Dryland East Asia
Land Dynamics Amid Social and Climate Change

Jiquan Chen, Shiqiang Wan,
Geoffrey Henebry,
Jiaguo Qi, Garik Gutman, Ge Sun,
Martin Kappas (Eds.)

Dryland East Asia
Land Dynamics Amid Social and Climate Change

Editors:

Jiquan Chen, Shiqiang Wan,
Geoffrey Henebry,
Jiaguo Qi, Garik Gutman, Ge Sun,
Martin Kappas

Technical Editors:

Alona Gutman, Lisa Delp Taylor

List of Contributors

Agrawal, Arun
School of Natural Resources and Environment, University of Michigan, Ann Arbor, MI, USA
arunagra@umich.edu

Ai, Likun
Chinese Academy of Sciences, Beijing, China
aili@mairs-essp.org

Batkhishig, Ochirbat
Institute of Geography, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia
batkhishig@gmail.com

Becker, Richard H.
Department of Environmental Sciences, University of Toledo, Toledo, OH, USA
rbecker7@utnet.utoledo.edu

Brown, G. Daniel
School of Natural Resources and Environment, University of Michigan, Ann Arbor, MI, USA
danbrown@umich.edu

Chen, Jiquan
Landscape Ecology & Ecosystem Science (LEES) Lab, Department of Environmental Sciences, University of Toledo, Toledo, OH, USA
Jiquan.Chen@utoledo.edu

Chen, Liding
Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, China
ldchen@rcees.ac.cn

Chen, Shiping
Institute of Botany, Chinese Academy of Sciences, Beijing, China
spchen@ibcas.ac.cn

Chen, Xi
Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Ürümqi, China
chenxi@ms.xjb.ac.cn

Chen, Yaning
Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Ürümqi, China
Chenyn@mx.xjb.ac.cn

Chuluun, Togtohyn
Dryland Sustainability Institute, Ulaanbaatar, Mongolia
chuluunjim@yahoo.com

Darmenova, Kremena
School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA, USA
kdarmenova@gatech.edu

de Beurs, Kirsten M.
Department of Geography and Environmental Sustainability, University of Oklahoma, Norman, OK, USA
kdebeurs@ou.edu

Fan, Peilei
Center for Global Change and Earth Observation, Michigan State University, East Lansing, MI, USA
fanpeile@msu.edu

Feng, Xiaoming
Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, China
fengxm@rcees.ac.cn

Fu, Bojie
Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, China
bfu@rcees.ac.cn

Gao, Liping
School of Forestry and Wildlife Sciences, Auburn University, AL, USA
lzg0005@tigermail.auburn.edu

Groisman, Pavel
NOAA National Climatic Data Center, Asheville, NC, USA
pasha.groisman@noaa.gov

Guo, Ke
Institute of Botany, Chinese Academy of Sciences, Beijing, China
guoke@ibcas.ac.cn

Gutman, Garik
NASA Land-Cover/Land-Use Change Program, Washington, DC, USA
garik.gutman@nasa.gov

Han, Guodong
Inner Mongolia Agricultural University, Hohhot, China
nmghanguodong@163.com

Havstad, Kris
USDA-ARS, Jornada Experimental Range, Las Cruces, NM, USA
khavstad@nmsu.edu

Henebry, Geoffrey M.
Geographic Information Science Center of Excellence, South Dakota State University, Brookings, SD, USA
Geoffrey.Henebry@sdstate.edu

Herrick, Jeffery E.
USDA-ARS, Jornada Experimental Range, Las Cruces, NM, USA
jherrick@ad.nmsu.edu

Huang, Huiqing
Center for Global Change and Earth Observation, East Lansing, MI, USA
Huiqingh@msu.edu

Huang, Jianping
College of Atmospheric Sciences, Lanzhou University, Lanzhou, China
hjp@lzu.edu.cn

John, Ranjeet
Landscape Ecology & Ecosystem Science (LEES) Lab, Department of Environmental Sciences, University of Toledo, Toledo, OH, USA
Ranjeet.John@utoledo.edu

Kalashnikova, Olga
Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
olga.kalashnikova@jpl.nasa.gov

Kappas, Martin
Institute of Geography, Georg-August University of Goettingen, Germany
mkappas@gwdg.de

Karnieli, Arnon
Jacob Blaustein Institutes for Desert Research, Ben Gurion University of the Negev, Israel
karnieli@bgu.ac.il

Kemp, David
Charles Sturt University, Orange, Australia
dkemp@csu.edu.au

Kurban, Alishir
Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Ürümqi, Xinjiang, China.
alishir@ms.xjb.ac.cn

Kurosaki, Yasunori
School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA, USA
kuro@alrc.tottori-u.ac.jp

Li, Fengmin
School of Life Sciences, Lanzhou University, Lanzhou, China
fmli@lzu.edu.cn

Li, Linghao
Institute of Botany, Chinese Academy of Sciences, Beijing, China
llinghao@ibcas.ac.cn

Li, Xue
Center for Global Change and Earth Observation, East Lansing, MI, USA
lixue@msu.edu

Li, Zhiguo
Inner Mongolia Agriculture University, Hohhot, China
nmndlzg@163.com

Lioubimtseva, Elena
Department of Geography and Planning, Grand Valley State University, Allendale, MI, USA
lioubime@gvsu.edu

Liu, Tong
Inner Mongolia Agricultural University, Hohhot, China
h_liutong@yahoo.cn

Long, Ruijun
Engineering Research Centre for Arid Agriculture and Ecological Rehabilitation, Lanzhou University, Lanzhou, China
longrj@gsau.edu.cn

Lu, Nan
Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, China
nanlv@rcees.ac.cn

Mátyás, Csaba
Institute of Environmental and Earth Sciences, University of West Hungary, Hungary
cm@emk.nyme.hu

Messina, Joseph
Center for Global Change and Earth Observation, East Lansing, MI, USA
jpm@msu.edu

Niu, Shuli
Key Laboratory of Ecosystem Network Observation and Modeling, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing, China
sniu@ou.edu

Ouyang, Zutao
Landscape Ecology & Ecosystem Science, University of Toledo, Toledo, OH, USA
Zutao.Yang@rockets.utoledo.edu

Ozdogan, Mutlu
Center for Sustainability and the Global Environment, University of Wisconsin, Madison, WI, USA
ozdogan@wisc.edu

Piao, Shilong
College of Urban and Environmental Sciences, Peking University, Beijing, China
slpiao@pku.edu.cn

Propastin, Pavel
Institute of Geography, Georg-August University of Goettingen, Germany
ppropas@uni-goettingen.de

Qi, Jiaguo
Center for Global Change and Earth Observation, Michigan State University, East Lansing, MI, USA
qi@msu.edu

Qiao, Guanghua
College of Economics and Management, Inner Mongolia Agricultural University, Huhhot, China
qiao_imau@126.com

Reynolds, James F.
Nicholas School of the Environment, Duke University, Durham, NC, USA
james.f.reynolds@duke.edu

Reynolds, Julie A.
Department of Biology, Duke University, Durham, NC, USA
julie.a.reynolds@duke.edu

Shao, Changliang
Institute of Botany, Chinese Academy of Sciences, Beijing, China
zkyscl@ibcas.ac.cn

Shiklomanov, Alex
Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, Durham, NH, USA
alex.shiklomanov@unh.edu

Sokolik, Irina N.
School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA, USA
isokolik@eas.gatech.edu

Sun, Ge
Eastern Forest Environmental Threat Assessment Center, Southern Research USDA Forest Service, Raleigh, NC, USA
gesun@fs.fed.us

Wan, Shiqiang
College of Life Sciences, Henan University, Kaifeng, Henan, China
swan@ibcas.ac.cn

Wang, Jun
School of Natural Resources and Environment, University of Michigan, Ann Arbor, MI, USA
junw@umich.edu

Wang, Xuhui
College of Urban and Environmental Sciences, Peking University, Beijing, China
wxh.pku@gmail.com

Wang, Shengping
Key Laboratory of Regional Energy System Optimization, North China Electric Power University, Beijing, China
wangshp418@yahoo.com.cn

Wang, Shuai
Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, China
shuaiwangnmg@gmail.com

Wang, Zhongwu
Inner Mongolia Agricultural University, Hohhot, China
zhongwuwang1979@yahoo.com

Wright, Christopher K.
Geographic Information Science Center of Excellence, South Dakota State University, Brookings, SD, USA
Christopher.Wright@sdstate.edu

Wu, Jianguo
School of Life Sciences & School of Sustainability, Arizona State University, Tempe, AZ, USA
Jingle.Wu@asu.e

Xi, Xin
School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA, USA
xin.xi@eas.gatech.edu

Xia, Jianyang
Department of Microbiology and Plant Biology, University of Oklahoma, Norman, OK, USA
jxia@ou.edu

Xiao, Jingfeng
Earth Systems Research Center, Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, Durham, NH, USA
j.xiao@unh.edu

Yan, Dong
Department of Geography and Environmental Sustainability, University of Oklahoma, Norman, OK, USA
Dong.Yan-1@ou.edu

Yan, Liming
School of Life Sciences, Fudan University, Shanghai, China
yanliming0108@gmail.com

Ye, Jiansheng
School of Life Sciences, Lanzhou University, Lanzhou, China
yejiansheng30@gmail.com

Yuan, Wenping
College of Global Change and Earth System Science, Beijing Normal University, Beijing, China
wyuan@bnu.edu.cn

Zhang, Li
Key Laboratory of Digital Earth Science, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, Beijing, China
lizhang@ceode.ac.cn

Zhang, Yaoqi
School of Forestry & Wildlife Sciences, Auburn University, AL, USA
yaoqi.zhang@auburn.edu

Zhang, Zhiqiang
College of Soil and Water Conservation, Beijing Forestry University, Beijing, China
zhqzhang@bjfu.edu.cn

Zhao, Mengli
Inner Mongolia Agriculture University, Hohhot, China
menglizhao@yahoo.com

Zmijewski, Kirk A.
Department of Environmental Sciences, University of Toledo, Toledo, OH, USA
kirk.zmijewski@rockets.utoledo.edu

Abbreviations

3Ns and YRB	Three North and the Yangtze River Basin
ADB	Asia Development Bank
AI	Aerosol Index
ANPP	Aboveground Net Prime Productivity
AO	Arctic Oscillation
AOD	Aerosol Optical Depth
AP	Annual Precipitation
AVHRR	Advanced Very High Resolution Radiometer
BII	Biodiversity Intactness Index
BNPP	Belowground Net Prime Productivity
BSC	Biological Soil Crusts
C	Carbon
CAI	Cellulose Absorption Index
CAS	Chinese Academy of Science
CBD	Convention on Biological Diversity
CBRM	Community-Based Resource Management
CCFP	Cropland Conversion to Forests Program
CMG	Climate Modeling Grid
CMS	Carbon Monitoring System
CNH	Coupled Natural and Human
CRU	Climatic Research Unit
CSDF	French Scientific Committee on Desertification
CST	Committee on Science and Technology
DC	Duolun Cropland
DCA	Drylands of Central Asia
DDP	Dryland Development Paradigm
DEA	Dryland East Asia
DLDD	Desertification/Land Degradation and Drought
DNA	Drylands of North America
DPSIR	Driving Force-Pressure-State-Impact-Response
DS	Duolun Steppe
DTR	Diurnal Temperature Range
DWG	Dryland Working Group
ECVs	Essential Climate Variables
EDN	European DesertNet
EEA	European Environment Agency

ENSO	El Niño-Southern Oscillation
EOS	Earth Observing System
ER	Ecosystem Respiration
EROS	Earth Resources Observation and Science
ESA	Ecosystem Science and Applications
ESIP	Earth Science Information Partner
ESS	Earth System Science
ESSP	Earth System Science Partnership
ET	Evapotranspiration
ETM	Enhanced Thematic Mapper
EVI	Enhanced Vegetation Index
FAO	Food and Agriculture Organization
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
FLAASH	Fast Line-of-Sight Atmospheric Analysis of Spectral Hypercubes
fPAR	Fraction of Photosynthetically Active Radiation
GMAO	Global Modeling and Assimilation Office
GCM	Global Climate Model
GCMs	Global Circulation Models
GCOS	Global Climate Observing System
GDOS	Global Drylands Observing System
GDP	Gross Domestic Product
GEP	Gross Ecosystem Productivity
GfGP	Grain for Green Program
GIMMS	Global Inventory Modeling and Mapping Studies
GMAO	Global Modeling and Assimilation Office
GPCC	Global Precipitation Climatology Centre
GPCP	Global Precipitation Climatology Project
GPP	Gross Primary Productivity
GS	Gansu Province
HDI	Human Development Index
H-E	Human-Environmental
HEC	Human-Environment-Climate
HPRS	Household Production Responsibility System
HS	Human System
HYDE	History Database of Global Environment
IGBP	International Geosphere-Bioshpere Programme
IGSNRR-CAS	Institute of Geographic Sciences and Natural Resources Research, CAS
IM	Inner Mongolia Autonomous Region
LAI	Leaf Area Index
LC	Land Cover
LCLU	Land Cover and Land Use
LCLUC	Land Cover and Land Use Change
LDA	Land Degradation Assessment
LDCM	Landsat Data Continuity Mission

LTK	Local Traditional Knowledge
LUE	Light Use Efficiency
LUR	Land Use Rights
LUT	Look Up Tables
MA	Millennium Assessment
MAIRS	Monsoon Asia Integrated Regional Study
MAT	Mean Annual Temperature
ME	Metabolisable Energy
MEA	Millennium Ecosystem Assessment
MERRA	Modern Era Retrospective-Analysis for Research and Applications
MG	Mongolia
MISR	Multi-angle Imaging Spectro-Radiometer
MODIS	Moderate Resolution Imaging Spectroradiometer
MSP	Medium Scale Project
MSS	Multispectral Scanner
N	Nitrogen
NAM	Northern Annular Mode
NAO	North Atlantic Oscillation
NARCM	Northern Aerosol Regional Climate Model
NASA	National Aeronautics and Space Administration
NBAR	Nadir BRDF-Adjusted Reflectance
NBSA	National Bureau of Statistics of China
NCAR	National Center For Atmospheric Research
NCEP	National Centers for Environmental Prediction
NDI	Normalized Difference Index
NDVI	Normalized Difference Vegetation Index
NEE	Net Ecosystem Exchange
NEESPI	Northern Eurasia Earth Science Partnership Initiative
NEP	Net Ecosystem Production
NFCP	Natural Forest Conservation Program
NFPP	Natural Forest Protection Program
NOAA	National Oceanic and Atmospheric Administration
NPP	Net Primary Production
NS	Natural System
NX	Ningxia Hui Autonomous Region
OLI	Operational Land Imager
OLS	Ordinary Least Squares
OMI	Ozone Monitoring Instrument
ORCHIDEE	Organizing Carbon and Hydrology in Dynamic Ecosystems
OS	Observation System
PAR	Photosynthetically Active Radiation
PES	Payment for Environmental Services
PPFD	Photosynthetic Photon Flux Density
PPP	Purchasing Power Parity
PRI	Photosynthetic Reflectance Index

PSR	Pressure-State-Response
PSURC	Pressure-State-Use-Response-Capacity
RAS	Russian Academy of Sciences
RCM	Regional Climate Model
RS	Remote Sensing
SACRI	Soil Adjusted Corn Residue Index
SAR	Synthetic Aperture Radar
SAVI	Soil-Adjusted Vegetation Index
SCP	Sand Control Program
SD	Standard Deviation
SeaWiFS	Sea-Viewing Wide Field-of-View Sensor
SK	Seasonal Kendall
SKFPs	State Key Forestry Programs
SLM	Sustainable Land Management
SMK	Seasonal Mann–Kendall
SOM	Soil Organic Matter
SRB	Surface Radiation Balance
SRTM	Shuttle Radar Topography Mission
SSC	Science Steering Committee
START	System for Analysis, Research and Training
START TEA	START Tropical East Asia
SWC	Soil Volumetric Water Content
TEA	Tropical East Asia
TIRS	Thermal Infrared Sensor
TM	Thematic Mapper
TNSFP	Three Norths Shelterbelt Forest Program
TOMS	Total Ozone Mapping Spectrometer
TPN	Thematic Program Network
UHDZ	Ürümqi High-tech Development Zone
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	UN Framework Convention on Climate Change
USGS	U.S. Geological Survey
VI	Vegetation Index
VPD	Vapor Pressure Deficit
WAD	World Atlas of Desertification
WBM	Water Balance Model
WCDP	West China Development Program
WIST	Warehouse Inventory Search Tool
WMO	World Meteorological Organization
WRF	Weather Research and Forecast
XD	Xilinhot Degraded Steppe
XF	Xilinhot Fenced Steppe
XJ	Xinjiang Uygur Autonomous Region

Preface

Among many pressing challenges facing the world today, understanding global changes and their consequences to society have not been well-investigated at regional levels. Based on previous and active research conducted in the Dryland East Asia (DEA) region of Northern Eurasia, various teams have built rich databases on climate, socioeconomic changes, remote sensing products, direct measurements of vegetation, soil, carbon and water fluxes, and demography at county/prefecture levels. One of the greatest challenges in this context is to develop a full picture and synthesis on how dryland ecosystems respond to changes in climate, environment, and human activities. This volume is designed to summarize the accumulated knowledge thus far and to direct future efforts of investigations. A new paradigm—coupled natural and human (CNH) systems—has evolved in recent years as a unifying concept for interdisciplinary research toward the goal of a sustainable society and environment. We instructed the contributors to use the CNH concept in developing their chapters. Our longer-term goal is to develop a synthesis of the data and knowledge on the coupled DEA systems at multiple temporal and spatial scales. We are fully aware that highly variable and changing climatic conditions influence the land cover, land use, and land conditions dynamically and interactively. Likewise, socioeconomic pressures influence land change dynamics and have complex biogeophysical and biogeochemical consequences that cascade through the elements of CNH systems.

A workshop was organized at Henan University in Kaifeng, China during July 18–20, 2011 with co-sponsorship of the Land-Cover and Land-Use Change (LCLUC) Program of NASA, Henan University, and National Natural Science Foundation of China (NSFC). During the workshop, over 40 participants, all active researchers on DEA or other dryland ecosystems, brought up many stimulating questions and suggestions for forming a synthesis study. Two review papers and these book chapters involved 76 authors from 7 countries. These publications move the scientific community closer to understanding processes in DEA. One particular notification for this text is about the administrative boundaries used in almost all chapters. DEA happened to be a region that has experienced some changes in administrative boundaries at provincial, national, and international levels in recent years. Here, we define DEA as a scientific study area, rather than accurate political region; although, we attempted to get the

most accurate information from various governments. Some maps were re-used from published literature where full citations are provided for the responsibility of the data sources.

Many students and researchers at the College of Life Sciences, Henan University provided excellent services that made the workshop a great success. The text of the 19 chapters in this book has been improved through the constructive contributions of both the editors and many reviewers, including Kirsten M. de Beurs, Peilei Fan, Xiaoming Feng, Pavel Groisman, Arnon Karnieli, Shilong Piao, Gabriel Senay, Andres Vina, and Ming Xu. Many others (Chenlu Zhang, Cancan Zhao, Yinzhan Liu, Tingjuan Wu, Lei Wang, Fude Shang, Rumin Gao and Weikai Bao, etc.) also helped with some technical parts of this volume. Dr. Li Zhang of the Chinese Academy of Sciences spent a great deal of time and assistance for the final illustrations—we owe her a sincere thank you. We owe much to Dr. Bingxiang Li of the Higher Education Press (HEP), who has been a long-time supporter of the research in DEA and the current volume. The careful managing editorial work of Yan Guan, Alona Gutman, and Lisa Delp Taylor were critical for the completion of this book. Stephanie Dawson of De Gruyer provided speedy support for the establishment of the book series and proposal reviews on Ecosystem Science and Applications (ESA).

The Editors