meadow/mountain steppe complex to the north of Ulaanbaatar, in the Gorkhi-Terelj National Park as well as 4 flux towers on east and west of Ulaanbaatar (Fig. 1).

b. Drs. Jiquan Chen and Ginger Allington also conducted ground surveys (6/26/16–7/10/16) in the Gobi desert steppe, covering a distance >3000 km in Western Inner Mongolia and in the provinces of Tov, Dundgovi, Omnogovi, and Dornogovi in July 2016. In addition, this survey yielded a total of 37 sites (Fig. 1). These sites were selected because our recent synthesis indicted that they are land cover/use change hot spots on the Mongolian Plateau.

The health and condition of a typical steppe, dry steppe and meadow steppe vegetation, and the dominant land cover/use and level of grassland degradation were measured at 42 sites, 50km apart to prevent spatial auto-correlation, ensuring independence of sampled variables. The intensive measurements include surface reflectance spectra of the dominant steppe species using a Fieldspec 3 ASD Spectro-radiometer, percent canopy cover, panorama, downward-looking photos, soil temperature (5 & 10 cm), volumetric water content (VWC), wet and dry biomass using 0.5x 0.5m quadrats. The survey was conducted across precipitation and grazing gradients and monitored species communities at sample sites using line intercept transects, which measured species richness and foliar height. In addition, Dr. John used a FARO Focus3D X 330 terrestrial Lidar to obtain the vegetation structure at 25 out of the 42 sites sampled.

c. PhD student, Hogeun Park, focused on synthesizing socioeconomic and Landsat -derived land cover data using Structural Equation Modeling (SEM) in order to understand the urbanization process on the Mongolian Plateau. The research verified different underlying mechanisms of urbanization, which diverge depending on the local governmental scheme, the economic structures, and the capacity of social services. In addition, he did semi-structured interviews with local residents both in Inner Mongolia and Mongolia in 2015 and 2016 summer, respectively. These first-hand observations and qualitative perspectives interweave the research gaps and the public's needs.

8) ***Model synthesis*** *(Task 3):* We link our knowledge of vegetation ecological processes with broader changes in land cover and livelihoods on the Mongolian Plateau, in order to better understand current and future drivers of change in the rangeland system. We developed a system dynamics model to understand how the human, natural, and land-use processes in the Mongolian rangeland ecosystem interact to produce dynamic outcomes in both grassland productivity and livestock
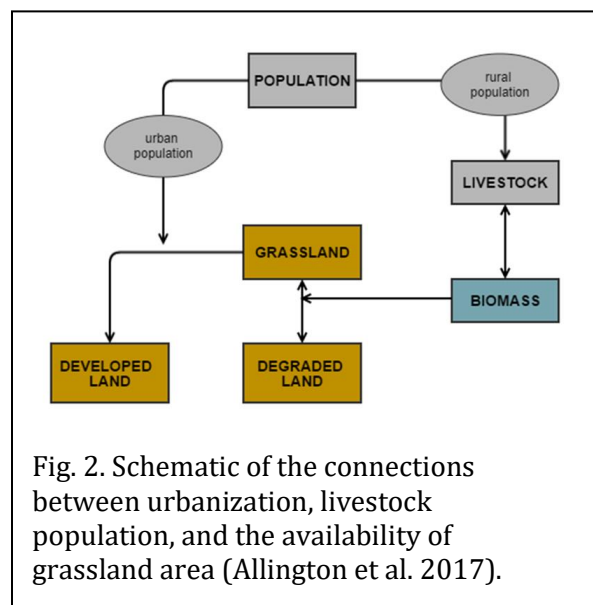

Fig. 2. Schematic of the connections between urbanization, livestock population, and the availability of grassland area (Allington et al. 2017).

populations. We developed two separate models based on a common integrative framework for two case study areas: Suhkbaatar Aimag in Mongolia and Xilingol League in Inner Mongolia (Fig. x). We used future scenarios for each region generated with stakeholder input to forecast trends in grassland area, livestock numbers, and biomass under alternative climate, socioeconomic, and land-use futures.

Our results present somewhat hopeful predictions for the future resilience of the rangelands of the Mongolian Plateau. However, this resilience is dependent on two factors, namely the continuation of grassland protection policies in China and continued rural out-migration in both countries. It is unclear how sustainable this urban migration might be, and how such a demographic shift might affect food security or increasing demand for arable lands in the region. Our simulations suggest that future dynamics in the two systems are strongly influenced by urbanization trends, which alter the spatial distribution of the population, the area of urban settlements, and the makeup of the rural workforce available for herding (Fig). Urbanization is often perceived as a cause of grassland loss, due to conversion of pasture land to development. Our analyses of current dynamics on the plateau and scenario-based simulations show that the effects of future urbanization need additional attention (Allington et al. 2017).

SIGNIFICANT RESULTS

By applying the concept of the coupled natural and human system (CNH), we compared spatiotemporal changes in livestock, land cover, and ecosystem production to understand the relative roles that natural and social driving forces have on CNH dynamics on the Mongolian Plateau. We used socioeconomic and physical data at prefecture level for Inner Mongolia and Mongolia from 1981 through 2010 to represent changes in net primary productivity (NPP), enhanced vegetation index (EVI), precipitation, annual average temperature, livestock (LSK), livestock density (LSKD), land cover change (LCC), gross domestic production (GDP), and population (POP). The ratios such as LSK: NPP, LSKD: EVI, LSKD: albedo, LSK: POP, and LSK: GDP were examined and compared between Inner Mongolia and Mongolia, and SEM was applied to quantify the complex interactions. Substantial differences in LSK, POP, and economic development were found among the biomes and between Inner Mongolia and Mongolia. When various indicators for policy shifts—such as the World Trade Organization (WTO) for China, the Third Campaign to Reclaim Abandoned Agriculture Lands (ATAR-3), and the Grain for Green Program for China (GFG)—were added into our SEM, the results showed
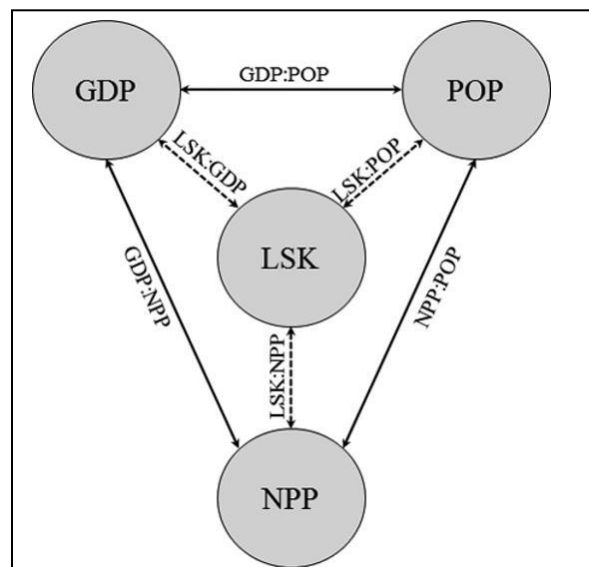

Fig. 3. The working framework connecting the dots representing social, economic, and ecosystem functions and land use. The quantitative measure for each dot is population (POP), gross domestic product (GDP), net primary productivity (NPP) of ecosystems, and livestock (LSK), respectively. We focus on the changes in ratios between any two measures in Inner Mongolia (IM) and Mongolia (MG) between 1981 and 2010 (Chen et al. 2015).

significant change in the strength of the above relationships. After China joined the WTO, the relationships in Inner Mongolia between LSKD: LCC and LSKD: NPP were immensely strengthened, whereas relationships in NPP: LCC were weakened. In Mongolia, the ATAR-3 program first appeared to be an insignificant policy, but the Collapse of the Soviet Union enhanced the correlation between LSKD: LCC, weakened the connection of LCC: NPP, and did not affect LSKD: NPP. We conclude that human influences on the Mongolian CNH system exceeded those of the biophysical changes, but that the significance varies in time and per biome, as well as between Inner Mongolia and Mongolia (Chen et al. 2015a, 2015b) in *Bioscience* and *Environmental Research letters*. Our *Bioscience* paper also was selected as the cover page by *Bioscience* and an online news release (http://bioscience.oxfordjournals.org/content/65/6.cover-expansion).

Ecosystem production of grazed grasslands: A cluster of four eddy covariance towers were set up to answer how C fluxes shift among four dominant ecosystems in Mongolia – meadow steppe (MDW), typical steppe (TPL), dry typical steppe (DRT) and shrubland (SHB) during two growing seasons (2014 and 2015). Results: Large variations were observed for the annual net ecosystem exchange (NEE) from 59 to 193 g C m^{-2}, though all four sites acted as a C source. During the two growing seasons, MDW acted as a C sink, TPL and DRT were C neutral, while SHB acted as a C source. MDW to SHB and TPL conversions resulted in a 2.6- and 2.2-fold increase in C release, respectively, whereas the TPL to SHB conversion resulted in a 1.1-fold increase at the annual scale. C assimilation was higher at MDW than those at the other three ecosystems due to its greater C assimilation ability and longer C assimilation times during the day

Fig. 4. Two year accumulative variations in carbon fluxes (g C m−2 d−1) of the net ecosystem CO2 exchange (NEE), ecosystem respiration (ER), and gross ecosystem production (GEP) in the four ecosystems on the Mongolian Plateau in 2014 and 2015 (Shao et al. 2017)

and growing period. On the other hand, C release was highest at SHB due to significantly lower photosynthetic production and relatively higher ecosystem respiration (ER). A stepwise multiple regression analysis showed that the seasonal variations in NEE, ER and gross ecosystem production (GEP) were controlled by air temperature at MDW, while they were controlled mainly by soil moisture at TPL, DRT and SHB. When air temperature increased, the NEE at MDW and TPL changed more dramatically than at DRT and SHB, suggesting not only a stronger C release ability but also a higher temperature sensitivity at MDW and TPL.
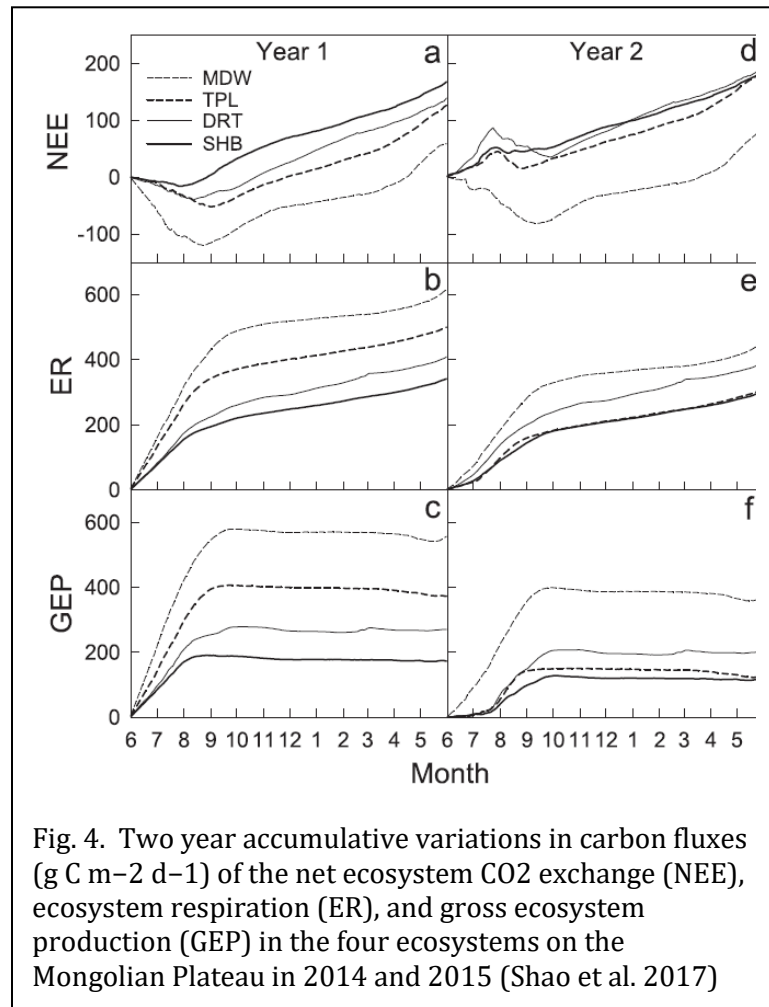
9

Conclusions: The ongoing and predicted global changes in Mongolia likely impact the C exchange at MDW and TPL more than at DRT and SHB in Mongolia. Our results suggest that, with increasing drought and vegetation type succession, a clear trend for greater CO_2 emissions may result in further global warming in the future. This study implies that diverse grassland ecosystems will respond differently to climate change in the future and can be seen as nature-based solutions (NBS) supporting climate change adaptation and mitigation strategies.

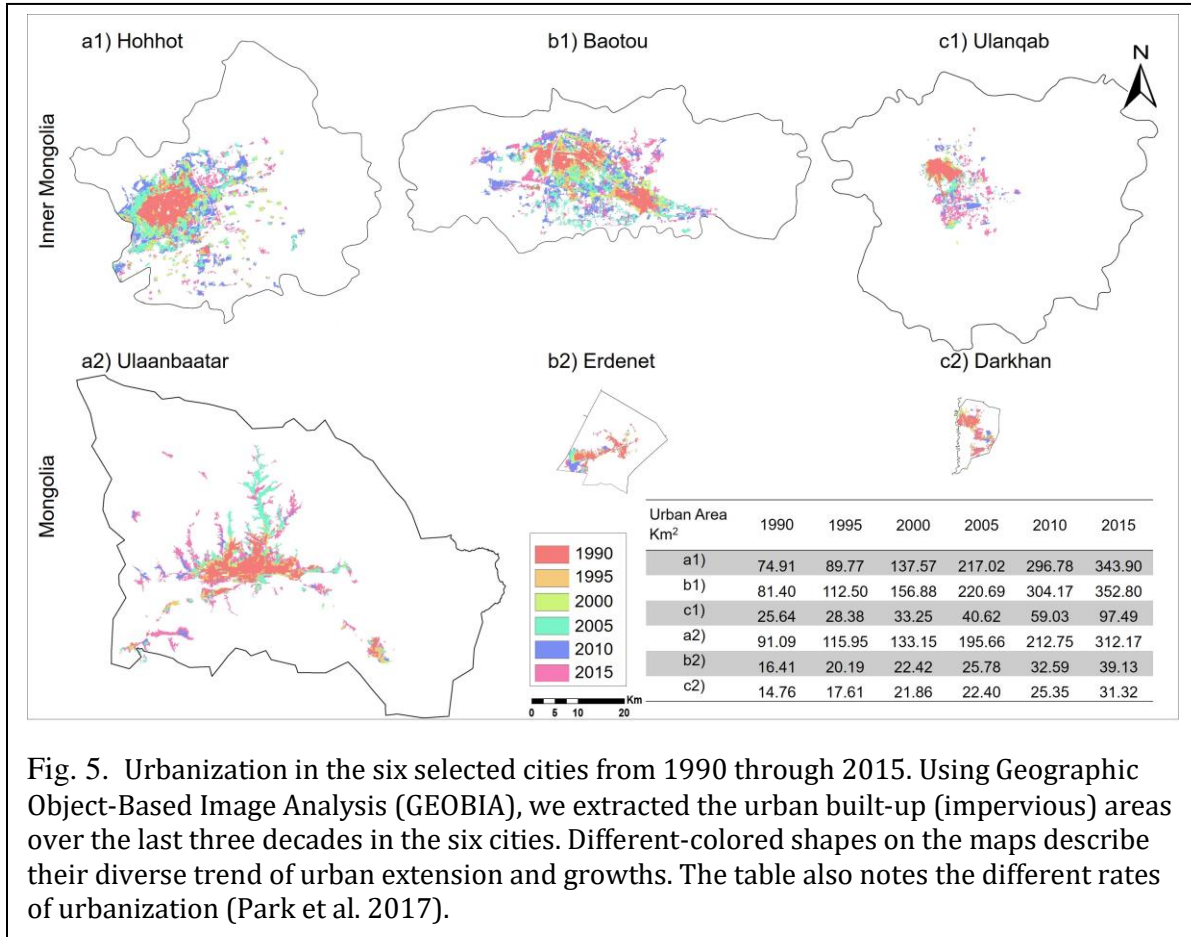| Urban Area Km²	1990	1995	2000	2005	2010	2015
a1)	74.91	89.77	137.57	217.02	296.78	343.90
b1)	81.40	112.50	156.88	220.69	304.17	352.80
c1)	25.64	28.38	33.25	40.62	59.03	97.49
a2)	91.09	115.95	133.15	195.66	212.75	312.17
b2)	16.41	20.19	22.42	25.78	32.59	39.13
c2)	14.76	17.61	21.86	22.40	25.35	31.32

Fig. 5. Urbanization in the six selected cities from 1990 through 2015. Using Geographic Object-Based Image Analysis (GEOBIA), we extracted the urban built-up (impervious) areas over the last three decades in the six cities. Different-colored shapes on the maps describe their diverse trend of urban extension and growths. The table also notes the different rates of urbanization (Park et al. 2017).

We found that the spatial characteristics of urbanization in IM and MG have both similarities and differences. The cities in IM and MG have experienced rapid urban expansion, with urban areas increasing by 4.36 times and 3.12 times, respectively, since 1990. Cities in IM, however, were less dense and more sprawling whereas cities in MG were linearly aggregated. We also found through PLSSEM that multiple driving forces affected urbanization in IM and MG during the transitional period. Results (path coef.) demonstrated that economic development (0.559) is a major driver for urbanization in IM, whereas social goods (0.646) and economic development (0.433) strongly influence urbanization in MG. These differences are likely due to the divergent governmental roles in urban development and in infrastructure/social support, as well as the differing economic structures in IM and MG.

PUBLICATIONS (n=28)

1. Allington, G.R.H. and D.G. Brown. Leveraging a time series of remotely sensed data to better characterize the dynamics of grassland degradation and restoration on the Mongolian Plateau. In Preparation for *Ecosphere*.
2. Allington, G.R., Fernandez-Gimenez, M., Chen, J., Brown, D.G. Using 'Story and Simulation' to Uncover Drivers and Possible Futures of a Grassland Ecosystem. Revised and Resubmitted for Ecology and Society.
3. Allington, G. R., W. Li, & D.G. Brown (2017). Urbanization and environmental policy effects on the future availability of grazing resources on the Mongolian Plateau: Modeling socio-environmental system dynamics. Environmental Science & Policy 68: 35-46.
4. Amarjargal A., Y. Zhang, J. Chen (2015) How does local mining impact on rural immigration? Case of Mongolia. Proceedings of the trans-disciplinary research conference: building resilience of Mongolian Rangelands. Pages 195-199.
5. Chen, J. (2015). Editorial: Coupled human and natural system. *BioScience* 65(6); 539.
6. Chen, J., R. John, Y. Zhang, C. Shao, D. G. Brown, O. Batkhishig, A. Amarjargal, Z. Ouyang, G. Dong, D. Wang, and J. Qi. (2015). Divergences of Two Coupled Human and Natural Systems on the Mongolia Plateau. *BioScience* 65(6): 559-570.
7. Chen, J., R. John, C. Shao., Y. Fan, Y. Zhang, A. Amarjargal, D. Brown, J. Qi, J. Han, R. Lafortezza, G. Dong & L. Li (2015). Policy shifts influence the functional changes of the CHN systems on the Mongolian plateau. *Environmental Research Letters,* doi:10.1088/1748-9326/10/8/085003.
8. Fan, P., Chen, J., John, R. (2016). Urban landscape and environment change during the economic transition in the Mongolian Plateau: A comparative study of Hohhot and Ulaanbaatar, 1990–2010. *Environment Research*, 120, 96-112.
9. Fan, Y, J. Chen, G. Shirkey, R. John, R. Wu, H. Park, C. Shao. (2016). Applications of structural equation modeling (SEM) in ecological research: An updated review. *Ecological Processes* 5:19 DOI: 10.1186/s13717-016-0063-3
10. Huettmann, F, J. Chen, H. park, C. Shao, R. John, et al. The Mongolian Plateau as a global showcase for big data resources: a first compilation and assessment of 450 dataset. ESSD, in preparation.
11. Giannico, V., J. Chen, C. Shao, R. John, Z. Ouyang, and R. Lafortezza. Contributions of landscape heterogeneity within the footprint of eddy-covariance towers to flux measurements. *Agricultural and Forest Meteorology*, near submission.
12. Groisman, P.Y.., H.H. Shugart, D. Kicklighter, G. Henebry, N. Tchebakova, Sh. Maksyutov, E. Monier, G. Gutman, S. Gulev, J. Qi, A. Prishchepov, E. Kukavskaya, B. Porfiriev, A. Shiklomanov, T. Loboda, N. Shiklomanov, S. Nghiem, K. Bergen, J. Albrechtová , J. Chen, M. Shahgedanova, A. Shvidenko N. Speranskaya, A. Soja, K. deBeurs, O. Bulygina, J. McCarty, Q. Zhuang, ¹O. Zolina, and The NEFI Science Plan Preparation Team, 2017: Northern Eurasia Future Initiative (NEFI): Facing the Challenges and Pathways of Global Change in the 21st Century. *Progress in Earth and Planetary Science (in review).*
13. Han, J., J. Chen, L. Li, H. Chu, Y. Miao, S. Chen (2016). The Effects of grazing and watering on ecosystem CO2 fluxes vary by community phenology. *Environmental Research* 144: 64-71.
14. Han, J., J Chen, J Xia, L Li. (2015). Grazing and precipitation produce complex consequences on phenological successes and processes in a desert steppe. *Plant Ecology* 216:599–613.
15. Han, J., J. Chen, G. Han, C. Shao, H. Sun, and L. Li. 2014. Legacy effects from historical grazing enhanced carbon sequestration in a desert steppe. *Journal of Arid Environment* 107: 1-9.
16. John, R., J. Chen, V. Gianicco, H. Park, J. Xiao, G. Shirkey, Z. Ouyang, C. Shao, R Lafortezza, & J. Qi. (2017). Canopy cover and herbaceous aboveground biomass on the Mongolian Plateau:

spatio-temporal estimates and controlling factors. *Remote Sensing of the Environment* (submitted).

17. John, R., Chen, J., Kim, Y., Ouyang, Z., Park, H., Xiao, J., Shao, C., Amarjargal, A., Zhang, Y., Bakshishig, O., and Qi, J. (2016). Differentiating anthropogenic modification and precipitation-driven change on vegetation productivity on the Mongolian Plateau. *Landscape Ecology*, 31, 547-566, doi: 10.1007/s10980-015-0261-x.s

18. Liu, Y. Q. Zhuang, Z. Pan, D. Miralles, D. Kicklighter, Q. Zhu, Y. He, J. Chen, D. Niyogi, N. Tchebakova, A. Sirin, J. Melillo. (2015). Evapotranspiration in Northern Eurasia: Impact of forcing uncertainties on terrestrial ecosystem model estimates, J. Geophys. Res. Atmos. 120: doi:10.1002/2014JD022531

19. Liu, Y., Q. Zhuang, Z. Pan, N. Tchebakova, D. Kicklighter, D. Miralles, J. Chen, A. Sirin, J. Melillo, (2014). Responses of evapotranspiration and water availability to the changing climate in Northern Eurasia. *Climatic Change* 126:413–427.

20. Park, H., P. Fan, R. John, and J. Chen. (2017). Urbanization on the Mongolian Plateau after economic reform: Changes and causes. *Applied Geography* 86: 118–127.

21. Qi, J., J. Chen, R Lafortezza, and L. Zhang (2017). Remote sensing for ecosystem sustainability. In S. Liang (editor), "*Comprehensive Remote Sensing*", Elsevier (in press)

22. Qi, J., J., X. Xin, R. John, P. Groisman, and J. Chen. (2017). Understanding livestock production and sustainability of grassland ecosystems in the Asian Dryland Belt. *Ecological Processes* 6:22. DOI: 10.1186/s13717-017-0087-3

23. Qu, L., J. Chen, G. Dong, S. Jiang, L. Li, C. Shao, and J. Guo (2016). Heat waves reduce ecosystem carbon sink strength in a Eurasian meadow steppe. *Environmental Research* 144: 39-48.

24. Shao, C., J. Chen, H. Chu, R. Lafortezza, G. Dong, M. Abraha, O. Batkhishig, R. John, Z. Ouyang, J. Qi. (2017). Grassland productivity and carbon sequestration in Mongolian grasslands: The underlying mechanisms and nomadic implications. *Environmental Research* 159: 124-134.

25. Shao, C., J. Chen, L. Li, G. Dong, J. Han, M. Abraha, and R. John. (2017). Grazing effects on energy fluxes in a desert steppe on the Mongolian Plateau. *Ecological Applications* 27: 485–502.

26. Shao, C., L Li, G. Dong, J. Chen. (2014). Spatial variation of net radiation and its contribution to energy balance closure in grassland ecosystems. *Ecological Processes* 3 (1): 1-11.

27. Xu, Y. and Y. Zhang, J. Chen. "Understanding Migration Pattern in Mongolia". In Preparation.

28. Zhang, M., L. Zhang, Y. Xu, Y. Zhang, and J. Chen. (2017). Pastureland transfer as a livelihood adaptation strategy for the herdsmen: A case study of Xilingol, Inner Mongolia. *Rangeland Journal* 39(2):179-187.

VIDEO INTEEVIEW(S)

Allington, G. Approaches and methods to integrate diverse socio-environmental data. SESYNC Video Series, No. 3, Social-Ecological Synthesis.

Fig. Allington, G. Approaches and methods to integrate diverse socio-environmental data. SESYNC Video Series, No. 3, Social-Ecological Synthesis. Sept., 2017
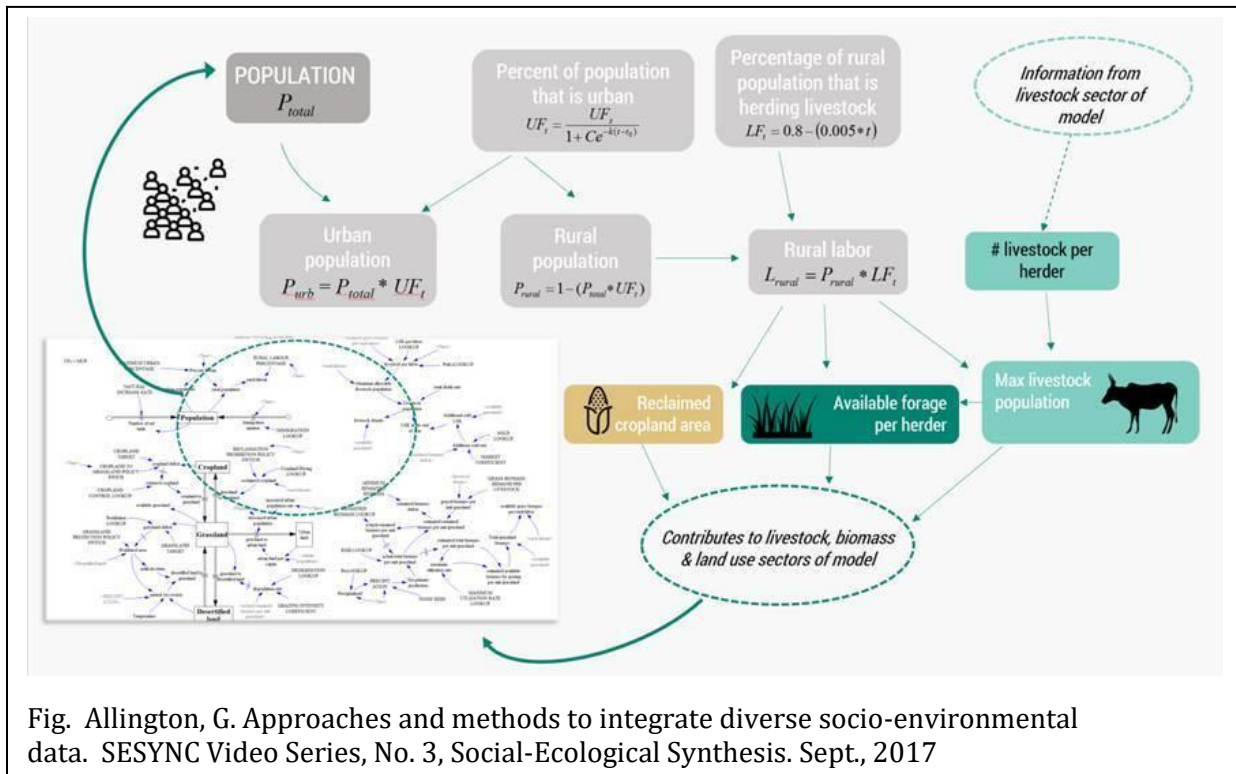
PRESENTATIONS (n=40)
1. Chen, J., John, R., Allington, G., Li, F., Shao, C., Zhang, Y, Brown D.G., Qi, J., Gang, B., & Fernández-Giménez, M.E. (2017). Japan Geoscience Union Meeting, May 20, 2017, Chiba, Japan.
2. John, R., Gianicco, V., Chen, J., Park, H., Xiao, J., Ouyang, Z., Shirkey, G., Lafortezza, R. & Qi, J. (2017). Spatio-temporal estimates of herbaceous aboveground biomass on the Mongolian Plateau: their climate controls and anthropogenic drivers. American Association of Geographers (AAG), Annual meeting, April 5-9, Boston, MA.
3. Park, H., Fan, P., John, R., & Chen, J. Urban sprawl, informal settlements, and inequality: Spatiotemporal patterns and drivers of *Ger* districts in Ulaanbaatar, Mongolia (2017). Annual meeting of US-International Association of Landscape Ecology (US-IALE), April 9-13, Baltimore.
4. Park, H., Fan, P., John, R., Chen, J. (2017). Urban sprawl and informal settlements: Spatiotemporal trends of *Ger* districts in Ulaanbaatar, Mongolia. NASA LCLUC Spring Science Team Meeting, Rockville, USA
5. Park, H., Fan, P., John, R., Chen, J. (2017). Urban sprawl, informal settlements, and inequality: Spatiotemporal patterns and drivers of *Ger* districts in Ulaanbaatar, Mongolia. US-IALE, Baltimore, USA

6. Chen, J., John, R., Shao, C., Ouyang, Z., Mack, E., & Lafortezza, R., and Qi, J. (2016). Asian dryland hierarchies in rapidly evolving institutional environments. The 3rd Open Science Meeting, Global Land Programme, Beijing, China, 10/27-27, 2016.
7. Shao, C., Chen, J., Li, L., John, R., & Ouyang, Z. (2015). Grazing Effects on Water Use Efficiency on a Mongolian Desert Steppe. GC13B-1137 in GC13B: Climate-Vegetation Interaction and Land Cover/Land Use Change in Semi-Arid Grassland Ecosystems II Posters, AGU Fall 2015 Meeting, Dec. 14–18, San Francisco, CA.
8. Chen, J., Ouyang, Z., John, R., Henebry, G., Xie, Y., de Beurs, K., Fan, Y., Shao, C., Qi, J., Wu, J. & Li, Y. (2015). Regulations of evapotranspiration and ecosystem productivity from biophysical and human drivers in drylands Northern Eurasia. GC31B-1174 in GC31B: Environmental, Socioeconomic, and Climatic Changes in Northern Eurasia and Their Feedbacks to the Global Earth System and Society I Posters, AGU Fall 2015 Meeting, Dec. 14–18, San Francisco, CA.
9. John, R., Kim, Y., & Shao, C. (2015). GC11I: Climate-Vegetation Interaction and Land Cover/Land Use Change in Semi-Arid Grassland Ecosystems I Oral, AGU Fall 2015 Meeting, Dec. 14–18, San Francisco, CA.
10. John, R., Kim, Y., & Shao, C. (2015). GC11I: Climate-Vegetation Interaction and Land Cover/Land Use Change in Semi-Arid Grassland Ecosystems II Posters, AGU Fall 2015 Meeting, Dec. 14–18, San Francisco, CA.
11. John, R., Chen, J., Kim, Y., Ouyang, Z., Park, H., & Shao, C. (2015). Remote Sensing-based estimates of herbaceous aboveground biomass on the Mongolian Plateau. GC13B-1136 in GC13B: Climate-Vegetation Interaction and Land Cover/Land Use Change in Semi-Arid Grassland Ecosystems II Posters, *AGU Fall 2015 Meeting*, Dec. 14–18, San Francisco, CA.
12. Shao, C., Chen, J., Li, L., John, R., & Ouyang, Z. (2015). Grazing Effects on Water Use Efficiency on a Mongolian Desert Steppe. GC13B-1137 in GC13B: Climate-Vegetation Interaction and Land Cover/Land Use Change in Semi-Arid Grassland Ecosystems II Posters, *AGU Fall 2015 Meeting*, Dec. 14–18, San Francisco, CA.
13. Chen, J., Ouyang, Z., John, R., Henebry, G., Xie, Y., de Beurs, K., Fan, Y., Shao, C., Qi, J., Wu, J. & Li, Y. (2015). Regulations of evapotranspiration and ecosystem productivity from biophysical and human drivers in drylands Northern Eurasia. GC31B-1174 in GC31B: Environmental, Socioeconomic, and Climatic Changes in Northern Eurasia and Their Feedbacks to the Global Earth System and Society I Posters, *AGU Fall 2015 Meeting*, Dec. 14–18, San Francisco, CA.
14. Allington, G. R. H. and D.G. Brown. *Leveraging satellite data to characterize the dynamics of grassland degradation and restoration on the Mongolian Plateau.* Ecological Society of America Annual Meeting, Baltimore, MD: August 2015
15. Thompson, K. and G.R.H. Allington. *Mapping Movement: Using GIS to Understand Livestock and Development Patterns in Mongolia*. University of Michigan Doris Duke Conservation Scholars Program Poster Presentations. July 28, 2016
16. Allington, G.R.H. and D.G. Brown. *Shared and divergent histories drive future dynamics on the Mongolian Plateau.* International Association of Landscape Ecologists Meeting, Portland, OR. July 2015.
17. Allington, G.R.H., W. Li and D.G. Brown. *Modeling system dynamics in rangelands of the Mongolian Plateau.* Building Resilience of Mongolian Rangelands Conference, June 9-10, 2015. Blue Sky Hotel, Ulaanbaatar.
18. John, R., Chen, J., Shao, C., Kim, Y., Ouyang, Z., Xiao, J., Park, H., et al. (2015). Differentiating between anthropogenic modification and climate change using long–term vegetation index

trends adjusted for precipitation on the Mongolian plateau. Building Resilience of Mongolian Rangelands Conference, June 9-10, Blue Sky Hotel, Ulaanbaatar.

19. Shao, C., Chen, J., John, R., Li, L., Dong, G., Ochirbat, B. (2015) Grazing effects on energy fluxes in a desert steppe on the Mongolian Plateau. Building Resilience of Mongolian Rangelands Conference, June 9-10, Blue Sky Hotel, Ulaanbaatar.

20. Fan, P., Chen, J., John, R., and Park, H. (2015). Urban landscape and environment change during the economic transition in Mongolian Plateau: A comparative study of Hohhot and Ulaanbaatar, 1990-2010, Association of American Geographers 2015 Annual Meeting, Chicago, USA

21. Chen, J., John, R.., Brown, D., Shao, C., Allington, A., Zhuang, Q., Xiao, J., Xie, Y., Sun, G., Fan, P., & Qi, J. (2015). LCLUC Synthesis: Ecosystem-Society Interactions on a Changing Mongolian Plateau. Session: Theme 4: Human influence on global ecosystems, NASA Carbon Science and Ecosystems joint science workshop, April 20-24, 2015, College Park Marriott Hotel and Conference Center, Maryland.

22. Fan, P., Chen, J., John, R. (2015). Urban landscape and environment change during the economic transition in Mongolian Plateau: A comparative study of Hohhot and Ulaanbaatar, 1990-2010. Session: Theme 4: Human influence on global ecosystems, NASA Carbon Science and Ecosystems joint science workshop, April 20-24, 2015, College Park Marriott Hotel and Conference Center, Maryland.

23. Chen, J., Ouyang, Z., John, R., Dong, G., Fan, P., (2015). Co-Evolutions of Ecosystems, Societies, and Economy in Dryland Asia. Vol. 17, EGU2015-6519-1, April 12-17, EGU General Assembly 2015, Vienna, Austria.

24. Allington, G.R.H. and D.G. Brown. *New ontology and classification system for arid grasslands, toward a new land cover product*. US-IALE Annual Conference, Asheville, NC: April 4, 2016

25. Allington, G.R.H. *Mapping and modelling dynamics processes in rangelands.* Invited presentation at the National Social-Ecological Synthesis Center, Annapolis, MD. March 23, 2016

26. John, R., Chen, J., Kim, Y., Ouyang, Z., Xiao, J, Shao, C., & Batkishig, O. (2014). Differentiating between Land Use and Climate-driven Change using Long–term Vegetation Index Trends adjusted for Precipitation on the Mongolian Plateau. GC31B-0474 in GC31B. Environmental, Socioeconomic, and Climatic Changes in Northern Eurasia and Their Feedbacks to the Global Earth System I Posters, *AGU Fall 2014 Meeting*, Dec 15-19, San Francisco, CA.

27. Zhang, Y., Amarjargal, A. 2015. Evolution of Common Resource Tenure and Governing: Evidence from Pastureland in Mongolia Plateau. Proceedings of the Trans-disciplinary Research Conference: Building Resilience of Mongolian Rangelands, Ulaanbaatar Mongolia, June 9-10, 2015.

28. Ge, W., Kinnucan, H. The Influence of the Booming Mining Industry on the Agricultural Sector in Mongolia. Proceedings of the Trans-disciplinary Research Conference: Building Resilience of Mongolian Rangelands, Ulaanbaatar Mongolia, June 9-10, 2015.

29. Xu, Y., Zhang, Y., Gao, L., Qiao, G., Chen, J. To fence or not to fence? Perceptions and attitudes of herders in Inner Mongolia. Proceedings of the Trans-disciplinary Research Conference: Building Resilience of Mongolian Rangelands, Ulaanbaatar Mongolia, June 9-10, 2015.

30. Amarjargal, A., Zhang, Y., Chen, J. How does local mining impact on rural immigration: Case of Mongolia. Proceedings of the Trans-disciplinary Research Conference: Building Resilience of Mongolian Rangelands, Ulaanbaatar Mongolia, June 9-10, 2015.

31. John, R., J. Chen, Z. Yang, J. Xiao, M. Abd Salam M. El Vilaly, A. Samanta, S. Ganguly, O. Batkhishig and G. Zhang. Long term trends in GPP and ET on the Mongolian Plateau in

context of climate and land cover/land use change. The 2013 AGU Fall Meeting. San Francisco, California. December 9-13, 2013 (invited speaker).

32. Chen, J. Harmonizing People and Nature on Mongolia Plateau and Elsewhere. Department of Geography, University of Toronto, Canada, October 21, 2013.

33. Chen, J. Harmonizing People and Nature on Mongolia Plateau and Elsewhere. Center for Global Change & Earth Observations, Michigan State University, Michigan, October 24, 2013.

34. Chen, J. Human and Nature Systems on Mongolia Plateau: The Renewed Challenge for Science & Societies. Future Earth: MAIRS Open Science Conference, Beijing, April 9, 2014.

35. Chen, J. Harmonizing Humans and Nature for the Changing Globe. The Weaver Lecture Series, Auburn University, March 27, 2014.

36. Zhang, Y., Amarjargal, A. 2015. Evolution of Common Resource Tenure and Governing: Evidence from Pastureland in Mongolia Plateau. Presented at Trans-disciplinary Research Conference: Building Resilience of Mongolian Rangelands, Ulaanbaatar Mongolia, June 9-10, 2015.

37. Ge, W., Kinnucan, H. The Influence of the Booming Mining Industry on the Agricultural Sector in Mongolia. Presented at Trans-disciplinary Research Conference: Building Resilience of Mongolian Rangelands, Ulaanbaatar Mongolia, June 9-10, 2015.

38. Xu, Y., Zhang, Y., Gao, L., Qiao, G., Chen, J. To fence or not to fence?   Perceptions and attitudes of herders in Inner Mongolia. Presented at Trans-disciplinary Research Conference: Building Resilience of Mongolian Rangelands, Ulaanbaatar Mongolia, June 9-10, 2015.

39. Amarjargal, A., Zhang, Y., Chen, J. How local mining impact on rural immigration does: Case of Mongolia Presented at Trans-disciplinary Research Conference: Building Resilience of Mongolian Rangelands, Ulaanbaatar Mongolia, June 9-10, 2015.

40. Zhang, Y. Land use/ land ownership change in the process of rural-urban integration, Hohhot, Inner Mongolia Agricultural University, December 8, 2014.