



Edited by
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NANCY H. F. FRENCH • BRADLEY C. REED

LAND USE

AND THE

CARBON CYCLE

**Advances in
Integrated Science,
Management,
and Policy**

CAMBRIDGE

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LAND USE AND THE CARBON CYCLE

Advances in Integrated Science, Management, and Policy

As governments and international institutions work to ameliorate the effects of anthropogenic carbon dioxide emissions on global climate, there is an increasing need to understand how land-use and land-cover change is coupled to the carbon cycle, and how land management can be used to mitigate their effects. This book brings an interdisciplinary team of fifty-six international researchers to share novel approaches, concepts, theories, and knowledge on land use and the carbon cycle.

The book examines how the social, political, economic, and ecosystem processes associated with land use and land management drive carbon flux and storage in terrestrial ecosystems. The central theme is that land use and land management are tightly integrated with the carbon cycle, and thus it is necessary to study these processes as a single natural-human system to improve carbon accounting and mitigate climate change.

Land Use and the Carbon Cycle is an invaluable resource for advanced students, researchers, land-use planners, and policy makers in natural resources, geography, forestry, agricultural science, ecology, atmospheric science, and environmental economics.

DANIEL G. BROWN is a Professor in the School of Natural Resources and Environment at the University of Michigan. His work, published in more than 100 peer-reviewed publications, aims to understand human-environment interactions through a focus on land-use and land-cover changes, modeling these changes, and spatial analysis and remote sensing methods for characterizing landscape patterns. He has chaired the Land Use Steering Group under the auspices of the U.S. Climate Change Science Program and has served as a member of the Carbon Cycle Steering Group and the NASA Land-Cover and Land-Use Change Science Team, as well as on a variety of panels for the National Research Council, NASA, the National Science Foundation, and the European Research Council. He has served on the editorial boards for the journal *Landscape Ecology*; the journal *Computers, Environment, and Urban Systems*; and the journal *Land Use Science*. In 2009, he was elected a Fellow of the American Association for the Advancement of Science.

DEREK T. ROBINSON is an Assistant Professor in the Department of Geography and Environmental Management at the University of Waterloo. Dr. Robinson has been developing and publishing land-use research using geographical information science (GIS) and agent-based modeling approaches for ten years, which includes substantive contributions to research projects in Europe and North America. His research typically involves using agent-based models to integrate geographical information systems (GISystems) and ecological and human decision-making models to evaluate how socioeconomic contexts and policy scenarios affect changes in land use, ecological function, and human well-being.

NANCY H. F. FRENCH is a Senior Scientist at the Michigan Tech Research Institute of Michigan Technological University. Dr. French has been working on applications of remote sensing to ecology and vegetation studies for more than twenty years. Her primary interests are in the study of forest ecosystems and the application of remote sensing and geospatial analysis techniques to ecosystem studies. She serves on the editorial board and as an assistant editor for the *International Journal of Wildland Fire*. She is a member of the North American Carbon Program Scientific Steering Group and serves on the NASA Carbon Monitoring System Science Definition Team. She has authored or coauthored twenty-five journal articles and more than ten book chapters.

BRADLEY C. REED is Associate Program Coordinator in the Geographic Analysis and Monitoring Program of the U.S. Geological Survey (USGS), Reston, Virginia. Dr. Reed has been involved in a number of research endeavors, including developing a global land-cover map (DISCover) using Earth Observations, developing new methods for characterizing phenology from Earth Observation data, and assessing biological carbon sequestration for the United States. He worked at the USGS Earth Resources Observation and Science (EROS) Data Center for several years. He recently completed an assignment in Geneva, Switzerland, as the U.S. representative to the Group on Earth Observations (GEO), where he supported work in the Ecosystems and Biodiversity Societal Benefit Areas.

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Acronyms

| | |
|--------------------|---|
| A/R: | afforestation and reforestation |
| A/R/AF: | afforestation, reforestation, and agroforestry |
| A/R Working Group: | Afforestation/Reforestation Working Group |
| ACR: | American Carbon Registry |
| AFOLU: | agriculture, forestry, and other land-use activities |
| AFTA: | Association for Temperate Agroforestry |
| AIRS: | Atmospheric Infrared Sounder, aboard the NASA Aqua Satellite |
| ANPP: | annual net primary productivity |
| APA: | American Power Act |
| ASCENDS: | Active Sensing of CO ₂ Emissions over Nights, Days, and Seasons satellite |
| BAU: | business as usual |
| BLM: | Bureau of Land Management |
| BMP: | best management practice |
| BNF: | biological nitrogen fixation |
| C:N: | carbon to nitrogen ratios, DayCent model variable |
| CAR: | Climate Action Reserve offset registry (California) |
| CarboNA: | Joint Canada-Mexico-USA Carbon Program |
| CASA: | Carnegie-Ames-Stanford Approach Model |
| CCBA: | Climate, Community, and Biodiversity Alliance |
| CCX: | Chicago Climate Exchange |
| CDIAC: | Carbon Dioxide Information Analysis Center |
| CDM: | Clean Development Mechanism |
| CDM EB: | Clean Development Mechanism Executive Board |
| CEQ: | Council on Environmental Quality |
| ChEAS: | Chequamegon Ecosystem-Atmosphere Study |
| CNH: | Dynamics of Coupled Natural and Human Systems |
| COBRA: | CO ₂ Budget and Regional Airborne Study |
| COP 15/MOP 5: | Convention of Parties 15 / Meeting of Parties 5 (United Nations Framework Convention on Climate Change, Copenhagen, 2009) |

| | |
|---------|--|
| CRP: | Conservation Reserve Program |
| CRU TS: | Climate Research Unit Time-Series |
| CStP: | Conservation Stewardship Program |
| CT: | conventional tillage |
| CTCC: | Tree Carbon Calculator (from the Center for Urban Forest Research) |
| CWD: | coarse woody debris |
| DA: | data assimilation |
| dbh: | diameter at breast height |
| DDGS: | distillers dried grains with solubles |
| Death: | death rate of plant components, DayCent model variable |
| Decomp: | decomposition factor, DayCent model variable |
| Den: | denitrification, DayCent model variable |
| DGS: | wet distillers grains with solubles |
| DOC: | dissolved organic carbon |
| DoD: | Department of Defense |
| DSN: | distributed sensor network |
| DSS: | decision-support systems |
| ECV: | essential climate variable |
| EIA: | Energy Information Administration |
| EIS: | Environmental Impact Statement |
| EISA: | Energy Independence and Security Act |
| EM: | Ecological Modeling |
| EPACT: | Energy Policy Act |
| EPL: | ethical poverty level |
| EQIP: | Environmental Quality Incentives Program |
| ESA: | Endangered Species Act |
| ESA: | European Space Agency |
| ESRL: | Earth System Research Laboratory |
| ESSP: | Earth System Science Partnership |
| ET: | evapotranspiration, DayCent model variable |
| EU: | European Union |
| FAIR: | Federal Agriculture Improvement and Reform Act (Farm Act of 1997) |
| FAO: | Food and Agricultural Organization (United Nations) |
| FAPAR: | fraction of absorbed photosynthetically active radiation |
| FAPRI: | Food and Agricultural Policy Research Institute |
| FCPF: | Forest Carbon Partnership Facility (World Bank) |
| FIA: | Forest Inventory and Analysis Database |
| FLPMA: | Federal Land Policy and Management Act |
| FP: | Framework Programme |
| FPAR: | fraction of absorbed photosynthetically active radiation |
| FPS: | Forest Projection and Planning Systems |
| FRA: | Forest Resources Assessment |

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|------------------------|--|
| FSA: | Farm Service Agency, USDA |
| FWS: | Fish and Wildlife Service |
| GCB: | Global Change Biology |
| GCTE: | Global Change and Terrestrial Ecosystems |
| GDP: | gross domestic product |
| GEO: | Global Earth Observation |
| GEOBIA: | geographic object-based image analysis |
| GHG: | greenhouse gas |
| GIS: | geographic information system |
| GLP: | Global Land Project |
| GMES: | Global Monitoring for Environment and Security |
| GOSAT: | JAXA/NIES Greenhouse Gas Observing Satellite, also known as Ibuki |
| GPG-LULUCF: | Good Practice Guidance for Land Use, Land-Use Change, and Forestry |
| GPGPU: | general-purpose graphics processing units |
| GPP: | gross primary production |
| GRP: | Grassland Reserve Program |
| Gt C: | Gigatons (10 billion tons) carbon |
| GYM: | growth and yield model |
| H ₂ O soil: | soil moisture, DayCent model variable |
| HELIA: | Human-Environment Land-Integrated Assessment Model |
| HFT: | human functional type |
| HH: | Houghton and Hackler data set |
| HIPPO: | HIAPER Pole-to-Pole Observations |
| HPC: | high-performance computing |
| HYDE: | History Database of the Global Environment data set |
| IASI: | Infrared Atmospheric Sounding Interferometer, launched as part of the European Space Agency MetOp series of satellites |
| IGBP: | International Geosphere-Biosphere Programme |
| IHDP: | International Human Dimensions Programme on Global Environmental Change |
| IMAGE: | Integrated Model to Assess the Global Environment |
| IPCC: | Intergovernmental Panel on Climate Change |
| IPCC AR4: | Fourth Assessment Report of the Intergovernmental Panel on Climate Change |
| ISAM-NC: | Integrated Science Assessment Model's Carbon-Nitrogen Cycle Model |
| ITTO: | International Tropical Timber Organization |
| JI: | Joint Implementation |
| JLUS: | <i>Journal of Land Use Science</i> |
| LAI: | leaf-area index |
| LBA: | Large-scale Biosphere-Atmosphere Experiment, Amazonia |
| LCA: | life cycle assessment |